52ND
ANNUAL MEETING & COURSE 2017
SEPTEMBER 6-9
PHILADELPHIA PA USA

# FINAL PROGRAM

SPONSORED BY THE SCOLIOSIS RESEARCH SOCIETY

# CORPORATE SUPPORT

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2017.

Support levels are based on total contributions throughout the year and include the Annual Meeting, IMAST, Global Outreach Scholarships, Edgar Dawson Memorial Scholarships, SRS Traveling Fellowships and the Research Education Outreach (REO) Fund.

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RSC Bracing, South Africa

Telefield Medical Imaging

# GENERAL MEETING INFORMATION

SCOLIOSIS RESEARCH SOCIETY
52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges DePuy Synthes for their overall support of the Annual Meeting & Course and Annual Meeting Video Archives.

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## SRS EXECUTIVE OFFICE


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# President's Message

Welcome to the 52nd Annual Meeting & Course of the Scoliosis Research Society!

For the past 51 years, the Annual Meeting has been the flagship event of our society, and a meeting that spinal deformity surgeons and scientists from around the world attend to obtain the latest information in this field. This 52nd meeting will continue this tradition with a theme on global spine care and innovative educational formats. There were 1506 submitted abstracts; 129 were accepted for podium presentation, 45% of which are from presenters outside of the USA. In addition, we have 104 e-posters, 15 e-presentations, and 12 case discussions. Muharrem Yazici, MD and the Program Committee have done masterful work in reviewing all of the submissions and putting together a truly outstanding program.

New this year are the e-presentations, 15 highly ranked abstracts that could not be included as podium presentations, will be recorded and made available on the SRS website after the meeting for additional CME credit. The e-presentation abstracts are also included in the Final Program and are available for viewing on the E-Poster Kiosks.

Praveen Mummaneni, MD and the Education Committee have put together an excellent set of offerings starting with the Pre-Meeting Course, "A Multidisciplinary Approach to Global Spine Care". After the Pre-Meeting Course on Wednesday will be case discussions followed by the Opening Ceremonies and the Steel Lecture, presented by Michael Smerconish, host of CNN's Smerconish. He will share with us his perspective on the 2016 US Presidential Election. This promises to be insightful and entertaining.

Thursday morning begins the scientific program, presentation of the Lifetime Achievement Awards to G. Dean MacEwen, MD and Howard H. Steel, MD, and my Presidential Address. The Half-Day Courses follow. Thursday evening will be a wonderful opportunity for you to sightsee around Philadelphia and catch up with friends.

Friday will be a full day of scientific sessions, including the Harrington Lecture, presented by Christopher J.L. Murray, MD, Professor of Global Burden at the University of Washington, and author of the Lancet articles on Global Burden of Disease Study. In the evening, the farewell reception will be at the National Constitution Center, a beautiful museum with birds-eye views of Philadelphia's historic landmarks and a rotating collection of rare artifacts celebrating the creation and legacy of the United States' Constitution. Tickets are required, please come join us for an evening of fun and networking.

New this year for the Saturday half-day, will be a final "highlights session" whereby take-home points from each of the scientific sessions will be presented. So, if you have missed any of the sessions, this would be an excellent time to catch up!

I want to personally thank the committee of local hosts, led by Patrick J. Cahill, MD and including Vincet Arlet, MD; Randal R. Betz, MD; Robert M. Campbell, Jr., MD; David H. Clements, III, MD; John M. Flynn, MD; Peter G. Gabos, MD; Martin J. Herman, MD; Joshua Pahys, MD; Amer F. Samdani, MD; and Suken A. Shah, MD. Please take some time during the meeting and enjoy this spectacular and historic city.

The SRS staff, led by Executive Director, Tressa Goulding, deserves special recognition for all of their tremendous efforts; they make the work of being SRS President so much easier.

It has been a pleasure and an honor to serve this year as your President of this great Society. I want to especially thank my fellow Presidential Line colleagues who have supported me and made my work fun; Past President II, John Dormans, MD; Immediate Past President David W. Polly, Jr., MD; President-Elect Todd Albert, MD; and Vice President Peter Newton, MD. I know that SRS is in great hands as Todd Albert, takes the reins and does great things with our Society.

Best wishes to all for a great meeting!

Kenneth MC Cheung, MD
Scoliosis Research Society President 2016-2017

# Board of Directors – 2016-2017

**Kenneth MC Cheung, MD**
President

**Todd J. Albert, MD**
President Elect

**Peter O. Newton, MD**
Vice President

**Mark Weidenbaum, MD**
Secretary

**J. Abbott Byrd, III, MD**
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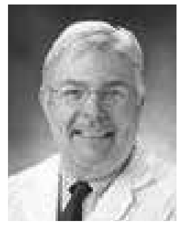
**David W. Polly, Jr., MD**
Past President I



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Director at Large

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Research Council Chair

**John R. Dimar, II, MD**
Education Council Chair

# Annual Meeting Committees

## 2017 SRS PRESIDENT

Kenneth MC Cheung, MD

## 2017 LOCAL ORGANIZING HOST COMMITTEE

Patrick J. Cahill, MD
Amer F. Samdani, MD
John M. Flynn, MD
Robert M. Campbell, Jr., MD
Randal R. Betz, MD
Suken A. Shah, MD
David H. Clements, III, MD
Martin J. Herman, MD
Peter G. Gabos, MD
Joshua Pahys, MD
Vincent Arlet, MD

## 2017 PROGRAM REVIEWERS

Kariman Abelin-Genevois, MD, PhD
D. Greg Anderson, MD
Ravi S. Bains, MD
Paloma Bas Hermida, MD
John M. Caridi, MD
Samuel K. Cho, MD
Matthew E. Cunningham, MD, PhD
Michael D. Daubs, MD
Vedat Deviren, MD
William F. Donaldson, III, MD
Robert N. Dunn, FCS (SA) Orth
Robert K. Eastlack, MD
Mohammad El-Sharkawi, MD
Michael J. Goytan, MD, FRCSC
Jeffrey L. Gum, MD
Lawrence L. Haber, MD
Sajan K. Hegde, MD
Michael H. Jofe, MD
Daniel G. Kang, MD
Eric O. Klineberg, MD
Deniz Konya, MD
Panagiotis Korovessis, MD, PhD
Moyo Kruyt, MD, PhD
John P. Lubicky, MD, FAAOS, FAAP
Jwalant Mehta, FRCS(Orth)
Mohammed Mossaad, MD
Colin Nnadi, FRCS (Orth)
Timothy S. Oswald, MD
Joshua Pahys, MD
Howard M. Place, MD
Michael Ruf, MD
Vishal Sarwahi, MD
Suken A. Shah, MD
Fernando E. Silva, MD
John T. Smith, MD
Vincent C. Traynelis, MD
William C. Warner, MD
Yat Wa Wong, MD

## EDUCATION COMMITTEE

Praveen V. Mummaneni, MD, Chair
Theodore T. Choma, MD, Past Chair
Suken A. Shah, MD, Chair Elect
Kariman Abelin-Genevois, MD, PhD
Santiago Tomas Bosio, MD
Marco Brayda-Bruno, MD
Robert H. Cho, MD
David H. Clements, III, MD
Charles H. Crawford III, MD
Benny T. Dahl, MD, PhD, DMSci
Michael D. Daubs, MD
Richard H. Gross, MD
Isaac O. Karikari, MD
Nathan H. Lebwohl, MD
Olavo B Letaif, MD, MSc
Ripul R. Panchal, DO FACOS
Paul Park, MD
S. Rajasekaran, MD, FRCS, PhD
Paul T. Rubery, MD
Scott S. Russo, Jr., MD
Cristina Sacramento Dominguez, MD, PhD
Jason W. Savage, MD
Yan Wang, MD
Burt Yaszay, MD
Muharrem Yazici, MD

## PROGRAM COMMITTEE

Muharrem Yazici, MD. Chair
Justin S. Smith, MD, PhD, Past Chair
Gregory M. Mundis, Jr., MD, Chair Elect
Daniel P. Borschneck, MD, BSc, MSc, FRCSC
Kai Cao, MD, PhD
David H. Clements, III, MD
David W. Gray, MD
Stuart H. Hershman, MD
Michael P. Kelly, MD
Han Jo Kim, MD
Tyler Koski, MD
Stephen J. Lewis, MD, MSc, FRCSC
Isador H. Lieberman, MD, MBA, FRCSC
Firoz Miyanji, MD, FRCSC
Hillard T. Spencer, MD
Yong Qiu, MD

# General Meeting Information

## VENUE INFORMATION

Philadelphia Marriott Downtown
1201 Market Street
Philadelphia, PA 19107

## ABSTRACT VOLUME

All abstracts accepted for presentation at the 52nd Annual Meeting have been published in the Final Program (pages 197-288). Each attendee will receive one copy of the program along with their registration materials. Abstracts have also been posted online to the Program tab of the SRS Annual Meeting website (http://www.srs.org/am17/program).

## ADMISSION TO SESSIONS

Official name badges will be required for admission to all sessions. All Annual Meeting attendees receive a name badge with their registration materials. Name badges should be worn at all time inside the Philadelphia Marriott Downtown, as badges will be used to control access to sessions and activities. Attendees are cautioned against wearing their name badges while away from the venue, as badges draw unwanted attention to your status as visitors to the city.

## ADMISSION BY TICKETS

Tickets will be required for admission to the Farewell Reception. The Farewell Reception will take place at The National Constitution Center, at an additional $50 fee per ticket for registered delegates and registered guests. If you pre-registered, tickets will be distributed with your registration materials and name badge. A limited number of tickets may be available at the Registration Desk.

## ATTIRE

Business casual (polo or dress shirts, sports coats) is appropriate for meeting sessions and for all Annual Meeting & Course sessions; ties are not required. The Farewell Reception dress code is cocktail attire.

## CELL PHONE PROTOCOL

Please ensure that cell phone ringers, pagers and electronic devices are silenced or turned off during all sessions.

## EMERGENCY & FIRST AID

The Philadelphia Marriott Downtown is fully prepared to handle emergency requests and first aid. Contact an SRS staff person for support. Remember to note all emergency exits within the venue.

## E-POSTERS

There are over 100 E-Posters available for your review on the E-Poster kiosks in the Ballroom Foyer on the 5th Floor of the Philadelphia Marriott Downtown. The E-Posters are also available on the USB included with your registration materials.

*E-Poster Kiosks are supported, in part, by a grant from Medtronic.*

*E-Poster USBs are supported, in part, by a grant from NuVasive.*

## E-PRESENTATIONS **NEW SESSION**

Fifteen abstracts have been selected in a new category, E-Presentation. These abstracts will be presented and filmed on-site at the Annual Meeting and the video will be posted to the Annual Meeting website approximately two weeks after the meeting. This video will be available for all attendees to view and to claim an extra CME credit. The abstracts are included in the Final Program and the presentations are available for viewing on the E-Poster Kiosks.

## SESSION 10: MEETING HIGHLIGHTS AND WRAP-UP **NEW SESSION**

Saturday, September 9, 12:51-13:30

This final session of the meeting will feature highlights from each session, including Lunchtime Symposia, Half-Day Courses and the E-Presentations. Moderators from every session will present three minutes of highlights from their session so that attendees can have an overall picture of the meeting as a whole before it is adjourned.

## EVALUATIONS

Please take time to complete the online evaluation forms provided for each session you attend. Your input and comments are essential in planning future Annual Meetings.

## GUEST HOSPITALITY PROGRAM

Registered guests of Annual Meeting & Course are welcome to attend the Welcome Reception for the base registration fee on Wednesday, September 6 and the Farewell Reception on Friday, September 8 for the additional cost of $50.

Registered guests of Annual Meeting & Course are welcome to meet and plan their days over a continental breakfast, courtesy of SRS. The Guest Hospitality Suite is open Thursday, September 7 through Saturday, September 9 from 7:30 – 10:00am in room 405 on the 4th floor of the Philadelphia Marriott Downtown, the headquarter hotels and meeting venue of the Annual Meeting & Course.

## WIRELESS INTERNET

Wireless Internet access is available throughout the Philadelphia Marriott Downtown, to log on select:

Network: Spine2017
Password: AM17

## LANGUAGE

English will be the official language of the SRS Annual Meeting & Course

## LOST & FOUND

Please feel free to stop by the SRS Registration Desk if you have lost or found an item during the course of the Annual Meeting.

## MEMBERS BUSINESS MEETINGS

Location: Franklin Hall B – 4th Floor

# General Meeting Information

All SRS members are invited to attend the Members Business Meetings, held Thursday, September 7 through Saturday, September 9 from 6:30 – 7:45am in Franklin Hall B on the 4th floor of the Philadelphia Marriott Downtown. Agendas will include reports from the various SRS committees, presentations by the 2016 Travelling Fellows and Edgar Dawson Scholarship recipients, and updates on SRS activities and programs. A hot breakfast will be served.

## ANNOUNCEMENT BOARD

A self-service announcement board (non-electronic) will be available in the Registration Area for attendees to post notes or leave messages for other attendees. SRS staff will also post meeting updates and announcements on the board. Please remember to check for any messages that may be left for you.

*The announcement board is supported, in part, by a grant from OrthoPediatrics.*

## NON-MEMBERS CONTINENTAL BREAKFAST

Location: Ballroom Foyer – 5th Floor
All non-member delegates to the SRS Annual Meeting are invited to meet with their colleagues and network over coffee and a continental breakfast served Thursday, September 7 through Saturday, September 9 from 6:30 – 7:45am in the Ballroom Foyer on the 5th floor at the Philadelphia Marriott Downtown.

## PHOTOGRAPHY POLICY

SRS will be taking photographs throughout the Annual Meeting & Course. SRS will use these photos in publications and to produce related literature and products for public release. Individuals photographed will not receive compensation for the use and release of these photos and will be deemed to have consented to the use and release of photos in which they appear. If you are opposed to being photographed, please immediately notify the photographer or an SRS staff member if your picture is taken. Thank you for your cooperation.

## REGISTRATION DESK

Location: Ballroom Foyer – 5th Floor

| | |
|---|---|
| Tuesday, September 5 | 14:00 – 17:00 |
| Wednesday, September 6 | 6:30 – 18:00 |
| Thursday, September 7 | 6:30 – 16:00 |
| Friday, September 8 | 6:30 – 17:00 |
| Saturday, September 9 | 6:30 – 12:00 |

## SMOKING POLICY

Smoking is not permitted during any meeting activity or event.

## SPEAKER UPLOAD AREA

Location: Room 501

## SRS ANNUAL MEETING & COURSE MOBILE APP

A mobile app will be available to all delegates during the 52nd Annual Meeting & Course. The app is designed to provide all the information about the Annual Meeting & Course and Philadelphia in one convenient location and can be accessed from any smart phone or tablet with an internet connection.

Download the Annual Meeting mobile app from the Apple App Store or Google Play Store by searching "SRS AM17" and downloading the app on your deceive.

The Annual Meeting Mobile App includes:

- The ability to download all the abstracts and final program right from the app!
- An offline mode will allow delegates to access all static content, including the agenda, speaker listing and info booth, on the app without an internet connection.
- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule.
- An "information booth" featuring everything you need to know about the Annual Meeting & Course, and its host city of Philadelphia, including scientific and social program details, information on the Philadelphia Marriott Downtown
- Hibbs Award voting poll on Friday, September 8.
- Maps of the Philadelphia Marriott Downtown and meeting space.
- An alert system for real-time updates from SRS - program changes, tour and social event notifications, and breaking news as it happens.
- A complete list of Annual Meeting faculty and podium presenters, including presentation titles, times, dates, and locations.
- Meeting Evaluations

*Please remember to activate your wireless access on your mobile device or tablet to utilize the mobile app without incurring international fees and charges!*
*Network: Spine2017*
*Password: AM17*

# General Meeting Information

Presenters may upload their PowerPoint presentations in the Presentation Upload Area, located at the back of the general session room, Room 501, 5thh floor. **Presentations may not be uploaded in individual rooms but must be uploaded in the Presentation Upload Area.**

| | |
|---|---|
| Wednesday, September 6 | 6:30 – 18:00 |
| Thursday, September 7 | 6:30 – 16:30 |
| Friday, September 8 | 6:30 – 17:30 |
| Saturday, September 9 | 6:30 – 12:00 |

## SPECIAL NEEDS

If you have any health issues for which you may require special accommodations or assistance, please notify the SRS staff at the Registration Desk. We will make every effort to accommodate any special needs.

## VIDEO RECORDING PROHIBITED

SRS does not allow personal video recording of the presentations of any kind. SRS holds the right to confiscate any and all recording taken of any of the presentations. All session rooms will be recorded and will be available to delegates after the meeting on the SRS website.

# CME Information

## MEETING DESCRIPTION

The Scoliosis Research Society (SRS) Annual Meeting & Course is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Over 125 papers will be presented on an array of topics, including adolescent idiopathic scoliosis, growing spine, kyphosis, adult deformity, trauma, neuromuscular scoliosis and tumors.

## LEARNING OBJECTIVES

Upon completion of the Annual Meeting, participants should be able to:

- Identify the Pre/Intra/Post Operative factors that can be effectively modified to improve patient outcomes and reduce complications.
- Apply useful strategies to self-evaluate and strengthen private and academic practices.
- Compare risks and benefits of new techniques to optimize treatment success for patients with spinal deformity.
- Describe the informed consent process required to maximize patient understanding of the risks, benefits, & treatment options available for their spine problem.
- Consider developing a multidisciplinary team approach of risk management for the treatment of spine deformities.

## TARGET AUDIENCE

Spine surgeons (orthopaedic and neurological surgeons), residents, fellows, nurses, nurse practitioners, physician assistants, engineers and company personnel.

## ACCREDITATION STATEMENT

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the sponsorship of the Scoliosis Research Society (SRS). SRS is accredited by the ACCME to provide continuing medical education for physicians.

## VIDEO ARCHIVES

Instant video archives will be available to all meeting delegates on the SRS website (http://www.srs.org/professionals/online-education-and-resources/past-meeting-archives) four to six weeks after the meeting. All session rooms, both main ballrooms and break-out rooms, are being recorded. If you were unable to attend a concurrent session, don't forget to watch it on the website!

## CREDIT DESIGNATION

SRS designates this live activity for a maximum of 28 (7.5 for Pre-Meeting Course, 20.5 for Annual Meeting) *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

## DISCLOSURE OF CONFLICT OF INTEREST

It is the policy of SRS to insure balance, independence, objectivity and scientific rigor in all of their educational activities. In accordance with this policy, SRS identifies conflicts of interest with instructors, content managers and other individuals who are in a position to control the content of an activity. Conflicts are resolved by SRS to ensure that all scientific research referred to, reported or used in a CME activity conforms to the generally accepted standards of experimental design, data collection and analysis. Complete faculty disclosures will be included in the final program.

## FDA STATEMENT (UNITED STATES)

Some drugs and medical devices demonstrated during this course have limited FDA labeling and marketing clearance. It is the responsibility of the physician to be aware of drug or device FDA labeling and marketing status.

## INSURANCE/LIABILITIES AND DISCLAIMER

SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting & Course including those participating in tours and social events. Participants and guests are encouraged to take out insurance to cover loss incurred in the event of cancellation, medical expenses or damage to or loss of personal effects when traveling outside of their own countries. SRS cannot be held liable for any hindrance or disruption of the Annual Meeting & Course proceedings arising from natural, political, social or economic events or other unforeseen incidents beyond its control. Registration of a participant or guest implies acceptance of this condition. The materials presented at this Continuing Medical Education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement or opinion of the faculty that may be helpful to others who face similar situations. SRS disclaims any and all liability for injury or other damages resulting to any individual attending a scientific meeting and for all claims that may arise out of the use of techniques demonstrated therein by such individuals, whether these claims shall be asserted by a physician or any other person.

# Philadelphia Marriott Downtown Floorplans

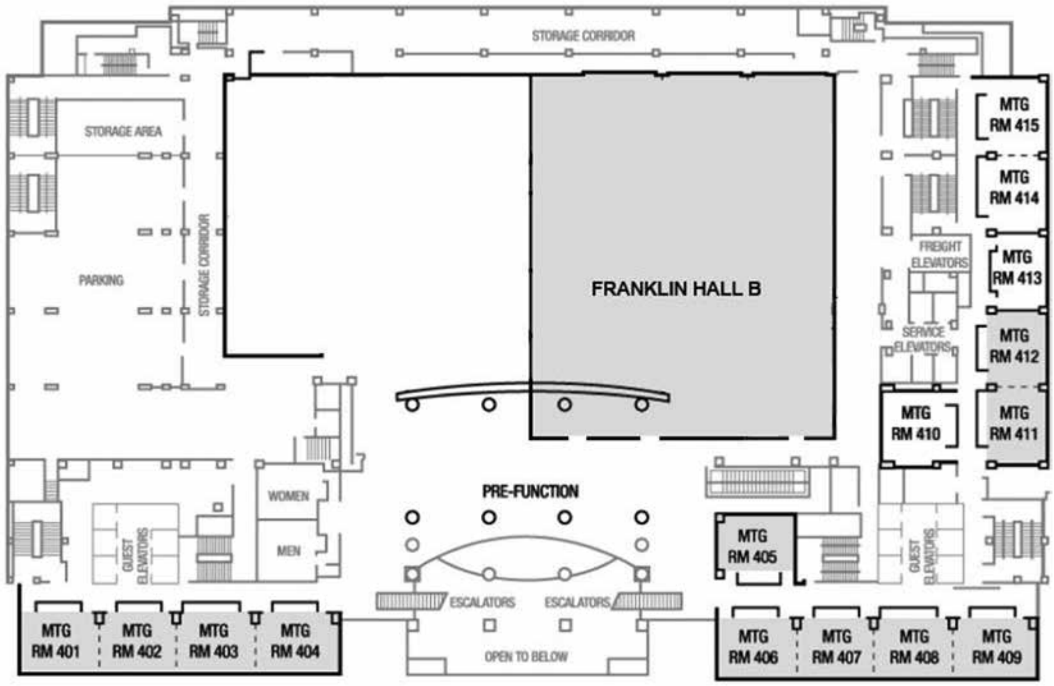
## 4TH FLOOR

**401-407** – Corporate Supporter Rooms, Committee Meeting Rooms

**405** – Guest Hospitality Suite

**411-412** – Pop-Up Committee Meeting Rooms

**Franklin Hall B** – SRS Membership Meeting & Breakfast




## 5TH FLOOR

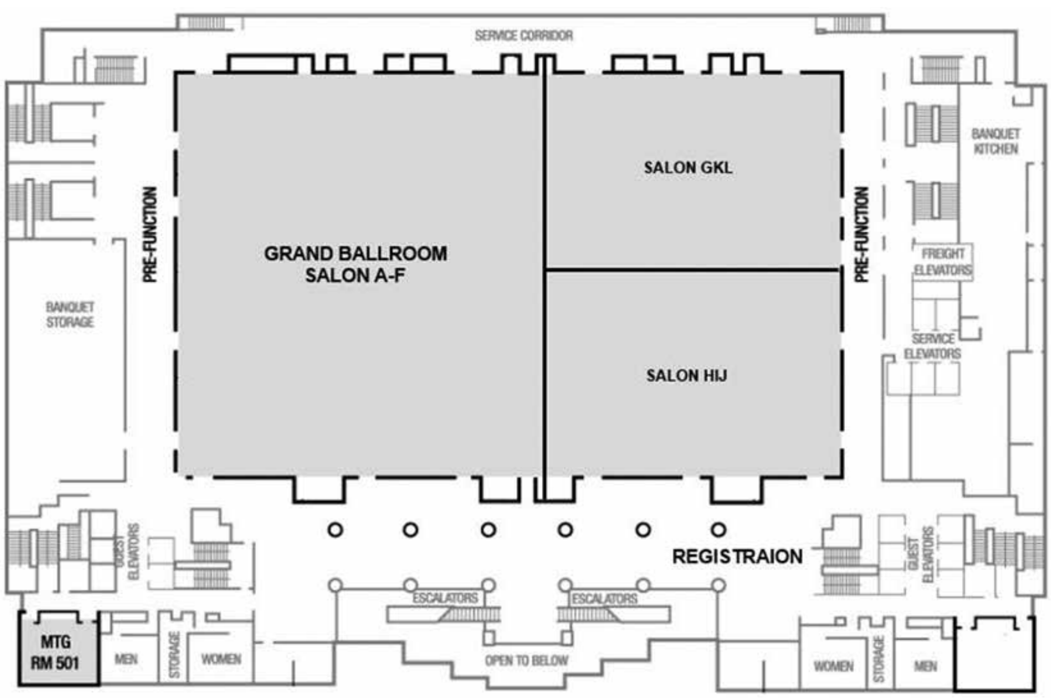
**Grand Ballroom Salon A-F** – General Session, Pre-Meeting Course

**Ballroom Foyer** – Registration, SRS Membership Table, Non-Member Breakfast, Breaks, Lunch

**Salon GKL** – Concurrent Sessions

**Salon HIJ** – Concurrent Sessions, General Session Overflow Seating

**501** – Speaker Ready Room



# Meeting Outline

| | |
|---|---|
| **Monday, September 4, 2017** | |
| 8:00 - 16:00 | Board of Directors Meeting |
| 17:00 - 19:00 | Incoming Committee Chair Reception (by invitation only) |
| **Tuesday, September 5, 2017** | |
| 7:00 - 17:00 | SRS Committee Meetings |
| 13:00 - 18:15 | Hibbs Society Meeting |
| 14:00 - 17:00 | Registration Open |
| 19:00 - 22:00 | SRS Leadership Dinner (by invitation only) |
| **Wednesday, September 6, 2017** | |
| 6:30 - 18:00 | Registration Open/ E-Posters Open |
| 7:45 - 12:20 | Pre-Meeting Course – Morning Sessions |
| 12:35 - 13:35 | Lunchtime Symposia |
| 13:45 - 16:30 | Pre-Meeting Course – Afternoon Sessions |
| 16:45 - 17:45 | Case Discussions |
| 18:00 - 19:15 | Opening Ceremonies |
| 19:15 - 21:00 | Welcome Reception |
| **Thursday, September 7, 2017** | |
| 6:30 - 16:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 12:30 | Scientific Program |
| 12:35 - 13:30 | Half-Day Course Lunch |
| | Member Information Session |
| 13:30 - 16:30 | Half-Day Courses |
| **Friday, September 8, 2017** | |
| 6:30 - 17:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 11:50 | Scientific Program |
| 12:05 - 13:05 | Lunchtime Symposia |
| 13:15 - 17:15 | Scientific Program |
| 19:00 - 22:00 | Farewell Reception |
| **Saturday, September 9, 2017** | |
| 6:30 - 12:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 13:30 | Scientific Program |
| 13:45 - 15:30 | Board of Directors Meeting |

# Guest Lecturers & Award Recipients

## HOWARD STEEL LECTURE

**Wednesday, September 6, 2017**

### Divided We Stand

**Michael Smerconish**

Michael Smerconish is the host of a daily radio program heard on SiriusXM's POTUS channel. He is also the host of CNN's Smerconish, which airs Saturdays at 9 am and 6 pm He is a newspaper columnist for the Sunday Philadelphia Inquirer and his columns are routinely reprinted in newspapers all across the country. He has authored six books, the most recent of which,TALK, is a novel for which the television rights were optioned by Warner Brothers. He is a 1984 Phi Beta Kappa graduate of Lehigh University and a 1987 graduate of the University of Pennsylvania Law School. Smerconish is of counsel to the Philadelphia law firm of Kline & Specter, and resides in the Philadelphia suburbs where he and his wife have raised four children.

## HARRINGTON LECTURE

**Friday, September 8, 2017**

### Global Burden of Disease Study 2016: Key Findings and Implications for Musculoskeletal Research

**Christopher J. L. Murray, MD, DPhil**
*Director, Institute for Health Metrics and Evaluation*

Christopher J.L. Murray, MD, DPhil, is a Professor of Global Health at the University of Washington and Institute Director of the Institute for Health Metrics and Evaluation (IHME) whose career has focused on improving health for everyone worldwide by improving health evidence. A physician and health economist, his work has led to the development of a range of new methods and empirical studies to strengthen health measurement, analyze the performance of public health and medical care systems, and assess the cost effectiveness of health technologies. Dr. Murray is a founder of the Global Burden of Disease (GBD) approach, a systematic effort to quantify the comparative magnitude of health loss due to diseases, injuries, and risk factors by age, sex, and geography over time. He led the collaborative of almost 500 researchers from 50 countries that produced the Global Burden of Diseases, Injuries, and Risk Factors Study 2010 (GBD 2010).

In his earlier work, Dr. Murray focused on tuberculosis control and the development with Dr. Alan Lopez of the GBD methods and applications. From 1998 to 2003, Dr. Murray worked at the World Health Organization (WHO), where he served as the Executive Director of the Evidence and Information for Policy Cluster while Dr. Gro Harlem Brundtland was Director-General. He went on to become Director of the Harvard Initiative for Global Health and the Harvard Center for Population and Development Studies, as well as the Richard Saltonstall Professor of Public Policy at the Harvard School of Public Health, from 2003 until 2007. Dr. Murray has authored or edited 15 books, many book chapters, and more than 300 journal articles in internationally peer-reviewed publications. He holds Bachelor of Arts and Science degrees from Harvard University, a DPhil in International Health Economics from Oxford University, and a medical degree from Harvard Medical School.

## WALTER P. BLOUNT HUMANITARIAN AWARD RECIPIENT

The 2017 Walter P. Blount Humanitarian Award will be presented on **Wednesday, September 6**, acknowledging outstanding service to those with spinal deformity, and for generosity to the profession and society.

### Kenneth J. Paonessa, MD

Dr. Kenneth Paonessa is an orthopedic spine surgeon, practicing at Orthopedic Partners, serving southeastern Connecticut. He attended the New Jersey Medical School, followed by a residency in orthopedic surgery from the Seton Hall University Medical School in New Jersey, and then completed a fellowship in scoliosis and spinal surgery at the New York University School of Medicine in New York City.

Dr. Paonessa began doing volunteer surgery in Ghana West Africa with Dr. Oheneba Boachie in 2003 with the FOCOS group of surgeons. While working with FOCOS he also traveled to Ethiopia in East Africa to do clinics in Addis Ababa at the Mother Theresa's mission house where he examined both preoperative and postoperative patients who had undergone scoliosis and spinal deformity surgery. After participating in multiple trips to Ghana with FOCOS he was asked to become the surgical director of the Duncan Tree Foundation. The Duncan Tree Foundation recently celebrated their 100th surgery for scoliosis deformity. As part of the surgical team participating in the trips to Jamaica and the Philippines Dr. Paonessa has given multiple lectures and teaching seminars to the residents of the University of the West Indies and the University of the Southern Philippines who he has had the pleasure to work with and help train.

Dr. Paonessa is currently a vice president of the board of the Duncan Tree Foundation. He has helped with the growth of the Duncan Tree Foundation to become an endorsed site from the Global Outreach Committee of the Scoliosis Research Society. The Duncan Tree Foundation is recently partnered with Dr. Vincent Arlet to help coordinate his global outreach site in Trinidad and is hoping to help organize and plan scoliosis mission trips to Barbados and Guyana.

Dr. Paonessa has been a member of the Scoliosis Research Society since completing his spinal surgery fellowship and has been involved as a committee member of the Global Outreach Committee, the Worldwide Course Committee, and the Adult Deformity Committee. During his fellowship he was chairman of the Global Outreach Committee and has participated as an abstract reviewer for the Program Committee for the Scoliosis Research Society.

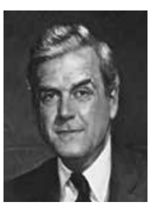
In 2013 he received the humanitarian of the year award from the Duncan Tree Foundation for his participation in their scoliosis outreach trips and for his help with the scoliosis clinics at the Kingston Public Hospital and Cornwall Regional Hospital in Jamaica. In 2013 he also received a certificate of special congressional recognition from Congresswoman Yvette Clarke in recognition of outstanding and invaluable service to the community. In 2017 he received a special certificate of recognition from the city of Hartford, Connecticut for his volunteer participation in spinal deformity and scoliosis care.

Dr. Paonessa has given multiple lectures in the Connecticut and New England area as a member of the New England Spine Study Group. He has presented some of his research to multiple national and international societies including the Scoliosis Research Society, the North American Spine Society, and the American Academy of Orthopedic Surgeons. It was his privilege to be a co-author on several papers that involved research on the patients that he participated in their care with during the FOCOS group in Ghana. In the Complex Spine Study Group, sponsored by K2M, he was a participating surgeon.

Dr. Paonessa has valued the friendships and collegial comradery he has fostered with the numerous physicians and residents that he has worked with and helped train in his travels overseas. He hopes to continue his volunteer efforts globally and as a member of the Scoliosis Research Society to encourage its membership to help with this important goal.

## LIFETIME ACHIEVEMENT AWARD RECIPIENTS

The 2017 Lifetime Achievement Awards will be presented on **Thursday, September** 7. The Lifetime Achievement Award Recipients were chosen from among the SRS membership, based on long and distinguished service to the Society and spinal deformity research and care.



### G. Dean MacEwen, MD

G. Dean MacEwen spent his early years in Ontario, Canada and received his medical education from Queen's University in 1953. Dr. MacEwen served as the Medical Director of the Alfred I. duPont Institute from 1969 – 1986. He was recruited and trained by Alfred R. Shands, Jr., MD when pediatric orthopedics was beginning to emerge as a specialty.

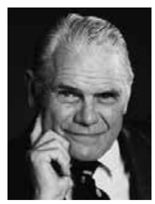
Dr. MacEwen's pioneering work in treating scoliosis and a myriad of other pediatric orthopedic problems has laid the groundwork for today's treatments. He helped to develop the "Wilmington brace" – used world-wide to correct scoliosis – and instituted community screening programs to identify spine problems at an early age.

In the early days of the Scoliosis Research Society he studied the neurological complications of scoliosis. He is a founding member of the Scoliosis Research Society, served as President, and was a member of various Committees from 1969 – 1980. He has participated in most Annual Meetings and has been active in IMAST since its inception. In addition, he continues as a member of AOA, AAOS, SICOT and is a charter member of POSNA.

The education of orthopedic surgeons has been a large part of Dr. MacEwen's activities since the late 1950's. Over 200 peer reviewed manuscripts and 25 text book chapters have been published. He has been a visiting professor at more than 150 locations around the world and has chaired educational courses on over 750 occasions. Individuals starting their careers in orthopedics continue to seek residencies and fellowships at A.I. duPont Institute (now Nemours /A.I. duPont Hospital for Children) to develop a firm foundation and add a level of excellence to their education and practice of pediatric orthopedics.

Dr. MacEwen is known not only for his successful treatment of thousands of children, but for training hundreds of young surgeons who now head orthopedic teams around the globe. He remains active with various medical and community service organizations.

Dr. & Mrs. MacEwen reside in New Castle, Delaware. Their five children along with their spouses, nine grandchildren and one great-grandchild reside across the country. One of their grandchildren is currently in medical school with another considering a medical career.



### Howard H. Steel, MD

Howard Steel was born in Philadelphia and raised in Atlantic City, NJ. He received his undergraduate education at Colgate University, majoring in chemistry. Following service in the Navy during World War II, he enrolled at Temple University School of Medicine and graduated in 2-1/2 years from their accelerated program. He later earned a PhD in anatomy. He undertook an orthopaedic residency with Dr. John Royal Moore at Temple University Hospital's Department of Orthopaedics and then remained on the attending staff.

Appointed Chief of Staff at Shriners Hospitals for Children-Philadelphia in 1966, he founded the first ever pediatric spinal cord injury unit in 1980. He was one of the early members of the SRS. He founded the Eastern Orthopaedic Association in 1970 and served as president for the first two years and managing director until 1976. He was a founding member of the Pediatric Orthopaedic Society, later to become POSNA.

Dr. Steel pioneered some of the most innovative surgical treatments for their time, many still in use today. He developed the triple innominate osteotomy for acetabular dysplasia. He took a non-traditional approach to extreme lumbar kyphosis secondary to lumboperitoneal shunt in patients with myelodysplasia, treating them with a hanging gravity correction cast. His PhD dissertation entitled "Anatomical and Mechanical Considerations of Traumatic Interruption of the Atlanto-Axial Articulations" led to Steel's Rule of Thirds. He also championed resection of the rib deformity in scoliosis for bone grafting and improvement in appearance.

His hemipelvectomy without amputation for treatment of malignant tumors of the pelvis spared patients the mutilation of hindquarter amputation. A group of grateful patients who underwent hemipelvectomy formed the Howard Steel Orthopaedic Foundation in his honor. Funds from the Foundation support lectures at multiple orthopaedic associations' annual meetings, including the EOA, WOA, POSNA, AOA, and SRS. His only qualification is that the topics of the talks are non-medical, reflecting his belief in well-rounded knowledge on other life subjects. He is a life-long daredevil and athlete, a globe-trotter, a world-renowned authority on wine of the Rhine Valley and Madeira, a musician, and a great admirer of world languages. Dr. Steel is truly a Renaissance Man.

Dr. Steel is the beloved teacher, mentor, and true friend to three generations of orthopaedic residents and fellows. They learned from his presentations but mostly by observation of the elevated standards of the excellence that he demanded of himself, the compassion he showed for his patients, and the joie de vivre that he brought to work every single day. He engendered tremendous camaraderie and loyalty amongst his students and peers and still obviously loves his profession.

The proud parents of 8 children, Dr. Steel and his wife Betty Jo currently reside in Villanova, PA.

# Social Events & Tours

## SOCIAL EVENTS

### Opening Ceremonies

Wednesday, September 6, 2017
18:00-21:00

Open to all registered delegates and their registered guests at no additional fee. Name badges are required.

The Annual Meeting will officially begin with the Opening Ceremonies and this year's Howard Steel Lecture, presented by Michael Smerconish. The evening will include an introduction of the SRS officers. All delegates and registered guests are invited and encourage to attend the Opening Ceremonies. Following the Opening Ceremonies, we will move to a hosted reception featuring heavy hors d'oeuvres, cocktails, and plenty of lively conversations and reunions with colleagues and friends. For the complete Opening Ceremonies Agenda, see page 15.

*The Welcome Reception is supported, in part, by grants from Medtronic, NuVasive, and Zimmer Biomet.*

### Farewell Reception

Friday, September 8, 2017
19:00-22:00

The 52nd Annual Meeting & Course will culminate with a reception at the National Constitution Center in historic Philadelphia. The National Constitution Center offers breathtaking birds-eye view of Philadelphia's historic landmarks. Farewell Reception attendees will also be able to visit the museum's popular attractions including the *Signer's Hall* and *The Story of We The People* which celebrates the Unites States' Constitution's legacy of freedom with a rotating collection of rare artifacts.

Open to all registered delegates and registered guests. Tickets are $50 each and should be purchased in advance. A limited number of tickets may be available onsite but SRS strongly urges delegates and guests to purchase tickets at the time of registration. Name badges are required. Cocktail dress is appropriate for the Farewell Reception.

# Social Events & Tours

## OPTIONAL TOURS

The following tours are available to registered delegates and guests through Stockton & Partners, our partners in Philadelphia. All tour reservations must be made directly on the Stockton & Partners' website, accessible on the Tours tab of the Annual Meeting website (http://www.srs.org/am17/tours). Any questions regarding registration or tour details should be directed to Stockton & Partners.

**Tours depart and return to the Philadelphia Marriott Downtown**

| | |
|---|---|
| Wednesday, September 6 | |
| Historic Philadelphia | $50 – Regular |
| Thursday, September 7 – EVENING TOUR | |
| Philadelphia Lights by Night | $50 – Regular |
| Friday, September 8 | |
| Philadelphia Old and New | $65 – Regular |

## TOUR DETAILS

### Historic Philadelphia – Wednesday

The birthplace of the nation includes the country's most historic mile. Beginning with our first step out to Philadelphia's modern day Market Street and we will learn how it got its name from the colonial market stalls that bustled with life in the 1700s as explore Independence National Historical Park.

Hear the stories of the people, places and things that made Colonial Philadelphia the seat of government for the young nation. Visit neighborhoods where the Founding Fathers' lived and see how contemporary Philadelphians have made them their own. See the same tiny courtyards and by-ways of colonial Philadelphians – only seen while on foot!

Sites include*: Liberty Bell Center, Independence Hall (ticketed interior tour), Congress Hall, Old City Hall (site of the first Supreme Court), Benjamin Franklin's print shop, Betsy Ross House, Franklin's grave, Elfreth's Alley and Christ Church.

Date: Wednesday, September 6
Tour Length: 3-4 Hours
Type of Tour: Walking Tour
Price per Person: $50 – Regular / $45 – Early Bird Savings

### Philadelphia Lights by Night – Thursday Evening

When the sun goes down, Philadelphia transforms into a glistening jewel that contrasts the illuminated historic elegance with the glittering modern sleekness.

Boat House Row, the Art Museum, and Swan Fountain are even more beautiful at night!

See where Philadelphian's kick back, relax and take in our city. From exciting new restaurants and cafés, to chic boutiques and galleries, to bowling clubs and martini lounges.

See the Philadelphia that today's Philadelphians have created alongside historic Philadelphia!

Date: Thursday, September 7 - Evening
Tour Length: 2.5 hours
Type of Tour: Combination bus and walking tour
Price per Person: $50 – Regular / $45 – Early Bird Savings

### Philadelphia Old & New – Friday

The most comprehensive full-city tour, Philadelphia Then & Now, is a fully guided tour via deluxe transportation through four centuries of art, architecture and Philadelphia's growth to a modern metropolis.

Beginning before 1776, hear the stories of the people, places and things that made Colonial Philadelphia the seat of government for the young nation and one of the largest English speaking cities in the world.

See such sites as the Liberty Bell, Independence Hall, Congress Hall, Betsy Ross House, Franklin's grave, Christ Church, Elfreth's Alley and the neighborhood of Society Hill. Embracing the modern day, we will visit neighborhoods where the Founding Fathers' lived and see how contemporary Philadelphians have made them their own.

Going beyond the colonial period, visit the bustling business district, Museum Mile of the Benjamin Franklin Parkway, the famous Rocky steps, Philadelphia's vibrant theater district, Antique Row, and much more.

Off-coach photo opportunities will occur throughout the tour.

Date: Friday, September 8
Tour Length: 3 hours
Type of Tour: Bus Tour with several off-coach photo opportunities
Price per Person: $65 – Regular / $59– Early Bird Savings

# Restaurant Recommendations

Philadelphia is a nationally recognized culinary destination with a thriving dining scene and award-winning chefs. The list below represents some of Philly's most highly rated and beloved restaurants. Distances are measured from the Philadelphia Marriott Downtown.

## ASIAN

**Buddakan** $$$ (RR)
325 Chestnut Street, 215-574-9440, 0.9 miles

**Morimoto** *Japanese* $$$$ (RR)
723 Chestnut Street, 215-413-9070, 0.6 miles

**Double Knot** *Japanese* $$ (RR)
120 S. 13th Street, 215-631-3868, 0.3 miles

## EUROPEAN

**Vetri** *Italian* $$$$ (R!)
1312 Spruce Street, 215-732-3478, 0.5 miles

**Little Nonna** *Italian* $$ (RR)
1234 Locust Street, 215-546-2100, 0.4 miles

**Amis** *Italian* $$ (RR)
412 S. 13th Street, 215-732-2647, 0.6 miles

**Osteria** *Italian* $$$ (RR)
640 N. Broad Street, 215-763-0920, 1 mile

**Amada** *Spanish* $$$ (RR)
217 Chestnut Street, 215-625-2450, 1.1 miles

**Tinto** *Spanish* $$$ (RR)
114 S. 20th Street, 215-665-9150, 0.9 miles

**Laurel** *French* $$ (R!) (BYOB)
1617 E. Passyunk Avenue, 215-271-8299, 1.7 miles

**Parc** *French* $$ (RR)
227 S. 18th Street, 215-545-2262, 0.9 miles

**Bibou** *French* $$ (RR) (BYOB)
1009 S. 8th Street, 215-965-8290, 1.4 miles

**Townsend** *French* $$$ (RR)
1623 E. Passyunk Avenue, 267-639-3203, 1.7 miles

**Estia** *Greek* $$$$ (RR)
1405 Locust Street, 215-735-7700, 0.6 miles

**Opa** *Greek* $$ (RR)
1311 Sansom Street, 215-545-0170, 0.3 miles

**Monk's Café** *Belgian Gastropub* $$
264 S. 16th Street, 215-545-7005, 0.8 miles

**Dandelion** *English Gastropub* $$ (RR)
124 S. 18th Street, 215-558-2500, 0.7 miles

**Abe Fisher** *Jewish* $$$ (RR)
1623 Sansom Street, 215-867-0088, 0.6 miles

## LATIN

**El Vez** *Mexican* $$ (RR)
121 S. 13th Street, 215-928-9800, 0.3 miles

**Lolita** *Mexican* $$$ (RR)
106 S. 13th Street, 215-546-7100, 0.3 miles

**Alma De Cuba** *Cuban* $$$ (RR)
1623 Walnut Street, 215-988-1799, 0.7 miles

## MEDITERRANEAN

**Barbuzzo** $$$ (RR)
110 S. 13th Street, 215-546-9300, 0.3 miles

**Zahav** *Israeli* $$$ (R!)
237 St. James Place, 215-625-8800, 1.2 miles

## AMERICAN

**Vernick Food & Drink** $$$ (R!)
2031 Walnut Street, 267-639-6644, 1 mile

**Serpico** $$$ (RR)
604 South Street, 215-925-3001, 1.2 miles

**Hungry Pigeon** $$ (R!)
743 S. 4th Street, 215-278-2736, 1.6 miles

**Fork** $$$ (RR)
306 Market Street, 215-625-9425, 0.9 miles

**High Street on Market** $$ (RR)
308 Market Street, 215-625-0988, 0.9 miles

**Russet** $$$ (RR) (BYOB)
1521 Spruce Street, 215-546-1521, 0.7 miles

**Talulah's Garden** $$$ (RR)
210 W. Washington Square, 215-592-7787, 0.8 miles

**Bud & Marilyn's** $$ (RR)
1234 Locust Street, 215-546-2220, 0.4 miles

**Volver** $$$ (RR)
300 S. Broad Street, 215-670-2303, 0.6 miles

**Barclay Prime** *Steakhouse* $$$$ (RR)
237 S. 18th Street, 215-732-7560, 0.9 miles

**Butcher & Singer** *Steakhouse* $$$$ (RR)
1500 Walnut Street, 215-732-4444, 0.5 miles

**Little Fish** *Seafood* $$$ (RR) (BYOB)
746 S. 6th Street, 267-455-0172, 1.3 miles

## VEGETARIAN

**Vedge** $$$ (R!)
1221 Locust Street, 215-320-7500, 0.5 miles

**V Street** $$ (RR)
126 S. 19th Street, 215-278-7943, 0.8 miles

## FAMOUS CHEESESTEAK ESTABLISHMENTS

**Jim's Steaks South Street** 400 South Street, 1.4 miles

**Pat's King of Steaks** 1237 E. Passyunk Ave, 1.6 miles

**Geno's Steaks** 1219 S. 9th Street, 1.6 miles

## OUTDOOR BEER GARDENS & ROOFTOP LOUNGES

**Independence Beer Garden** 100 S. Independence Mall West
*Steps from the Liberty Bell, 0.7 miles*

**Spruce Street Harbor Park** Columbus Blvd & Spruce Street
*Riverfront, Hammocks, Food Trucks, 1.4 miles*

**Assembly Rooftop Lounge** 1840 Benjamin Franklin Parkway
*Atop the Logan Hotel, Panoramic city views, 0.7 miles*

**SkyGarten at Three Logan** 1717 Arch Street
*51st story views, 0.6 miles*

**Dilworth Park Café & Air Grille** 1 S. 15th Street
*Pop-up outside City Hall, 0.3 miles*

**Morgan's Pier** 221 N. Columbus Boulevard
*Riverfront, Views of Ben Franklin Bridge, 1.4 miles*

**The Deck at the Moshulu** 401 S. Columbus Boulevard
*Floating deck, Incredible views of city & river, 1.6 miles*

**Uptown Beer Garden** 1735 Market Street
*Pop-up outside the BNY Mellon building, 0.6 miles*

KEY: (R!) Reservations ASAP (RR) Reservations Recommended (BYOB) BYOB

# Opening Ceremonies Agenda

**Wednesday, September 6, 2017**
Philadelphia Marriott Downtown, Ballroom - Salon A-F

| | |
|---|---|
| 18:00 - 18:05 | **Welcome to Philadelphia**<br>*2017 Local Host Committee* |
| 18:05 - 18:10 | **Presidential Welcome**<br>*Kenneth MC Cheung, MD* |
| 18:10 - 18:20 | **Introduction of Visiting Presidents**<br>**Introduction of SRS Traveling Fellows**<br>**Introduction of Fellowship and Award Recipients**<br>*Kenneth MC Cheung, MD* |
| 18:20 - 18:25 | **Presentation of Blount Humanitarian Award**<br>*Introduction by Kenneth MC Cheung, MD, President*<br>*Presentation by Jeffrey S. Kanel, MD, Awards & Scholarships Committee Chair* |
| 18:25 - 18:35 | **Acknowledgement of Corporate Supporters**<br>*Introduction by Kenneth MC Cheung, MD, President*<br>*Presentation by David W. Polly, Jr., MD, Past President & Corporate Relations Committee Chair* |
| 18:35 - 18:40 | **Introduction of Howard Steel Lecturer**<br>*Todd J. Albert, MD* |
| 18:40 - 19:10 | **Howard Steel Lecture**<br>*Michael Smerconish* |
| 19:10 - 19:15 | **Closing Remarks**<br>*Kenneth MC Cheung, MD, President* |

**Please join us for the Welcome Reception, immediately following the Opening Ceremonies.**

19:15 - 21:00

*The Welcome Reception is supported, in part, by grants from Medtronic, NuVasive, and Zimmer Biomet*

# Notes

# Notes

## Notes

# CONFLICT OF INTEREST DISCLOSURES

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges K2M for their support of the Annual Meeting & Course Pocket Guide and Directional Signage.

# Conflict of Interest Disclosures

| | | |
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**If noted, the Relationship disclosed are as follows:**

(a) Grants/ Research Support (b) Consultant (c) Stock/ Shareholder (self-managed) (d) Speaker's Bureau (e) Advisory Board or Panel (f) Salary, Contractual Services (g) Other Financial Or Material Support (royalties, patents, etc.)

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SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges NuVasive, Medtronic, and Orthofix for their support of the Pre-Meeting Course.

# A Multidisciplinary Approach to Global Spine Care

Course Chair:
Praveen V. Mummaneni, MD

Co-Chairs:
John R. Dimar, II, MD and Suken A. Shah, MD

Wednesday, September 6, 2017

8:00 – 16:30

Philadelphia, USA

Sponsored by the Scoliosis Research Society

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**Scoliosis Research Society • Pre-Meeting Course**

Wednesday, September 6, 2017
8:00 – 16:30
Philadelphia Marriott Downtown
Philadelphia, Pennsylvania, USA

**Chair:** Praveen Mummaneni, MD

**Co-Chairs:**
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**Course Objectives and Outcomes**
As a result of participating in this activity, participants should be able to:

- **Describe the multidisciplinary preoperative workup for spinal deformity patients with coexisting medical comorbidities.**
- **Describe the current options for neuromonitoring and advantages and disadvantages of each.**
- **Describe the management strategies for intraoperative acute blood loss anemia in the pediatric patient.**
- **Describe potential postoperative complications of surgical treatment of spinal deformity as well as complication management strategies.**

**Target Audience**
Presentations at SRS Annual Meeting & Course will have value for physicians and allied health personnel who treat spinal deformities at all levels and in all ages of patients. Medical students, residents, fellows and researchers with an interest in spinal deformities will also benefit from the materials presented.

**Continuing Medical Education (CME) Accreditation**
This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for

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SRS designates this live activity for a maximum of *7.5 AMA PRA category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

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# Pre-Meeting Course Program

*The 2017 Pre-Meeting Course is supported by grants from Medtronic, NuVasive, and Orthofix.*

## LUNCHTIME SESSIONS

The following symposia will take place during the lunch hour:

### Developing Your Academic Footprint

Session focusing on the education of both young and more experienced researchers on how to produce better quality studies and scientific works.

Room: Ballroom - Salon GKL

| **Chairs: Olavo B. Letaif, MD, MSc & David W. Polly, Jr., MD** | | |
|---|---|---|
| **Time** | **Title** | **Speaker** |
| 12:35-12:43 | Starting a Deformity Study: 1. Asking a Good Research Question. 2. Collecting Outcomes Data | Steven D. Glassman, MD |
| 12:43-12:50 | Researching Tools: Internet/Database Searches, Tools for Radiographic Analysis, Helpful Software | Charla R. Fischer, MD |
| 12:50-12:58 | Assembling the Researching Environment: 1. Researching Team. 2. Study Groups. 3. Institutional Facilities | Leah Y. Carreon, MD, MSc |
| 12:58-13:06 | Organizing the Data, the Protocols and the Follow Up | A. Noelle Larson, MD |
| 13:06-13:13 | Choosing the Appropriate Journal or Meeting for Your Paper | Paul D. Sponseller, MD, MBA |
| 13:13-13:20 | Reviewer Perspective of the Most Common Mistakes and Flaws in a Paper | Ferran Pellisé, MD, PhD |
| 13:20-13:27 | Pearls and Tips to Write a Good Paper and Abstract | John E. Lonstein, MD |
| 13:27-13:35 | Closing remarks, Discussion, and Questions | Olavo Letaif, MD, MSc;<br>David W. Polly, Jr., MD |

### Intraspinal Anomalies and Spine Deformity

This symposium will focus on the management of spinal deformity patients who harbor an intraspinal anomaly. Through a case based approach, the topics covered will include those patients with Chiari malformation, tethered cord, and split cord malformation. We will also explore the role of spinal column shortening in these patients.

Room: Ballroom - Salon A-F

| **Chair: Amer F. Samdani, MD & Ahmet Alanay, MD** | | |
|---|---|---|
| **Time** | **Title** | **Speaker** |
| 12:35-12:40 | Welcome and Introduction | Amer F. Samdani, MD |
| 12:40-12:50 | Most Common Intraspinal Anomlies | Steven W. Hwang, MD |
| 12:50-13:00 | Chiari/Syrinx and Scoliosis: Management Strategies | Daniel J. Sucato, MD, MS |
| 13:00-13:10 | Split Cord Malformation: When to Remove Prior to Deformity Correction | Muharrem Yazici, MD |
| 13:10-13:20 | Severe Deformity and Intraspinal Anomaly: Role of VCR | Amer F. Samdani, MD |
| 13:20-13:35 | Panel Case Discussion | |

# Pre-Meeting Course Program

## Non-Operative Treatment of Adult Spinal Deformity

The symposium will focus on multidisciplinary evaluation and treatment of the symptomatic adult spinal deformity patient and will include an evidence based review of non-operative treatment options.

Room: Ballroom - Salon HIJ

| **Chair: Richard Hostin, Jr., MD & Frank J. Schwab, MD** | | |
|---|---|---|
| **Time** | **Title** | **Speaker** |
| 12:35-12:45 | Where Does the Literature Stand on Non-operative Treatment Modalities of Adult Spinal Deformity in 2017? | Richard Hostin, Jr., MD |
| 12:45-12:55 | Review of Recent Multicenter Non-operative Data from Prospective Multi-center Database / Where is Future Research Headed? | Frank J. Schwab, MD |
| 12:55-13:05 | Physical Therapy Evaluation and Treatment Options for the Adult Spinal Deformity Patient | Pamela R. Morrison, MS, PT, BS, DHS |
| 13:05-13:15 | Interventional and Non-interventional Pain Management Options for the Adult Spinal Deformity Patient | Allen S. Chen, MD, MPH |
| 13:15-13:35 | Case Panel and Discussion | Richard Hostin, Jr., MD |

# Pre-Meeting Course Program

## A Multidisciplinary Approach to Global Spine Care

Wednesday, September 6, 2017
Chair: Praveen Mummaneni, MD
Co-Chairs: John R. Dimar, II, MD and Suken A. Shah, MD
8:00 – 16:30
Room: Ballroom - Salon A-F

| **Session 1: Pre-Op** | | |
|---|---|---|
| **Moderators: John R. Dimar, II, MD & Praveen V. Mummaneni, MD** | | |
| **Time: 8:00 – 10:16** | **Title** | **Speaker** |
| 8:00 – 8:05 | Introduction to the Pre-Meeting Course | Kenneth MC Cheung, MD |
| 8:05-8:12 | Protocol for Preoperative Medical Clearance | Geno Merli, MD |
| 8:12-8:19 | Pediatric Pulmonary Pitfalls and Prevention of Pulmonary Complications in Pediatric Deformity Surgery | Aaron C. Chidekel, MD |
| 8:19-8:26 | Identifying Adults Who Need Pulmonary Clearance | Gregory Kane, MD |
| 8:26-8:33 | The Critical Need For Obesity & Diabetic Management Preoperatively | John R. Dimar, II, MD |
| 8:33-8:43 | Discussion | |
| 8:43-8:50 | Pediatric Patients with Bone Quality Issues & How to Correct the Problem | Michael To, FRCSEd (Ortho), FHKC |
| 8:50-8:57 | Optimization of Bone Health in Adult Patients in Preparation for Surgery | Joseph M. Lane, MD |
| 8:57-9:04 | Potential Hematological Problems and Planning for Blood Loss in Complex Spinal Deformity Surgery (Multidisciplinary Preop Optimization) | Rajiv K. Sethi, MD |
| 9:04-9:11 | Why Anesthesia Clearance is Critical Preoperatively for Complex Adult Spinal Deformity: Stress Dose Steroids, Protocol for Narcotic Usage (Lidocaine Drips) | Bhiken I. Naik, MBBCh, MD |
| 9:11-9:21 | Discussion | |
| 9:21-9:28 | Assessment & Management of Nutritional Status to Maximize Surgical Outcomes in Complex Spinal Surgery | Munish C. Gupta, MD |
| 9:28-9:35 | Preoperative Planning for Instrumentation Application in Deformity Surgery for Children | Suken A. Shah, MD |
| 9:35-9:42 | Preoperative Planning for Instrumentation Application in Deformity Surgery for Adults | Sigurd H. Berven, MD |
| 9:42-9:49 | Assembling Superior Team to Minimize Complications and Maximize Surgical Outcomes | Todd J. Albert, MD |
| 9:49-10:00 | Discussion | |
| 10:00-10:16 | Break | |

| Session 2: Intra-Op | | |
|---|---|---|
| **Moderators: Christopher I. Shaffrey, MD & Suken A. Shah, MD** | | |
| **Time: 10:16-12:20** | **Title** | **Speaker** |
| 10:16-10:24 | Techniques for Reducing Intra-Operative Blood Loss in Pediatric & Adult Deformity | Burt Yaszay, MD |
| 10:24-10:32 | Neuromonitoring Alert: Stepwise Management of Lost Signals…Now What? | Praveen V. Mummaneni, MD |
| 10:32-10:40 | Surgical Site Infection (SSI) Algorithm to Avoid A Never Event | James S. Harrop, MD |
| 10:40-10:48 | Management of a Catastrophic Intra-Operative Events: The WHO Standard of Care in Handling these Events | Lawrence G. Lenke, MD |
| 10:48-10:56 | Alternative Strategies of Instrumentation: Know the Full Array of Spinal Fixation & Fusion Techniques When All Else Fails | Christopher I. Shaffrey, MD |
| 10:56-11:06 | Discussion | |
| 11:06-11:28 | Case Presentation Pairing 2 Cases of How the Use of Checklists Can Prevent Intra-Operative Complications: Pediatric and Adult | Moderator: Suken A. Shah, MD<br>Panel: Douglas C. Burton, MD; Amer F. Samdani, MD; Jason W. Savage, MD; Lindsay M. Andras, MD |
| 11:29-11:51 | Case Presentation Pairing 2 Cases of Neuromonitoring Alerts: Pediatric and Adult | Moderator: Juan S. Uribe, MD<br>Panel: Paul Park, MD; Burt Yaszay, MD; Isaac O. Karikari, MD |
| 11:52-12:14 | Case Presentation Pairing 2 Case of Asystole: How to Do Effective Crisis Management To Achieve Successful Resuscitation | Moderator: Kit Song, MD, MHA<br>Panel: Michael D. Daubs, MD; Marco Braydo-Bruno, MD; Scott S. Russo, Jr., MD |
| 12:14-12:20 | Discussion | |

| | | |
|---|---|---|
| 12:20- 13:45 | Lunchtime Symposia 12:35-13:35 | 1 hour plus 15 min pass time before and 10 min after |

# Pre-Meeting Course Program

| Session 3: Post-Op | | |
|---|---|---|
| **Moderators: Charles H. Crawford, III, MD & Marinus De Kleuver, MD, PhD** | | |
| **Time: 13:45-16:30** | **Title** | **Speaker** |
| 13:45-13:53 | How to Prevent & Treat Cardiopulmonary Failure Following Surgery | Frances Mae West, MD |
| 13:53-14:01 | The Threshold for Treatment of Post-Operative Anemia and Coagulopathies | Ronald A. Lehman, Jr., MD |
| 14:01-14:09 | Early Identification & Management of Post-Op Infections: Short & Long Term Ramifications | Michael P. Glotzbecker, MD |
| 14:09-14:17 | Acute Post-Operative Renal Failure: Prevention, Identification and Treatment | Michael P. Kelly, MD, MSc |
| 14:17-14:27 | Discussion | |
| 14:27-14:35 | Post-Op Pain: In Today's Climate When is it Necessary to Involve a Pain Management Specialist? | Bhiken I. Naik, MBBCh, MD |
| 14:35-14:43 | Proximal Junctional Kyphosis: Prevention and Management | David W. Polly, Jr., MD |
| 14:43-14:51 | Enhanced Recovery After Surgery (ERAS) | Benny T. Dahl, MD, PhD, DMSci |
| 14:51-14:59 | Rapid Recovery Pathway for Adolescent Idiopathic Scoliosis | Peter O. Newton, MD |
| 14:59-15:07 | Making the Best Use of Inpatient Management Trends: Safely Minimizing Hospital Stay Following Surgery | Alexander R. Vaccaro, MD, PhD, MBA |
| 15:07-15:17 | Discussion | |
| 15:17-15:32 | Break | |
| 15:32-15:50 | Case Presentation Series Early Instrumentation Failure: How Poor Planning Leads to Unforeseen Complications – Pediatric & Adult Cases | Moderator: Ian J. Harding, BA, FRCS (Orth)<br>Panel: Morio Matsumoto, MD; Yan Wang, MD; Robert H. Cho, MD |
| 15:50-16:05 | Case Presentation Series How a Missed Post-Operative Complication Can Lead to Cascading Consequences: Pediatric & Adult Cases | Moderator: Mark Weidenbaum, MD<br>Panel: Richard H. Gross, MD; Paul T. Rubery, Jr., MD; Frank J. Schwab, MD |
| 16:05-16:25 | Case Presentation Series Nothing Trumps Good Results Better Than Long Term Follow-up (Delayed Complications – PJK and Pseudarthrosis) | Moderator: Shay Bess, MD<br>Panel: J. Abbott Byrd, MD; Frank La Marca, MD; Kariman Abelin Genevois, MD, PhD |
| 16:25-16:30 | Discussion | |
| 16:30 | Adjourn | |

# Pre-Op

Room: Ballroom - Salon A-F

Moderators:
John R. Dimar, II, MD & Praveen V. Mummaneni, MD

Faculty:
Todd J. Albert, MD; Sigurd H. Berven, MD; Kenneth MC Cheung, MD; Aaron C. Chidekel, MD; Munish C. Gupta, MD; Gregory Kane MD; Joseph M. Lane, MD; Geno Merli MD; Bhiken I. Naik, MBBCh, MD; Rajiv K. Sethi, MD; Suken A. Shah, MD; Michael To, FRCSEd (Ortho), FHKC

## Protocol for Preoperative Medical Clearance

**Geno J Merli, MD, MACP, FSVM, FHM**
Philadelphia, Pennsylvania, USA

I. Cardiac Risk Assess prior to major spine surgery should focus on two risk assessment tools
   a. The Revised Cardiac Risk Index
      i. Rate of MI, PE, Ventricular Fibrillation, Cardiac Arrest, Complete Heart Block
   b. The Gupta Cardiac Index
      i. Estimated Perioperative risk for Myocardial Infarction or Cardiac Arrest
II. Pulmonary Risk Assessment prior to surgery in a patient with COPD
   a. Arozullah Postop Pneumonia Index
   b. Arozullah Postop Respiratory Failure Index
   c. ICOUGH Program to reduce postoperative pulmonary complications
III. Preoperative Risk Assessment for Deep Vein Thrombosis and Pulmonary Embolism
   a. American College of Chest Physicians VTE risk assessment tool
   b. Caprini VTE Risk Index
   c. Recommendation of VTE Prophylaxis in Spine Surgery

## Role of the pediatric pulmonologist in the management of complex scoliosis surgery

**Aaron Chidekel, MD**
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Scoliosis surgery represents a major stress on the respiratory system and results in alterations of respiratory function and airway mechanics that are incompletely understood. In the best of circumstance, acute worsening of respiratory status in the peri-operative period with gradual recovery and stabilization is what is expected. Assessing and addressing common and predictable respiratory pitfalls will help to ensure the smoothest transition possible through the stages of scoliosis repair from pre-operative planning and conditioning to post-operative management and recovery.

**Themes:**
- Collaboration
- Adequate time to identify and address common co-morbidities
- Adequate time to prepare the patient for surgery
- Avoid surprises and pitfalls in the peri-operative period
- Recognize and manage unexpected short and long-term complications

**Rationale:**
- Pre-operative identification and management of common problems can impact:
- Pre-operative problem list
- Post-operative morbidity
- Pre-planning for any additional medications or durable medical equipment
- Length of stay
- Long-term outcomes

**Pre-operative assessment:**
- *Upper Airway:*
  - Anatomy and function
  - Noisy breathing
  - Secretion management
  - Obstructive sleep apnea-hypopnea syndrome
- *Lower Airway:*
  - Noisy breathing
  - Asthma syndrome
  - Chronic cough
  - Recurrent wheeze
- *Lung parenchyma:*
  - Pneumonia
  - Atelectasis
  - Scarring/bronchiectasis
- *Control of breathing:*
  - Central sleep apnea
  - Hypoventilation
  - Identifiable Syndromes and CNS co-morbidities:
    - Prader-Willi Syndrome
    - Rett Syndrome
    - Congenital myopathies
  - Unexpected!

**Specific clinical assessments:**
- *Upper airway:*
  - Clinical examination
  - Polysomnography
  - Radiography
  - Rarely bronchoscopy
- *Lower airway:*
  - Clinical assessment
  - Pulmonary function testing (when able)
  - Rarely bronchoscopy
- *Lung parenchyma:*
  - Imaging (CT scan often most useful)
  - Gas exchange (during wakefulness and sleep)
  - Rarely bronchoscopy
- *Control of breathing:*
  - Challenge testing
  - Polysomnography

**Pre-operative readiness:**
- *General considerations:*
  - Nutritional status optimized
  - Safe feeding plan
  - Vaccine status
- *Pulmonary considerations:*
  - Patient is at baseline status
  - No active or recent respiratory tract infection
  - Any chronic symptoms or conditions are controlled

**Post-operative considerations:**

- *Upper airway:*
  - Optimize airway patency
  - Ventilation
  - Non-Invasive Positive Pressure Ventilation (NIPPV)
  - Oxygen therapy
- *Lower airway:*
  - Inhaled Airway medications:
    - Bronchodilators
    - Mucus hydrators
    - Anti-Inflammatories
- *Lung parenchyma:*
  - Airway medications
  - Airway clearance
  - Antibiotics if indicated
- *Control of breathing:*
  - Ventilation (invasive or non-invasive)
  - Oxygen
  - Daytime and nighttime need independent assessments

Sedatives, analgesics and muscle relaxants impact all aspects of the respiratory system!

**Selected examples of therapeutic interventions:**

- *NIPPV:*
  - (BLPAP)
  - Challenging interface
  - Maintain airway patency and ventilation
  - Maintain lung volumes
- *High-flow nasal cannula:*
  - Hybrid therapy for airway support and oxygenation
- *Mechanical insufflation-exsufflation:*
  - (Cough-assist)
  - Challenging interface
  - Maintain lung volumes
  - Clear secretions

Chest wall oscillation, percussion and postural drainage can be challenging given the surgical considerations

**Discharge planning:**

- *Adequate airway and ventilatory status:*
  - During wakefulness and during sleep
- *Address any durable medical equipment needs:*
  - Oxygen
  - Suction
  - Clinical monitoring
  - Airway clearance devices
  - Airway medications
- *Medical follow-up as indicated*

Complex needs often require a team approach to discharge planning to avoid predictable delays in discharge due to medication, equipment or staffing issues.

**A word about evidence-based medicine:**

- *Over-arching clinical trial evidence is unavailable*
- *Identification and treatment of obstructive sleep apnea is supported by evidence*
- *Airway clearance devices are well studied and efficacious in numerous populations*

**Final thoughts:**

- *Including a Pediatric Pulmonologist in the peri-operative management of complex spinal surgery patients is important to avoid predictable problems*
- *Identification and management of common airway and lung problems in medically complex patients can improve surgical morbidity and outcomes and allow for more realistic peri-operative planning*
- *Specific research is lacking, but applied clinical research and experience is abundant!*

## Preoperative Evaluation of Scoliosis: Identifying Adults Who Need Pulmonary Clearance

**Gregory C. Kane, MD**
The Jane and Leonard Korman Professor and Chairman, Department of Medicine
Sidney Kimmel Medical College
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**I. Introduction-Assessment Tools and Who is at Risk?**

A. Traditionally degree of scoliosis was used to determine degree of physiologic abnormality
B. Identifying patients with respiratory impairment is key pre-op to reduce post-op morbidity and mortality.
C.


D. Measures to Prevent Post-op Complications

**II. What causes the pulmonary effects of Severe Kyphoscoliosis**

A. Angle (Cobb Angle)
B. Location
C. Kyphosis
D. Flexibility

**III. How severe scoliosis affects Respiration**

A. Limits Capacity
B. Risk of Atelectasis
C. Trouble with Secretions
D. Respiratory Failure
E. Trouble Weaning

**IV. Superimposed Lung Disease**

A. How lung disease (separate) an worsen limitation form Scoliosis

B. We will discuss obstructive diseases such as asthma and restrictive diseases such as obesity or Spinal Muscular Atrophy (SMA)

**V. Guideline for Pre-op Respiratory Evaluation**

A. There are no applicable specific guidelines

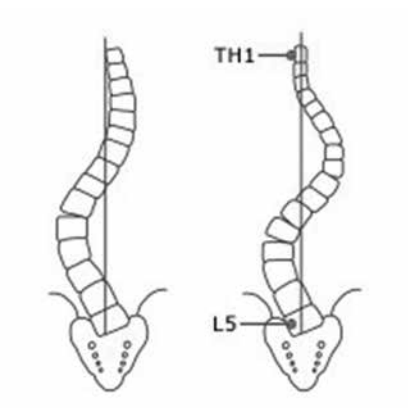
B. Full PFTs and baseline ABG suggested for consideration in Moderate to severe disease

**VI. Results of Preoperative Pulmonary Function Testing of Adolescents with Idiopathic Scoliosis: A Study of Six Hundred and Thirty-one Patients. (J Bone and Joint surgery)**

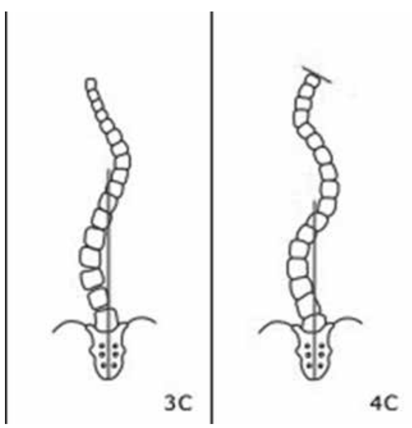
This study outlines the severity of PFT defects in patients based on Scoliosis. As the largest published data set and as such it is important to review. The key factors were

1. the angle of the Thoracic Curve,
2. the length of the Thoracic Curve, and
3. the effect of Thoracic Kyphosis.

A. King Classification for Severity of Scoliosis




B. Lenke Classification




C. Does Anesthesia Matter?
Broadly speaking, general anesthesia carries a greater risk of pulmonary complications post-operatively.

**VII. Pre-op Risk Assessment Models.**

There are a variety of models (3) to consider. However, these models from general surgery dot adequately address the unique needs of the scoliosis population. However, they are important to be aware of as they include up to 200,000 patients in their databases.

**VIII. What about Obesity?**

The effect of Obesity is hard to quantify but the main risk appears to be the risk of post-op sleep apnea.

**IX. Approaches to Decreasing Pre-op Risk?7 (Utrecht)**

A. Intensive Inspiratory Muscle Training (Hulzebos EH, PT MSc, et al JAMA2006; 296:1851-5

B. Smoking Cessation (Moller, et al, Lancet 2002)

**X. Approaches to Decreasing Post Op Risks?**

A. General Measures (Stein and Cassara, *JAMA*, 1970; Nelson etal. Br J Surg 2005; 92673-80.)

1. Early mobization
2. Cough and deep breathing
3. Chest Physiotherapy

These two publications focus on basic post-op care including early mobilization, cough and deep breathing, and chest physiotherapy. These simple measures greatly reduce post-op risks.

**References:**

Annals Intern Med 2006; 144:575-580

Results of Preoperative Pulmonary Function Testing of Adolescents with Idiopathic Scoliosis: A Study of Six Hundred and Thirty-one Patients.

**Newton, Peter; Faro, Frances; Gollogly, Sohrab; Betz, Randal; Lenke, Lawrence; Lowe, Thomas**

Journal of Bone & Joint Surgery - American Volume. 87(9):1937-1946, September 2005. DOI: 10.2106/JBJS.D.02209

Rodgers, BMJ, 2000.

Blouw, et al. AANA J 2003; 71: 45-50.

Hulzebos EH, PT MSc, et al JAMA2006; 296:1851-57

Moller, et al, Lancet 2002

Stein and Cassara, JAMA, 1970

Nelson etal. Br J Surg 2005; 92673-80.

Stein and Cassara, JAMA, 1970

Nelson etal. Br J Surg 2005; 92673-80.

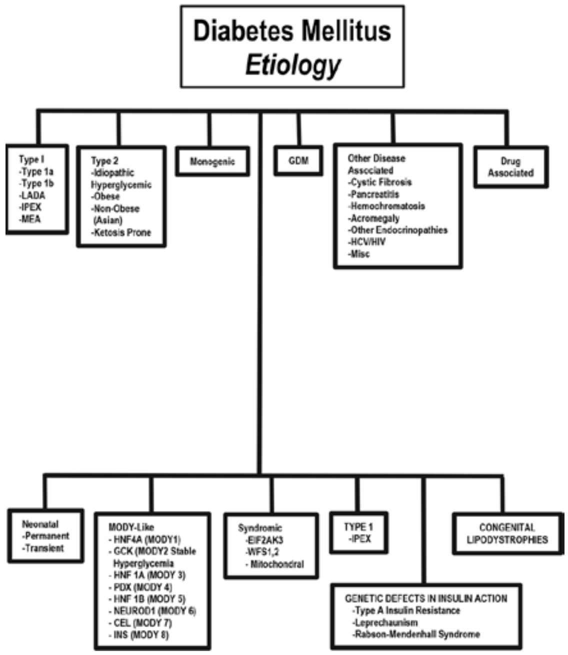
## The Critical Need for Obesity & Diabetic Management Preoperatively

### Diabetes Mellitus in Surgery

**Dr. John R. Dimar II, MD**
Norton Leatherman Spine Center
Louisville, Kentucky, USA

**Dr. John Fleming, MD**
Leatherman Spine Institute
Louisville, Kentucky, USA

1. DM Present in 5-20% patient's undergoing spine surgery1
2. DM is known risk factor for complications in multiple other surgeries1
3. Large multicenter studies have investigated DM effect on spine surgery
   a. Effect on clinical outcomes2-4
   b. Effect on Complication Profile5-10
   c. Reoperation rate1
4. Etiologies are Extensive [11]:




1. Diabetes Is Related to Worse Patient-Reported Outcomes at Two Years Following Spine Surgery Sheyan J Armaghani, MD
Findings:

- Prospective cohort of 1005 patient (Level II) at 2 year follow-up. DM pts had
  - Lower SF-12 Physical (34.4 vs 38.6)
  - Lower FQ-5D (0.67 vs. 0.74)
  - Higher ODI or NDI (32.1 vs 26.8) and
  - Higher NRS (5.1 vs 4.3), Significant ($p<0.5$) but small effect. In Cohort, DM and prior opioid use both independent predictors of poorer outcomes

*Diabetes Patients did Improved From Baseline, But Less Than Non-diabetic Patients.*

2. Characteristics of Diabetes Associated with Poor Improvements in Clinical Outcomes after Lumbar Spine Surgery Shinji Takahashi, MD
Findings:

- Retrospective Review of 165 Japanese patients, study evaluated what characterizes of DM associated with poorer outcomes
  - VAS for LBP higher in DM pts (29.3 vs 17.9, $P<0.02$)
  - HgbA1C >6.5% increased OR for postoperative poor improvement LBP only (OR=2.37)
  - DM for 20 or more years had increased OR for poor improvement LBP (OR =4.95), and leg numbness (OR=2.8)
  - Insulin use had higher OR for poor improvement leg numbness only (OR=4.49)

*Long Standing DM, Insulin Use, Hgb A1c > 6.5% Possibly Associated with Poorer Improvement*

3. The Impact of Diabetes on the Outcomes of Surgical and Nonsurgical Treatment of Patients in the Spine Patient Outcomes Research Trial Mitchell K. Freedman, MD

- Secondary retrospective analysis of prospectively collected data in SPORT, 2405 Enrolled patients, DM cohort of 199 Patients. Compared functional improvement for pts with intervertebral disc herniation (IDH), Spinal Stenosis (SpS), and degenerative spondylolisthesis (DS) after surgery for DM vs. non-DM pts
  - Primary outcome measure were ODI and SF-36
  - Patients with DM were significantly older, and higher BMI and more Co-morbidities
  - Diabetic Patients with HNP had no significant improvement with surgery
  - Patients with Spinal Stenosis and Degenerative Spondylolisthesis who had surgery obtained significantly greater improvement than those who had non-operative treatment
  - Diabetic patients had more blood loss and complications

*Diabetic Patients with Spinal Stenosis and Degenerative Spondylolisthesis benefit from surgery but older patients with diabetes have more post-operative complications and those with herniated disc did not benefit from surgery*

4. Diabetes and Early Postoperative Outcomes Following Lumbar Fusion James A. Browne, MD

- Retrospective Cohort of nationwide database with 197.461 patients, including DM cohort of 11,000, examined early postoperative complications/outcomes. Bivariate analysis concluded DM had significantly higher ($p<0.001$)
  - Infection, Transfusion, Pneumonia, Mortality, Non-routine discharge (need for SNF, Home health care, treatment facility, or death)
  - However, multivariate regression analysis suggested
  - No difference in mortality
  - Infection, transfusion, and non-routine discharge remained significant ($p>0.002$)
  - Higher inflation adjusted total charges ($p>0.001$)

*Diabetic Patients Require More Transfusion, Have Higher Early Infection Rate, & Garner More Hospital Charges*

5. High Preoperative Hemoglobin A1c is a Risk Factor for Surgical Site infection After Posterior Thoracic and Lumbar Spinal Instrumentation Surgery Tomorhiro Hikata, MD

- Retrospective review of pts who underwent thoracic and lumbar PSF to examine risk factors for surgical site infection (SSI). 36 patients with DM and 309 without DM reviewed
  - DM patients had a 16.7% rate of SSI, compared to 3.2% in non-DM pts
  - In pts who developed SSI, pre-operative HgbA1c was higher (7.6%) as compared to those who did not (6.9%)
  - SSI developed in 35.3% of pts with HgbA1c > or equal to 7.0% and in 0% of patients with HgbA1c < 7.0%

*Pre-operative HgbA1c of < 7.0% is recommended prior to surgery for DM pts to prevent SSI*

6. Complication Rates Following Elective Lumbar Fusion in Patients with Diabetes: Insulin Dependence Makes the Difference Nicholas S Golinvaux, MD

- Retrospective Cohort of 15,480 pts who underwent Lumbar Fusion, including 1,650 pts with NIDDM and 787 pts with IDDM, examined for RR of postoperative complications.

- NIDDM associated with increased risk wound dehiscence (RR = 2.3, P=0.033) and increased LOS (RR= 1.2, p=0.003)
- IDDM associated with risk of death (RR =2.7), Sepsis (RR=2.2), Unplanned intubation (RR =2.8), wound infection (RR = 1.9), UTI (RR=1.6) PNA (RR =3.1), Extended LOS (RR=1.5), and Readmission in 30 days (RR = 1.5)

*Comparing Type I (IDDM) to Type II (NIDDM), Complications are More Prevalent & of Greater Severity with IDDM. NIDDM Along With a Greater Risk of Wound Complications, Increased LOS When Compared to Non-diabetic Patients*

7. Perioperative Complications of Lumbar Instrumentation & Fusion in Patients with Diabetes Mellitus Steven D. Glassman, MD

- Retrospective Case-Control study of 94 DM pts and 43 controls followed after instrumented lumbar fusion to assess complication profile
  - Increased complication rate in NIDDM (53%) and IDDM (56%) vs. Control (21%)
  - Increased major complications consisted mostly of wound infection, nerve root lesion, and increased blood loss
  - Increased minor complications included UTI, urinary retention, ileus, AMS.
  - Nonunion rate was greater in NIDDM (22%) and IDDM (26%) than control (5%)

*Patients with Diabetes had a Greater Complication and Non-union Rate than Those without Diabetes after an Instrumented PSF*

8. Diabetes Associated with Increased Surgical Site Infections in Spinal Arthrodesis Sam Chen, MD

- Retrospective Review of 195 pts who underwent PSF, including 30 with DM and 165 without, to determine rate of SSI
  - Adjusted for, and studied known SSI risk factors including Age, smoking, BMI, ASA class, Surgical time, allograft use, EBL, and drain use
  - Adjusted RR for SSI if Diabetic was 4.1 (95% CI =1.37-12.32)
  - SSI rate in DM pts of 30%, all were deep
  - SSI rate in non-DM pts of 11%, 17/18 were deep
  - Only EBL was found as other significant independent factor for SSI (RR=1.6)

*Diabetes is a Significant Risk Factor for SSI % & a Completer Discussion Should be Included in the Pre-Operative Counseling Session*

9. Comparison of Spinal Deformity Surgery in Patients With Non–Insulin-Dependent Whojin Cho, MD

- Diabetes Mellitus (NIDDM) Versus Controls Retrospective Review of pts after Spinal Deformity Surgery, 23 pts with DM and 23 without.
  - No significant difference in major (p=0.33) minor (p=0.07) complications between cohorts
  - No difference Scoliosis Research Society (SRS) or ODI Scores
  - All outcomes improved postoperative for DM pts except for mental health (p=0.21) and pain (p=0.07) domains

*For Surgery in patients with Adult Spinal Deformity, There was No Difference in Complications or Additional Surgeries for Diabetes Patients*

10. The Relationship between Diabetes and the Reoperation Rate after Lumbar Spinal Surgery: A Nationwide Cohort Study Chi Heon Kim, MD

- Retrospective Cohort Study from national health insurance database in South Korea. Studied reoperation rate of 34,918 patients who underwent lumbar spinal surgery (fusion or decompression)
  - Incidence of DM was 24.5% in fusion group and 16.9% in decompression group
  - Overall reoperation rate all patients was 13.2% in fusion group and 14.0% in decompression group
  - After fusion, cumulative reoperation rate at 6 years was 12.7% in controls vs. 14.5% in DM pts (p=0.59), no significance
  - However, after decompression, cumulative reoperation rate at 6 years was 13.4% in controls vs. 16.9% in DM pts (p=0.01, HR 1.21 with 95% CI 1.08-1.35); Significant at all time points after 3 months post op

*Positive Relationship between Pre-operative Diabetes and Reoperation in Decompression Surgeries, But Not Fusion Surgeries.*

**Summary of Diabetes Risks in Surgery**

1. Overall Increase in Post-operative Complications
2. Increased SSIs
3. Increased Hospital Stay & Costs
4. Diabetes Increases Risks of Reoperation
5. Diabetics Have Frequent Co-morbidities Including HPT, Obesity, Kidney Disease, ASHD, Peripheral Neuropathy, Hyperlipidemia Which Should be Addressed Pre-operatively
6. Precise Control of Glucose Levels & Hgb A1c , 7.0% Mandatory Prior to Elective Surgery & Specialty Care during Hospitalization
7. Precise Post-op Glucose Control is Important Postoperatively to Prevent an SSI
8. Special Operative Measures to Decrease Complications Required: 2 Surgeons, Cell Salvage, TXA, Vancomycin, Iodopovidone Irrigation, Drains etc.
9. Events Such as SSI & Readmission are reported to Medicare & Propublica

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**Obesity in Spine Surgery**

1. 37% of American patients are obese and 34% are overweight
2. Obesity is known risk factor for complications during spine surgery
3. Large multicenter studies have investigated obesity's effect on spine surgery
   d. Effect on clinical outcomes
   e. Effect on Complication Profile
4. Reoperation rates are increased in obese patients but long term outcomes are generally equal that of normal weight patients

| Surgical Site Infection Rates by WHO Obesity Classification[1] | | |
|---|---|---|
| BMI Index kg/m² | WHO Class | Surgical Site Infection Rate (No./Total No.) |
| 18.5 | Underweight | 20% (1/5) |
| 18.5 – 24.9 | Normal | 5% (2/44) |
| 25.0 – 29.9 | Overweight | 4% (2/46) |
| 30.0 – 39.9 | Obese | 16% (7/45) |
| ≥ 40 | Morbidly Obese | 33% (3/9) |
| [1] Weight Class Was Associated with SSI Rate (p=.031), Although no Statistically Significant Difference in SSI rate Was Observed Between Weight Classes | | |

1. Risk of Infection Following Posterior Instrumented Lumbar Fusion for Degenerative Spine Disease in 817 Consecutive Cases Kaisorn L. Chaichana, MD
Findings:

- 817 Lumbar Procedures
- 37 (4.5%) Developed Post-op Infections
- Factors That Independently Influenced a Post of SSI:
  - Age
  - Diabetes
  - Obesity
  - Previous Surgery
  - Increased Hospital Stay
- Majority Responded to Debridement & Only 8 (3%) Required HWR

*Age, DM, Obesity, Previous Surgery & Long Hospital Stays All Independently Increase Post-op Infections*

| Independent Risk Factors Associated With Increased SSIs in 817 Patients | | | |
|---|---|---|---|
| | RR | CI (95% Level) | P Values |
| Age | 1.004 | 1.001-1.009 | P=0.049 |
| Diabetes | 5.583 | 1.322-19.737 | P = 0.02 |
| Obesity | 6.216 | 1.832 – 9.338 | P = 0.005 |
| Previous Surgery | 2.994 | 1.263 – 9.346 | P = 0.009 |
| Length of Hospital Stay | 1.155 | 1.076 - 1.230 | P = 0.003 |

2. Fat Thickness as a Risk Factor for Infection in Lumbar Spine Surgery John J. Lee MD
Findings:

- BMI Moderately Predicts Sub Q Fat Thickness
- Fat Thickness Provides a More Precise Predictor of SSI
- Fat Thickness at L4: Every Millimeter = 6% Increase in Infection
- Each Increase in kg/m²: 1.59 mm Increase in SQ Fat Thickness
- Fat Thickness > 50mm Results in a 4X Greater Risk of Infection
- Surgical Retraction of Fat Results in Necrosis & Dead Space

*Sub Q Fat Thickness Is a Superior Indicator to BMI When*

*Assessing a Patient's Risk of SSI Preoperatively*

3. The Distribution of Body Mass as a Significant Risk Factor for Lumbar Spinal Fusion Postoperative Infections AI Metta MD
Findings:

- 298 Spine Surgery Patients Reviewed
- Risk Factors Reviewed: Levels, BMI, & Fat Thickness Measured
- 24/298 Patients Had SSIs = 8%
  - Number of Levels Significant (P = 0.0078)
  - Obesity (BMI > 30) Significant Risk Factor (P = 0.025)
  - Thickness of Sub Q Fat at L4 Significant (P = 0.035)
  - Skin to Laminar Distance Significant (P = 0.046)

*Distribution of Body Mass is More Predictive of SSI after Lumbar Spine Fusion Surgery (Thickness of the Sub Q Fat Layer & Skin-Laminar Distance*

| Independent Risk Factors Associated With Increased SSIs in 817 Patients |
|---|

| | RR | CI (95% Level) | P Values |
|---|---|---|---|
| Age | 1.004 | 1.001-1.009 | P=0.049 |
| Diabetes | 5.583 | 1.322-19.737 | P = 0.02 |
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| Previous Surgery | 2.994 | 1.263 – 9.346 | P = 0.009 |
| Length of Hospital Stay | 1.155 | 1.076 - 1.230 | P = 0.003 |

4. Outcomes & Revision Rate in Normal, Overweight, & Obese Patients 5 Years after Lumbar Fusion R. Kirk Owens II, MD
Findings:
- Propensity Matched Case Control Series of PSF
- All Had 5 Year ODI, Back/Leg Pain Scores, SF-36 Scores
- Minimum 5 Year Follow-up of 3 BMI Groups:
  - ≥ 20 – 25 kg/m²
  - ≥ 25 ≤ 30 kg/m²
  - ≥ 30-40 kg/m²
- Compared Outcomes & Revision Rates Between Groups

*Blood Loss, Op Time Greater in Obese Patients But the Outcomes Were Revision Rates Were Similar in All Three Groups. Obesity is Not a Contraindication to Surgery with Appropriate Surgical Indications*

5. Morbid Obesity & Lumbar Fusion in Patients Older Than 65 Years Varun Puvanesarajah MD
Findings:
- Retrospective Review of Medicare Data Base 2005-12
- 3 BMI Groups:
  - ≥ 20 – 25: 48,210 Non-obese Patients
  - ≥ 25 ≤ 30: 5534 Obese Patients
  - ≥ 40: 2594 Morbidly Obese Patients
- 90 Day Medical & Surgical Complication Rate
- Obese & Morbidly Obese Patients Have A Significantly Higher Odds of Experiencing One Major Complication
  - Wound Infection: OR 3.71
  - Dehiscence: OR 3.80
  - 30 Day Admissions Increased
  - Hospital Costs Increased $8000

*In a Medicare Population The Risk of Major Medical Complications Are Significantly Increased In Obese Patients: Including Wound Infections, LOS, Hospital Costs & 30 Day Readmissions. These Events are Reported to Medicare & Propublica*

6. Obese Class III Patients at Significantly Greater Risk of Multiple Complications after Lumbar Surgery: An Analysis of 10,387 Patients in the ACS NSQUIP Database Rafael A. Buerba, MD
Findings:
- ACS NSQIP Review of 10,387 Patients
- Primary Outcomes: 30 Day Post-surgical Complications
- Secondary Outcomes: Blood Transfusion OR time, LOS, Re-op
- WHO Obesity Classification Noted Above Used for Stratification of Pts
- Compared Outcomes & Revision Rates Between Groups

WHO Classification of Obesity NSQUIP Complication Stratification

| Complications | Obese I | Obese II | Obese III |
|---|---|---|---|
| UTI | X | | X |
| Wound Complications | | X | X |
| Pulmonary Complications | | | X |
| Increase OR Time | | | X |
| Increased Hospitalization | | | X |
| Multiple Complications* | | | X |

Substantial Increase in Multiple Complications in Patients With a BMI > 40 (WHO Class III) *P < 0.05

7. Obesity Is an Independent Risk Factor of Early Complications after Revision Surgery David C. Sing BS
Findings:
- ACS-NSQIP Review of 2538 Patients
- WHO Obesity Classification Noted Above Used for Patient Stratification
- Univariate Regression Done to Assess Predictive Value of Obesity Level & Baseline Risk Factors

*Obesity is Associated with HPT, DM, Pulmonary Disease & Elevated ASA Scores (3&4). Obesity is an Independent Risk Factor for Increased Early Post-op Complications & May Be Modifiable*

7. Is Obesity in Adolescent Idiopathic Scoliosis Associated with Larger Curves & Worse Surgical Outcomes? Ying LI, MD
Findings:
- 588 Patients
- 3 Groups:
  - Healthy Weight
  - Over Weight
  - Obese
- Overweight & Obese Patients Presented with Larger Curves:
  - Over Weight: 49.3° vs. 43.9° (P < 0.0001)
  - Obese: 50.3° vs 43.9° (P .< 0.001)
  - Both Had Higher Thoracic Kyphosis: 30.8° vs 25.7°
  - Obese Patients Trended Toward a Higher Complication Rate

*Obese AIS Patients Had Significantly Larger Curves at Presentation & Have Increased Surgical Times, Higher SSIs, & More Post-op Complications*

8. Critical Care of Obese Patients during & After Spine Surgery Hossein Elgafy, MD
Findings:
- Obesity is Correlated with HPT, ASHS, CHF, & Diabetes
- Intra-operative Problems:
  - Inadequate Radiographs
  - Difficult to Position & Decubiti
  - Difficult Intubation & Ventilation
- Post-operative Complications:
  - Greater Risk of Reintubation
  - Difficult Pain Control
  - Increased Wound Infections
  - Increased Thrombophlebitis & Pulmonary Embolus

*Obesity is Not a Contraindication for Spinal Surgery But Requires*

*Special Considerations during Pre-op, Intra-op & Post-op Management Since These Patients Have Many Co-morbidities & Complications*

8. The Effects of Obesity on Spine Surgery: A Systematic Review of the Literature Keith L Jackson II MD
Findings:
- Obese Patients Are an Increasing Patient Population
- Complication Rates are Higher
  - DVTs, Infection, & Increased Mortality
- Outcomes of Spine Surgery In Obese Patients is Controversial
  - Multiple Studies Show No Difference in Long Term Outcomes (SPORT STUDY)
  - Obese Patients Have Greater Treatment Effect in Stenosis & Deg. Spondylolisthesis
  - Obese Non-operative Patients Have Worse Outcomes Those Operated On

*Obese Patients Are Riskier to Operate On, Have More Complications, Have Higher Costs, but Long Term Studies Show Greater Surgical Treatment Effect in Obese Patients When Compared to Non-op Obese Patient*

**Sport Analysis of Outcomes for Lumbar Spondylolisthesis**

| Outcome | 1 Year | 4 Years |
|---|---|---|
| SF-36 Body Pain | | |
| BMI < 30 | 16.7 | 13.8 |
| BMI > 30 | 20.7 | 17.2 |
| P Value | 0.26 | 0.43 |
| SF-36 Physical Function | | |
| BMI < 30 | 16 | 14 |
| BMI > 30 | 20.7 | 25.6 |
| P Value | 0.17 | 0.004 |
| ODI | | |
| BMI < 30 | - 15.4 | - 12.6 |
| BMI > 30 | -19.6 | - 17.5 |
| P Value | 0.11 | 0.12 |

**Sport Analysis of Outcomes for Lumbar Stenosis**

| Outcome | 1 Year | 4 Years |
|---|---|---|
| SF-36 Body Pain | | |
| BMI < 30 | 14.6 | 12.6 |
| BMI > 30 | 17.2 | 15.9 |
| P Value | 0.47 | 0.44 |
| SF-36 Physical Function | | |
| BMI < 30 | 13.5 | 7.4 |
| BMI > 30 | 16.3 | 12.8 |
| P Value | 0.40 | 0.17 |
| ODI | | |
| BMI < 30 | - 10.1 | - 7.4 |
| BMI > 30 | -15.7 | - 13.9 |
| P Value | 0.036 | 0.037 |

Summary of Obesity Risks in Surgery
1. Obesity is Present in 34% patient's undergoing spine surgery
2. Obesity is known risk factor for complications in all spine surgeries
3. Numerous studies have investigated obesity's effect on spine surgery
4. Ultimate Outcomes show obese patients show improvement with spine Surgery especially when compared to similar obese patients treated non- Operatively
   a. Effect on clinical outcomes
   b. Obesity Increases Complication Profile
   c. Reoperation rate is higher
   d. Strongly Consider Pre-operative Weight Reduction & Avoid Surgery In Patients with Other Co-morbidities, Particularly Diabetes
5. These Events are Reported to Medicare & Propublica

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## Paediatric Patients with Bone Quality Issues & How to Correct the Problem


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**Overview of Bone Quality Issues**
Bone strength is determined by the bone quantity, quality and their turnover. In children, the causes leading to their disturbance can be numerous. They can be due to the disorders of bone mineral homeostasis, imbalance of bone remodeling, disorders of collagen and drug related issues affecting calcium absorption.

A multidisciplinary team involving paediatricians, endocrinologists, geneticists, and orthopaedic surgeons can help to provide a comprehensive treatment for these children. It is important to assess the patients thoroughly through history taking, physical examination, laboratory tests and radiological assessment to determine the underlying cause.

Some of the causes are amenable to treatment e.g. rickets can be better controlled by proper dietary and supplements together with regular monitoring. However, some of the causes e.g. osteogenesis imperfecta cannot be fully corrected. The bone quality can instead be improved by proper education for fracture prevention, pharmacological treatment, and surgical intervention.

**Osteogenesis imperfecta**
Osteogenesis imperfecta (OI) is an inheritable bone fragility disease classically known to be due to type I collagen abnormality. The type I collagen abnormality results in reduced bone strength. Depending on the severity of involvement, the severely affected patients may present with repeated fractures shortly after birth, short stature, and multiple deformities in the limbs and spine. The disease is classified by Sillence into 4 types according to their clinical presentation1. With better understanding of the disease in particular the genetic mutation2, the classification of OI has expanded to 16 types over the past decade3-5.

At the moment, there is no medical treatment that can correct the underlying abnormality in OI. However, by either (1) inhibiting the action of osteoclast to reduce the rate of bone resorption or (2) increase bone production by the osteoblasts can help to improve bone formation. There is a good evidence supporting the use of bisphosphonate to improve the bone mineral density in particular the severe form. However, whether bisphosphonate can reduce fracture rate remains inconsistent6.

Bisphosphonate is the most commonly used medication in OI to improve the bone mineral density7,8. Treatment can be started as soon as the baby is given birth and continue until skeletal maturity. Regular monitoring of the clinical response and the bone mineral density are important. The commonly used bisphosphonates include pamidronate and zoledronic acid9-12. Their effect in improving the bone mineral density is fairly similar.

**Scoliosis in OI**
Scoliosis is common in OI and the severity increases with age. The more severe the scoliosis, the more likely it would affect the lung function13. It is estimated that about 25% of the OI patients aged between 1-5 have scoliosis. The number rises to as high as 80% in the OI patients > 12 years of age14. Not all OI patients' scoliosis progress that same. It is recognized that the more severely affected patients will have higher rate of deterioration (Type I: 1 degree per year; Type III: 6 degrees per year and Type IV: 4 degrees per year)15. The use of bisphosphonate can greatly improve the deterioration rate in Type III patients15.

**Future Development**
With better understanding of the pathogenesis of osteogenesis imperfecta, new treatment approaches are currently developing. These include antibodies against sclerostin and anti-TGF-b16,17. Both have good pre-clinical examination results and are currently on clinical trial.

**Conclusion**
Bone strength is governed by the bone quantity, quality and turn over. Any disturbance will result in reduced bone strength leading to bone fragility. Finding out the underlying cause of the bone fragility is the most important part in managing these children. Through proper diet, calcium, vitamin D supplement, and antiresportive agents e.g. bisphosphonate, the bone quality can be corrected.

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## Optimization of Bone Health in Adult Patients in Preparation for Surgery

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Bone strength is critical to successful spine surgery. (10-12). Strength is a combination of bone quantity and quality. Quantity is measured by DXA and CT. Bone quality is related to collagen and mineral status, micro-architecture, and bone turnover dynamics. Laboratory analysis best defines normal and abnormal quality. Several laboratory markers can identify bone at risk.

Bone density is an area measurement of bone mass at the spine and hip. Scoliosis inserts artifacts to the analysis and spine density measurements should not be used if the curve is over 30 degrees and/or there is osteoarthritis of the facet joints. Although there is only moderate relationship of the hip and spine densities, hip provides a good approximation of bone mass. Alternatively one can use a quantitative CT of the vertebra. It measures specifically the trabecular bone and will not be influenced by osteoarthritis of curve. Osteopenic bone (T -1.0 to -2.4) and especially osteoporotic (T worse than -2.5) bone lacks good purchase of spinal instrumentation and has a high risk for adjacent level compression fracture.

Bone quality is compromised in the face of low Vitamin D (25-OHvitamin D < 30ng/ml), low calcium (<9.2) and low bone specific alkaline phosphatase (<6.) (10-12). Vitamin D has many functions including mineralization of bone and muscle function. (4). Vitamin D is best measured by determining the 25(OH)vitamin D levels. Values below 30ng/ml compromise bone formation and mineralization. Values below 45ng/ml interfere with muscle related strength and speed as well as balance. 2000 to 4000 international units of vitamin D3 will correct vitamin D levels in 2 to 4 weeks and should be part of preoperative treatment.

Calcium is needed for cell function and mineral formation (4,10 – 12). Calcium and PTH have a close relationship. When calcium is low the PTH is high and resorbs calcium from the skeleton to remedy the deficiency. When calcium is high PTH is turned off. Thus by measuring the PTH one can discern the appropriate calcium need. If the PTH is over 50 there is a calcium deficiency, if below 20 there is a surplus of calcium and in the normal state the PTH should be around 30. The usual calcium requirement is 500 to 750 mg of calcium citrate per day in divided doses. Calcium C is better absorbed and prevents kidney stones.

Alkaline phosphatase is needed to mineralize the bone. There is an entity of hypophosphatasia where the bone specific alkaline phosphatase is less than 6. It interferes with growth, leads to premature loss of teeth and results in stress fractures. If vitamin B6 is elevated then there is the possibility that the patient has the genetic defect of inadequate levels of BSAP.

Collagen is critical to bone strength. It provides tensile strength. Most fractures result from bone failing in tension. It can be suspected in individuals who present with hypermobility in their fingers, elbows, flat feet and ease of touching their feet. Vitamin

C is the key cofactor that facilitates cross-linkage of the collagen. Any patient with hypermobility would best be served by being on 500mg Vitamin C per day.

Patients presenting with low body weight (BMI below 18.5), amenorrhea, poorly controlled diabetes (HGB A1C >8), history of low energy fractures and/or corticosteroid exposure all have a greater risk for fractures and spine fusion failure. Improve nutrition, correct the underlying medical disorders, and bring the patients under better diabetic control before scheduling spine surgery

Osteoporotic drugs influence spine surgery outcome. (2, 4, 10 -12). After correcting calcium and vitamin D status consider bone turnover. If the NTX or CTX is depressed (< 20 and 150 respectively) bone turnover is hibernating. Stop any antiresorptive agents (bisphosphonates and denosumab) and consider placing the patients on an anabolic agent such as PTH 1-34 (teriparatide). PTH anabolic analogues have significantly enhanced pelvic and distal radius fracture repair in randomized trials. (1, 9). Ohtori and his team (3, 5 – 8) in randomized spine fusion studies have demonstrated that teriparatide decreased spine fusion failure and implant pull out by over 50%. Pretreatment for one month enhanced insertional torque of pedicle screws. PTH 1-34 when given for six months post-surgery led to better fusion callus size than just three months . Unfortunately, teriparatide cannot be used in patients less than 18 years for fear of developing osteosarcoma.

In summary determine bone density by DXA in patients with low body mass undergoing spine fusion. Correct the calcium and vitamin D-3. Undernourished patients need nutritional guidance. Correct the Vitamin D and calcium. In those patients with clear osteoporosis consider using teriparatide preoperatively to gain bone mass and post operatively to enhance spine fusion and prevent implant failure.

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## Multidisciplinary Preoperative Optimization: Planning for Blood Loss in Spinal Deformity Surgery

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JNS SPINE CLINICAL ARTICLE

### A systematic multidisciplinary initiative for reducing the risk of complications in adult scoliosis surgery

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Melissa L. Anderson, MS,[3] Eric A. Baldwin, MS,[3] Robert S. Mecklenburg, MD,[1]
Jean-Christophe Leveque, MD,[1] Alicia M. Edwards, MBA,[1] Mary Shea, MA,[3] Lisa Ross, MPH,[3] and
Karen J. Wernli, PhD[3]

A multidisciplinary preoperative clearance conference with medicine and anesthesia lets you discuss hematological parameters BEFORE the morning of surgery together. All team members are well informed and ready to go on the morning of surgery.

Discussed several weeks before surgery:

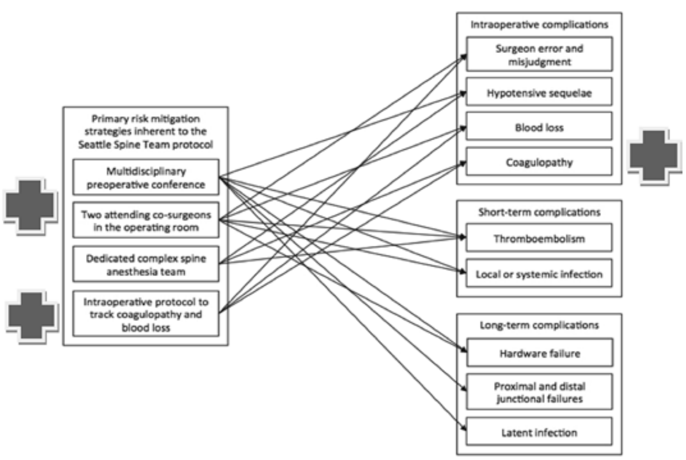
- TXA, Are there contraindications?
- Hematological concerns like Anemia, low platelets, liver disease, etc?
- What are your plans for massive blood loss, lines etc. Does anesthesia think that your proposed surgery is safe?
- Special tests and investigations/consultations are ordered and the patient is represented and not booked for surgery if there are any concerns

Curr Rev Musculoskelet Med
DOI 10.1007/s12178-016-9351-x

COMPLICATIONS IN SPINE SURGERY (E KLINEBERG, SECTION EDITOR)

### Complication avoidance with pre-operative screening: insights from the Seattle spine team

Quinlan D. Buchlak[1] · Vijay Yanamadala[1] · Jean-Christophe Leveque[1] · Rajiv Sethi[1,2]




This diagram reveals the effect of standardization of multiple series of complications seen in spinal deformity surgery. Please see the red safety signs as they correlate directly to blood loss and hematological concerns.

Spine Deformity
www.spine-deformity.org
Spine Deformity 2 (2014) 95–103

Clinical Series

### The Seattle Spine Team Approach to Adult Deformity Surgery: A Systems-Based Approach to Perioperative Care and Subsequent Reduction in Perioperative Complication Rates

Rajiv K. Sethi, MD[a,*], Ryan P. Pong, MD[b], Jean-Christophe Leveque, MD[c], Thomas C. Dean, MD[d], Stephen J. Olivar, MD[d], Stephen M. Rupp, MD[b]
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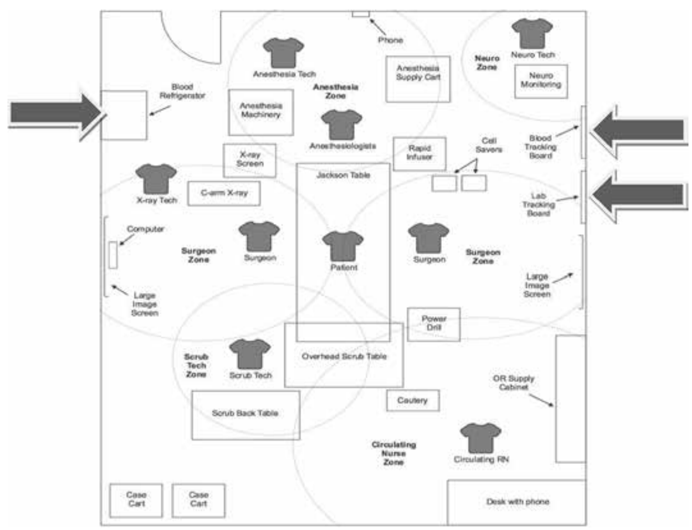
Received 6 May 2013; revised 4 December 2013; accepted 8 December 2013

| Time | Suction Canister | Cell Saver EBL | Field Irrigation | Total EBL | Hct | pH / BE | PT / INR | Platelet Count | Fibrinogen / D-dimer |
|---|---|---|---|---|---|---|---|---|---|
| 9:00 | N/A | N/A | N/A | N/A | 33 | 7.38 / -2.9 | 13.7 / 1.1 | 108 | 798 / 2.74 |
| 10:03 | 550 | 100 | 0 | 650 | 30 | 7.35 / -4.5 | 14.2 / 1.1 | 100 | 647 / 2.65 |
| 11:00 | 650 | 550 | 0 | 1200 | 29 | 7.38 / -3.6 | 15.3 / 1.2 | 95 | 497 / 2.94 |
| 12:00 | 800 | 1250 | 0 | 2050 | 31 | 7.34 / -4.2 | 16.4 / 1.3 | 90 | 411 / 2.92 |
| 13:04 | 1300 | 1700 | 0 | 3000 | 21 | 7.31 / -4.8 | 18.1 / 1.5 | 110 | 335 / 2.93 |
| 14:01 | 1500 | 2000 | 0 | 3500 | 31 | 7.30 / -4.5 | 17.3 / 1.4 | 125 | 280 / 3.95 |
| 15:05 | 1600 | 2200 | 0 | 3800 | 29 | 7.33 / -4.1 | 17.0 / 1.4 | 103 | 290 / 7.49 |

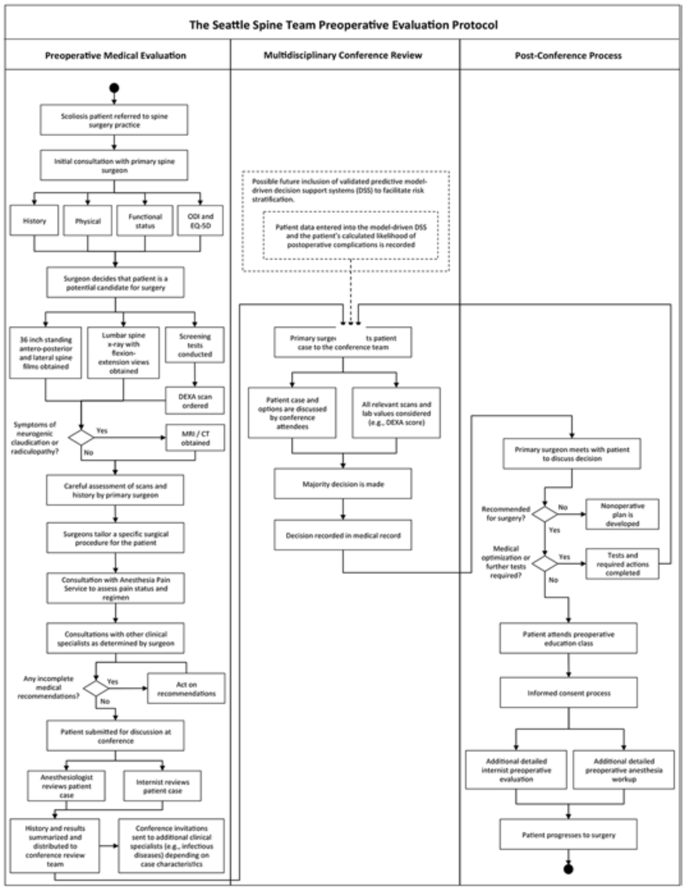
TRACK BLOOD LOSS FORMALLY!

Standardization of all complex spine cases using principles of the Toyota Production System. This is an example of "visual control" as a standard method of communication around coagulopathy and blood loss. Tracking blood loss in this manner lets everyone in the room be on the SAME PAGE.

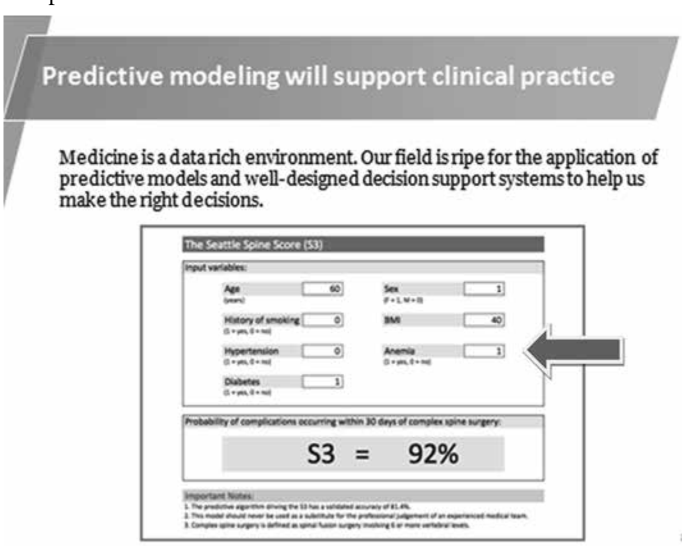



This operating room is designed for a complex spine procedure and its associated blood loss

This is an example of enhanced "flow" optimizing position of team members of the complex spine operating room using principles of the Toyota production system. Please see the location of the blood refrigerator and the visual blood loss and lab tracking boards.




Further attempts to use a risk stratification tool or "decision support tool" are being developed. We have recently developed the Seattle Spine Score (In press, Journal of Clinical Neurosciences. This takes into account preoperative anemia and its effects on complications.




## Why Anesthesia Clearance is Critical Preoperatively for Complex Adult Spinal Deformity: Stress Dose Steroids, Protocol for Narcotic Usage (Lidocaine Drips)

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Surgery for spine related disease has increased approximately 17% over the last five years. Due to the chronicity of spine-related disease and the associated somatic and neuropathic pain, patients presenting for spine surgery have a high prevalence of chronic opioid use. For spine surgery, 55-71% of patients utilize opioids preoperatively in contrast patients requiring colorectal surgery have a pre-procedure opioid prevalence of 33-44%.[1, 2] Despite surgery a significant percentage of spine surgery patients continue to require long-term opioids. Sixty-one percent of patients with preoperative opioid use continue to require a prescription for opioids twelve months following their procedure. Furthermore in the cohort of preoperative opioid-naïve patients, 21-26% continue to fill an opioid prescription one-year after surgery.[3] Perioperative interventions that reduce opioid use can potentially reduce the risk of long-term opioid dependence. Three perioperative interventions associated with reduced perioperative opioid use include:

- Intraoperative Methadone
- Perioperative lidocaine
- Perioperative ketamine

### Methadone

Methadone is a μ-opioid receptor agonist with one of the longest half-life of the clinically used opioids. Furthermore methadone has inhibitory effects on N-methyl-d-aspartate (NMDA) receptors, which are implicated in the development of opioid tolerance, hyperalgesia, and chronic pain. Due to the large percentage of spine surgery patients who are on preoperative opioids, intraoperative methadone has significant postoperative benefits. Recently Murphy et al. demonstrated decreased hydromorphone use on postoperative day 1 (4.56 vs. 9.90 mg), days 2 (0.60 vs. 3.15 mg) and 3 (0 vs. 0.4 mg; all P< 0.001) after complex spine surgery.[4] Furthermore pain scores at rest, with movement, and with coughing and overall satisfaction with pain management were better in the methadone group than in the hydromorphone group. The findings of this study are consistent with an earlier study from our group investigating methadone use for spine surgery.[5]

### Lidocaine

Systemic lidocaine has anti-inflammatory, analgesic and antihyperalgesic properties.

Farag et al. showed that an intraoperative infusion of lidocaine for patients undergoing spine surgery significant lowers mean verbal response scale pain scores (4.4 [CI 4.2-4.7] versus 5.3 [CI 5.0-5.5], p < 0.001) and decreased opioid consumption compared to placebo (mean morphine equivalent dosage 55 [36-84] versus 74 [49-111] mg, p = 0.0011).[6] Of great interest in this study was the improved quality of recovery as assessed by the Acute Short-Form [1 month (38 vs. 33; p = 0.002) and 3 months (39 vs. 34; p = 0.04) postoperatively]. Postoperative cognitive function is also positively impacted by the intraoperative administration of lidocaine.[7]

**Ketamine**

Ketamine is a N-methyl D-aspartate (NMDA) receptor antagonist and is an effective adjunct in chronic opioid users. Intraoperative ketamine is associated with reduced postoperative opioid use and improved quality of recovery. Loftus et al randomized patients undergoing spine surgery to placebo or ketamine (0.5 mg/kg load followed by 10 mcg/kg/min) vs. placebo.[8] They showed that total morphine consumption was decreased by approximately 30% at 24 hours after surgery (142 ± 82 mg treatment group versus 202 ± 176 mg placebo group, p = 0.032) and 37% at 48 hours (195 ± 111 mg treatment group versus 309 ± 341 mg placebo group, p = 0.029). At 6 weeks after surgery, there was a 71% reduction in morphine consumption in the treatment group compared to placebo (0.8 ± 1.1 mg/h intravenously in the treatment group versus 2.8 ± 6.9 mg/h intravenously for placebo, p = 0.041). Pain intensity was reduced by approximately 26% both immediately following surgery and 6 weeks postoperatively (p = 0.033 and 0.026, respectively). There is benefit to postoperative ketamine infusions as demonstrated by less postoperative pain at rest (NRS 3.6 treatment versus 5.5 placebo) and with physical therapy on postoperative day 1 (5.6 treatment versus 8.0 placebo).[9]

**Stress dose steroids**

There has been little progress made regarding recommendations for the management of chronic steroid therapy during the perioperative period, especially the question of stress dose steroids. This is related to the numerous retrospective or small-scale studies, lack of large, prospective, randomized controlled trial and the inherent low incidence of perioperative adrenal insufficiency. However based on the best evidence thus far the following recommendations can be advanced[10]:

- Assess length of therapy, corticosteroid dose and degree of surgical stress to prescribe the minimum amount of drug
- ACTH stress testing is not required
- Perioperative steroid dosing based on the extent of surgery
- Complex reconstructive spine surgery would be classified as moderate to severe surgical stress
- Moderate to severe surgical stress: 100-150 mg hydrocortisone IV or 30 mg methylprednisolone IV on the procedure day; return to previous dosage by lowering it over the next 1 to 2 days

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## Assessment & Management of Nutritional Status to Maximize Surgical Outcomes in Complex Spinal Surgery.


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**Preoperative Nutritional assessment**

Preoperative Nutritional assessment is important in identifying patients that may benefit from supplementation for elective spine surgery. At times, even a gastric tube has to be inserted for improving the nutritional status if all else fails. Preoperative hypoalbuminemia has been found to be an independent risk factor for postoperative complications for degenerative and deformity cases. One study found 28% of the patients were malnourished preoperatively.

Malnourished patients are found to have higher rate of wound infection, wound dehiscence and longer length of stay. Even the mortality was higher in these patients. Nutritional supplementation is considered a modifiable preoperative risk factor.

**Preoperative serum albumin level as a predictor of postoperative**

**complication after spine fusion.**
Adogwa O, Martin JR, Huang K, Verla T, Fatemi P, Thompson P, Cheng J, Kuchibhatla M, Lad SP, Bagley CA, Gottfried ON. Spine (Phila Pa 1976). 2014 Aug 15;39(18):1513-9

**Preoperative Nutritional Status is an Independent Predictor of 30-day Hospital Readmission After Elective Spine Surgery**
Owoicho Adogwa, MD, MPH,[y] Aladine A. Elsamadicy, BE, Ankit I. Mehta, MD,[z] Joseph Cheng, MD, MS,[§] Carlos A. Bagley, MD,[¦] and Isaac O. Karikari, MD SPINE Volume 41, Number 17, pp 1400–1404 ß 2016

**Poor Nutrition Status and Lumbar Spine Fusion Surgery in the Elderly: Readmissions, Complications, and Mortality**
VarunPuvanesarajahMD[1], AmitJainMD[1], KhaledKebaish-MD[1], Christopher I. Shaffrey MD,[2] Daniel M. Sciubba MD,[3] Rafael De la Garza-Ramos MD,[3] A. Jay Khanna MD,[1] Hamid Hassanzadeh MD[4] Spine 2016

**Perioperative weight loss**
Patients will often lose weight after surgery because they get a postoperative ileus or just do not have an appetite for many reasons. The postoperative weight loss has been found to have an effect on the outcome such as increase incidence of superficial wound infection.

**Anthropometric characteristics, high prevalence of undernutrition and weight loss: impact on outcomes in patients with adolescent idiopathic scoliosis after spinal fusion.**
Tarrant RC, Nugent M, Nugent AP, Queally JM, Moore DP, Kiely PJ. Eur **Spine** J. 2015 Feb;24(2):281-9.

**Obesity**
An elevated Body Mass index has been associated with a higher risk of wound infection and other complications. There are time that an elective surgery must be delayed to optimize the BMI to avoid perioperative complications and get the patient to be involved in improving the outcome of surgery rather than being a bystander.

**Patient factors, comorbidities, and surgical characteristics that increase mortality and complication risk after spinal arthrodesis: a prognostic study based on 5,887 patients.**
Schoenfeld AJ, Carey PA, Cleveland AW 3rd, Bader JO, Bono CM. Spine J. 2013 Oct;13(10):1171-9. doi: 10.1016/j.spinee.2013.02.071. Epub 2013 Apr 9.

**Impact of obesity on complications, infection, and patient-reported outcomes in adult spinal deformity surgery**.
Soroceanu A, Burton DC, Diebo BG, Smith JS, Hostin R, Shaffrey CI, Boachie-Adjei O, Mundis GM Jr, Ames C, Errico TJ, Bess S, Gupta MC, Hart RA, Schwab FJ, Lafage V; International Spine Study Group.J Neurosurg Spine. 2015 Jul 31:1-9. [Epub ahead of print]

**Obesity negatively affects spinal surgery in idiopathic scoliosis.**
Hardesty CK, Poe-Kochert C, Son-Hing JP, Thompson GH.Clin Orthop Relat Res. 2013 Apr;471(4):1230-5. doi: 10.1007/s11999-012-2696-6.

**Does obesity affect surgical outcomes in degenerative scoliosis?**
Fu L, Chang MS, Crandall DG, Revella J. Spine (Phila Pa 1976). 2014 Nov 15;39(24):2049-55.

## Preoperative Planning for Instrumentation Application in Deformity Surgery for Children

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sshah@nemours.org

**Objectives**
- Avoid loss of fixation
- Management of kyphosis
- Prevent add on phenomena / crankshaft / progression of deformity
- Miniminize complications
- Improvement in HRQoL

**Assessment of Deformity**
- Clinical
- Radiographic
  - Standing X-rays (low dose radiation, if available) PA and lateral
  - Bending films
  - Traction
- Classification
- Sagittal plane considerations
- Assessment of future growth / skeletal maturity

**Advanced Imaging**
- DEXA scan / eval of BMD
- MRI scan – evaluation of neural axis, soft tissue, disk
- CT scan – bony anatomy, complex congenital, pedicle anatomy, laminar defects
- Use of 3D models

**Multidisciplinary Preoperative Conference**
- Purpose
- Stakeholders
- Wisdom of Crowds
- Implant considerations / concerns

**Optimization of Bone Health**
- Calcium, Vitamin D supplementation
- Bisphosphonates

**Preoperative Halo Gravity Traction (HGT)**

**Intraoperative Techniques**
- Anesthesia
- Intraoperative Neurologic Monitoring
  - Checklist
- SSI Prevention Bundle
- Intraoperative Traction
  - Pearls
  - Pitfalls
- Releases, osteotomies, role of anterior surgery

Pedicle screw placement
- Techniques
- Which screws are the most difficult?
- Salvage

Alternative Vertebral Fixation
- Hooks
- Wires
- Sublaminar bands
- Rib / hybrid fixation

Pedicle Screw Augmentation

Pelvic Fixation – when, how and why?

**Post Operative Considerations**

- Pain management
- Halo, brace or cast
- Teaching at Discharge
- Activity Restrictions
- Assessment and Surveillance

## Preoperative Planning for Instrumentation Application in Deformity Surgery for Adults

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Key Points and Overview:

a. Defining Goals of Care
    i. Adults and self-reported HRQOL
    ii. Patient expectations/goals and outcomes
        1. "In order to win, you must expect to win"
    iii. Radiographic Goals of Care
        1. Age Adjustments
b. Preoperative Radiographic Measures
    i. Alignment
        1. Sagittal Plane
        2. Coronal Deformity/Trunk Shift
    ii. Flexibility
        1. Measuring Fixed vs Flexible Deformity
    iii. Fixation Strategies
        1. Bone Quality
        2. Fixation Points
c. Modelling intraoperative Correction
    i. Expected vs Observed outcomes
    ii. Computer modelling
        1. Surgimap
    iii. Limitations of Modelling
        1. Reciprocal changes

1) Defining the Goals of Care

There is significant variability in the management of deformity of the spine. Algorithms for decision-making begin with the decision to pursue operative versus non-operative approaches to deformity. An informed choice is based upon valid outcomes on the results of operative and non-operative care. There is limited information that may lend insight into an informed decision for the individual case. Variability in approaches to care is driven by factors including clinical presentation and symptoms of the patient, comorbities, patient preference, and surgeon recommendations.

There are important differences in the clinical presentation of adults and adolescents with spinal deformity. The adult with deformity of the spine presents with present pain and disability. Degenerative changes within the spine may lead to pain of spinal origin, neural symptoms, and progression of deformity. The goals of care for the adult with spinal deformity are to improve present pain and disability, and to improve self-assessment of health-related quality of life.

The adolescent with spinal deformity may also have pain and functional limitations, but subjective limitations are often absent in the adolescent. The goals of care for adolescents with deformity of the spine are to limit curve progression, and to avoid the future consequences of deformity progression. Bridwell et al. demonstrated that parents and patients both identified the avoidance of future pain and disability as an adult as the most important reason to have surgery as an adolescent.[1] The value of care in the adolescent may be underestimated by measuring only patient self-assessment of health status. The value of avoiding deformity progression and future consequences of deformity is difficult to measure.

In adult spinal deformity, there are important correlations between curve and deformity characteristics and patient clinical appearance. Global sagittal plane alignment is the most important radiographic characteristic that is associated with health status compromise including pain and functional limitations.[2] Schwab et al. proposed a clinical impact classification for adult scoliosis.[3] The authors demonstrated that radiographic factors associated with disability and surgery include lumbar hypolordosis and intervertebral subluxation. Subsequent work identified PT, SVA and the matching of Pelvic Incidence to Lumbar Lordosis as the primary determinants of health status in adults with spinal deformity.[4]

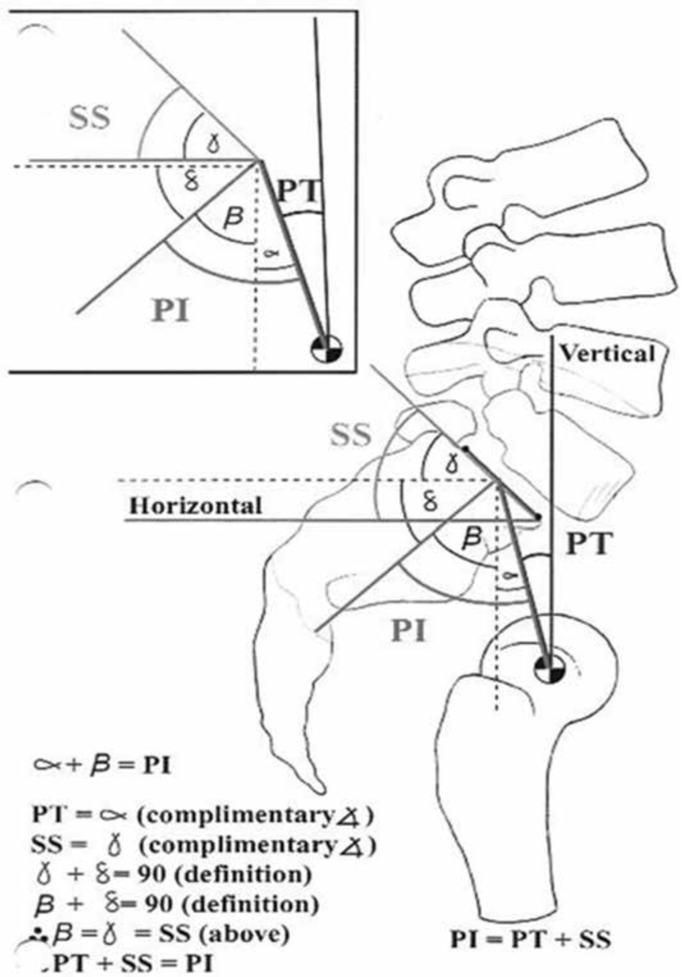
The decision to pursue care for spinal deformity is importantly based upon patient self-assessment of health status, and personal goals of care. Informed choice required patient and physician combined decision-making. Expectations of the patient and the physician are an important independent determinant of the choice to pursue care for spinal deformity.

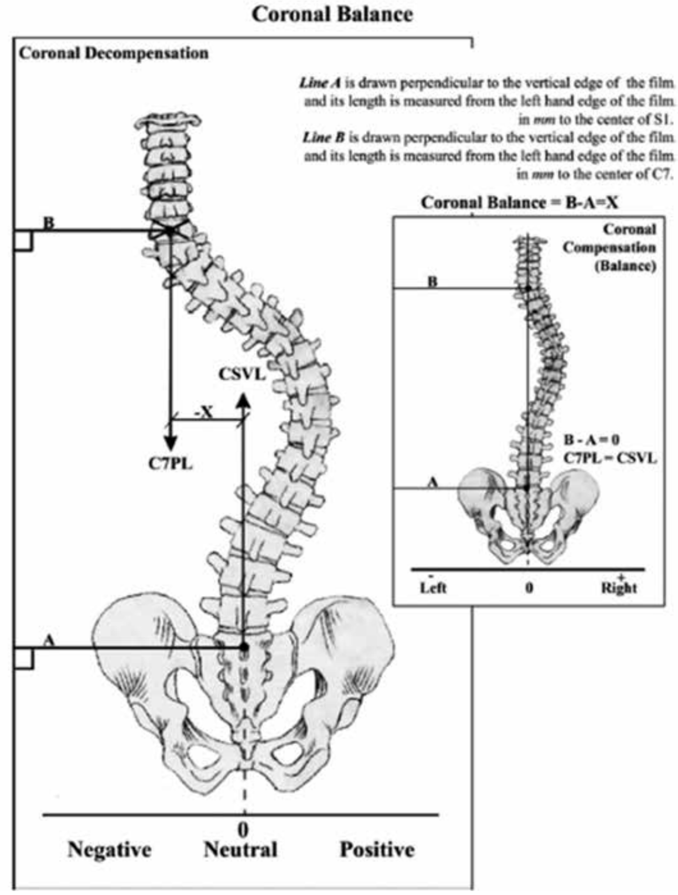
2) Radiographic Goals of Care

Realignment of the Spine in the sagittal and coronal plane is an important goal of surgical planning, and is moderately correlated with the clinical outcome of care.[5,6]

Radiographic goals for deformity correction include:

SVA<4cm from the posterior body of S1
PT<20 degrees
LL=PI +/- 10 degrees
Coronal SVA within 4cm of Harrington Line
Trunk/Shoulder balance



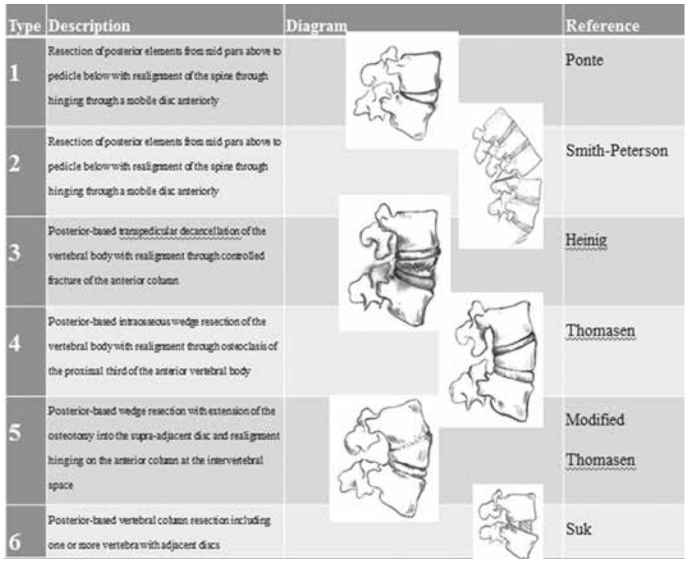




In Older patients, and patients with more longstanding deformity, the goals of sagittal plane realignment may be less, and and SVA up to 8cm, and LL that is 15 or 20degrees less than the PI may be appropriate for preoperative planning.[7]

3) Measuring Preoperative Flexibility

The flexibility of the spine is an important determinant of the type of osteotomy that is required for correction of deformity. Patients with a mobile motion segment may gain significant correction with a Ponte osteotomy, wirh a center axis of rotation at the middle of the vertebral body.

Patients with more rigid deformity may require osteoclasis with a Smith-Peterson osteotomy and an axis of rotation at the PLL, or a 3 column osteotomy with spinal column shortening for deformity correction.



| Type | Description | Diagram | Reference |
|---|---|---|---|
| 1 | Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly | | Ponte |
| 2 | Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly | | Smith-Peterson |
| 3 | Posterior-based transpedicular decancellation of the vertebral body with realignment through controlled fracture of the anterior column | | Heinig |
| 4 | Posterior-based intraosseous wedge resection of the vertebral body with realignment through osteoclasis of the proximal third of the anterior vertebral body | | Thomasen |
| 5 | Posterior-based wedge resection with extension of the osteotomy into the supra-adjacent disc and realignment hinging on the anterior column at the intervertebral space | | Modified Thomasen |
| 6 | Posterior-based vertebral column resection including one or more vertebra with adjacent discs | | Suk |

Standing films may overestimate spinal deformity because dynamic posture is dependent upon factors including balance and spinal stenosis. Therefore, alignment of the spine may be a reflection of dynamic factors including poor balance or symptomatic stenosis rather than anatomic factors.[8]

Radiographic evaluation of Spinal Mobility may Include:
Standing films: 36" or biplanar imaging system with 3D capabilities
- Global alignment
- Regional alignment
- Segmental alignment

Bending films
- Passive/Active
- Fulcrom/bolster
- Traction

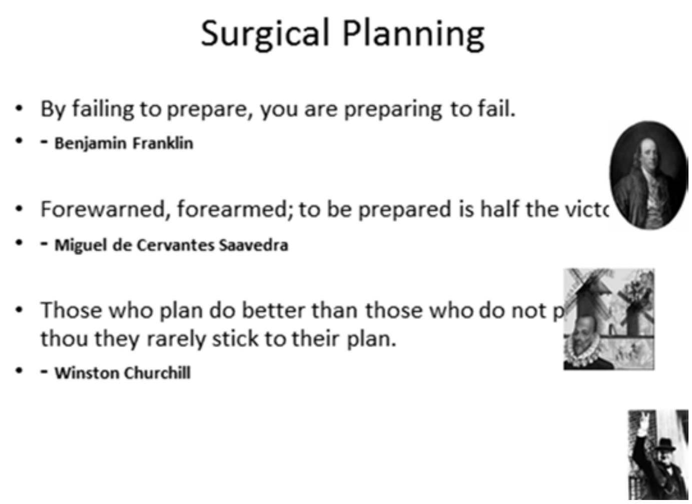
4) Preoperative Assessment of Fixation Strategies:
   a. Bone Quality
      i. DEXA of the spine may have limited utility in the setting of spinal deformity. Opportunistic bone density measures including evaluating HU from CT scan may be useful to assess bone density at specific levels of the spine.
      ii. Opportunistic Osteoporosis Screening
         1. Hounsfield Unit <160 is 90% sensitive to detect osteoporosis[9]
   b. Pedicle Size/Morphology
      i. CT scan is useful for measuring pedicle morphology and preoperative planning
   c. Alternative Fixation Techniques
      i. Hybrid fixation strategies including the use of wires at the lamina and transverse processes, and hooks are useful for preoperative planning and fixation alternatives to pedicle screws
      ii. Hybrid fixation is useful in the osteoporotic spine

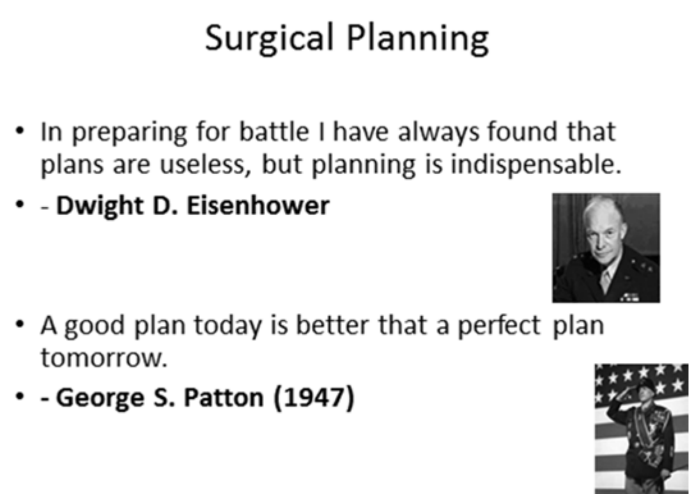
5) Computerized modelling of Correction
Modelling intraoperative correction is based upon expected realignment of the spine using standard techniques including anterior surgery, posterior-based osteotomies, and combined anterior and posterior approaches to the spine.

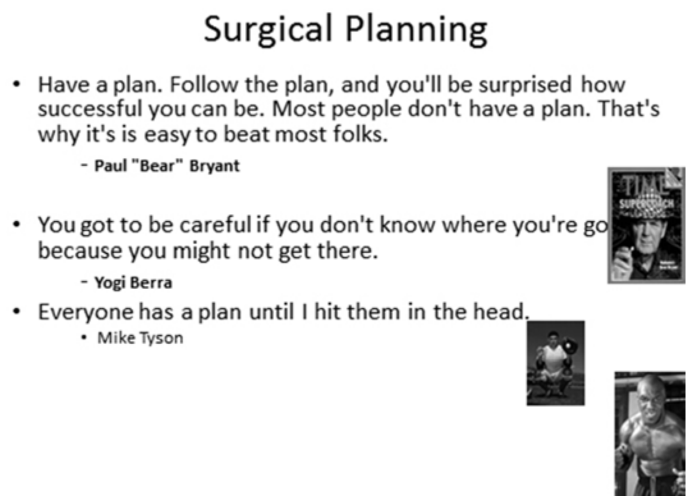
There is signficant variability in the observed correction using different surgical strategies, so the surgeon must be prepared to adjust surgical strategies based upon the correection observed in intraoperative measurement.

Computer modelling of expected corrections with software including a deformity measuring software program may be useful in preoperative planning.[10]

Limitations include the variability observed between expected and observed corrections, and reciprocal changes to the non-instrumented segments of the spine.






**(Endnotes)**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## Assembling Superior Teams to Minimize Complications and Maximize Surgical Outcomes


**Todd J. Albert, M.D.**
Surgeon-in-Chief and Medical Director
Korein-Wilson Professor of Orthopaedic Surgery
Hospital for Special Surgery

Chairman and Professor, Department of Orthopaedic Surgery
Weill Cornell Medical College


An example of minimization of complications and obtaining superior results is found at Hospital for Special Surgery where I lead. It is the largest single specialty musculoskeletal institution in the world. Its legacy of leadership traces back to 1863 where it was founded as the New York Society to the Relief of the Ruptured and Crippled. It originally treated polio patients and the underprivileged of New York and has grown through the last century and a half to become the preeminent global leader in musculoskeletal health. The academic and research hub is in the upper east side of New York with outpatient centers across the tri-state area. One percent of all the joint replacements in the United States are done at our institution and significant advances in MRI for orthopaedics have been made as well.

The team is made up not only of over 200 orthopaedic faculty with 113 orthopaedic surgeons sub-specializing across 10 service lines but 45 leaders in rheumatology (#2 in U.S. News and World Report) as well as all the related medical specialties that are critically important to have superior outcomes. These include perioperative medicine, radiology, physiatry, pain management, primary care sports medicine, anesthesiology and other specialties such as neurology and cardiology.

An example of fantastic leadership and a great team being helped by being led is the All Blacks Rugby Team. In a book by James Kerr entitled, *Legacy*, he chronicles what the New Zealand All Blacks can teach us about the business of life. This is applicable to the topic at hand. There are 15 lessons in leadership from this team's story and they are the following:

1. Character: Never be too big to do the small things that need to be done.
2. Adapt: A continuous competitive advantage in a culture that is constantly adapting.
3. Purpose: Knowing why you are taking the actions you are

creates belief and a sense of direction.

4. Responsibility: Leaders create leaders by passing responsibility and creating ownership, accountability and trust in their teams.
5. Learn: Create a learning environment. Leaders are teachers.
6. Whanau: Be a team 24/7. Whanau is a Maori word that means "to be born or to give birth" and refers to the relationship among extended family.
7. Expectation: Embrace expectations. There is a saying, "aim for the highest cloud so that if you miss it you will hit a lofty mountain". Vince Lombardi, the great American football coach, also said, "Gentleman, we are going to pursue perfection because in pursuing perfection we will at least attain excellence".
8. Preparation: Train to win. Practice under pressure.
9. Pressure: Keep a "blue head" and control your attention
10. Authenticity: Know thyself. Great leaders remain true to their deepest values.
11. Sacrifice: Find something you would die for and give your life to it.
12. Language: Invent a language. Sing your own world into existence.
13. Ritual: Ritualize to actualize and create a culture.
14. Whakapapa: Be a good ancestor. Plant trees you will never see - "leave the jersey in a better place".
15. Legacy: Write your legacy.

These principles are quite important individually and collectively to creating teams and/or a team that will lead to the best results.

We have tried to invoke many of these principles at our institution with excellent results regarding the safety, lower complications and patient satisfaction. Last year, 150,000 patients were cared for at HSS. We had a $40 million research budget, 30,000 surgeries were performed with 400,000 outpatient visits. People came from 95 countries and 50 states to represent our patient population and we have created alliances with orthopaedic surgeons under the International Society of Orthopaedic Centers from 16 countries and five continents. Last year, we had 400 academic visitors and 25,000 daily unique visitors at our website as well as 11,300 e-Academy enrollments. Our value model is patient focused and acknowledges the importance of the people, knowledge and focus. This has led to superior quality outcomes which will be shared and it has led to fewer spinal complications, higher percentage of patients being discharged home from the hospital, fewer infections and fewer readmissions. Our patient satisfaction hovers between 97% and 99%. All of this leads to high patient satisfaction and lower total cost in the episode of care.

In conclusion, excellent outcomes and low complication rate is value to the patient and value to the hospital and this is achieved through creating a great team but utilizing appropriate indications, defining if surgery is needed and doing the correct surgery the first time, lower complication rate, lower readmission rate, increased patient engagement in their care and continuous measurement and improvement in the patient experience.

# Notes

# Intra-Op

Room: Ballroom - Salon A-F

Moderators:
Christopher I. Shaffrey, MD & Suken A. Shah, MD

Faculty:
Lindsay M. Andras, MD; Marco Braydo-Bruno, MD; Douglas C. Burton, MD; Michael D. Daubs, MD; James S. Harrop, MD; Isaac O. Karikari, MD; Lawrence G. Lenke, MD; Praveen V. Mummaneni, MD; Paul Park, MD; S. Rajasekaran, MD, FRCS, MCh, PhD; Scott S. Russo, Jr., MD; Jason W. Savage, MD; Justin S. Smith, MD, PhD; Kit Song, MD, MHA; Burt Yaszay, MD

## Techniques for Reducing Intra-Operative Blood Loss in Pediatric & Adult Deformity

**Burt Yaszay, MD**
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Byaszay.rady@gmail.com

1. **Background**
    a. Acute blood loss risks
        i. Anemia
        ii. Coagulopathy
        iii. Longer hospitalization or ICU stay
        iv. Higher risk of complications
    b. Transfusion risk
        i. Transfusion reaction – anaphylaxis, acute lung injury
        ii. Infection
        iii. Fluid shifts
2. **Preoperative Management**
    a. Screen for Anemia/Coagulopathies
    b. Treat Anemia
        i. Iron Supplementation
        ii. EPO
        iii. Vitamin B12 and folic acid
    c. Treat Coagulopathies
        i. Stop NSAIDs and ASA
        ii. Vitamin K
        iii. Von Willebrand factor → Desmopressin

    ❖ Autologous predonation ineffective
3. **Intraoperative Management**
    a. Antifibrinolytics
        i. Tranexamic acid (TXA)
            1. AIS → less blood loss, transfusion and complication_
            2. Adults → less blood loss
            3. Dosing not standardized
                a. Loading 100-10 mg/kg
                b. Maintenance dose 10-1 mg/kg/hr
        ii. Aminocaproic acid (EACA)
            1. Benefits in AIS
            2. More costly then TXA
        iii. Concern
            1. ? risk of thromboembolism → dosage dependent
            2. Cardiac surgery → A fib, renal failure, seizure
    b. Cell saver
        i. Mixed reviews → recommended for major spine surgery
    c. Pressure regulation
        i. Controlled hypotension → exposure
        ii, Intraosseous pressure → blood loss

    ❖ Risks → blindness, spinal cord perfusion
    d. Temperature → avoid hypothermia
        i. Hypothermia → platelet and coagulant enzymatic dysfunction
    e. Acute normovolemic hemodilution (ANH)
        i. Autologous blood removal and replacement with crystalloid and/or colloid
        ii. Effectiveness debatable
        iii. May lead to hypercoagulable state
    f. Surgical Technique
        i. Minimizing exposure
            1. Minimally invasive surgery
            2. Epidural space exposure
        ii. Bipolar sealants
            1. Decreased blood loss and need for transfusion
        iii. Ultrasonic bone cutter → decreased blood loss
            1. Decreased operative time
            2. Seals bone edge
            3. Decreased epidural space exposure
        iv. Sealants
            1. Thrombin/fibrin material or gelatin matrices
            2. Safe and effective

        ❖ Caution → expansive → risk in closed spaces
        v. Patient positioning
            1. Minimize intra-abdominal pressure (IAP)
            2. High IAP → increased venous pressure (epidural)
            3. Abdomen should be hanging free in prone position
            4. Special attention to obese or small pediatric patients

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## Neuromonitoring Alert: Stepwise Management of Lost Signals…Now What?

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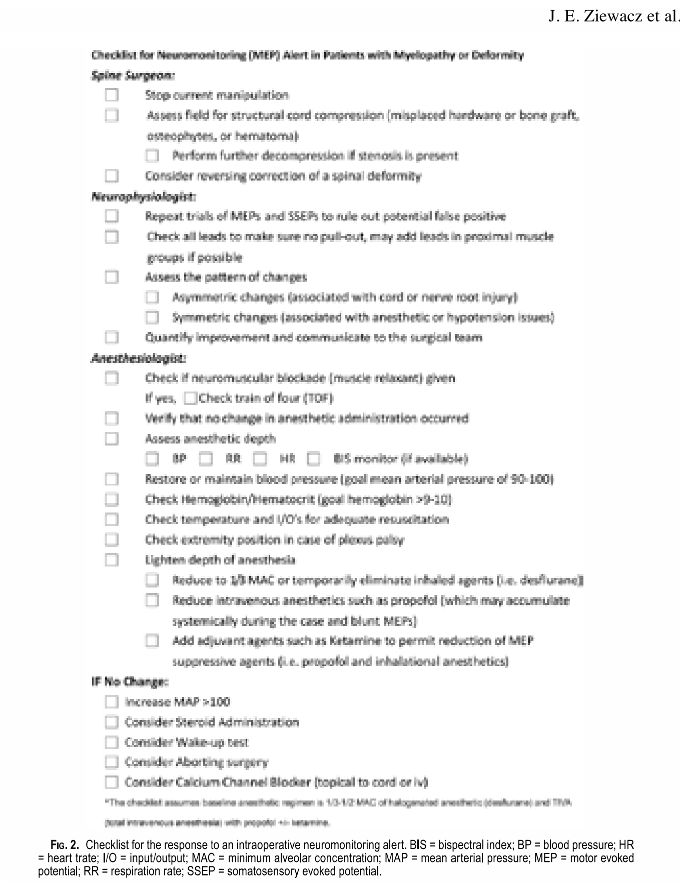
J. E. Ziewacz et al.

**Checklist for Neuromonitoring (MEP) Alert in Patients with Myelopathy or Deformity**

***Spine Surgeon:***

- ☐ Stop current manipulation
- ☐ Assess field for structural cord compression (misplaced hardware or bone graft, osteophytes, or hematoma)
  - ☐ Perform further decompression if stenosis is present
- ☐ Consider reversing correction of a spinal deformity

***Neurophysiologist:***

- ☐ Repeat trials of MEPs and SSEPs to rule out potential false positive
- ☐ Check all leads to make sure no pull-out, may add leads in proximal muscle groups if possible
- ☐ Assess the pattern of changes
  - ☐ Asymmetric changes (associated with cord or nerve root injury)
  - ☐ Symmetric changes (associated with anesthetic or hypotension issues)
- ☐ Quantify improvement and communicate to the surgical team

***Anesthesiologist:***

- ☐ Check if neuromuscular blockade (muscle relaxant) given
  If yes, ☐ Check train of four (TOF)
- ☐ Verify that no change in anesthetic administration occurred
- ☐ Assess anesthetic depth
  ☐ BP ☐ RR ☐ HR ☐ BIS monitor (if available)
- ☐ Restore or maintain blood pressure (goal mean arterial pressure of 90-100)
- ☐ Check Hemoglobin/Hematocrit (goal hemoglobin >9-10)
- ☐ Check temperature and I/O's for adequate resuscitation
- ☐ Check extremity position in case of plexus palsy
- ☐ Lighten depth of anesthesia
  - ☐ Reduce to 1/3 MAC or temporarily eliminate inhaled agents (i.e. desflurane)
  - ☐ Reduce intravenous anesthetics such as propofol (which may accumulate systemically during the case and blunt MEPs)
  - ☐ Add adjuvant agents such as Ketamine to permit reduction of MEP suppressive agents (i.e. propofol and inhalational anesthetics)

**IF No Change:**

- ☐ Increase MAP >100
- ☐ Consider Steroid Administration
- ☐ Consider Wake-up test
- ☐ Consider Aborting surgery
- ☐ Consider Calcium Channel Blocker (topical to cord or iv)

*The checklist assumes baseline anesthetic regimen is 1/3-1/2 MAC of halogenated anesthetic (desflurane) and TIVA (total intravenous anesthesia) with propofol +/- ketamine.

Fig. 2. Checklist for the response to an intraoperative neuromonitoring alert. BIS = bispectral index; BP = blood pressure; HR = heart trate; I/O = input/output; MAC = minimum alveolar concentration; MAP = mean arterial pressure; MEP = motor evoked potential; RR = respiration rate; SSEP = somatosensory evoked potential.

Ziewacz et. al., Neurosurg Focus 33 (5):E11, 2012
SRS – Neuromonitoring Checklist; Praveen Mummaneni, MD, 6/2017

## Surgical Site Infection (SSI) Algorithm to Avoid a Never Event

**James S. Harrop, MD**
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**Overview**

- Risk and Prevention
  1. Patient characteristics
  2. Preoperative issues
  3. Operative - Intraoperative issues
  4. Postoperative - Others
- Risk Factors
  - <u>Cervical spine</u>
    - Laminectomy: 1.2 - 2.9%
    - Posterior fusion/ instr.: 0-12%
      - Ghanayem AJ et al. Orthop Clin Clin N Amer 1996
      - Poelstra KA et al, Spine 2000
      - ! Kim T et al, Curr Opinion Orthop 2007
  - <u>Thoracolumbar spine:</u>
    - Spinal fusion No instr.: 1-5%
    - Spinal fusion with instr.: > 6% (1.3-12%)
      - Poelstra KA, Spine 2009
      - Massie JB, Clin Orthop Rel Res, 1992, no. 284, 99-105
      - Wisneski RJ, Orthop Clin N Amer, 1991, vol. 22, 491-500

**Prevention:**

- Preoperative antiseptic showering
- Preoperative hair removal "shave"
- Patient skin preparation in the operating room
- Preoperative hand/forearm antisepsis
- Management of infected or colonized surgical personnel
- Antimicrobial prophylaxis
  - Garibaldi RA. Prevention of intraoperative wound contamination with chlorhexidine shower and scrub. *J Hosp Infect* 1988;11(Suppl B):5-9
    - >700 pts - 2 preoperative antiseptic showers
      - Chlorhexidine
        - Reduced bacterial colony counts 9x (2.83102 to 0.3)
      - Povidone-iodine or triclocarban medicated soap
        - Reduced colony counts by 1.3x and 1.9x respectively
    - Confirmatory studies
      - Paulson DS. *Am J Infect Control* 1993;21(4):205-9
      - Hayek LJ. *J Hosp Infect* 1987;10: 165-72

**Problem –Reduction <u>not</u> illustrated in SSI reduction**

- Rotter ML. *J Hosp Infect* 1988;11:310-20, Leigh DA, *J Hosp Infect* 1983;4:229-35, Lynch W, *J Hosp Infect* 1992;21:179-91, Brady LM, *Med J Aust* 1990;152:240-5, Tuffnell DJ, *J Hosp Infect* 1987;10:255-9, Bartzokas CA, *N Engl J Med* 1984;311:1422-5

**EBM Summary: Pre-op shower?**

- Cochran Review 2011
- Webster J, Osborne S
- >10,000 pts vs chlorhexidine
- Conclusion:
  - "no clear evidence of benefit for preoperative showering or bathing with chlorhexidine over other wash products, to reduce surgical site infection"

**Preoperative "shaving" vs. depilatory agents or none**

- Night prior to OR - significantly higher SSI rate
  - Hamilton HW. *Can J Surg* 1977
  - Mehta G, *J Hosp Infect* 1988

- Seropian R. *Am J Surg* 1971;121:251-4
  – SSI + Razors -5.6%
  – SSI + Depilatory agent/None - 0.6%
- Pathophysiology:
  – Microabrasions
  – Bacterial multiplication
- Not associated with electronic "shavers"
  – Olson MM, *Surg Gynecol Obstet* 1986
- No relevant neurosurgical literature
  – Preoperative Hair Shaving
- 1891 Rosewell Park , U. Buffalo
  – Advised shaving 4 days prior and immediately prior
  – Also recommended surgeon to have short hair and shave

**EBM Summary: Hair Shave? Cochran Review 2008 -Tanner j, Moncaster K**

- 11 RCT Conclusion:
  – "No difference in SSIs among patients who have had hair removed prior to surgery and those who have not."
  – "If it is necessary to remove hair then both clipping and depilatory creams results in fewer SSIs than shaving using a razor."
  – "No difference in SSIs when patients are shaved or clipped one day before surgery or on the day of surgery."

**Preoperative Hair Shaving literature**

- 2009 series of 632 patients in Japan
  – All underwent craniotomy/burr hole without shaving
  – Care taken to keep hair out of wound on closure
  – Hair shampooed regularly postoperatively
    - 1.1% developed wound infections
- 2007 RCT of 789 spine patients in Istanbul
  – 1.07% infection rate in shaved group
  – 0.23% infection rate in unshaved group
  – Duration of procedure was no different
    - Not felt to impede performance of procedure
    - Antiseptic Agents

**Antimicrobial Agents:**

- Povidone-Iodine
  – Alcohol
  – Chlorhexidine
  – Scrub & Paint vs Paint only

**Povidone-Iodine**

- 2005 RCT of 234 patients in California
  – 5 minute Povidone-Iodine scrub → Povidone-Iodine paint
  – Povidone-Iodine paint only
- No difference in SSI rates
  – 10% in scrub + paint vs 10% in paint only
- Skin CFUs actually higher with scrub + paint
- Mechanism of iodination of lipids and oxidation of cytoplasmic and membrane compounds
  – Batericidal
  – Activity against bacteria (Gm+/-), fungi, protozoa, and viruses

**Chlorhexidine**

- Mechanism of membrane disruption
  – Batericidal and/or bacteriostatic
- More effective against gram-positive than gram-negative bacteria
  – Also some antifungal and antiviral activity
- Immediate, persistent, and residual antimicrobial properties

**Alcohol vs. Chlorhexidine vs Iodine**

- Better reduction of CFU with aqueous alcohol[* §]

**EBM Summary: Pt prep?**

- Cochran Review 2009 - Edwards P, Lipp A, Holmes A
- 7 RCT Conclusion:
  – Heterogeneity in comparisons
    - SSI significantly lower chlorhexidine vs iodine (1 trial) – Berry 1982
    - No evidence of benefit with iodophor impregnated drapes (4 trials)
  – Conclusion
    - "Insufficient research examining the effects of preoperative skin antiseptics …. Further research is needed"

**Neurotoxicity of Chlorohexadine**

- Rat experiment performed in Sweden (1984)
  – Chlorhexidine injected into anterior chamber of eye
  – Examined iris at 2, 6, 15, 51, and 59 days
  – Dose-dependent degeneration of nerves
  – Primarily effects axon terminals and spares preterminal axon bundles
- 2008 Retrospective analysis lumbar drains pts
  – Changed prep from iodine to chlorhexidine solution
    - Infection rate lowered to 1.8% from 4.7% (not significant)
    - No mention of adverse effects with chlorhexidine (5yrs)
- April 2004 to May 2008
  – 2% chlorhexidine gluconate & 70% isopropyl alcohol vs Povidone-Iodine
  – Endpoint of SSI within 30 days
  – Relative risk of SSI 0.59 with Chloraprep
    - Similar to 49% reduction in risk of central line placement

**Scrub Duration? CDC recommends 2-6 minutes**

- No difference in CFUs from 2 min to 3 min scrub
- Decrease in CFUs after 2 hours with 3 minute rub compared to 30 second rub
  – 3 minute rub as effective as 5 minute rub

**EBM Summary: Hand Antisepsis?**

- Cochran Review 2009 Tanner J, Swarbrook S, Stuart J
  – Chlorhexidine gluconate based aqueous scrubs more effective than povidone iodine based aqueous scrubs in terms of CFUs
- Traditional Scrub vs 'Dry' Scrub
- 2002 RCT held at multiple centers in France
  – 5 minute traditional scrub vs 5mL aqueous alcohol
  – No significant difference in SSI rates
    - 2.48% for traditional scrub
    - 2.44% for aqueous alcohol
  – Improved compliance with aqueous alcohol
    - Protocol based on amount used

- Less skin dryness/irritation

**EBM Summary: Hand Antisepsis?**
- Cochran Review 2009 Tanner J, Swarbrook S, Stuart J
- 10 RCT Conclusion:
  - Alcohol rubs as effective as aqueous scrubbing in preventing SSIs (Parienti 2002)
    - 4387 patients
  - No evidence to suggest any alcohol rub is better than another

**EBM Summary: Sterile Drape?**
- Cochran Review 2011 - Webster J, Alghamdi A
- 2 RCT (1113 pts) – no spine
- Conclusion: Iodine Drape vs No Drape – no difference

**Antibiotic prophylaxis**
- Prophylaxis: First or second generation cephalosporin (*e.g.*cefazolin)
- Low-risk of MRSA positive, but high-risk procedures (*i.e.*, implantation of foreign materials), should be screened for MRSA
  - Negative - cephalosporin
  - Positive - Glycopeptide (vancomycin or teicoplanin) and Gentamicin

**Operating Room Traffic**
- Increase traffic = increased infection?
  - TKR (Babkin Y. Scand. 2007)

**Wound Dressings?**
- Cochran Review 2011 - Dumville JC, Walter CJ, Sharp CA, Page T
- 16 RCT (2578 pts) - no spine
- Conclusions
  - No evidence dressing on surgical wounds (primary intention) reduces SSI
  - Nor one dressing is more effective than others in reducing SSI, pain, scar

**Drains**
- 21 studies: <u>No difference</u> in the incidence of:
  - Wound infection
  - Hematoma
  - Wound dehiscence
- Drain groups
  - Increased risk of re-operation
  - Increased blood transfusion
- No drains
  - Reinforce dressings
  - Bruising

**Nasal colonization**
- Perl TM. *Ann Pharmacother* 1998;32:S7-S16.
  - *S. aureus* in nares of 20-30% of healthy humans.
  - SSI definitely associated with colonization in surgical pts
- Kluytmans JA. *J Infect Dis* 1995;171:216-9.
  - Multivariate analysis noted colonization = most powerful independent risk factor for SSI
- Treatment - Mupirocin ointment
  - Kluytmans JA *Infect Control Hosp Epidemiol* 1996
    - SSI rates for 752 mupirocin pts c/w untreated group (928 historical control)
- Perl TM. Abstract IDSA 36th Annual Meet 1998;91(88)
  - Prospective, randomized clinical trial
  - 3,909 pts
  - Five types of operations – 2 facilities
  - Significant relationship between nasal carriage of *S. aureus* and subsequent SSI development.

**EBM Summary: Staph Carriers?**
- Cochran Review 2011 - Rijen M, Bonten M, Wenzel R, Kluytmans J
- 9 RCT (3396 pts) - no spine
- Conclusions
  - Nasal carriers (S.Aureus) increased risk for SSI
  - Mupirocin prevent S.Aureus SSI in carriers
  - Reduction in overall Staph Aureus Infections but not SSI (sample size small?)
- Prevalence of Staphylococcus aureus colonization in orthopaedic surgeons and their patients: A prospective cohort controlled study
- 74 Attending surgeons, 61 Residents and High-risk pts.
- Physicians
  - 1.5% MRSA+ and 35.7% MSSA+
  - Residents 0 MRSA+ and 59% MSSA+
  - Attending 2.7% MRSA+ and 23.3% MSSA+
- High risk pts
  - 2.2% MRSA+ and 18% MSSA+
- Prevalence of MSSA colonization in the surgeons (35.7%) was significantly higher than that in the high-risk patient group (18%) ($p < 0.01$).

**EBM Summary: Glucose Control?**
- Cochran Review 2009 -Kao LS, Meeks D, Moyer VA, Lally KP
- 5 RCT (2578 pts) - no spine
- Conclusions
  - Insufficient evidence: strict glycaemic control vs conventional management (glucose < 200mg/dL) prevents SSIs
  - No trials in the immediate pre-operative period or outside ICU setting

## Management of a Catastrophic Intraoperative Events: The WHO Standard of Care in Handling these Events

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Chief of Spinal Deformity Surgery
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Surgeon-in-Chief of The Spine Hospital at New York-Presbyterian/Allen
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**I. Types of Intraoperative Catastrophic Events**
**II. Intraoperative Treatment of Catastrophic Events**
**III. Avoidance of Catastrophic Events**
**IV. Lessons Learned**

**I. Types of Intraoperative Catastrophic Events**

A. Cardiac Arrest
B. Hypovolemic Shock due to Massive Blood Loss

C. Anaphylactic Reaction
D. MHS- Malignant Hyperthermia Syndrome
E. Pulmonary Embolus
F. Iatrogenic Large Vessel Tear
G.

**II. Intraop Treatment of Catastrophic Events**

A. Gain Control of the Room- ASAP
   1. Anesthesia Attending (s) summoned
   2. Other Surgical Consults Needed (ie. Vascular Surgery, CT Surgery)
   3. Determine if Pt. Needs to be flipped Supine?
   4. Pack Wound/Iodine-impregnated incision drape. Dressing placed and Stretcher brought in room
   5. Code Team/Rapid Response Team called if Needed
   6. Blood Products requested/brought if Needed- May have to Select someone to physically go to blood blank to retrieve and promptly bring back
   7. Determine if additional venous/arterial access is needed and ensure personnel available for placement

B. Cardiac/Pulmonary/Medical Issue
   1. Arrange for ICU transfer when stable
   2. Determine if possible to reposition Prone/lateral/supine to be able to resterilize region that was quickly packed
   3. If patient is deemed stable to continue, resterilize wound and ensure an exit strategy is in place if patient becomes unstable again
   4. Optimal strategy is to stabilize spine and perform prompt closure to exit out of the OR and return another day to complete the spine reconstruction
   5. Obtain necessary Intensivist consults/primary team care of the medical issues of the patient
   6. Peform any imaging of the spine necessary once patient is stabilized

C. Vascular Tear/Issue
   1. Primary Repair if possible if exposure is present or can be obtained quickly
   2. Stat consult with Vascular Surgeon
   3. Consider Embolization for Vessel tears/Hemorrhage that are not amenable to primary repair
   4. Need Endoscopic equipment and Vascular Surgeon/Interventional radiology to accomplish endovascular repair of a large bleeding vessel (ie IVC, Aorta, Iliac Vein)
   5. Can be life-saving

**III. Avoidance of Catastrophic Intraoperative Events**

A. Preop Considerations
   1. Assess Patient Frailty/Medical Co-Morbidities
   2. Preop PFT's- If < 40% Predicted, Risk of Prolonged Ventilation and Respiratory Problems Postop
   3. Preop PFT's , 30% Predicted, Risk of needing Tracheostomy postop…..Consider Preop placement?
   4. Cardiac Stress done performed Preop on all Pts. > age 60 and those younger who may have any risk factors of cardiac disease
   5. Carotid and LE Dopplers performed Preop on all Adults having significant Spinal Reconstructions
   6. All Patients need Medical Clearance prior to Surgery
   7. Be leary of Pts. who are without any family/friend support system during the preop counseling as they seem to have a higher risk of postop complications that become more difficult to manage due to the lack of help available.
   8. Bone Density in older adults as a proxy for "Fraility" with consideration for no surgery if T-score < - 3.0/3.5
   9. IVC Filter placed preop for pts. with prior VTE and or those at "high risk" of VTE undergoing substantial surgery
   10. All Pts. obtain Central Venous Access prior to Surgey either as an Outpatient the day prior to surgery or by anesthesia the day of surgery prior to starting Spine Surgery
   11. All patients with Arterial Lines placed prior to start of surgery

B. Intraop Considerations
   1. Surgeon should have free access to see Patient Vitals (HR/EKG/PO2 levels etc) continuously during surgery on Monitor
   2. Careful dissection to minimize bleeding no matter what the approach being performed
   3. Obtain proper access surgeons if necessary for anterior and lateral approaches
   4. Consider 2-Attending surgeon approach if it is the best interest of the Patient, especially in highly complex reconstructions (to perform on a same day vs. 2-day approach), when the primary attending spine surgeon is less experienced in the procedure being performed, or when there was a recent complication/problem that requires more spinal surgery to rectify or complete
   5. Always consider a plan for quick exit/closure in patients who are in any way showing signs of instability in the OR (ie, labile Blood Pressure, any drop in Arterial O2 Saturation, EKG abnormalities etc)
   6. Templating Temporary rods for placement if possible prior to quick closure to allow for patient safe mobilization postop without risk of spinal instability.
   7. Pay especially close attention to Arterial O2 saturations as when they start dropping that is a major issue for there is no good way to control that intraop (vs. hypotension which can at least temporarily be treated with various cardiac pressor agents). Decline in O2 sats is a reason for prompt closure and transfer to ICU

**IV. Lessons Learned**

A. MHS Case- Pediatric Patient, MHS protocol followed without sequelae
B. Cardiopulmonary Arrest Case- NM Cerebral Palsy Patient, survived temporarily
C. Intraop Aortic Tear- Salvaged by prompt placement of Endovascular graft
D. Intraop Pulmonary Embolus- Fatal
E. Severe Congenital Scoliosis- Use of Preop Halo traction with POD#1 Respiratory arrest
F. Severe Thoracic Kyphosis due to Multiple Myeloma infiltration of vertebrae – Use of Preop Halo traction to improve

radiographic alignment and overall physical conditioning to allow for successful reconstruction

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## Alternative Strategies of Instrumentation-Know the Full Array of Spinal Fixation Techniques When All Else Fails

**Christopher I. Shaffrey MD**
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1. When Are Alternative Strategies Needed?
   a. Poor bone quality/ osteoporosis
   b. Small pedicles
   c. Disrupted pedicles due to prior surgery
   d. Congenital malformations
   e. Neuromuscular deformity
2. Fixation Options for Poor bone quality/ osteoporosis
   a. 5.
   b. Anterior column load sharing
   c. Restoration of sagittal alignment but without overcorrection
   d. Vertebroplasty at index or adjacent levels
   e. Large diameter long screws (? Bicortical- risk vs. benefit)
   f. Substantial undertapping or no tapping of screws
   g. Preserve dorsal cortex
   h. Laminar hooks to back up end screws
   i. PMMA augmentation of screws
   j. Tethers, bands or wires
3. Cement Augmentation
   a. Maximal fill 8-10 ml in lumbar spine and 4-6 ml in thoracic spine
   b. Vertebroplasty, balloon augmented verebroplasty, fenestrated screw injection
   c. Balloon augmented verebroplasty: perhaps lower pressure fill and perhaps a lower rate of extravasation
   d. Patterns of extravasation: basivertebral vein, leak through cortex or veins, into disk space
   e. Fenestrated screws: must watch location of fenestrations
4. Pedicle Screw Salvage
   a. *Polly et al: Spine 23(12), 1998.* Effect of screw size and hole augmentation
      i. Insertional torque ↓ 34% by replacing screw
      ii. ↑ screw dia. by 2 mm ↑ torque 8.4%
      iii. No effect with ↑ length or placing shims in osteoporotic bone
   b. Change trajectory for failed pedicle screw/pedicle violation *Lehman/Kuklo: Spine, 28(18), 2003.*

| Salvage Option | % Change in Strength vs. Screws |
|---|---|
| Hooks[1] | 60% (T4-8); 74% (T9-12) of Screws |
| Revision Screws[2] | 34% IT less than original screw |
| Screw Diameter[2] | 8.4% increase IT |
| Augmentation[3] | Up to 384% increase in FF |
| Different Trajectory[4] | 39% MIT; 27% POS |

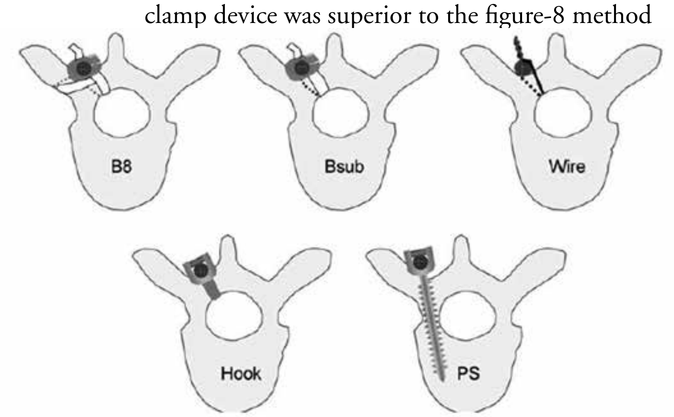
1 Liljenqvist et al: Acta Ortho Bel;67(2), 1994.
2 Polly et al: Spine(23), 1998
3 Yerby et al: Spine (23)15, 1998 and Motzkin et al: JBJS(Br); 76B, 1994
4 Lehman et al: IMAST (9th), May 2002.

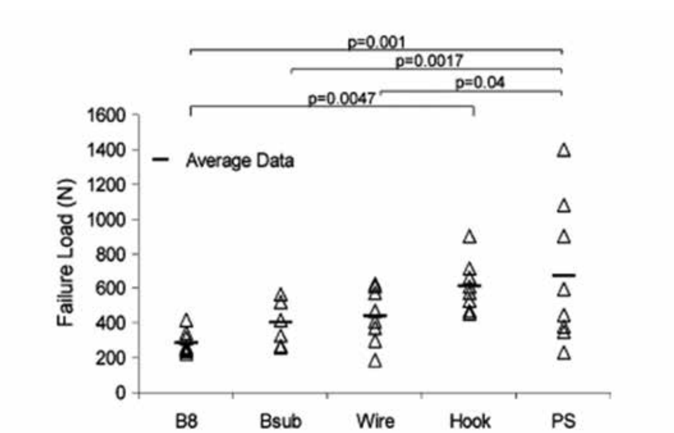
5. Hooks
   a. Less dependent on bone mineral density than pedicle screws
   b. Hook supplementation
      i. Supplement offset hooks ↑ construct *stiffness* for short segment pedicle instrumentation
      ii. Absorb some construct strain, ↓ screw bending moments
   c. Effective option (+/- screws) in osteoporotic bone
   d. Coe JD et al. Spine 15: 902-907, 1990
      i. Influence of BMD on thoracolumbar implants
      ii. Comparison of pedicle screws, laminar hooks, and spinous process wires
   e. Hasegawa K et al. Spine 22:958-62, 1997
      i. Study of method using a pedicle screw and laminar hook for the osteoporotic spine
   f. Hook biomechanics
      i. Biomechanical inferior vs. screws in normal BMP
      ii. Gaines RW et al. Experimental evaluation of seven different spinal fracture internal fixation devices using non-failure stability testing. The load-sharing and unstable-mechanism concepts. Spine 16:902-9, 1991
      iii. O'Brien MF: Failure load of 2 level construct with crosslink

| | |
|---|---|
| Intrapedicular screws | 3157 N |
| Extrapedicular screws | 2706 N |
| Transverse/pedicle hooks | 1691 N |
| Laminar/laminar hooks | 1231 N |

      iv. Two-level claws are better than one level screw and hook constructs
   g. Hook related complications
      i. Nerve root injury secondary to laminar hooks
      ii. Pseudarthrosis
      iii. Dislodgement of hooks from posterior elements
      iv. Dislodgement of hooks from rods
      v. Unwanted increase in rotation below instrumented segments (decompensation)
      vi. Delayed infection

6. Wire and Band Techniques
    a. Good resistance to pull-out
    b. May be used to supplement screws, hooks
    c. May increase risk of junctional kyphosis if used at ends of construct
    d. Eur Spine J (2009) 18:1213–1219
        i. Only the pedicle screw had a statistically significant higher failure load than the sublaminar clamp
        ii. The sublaminar method of applying the belt and clamp device was superior to the figure-8 method



# Post-Op

Room: Ballroom - Salon A-F

Moderators:
Charles H. Crawford, III, MD & Marinus De Kleuver, MD, PhD

Faculty:
Shay Bess, MD; Robert H. Cho, MD; Benny T. Dahl, MD, PhD, DMSci; Kariman Abelin Genevois, MD, PhD; Michael P. Glotzbecker, MD; Richard H. Gross, MD; Ian J. Harding, BA, FRCS (Orth); Manabu Ito, MD, PhD; Michael P. Kelly, MD, MSc; Frank La Marca, MD; Nathan H. Lebwohl, MD; Ronald A. Lehman, Jr., MD; Morio Matsumoto, MD; Bhiken I. Naik, MBBCh, MD; Peter O. Newton, MD; David W. Polly, Jr., MD; Paul T. Rubery, Jr., MD; Alexander R. Vaccaro, MD, PhD, MBA; Yan Wang, MD; Mark Weidenbaum, MD; Frances Mae West, MD

### How to Prevent and Treat Cardiopulmonary Failure Following Surgery for Scoliosis

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Risk factors for cardiopulmonary complications: male gender, advanced age, length of surgery, combination anterior/posterior surgical approach, single lung ventilation, and pre-existing comorbidities (especially pulmonary hypertension and severe restrictive ventilatory defects).

Cardiopulmonary complications can be divided into pulmonary/chest wall, pleural, and pulmonary vascular disorders:

**Pulmonary/chest wall disorders**
- Hypoventilation/atelectasis
  - More common in patients with neuromuscular scoliosis
  - Treatment/preventative modalities include noninvasive ventilation, incentive spirometry, chest physiotherapy, and mechanical cough assist.
- Acute Respiratory Distress Syndrome (ARDS)
  - From direct lung contusion, ventilator induced lung injury
  - Prevention and treatment: low stretch ventilatory strategy while maintaining low driving pressure through the application of positive end expiratory pressure (PEEP)
- Unilateral pulmonary edema (down lung syndrome)
  - Due to positioning during surgery
  - Treatment: supportive
- Pneumonia
  - From poor mucociliary clearance, prolonged mechanical ventilation
  - Prevention and treatment: Early liberation, chest physiotherapy, and antibiotics

**Pleural Disorders**
- Pleural Effusion
  - More common with combined anterior/posterior approach
  - Most are self-resolving, but hemorrhagic effusions need to be drained to prevent fibrothorax
- Chylothorax
  - Rare; due to injury to thoracic duct with anterior approach

**Pulmonary Vascular Disorders**
- Pulmonary Hypertension
  - From marrow embolization and bone debris
  - Risk related to embolic burden and pre-existing pulmonary hypertension
  - Treatment may include pulmonary vasodilators, diuretics, expert consultation recommended
- Pulmonary Embolism
  - Treatment: anticoagulation, systemic or catheter directed lytic therapy, surgical thrombectomy, IVC filter. Right ventricular support including pulmonary vasodilators, inotropes, ECMO

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### The Threshold for Treatment of Post-Operative Anemia and Coagulopathies: Anemia and Blood Loss Triggers

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The Spine Hospital
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**PreOp Evaluation**
•Check Hgb
•Anemia as frequent as 43% in over 65 y.o. veterans cohort undergoing surgery
•Can calculate max allowable EBL based on transfusion trigger and starting Hgb concentration
•Patients >60
•Folic acid
•B12 checked
**Sparing Blood In Spine Surgery**
§Potential areas of intervention
–Decrease need for homologous transfusion
–Decrease rate of bleeding
–Salvage lost blood
**Acute Normovolemic Hemodilution**
•Technique:
•Venous blood collection after induction
•Target crit ~30
•Compensate lost volume with colloids
•Effects:
•1. Tissue oxygenation maintained
•↓ viscosity → ↑ cardiac output and ↑ venous return
•2. Decreased loss of RBC
•Blood volume contains fewer cells
–Safe and effective in decreasing transfusion
§Spinal fusion (Hur et al. 1992)
§Scoliosis surgery (Copley et al. 1999)
–Lumbar PSIF

§76% avoided allogeneic transfusion (Epstein et al. 2006)

**Surgical Technique**

§Local vasoconstrictor infiltration

–Epinephrine → ↓ skin edge oozing

§Fast surgery

–Bovie set high (65/60)

–Surgeon comfort → ↓ surgical time

§Water-tight closure

–Tamponade oozing surfaces

**Trigger For Transfusion**

§AABB

§New Guidelines

§Hb=7 is appropriate for all hemodynamically stable patients except:

–Acute coronary syndro es

–Heme/Onc with severe thrombocytopenia

–Chronic transfusion dependent anema and hemoglobinopathies

**Pearls for Hemostasis**

1)Hypotensive Anesthesia

2)Reverse Trendelenberg

3)Bovies to 65 Coag (Aquamantis for Revisions)

4)Ensure abdomen is hanging "free" (decrease SVR and epidural congestion)

5)Inject skins with Epinephrine

6)Muscle Paralysis during exposure (after NM baselines)

7)Intraoperative Fibrinolytics (? Intrasite; DoD PRCT)

TXA (50mg/kg LOAD, then 5 mg/kg/hr maintenance)

8)Avoid Dural Tears (decreases tension on epidurals)

9)Bone Wax

## Early Identification & Management of Post-Op Infections: Short & Long Term Ramifications

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**SIGNIFICANCE**

- Surgical site infections (SSI) are the most common health care associated infection and the most frequent cause of unplanned readmissions (20%) after surgery. [1, 2]
- SSI extend each patients' hospital stay by an estimated 11 days and account for $3.2 billion in attributable cost per year in acute care hospitals.[1, 2]
- SSI rates after spinal fusion in idiopathic populations has been reported at 0.5-4.3%[3-7] and 8-24% in populations with neuromuscular disease.[5, 8-19]

**IMPORTANT QUESTIONS**

- How do you **diagnose** a postoperative spinal SSI?
- How do you **initially treat** a postoperative spinal SSI?
- What is the **long term treatment** for a postoperative spinal SSI?
- Can you **retain implants** when treating a postoperative spinal SSI?
- If you have to remove implants, is there **deformity progression** after removal?
- Does treatment differ if infection is acute or chronic?
- Does treatment differ in adults vs children?

**DEFINITIONS**

- The Center for Disease Control (CDC) defines a deep SSI as an infection of the fascial and muscle layers confirmed by purulent drainage, positive microbiological test, or detection on anatomical, histopathologic, or imaging tests.[1, 2]
- An acute deep SSI, according to the CDC, must occur less than 90 days after the operative procedure (definition changed 2014). [20]
- Chronic infections occur more than 90 days after the operative procedure

**DIAGNOSIS CLINICAL FINDINGS**

- Clinical diagnosis in the acute period is often fairly obvious
- Frequent symptoms/signs of an acute infection include pain, swelling, erythema around the incision, drainage, and/or systemic symptoms such as fever or sepsis
- Diagnosis in latent/chronic SSI can be much more challenging as the presentation is often more subtle. Signs/symptoms may include poorly defined pain but often may be identified by more subtle findings such as radiographic changes and/or evidence of pseudarthrosis.
- The virulence of an organism can affect its presentation and thus the time to diagnosis.
  – *Staphylococcus aureus* is the most commonly identified bacteria in SSI, which is often detected in acute SSI.[21]
  – However, many slow-growing microorganisms like *Propionibacterium acnes* tend to present later.[22]

**DIAGNOSIS: LABORATORY FINDINGS**

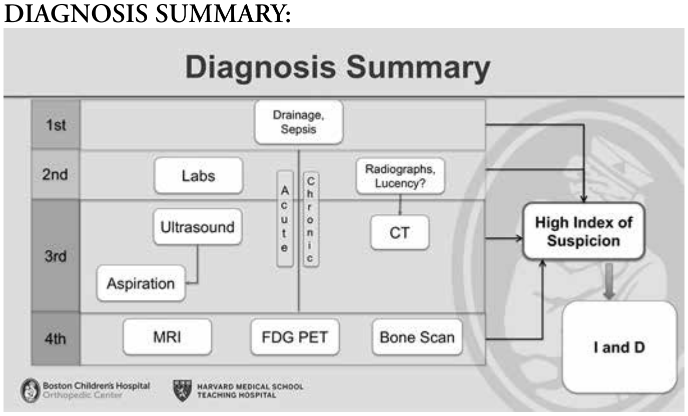
- Post-operative blood work such as persistent elevated C-reactive protein (CRP), white blood cell count (WBC), or erythrocyte sedimentation rate (ESR) may confirm suspected infection, especially in early infections.
- ESR may remain elevated for 21 days post surgery, so CRP can be used in the initial weeks after surgery as it should normalize within 7-10 days postoperatively
- In cases of late SSI, normal CRP and ESR are not sufficient to rule out late infection.[23]
- Serum procalcitonin is a more sensitive and specific marker of bacterial infection than CRP, but has not been commonly used.[24]

**DIAGNOSIS: IMAGING**

- Radiographs
  – Often first study obtained
  – Radiographs will remain normal in first 4-6 weeks of an infection[25]
  – Late changes may include lucency or other evidence of implant loosening and/or broken implants.
  – Therefore radiographs not often useful with an acute SSI, but may give subtle clues to help in identifying a chronic SSI and/or guide further imaging
- CT scan
  – Can further define bony abnormalities such as lucency around implants
  – Can identify pseudarthrosis which may be only clue to a latent infection[25]

- Bone scan
  - Can detect infection earlier than radiographs or CT scans
  - If ordered, Gallium 67 is a better choice than Technetium 99
  - However, bone scans are often not useful due to the reactive bone from the surgical procedure related to bony fusion.[26]
- MRI
  - Bony change in the setting of a SSI may include marrow signal changes, rim enhancing fluid collection, and/or epidural collections.[27, 28]
  - MRI more difficult to interpret with the presence of implants
  - Post surgical changes can also confound interpretation of the images in the acute period
  - Therefore, more useful in postdiskectomy diskitis/non-instrumented spinal surgeries
- 18-FDG-PET [29]
  - Relatively low radiation
  - Unaffected by implants
  - Highly sensitive/specific
  - Costly
- Ultrasound/CT aspiration
  - Unfortunately the yield in aspiration is fairly low (40%).[29]
  - It has fairly low risk, so in the presence of a fluid collection and or suspected disk infection it is likely worthwhile

**DIAGNOSIS SUMMARY:**




**TREATMENT: GENERAL**

- Given lack of evidence to guide treatment, treatment protocols are highly variable.
  - Single vs multiple debridements
  - Implant retention/removal/exchange
  - When to re-instrument
  - Remove/leave allograft
  - Secondary closure with VAC
  - Closed suction irrigation
  - IV antibiotics: How long? Which ones?
  - Oral antibiotics: How long? Which ones?
  - Use of topical antibiotics/irrigation solutions

**TREATMENT: PEDIATRIC CHRONIC SSI**

- Chronic SSI (>3 months) usually can not be treated with implant retention
  - Cahill et al demonstrated success with implant retention in 4/29 patients (13.8%).[5]
  - Hedequist et al demonstrated none of 26 patients with chronic SSI successfully treated with implant retention. [30]D. J.</author></authors></contributors><auth-address>Department of Orthopedic Surgery, Children's Hospital/Harvard Medical School, Boston, MA 02115, USA. daniel.hedequist@childrens.harvard.edu</auth-address><titles><title>Instrumentation and fusion for congenital spine deformities</title><secondary-title>Spine (Phila Pa 1976
  - Repeated trips to operating room have high direct and indirect costs
  - Several studies have demonstrated successful treatment of chronic SSI with implant removal and short course of antibiotics as it is believed to be a soft tissue infection rather than an infection of the bone.[6, 31-34]
  - Deformity progression after implant removal may occur in up to 60% of patients, but is not universal.[5, 35]
  - Acute exchange has been used but not published
  - **<u>Therefore, in general, evidence supports early removal of implants in a chronic SSI</u>**
    - 2-5 days IV antibiotics, 7-14 days oral antibiotics

**TREATMENT: PEDIATRIC ACUTE SSI**

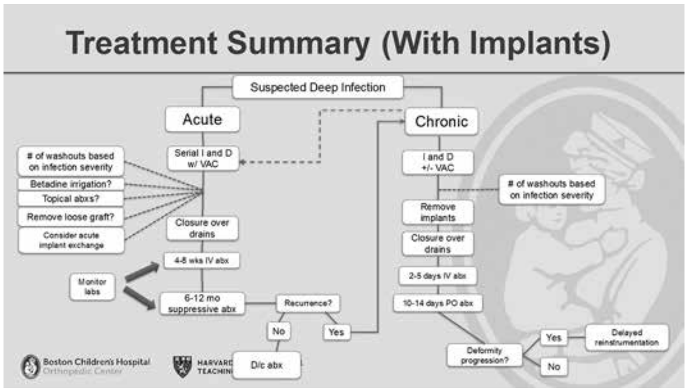
- Acute SSI (<3 months) may (not always) be successfully treated with implant retention
  - Cahill et al demonstrated 75% success rate with implant retention (24/32).[5]
  - Recent multicenter study demonstrated similar findings in 84 acute SSI where 63/84 patients were treated with implant retention (75%)36
    - Patients with stainless steel implants were far less likely to clear their infection with implant retention
  - **<u>Therefore, evidence suggests retention or immediate implant exchange in a pediatric acute SSI</u>**
    - Usually IV antibiotics for 4-6 weeks/oral antibiotics for 2-6 months

**TREATMENT: ADULT SSI [37, 38]**

- Postdiskectomy Diskitis
  - Try to get fluid/tissue culture which may be from the blood or tissue
  - First line treatment is IV antibiotics +/- a brace
  - Surgical indications include infection prevention, failure of antibiotics, extension into canal, neurologic deficit
- Uninstrumented Decompression
  - This often involves having a subfacial collection that is unlikely to resolve without surgical drainage
  - After debridement, IV antibiotics generally continued for 6 weeks
- Instrumented Fusion
  - First line treatment is I and D with closure over a drain
  - Use of a VAC may reduce the number of trips to the operating room

- Current literature supports implant retention unless solid fusion is already attained at which point implant removal may make sense
- Implants should be removed only if multiple debridements fail
- Studies have demonstrated success with implant retention in posterior segmented instrumentation (24/26) and with PLIF (8/8)

**TREATMENT SUMMARY:**





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## Acute Post-Operative Renal Failure: Prevention, Identification and Treatment


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**INTRODUCTION**

- Acute kidney injury
  - Rapid loss of renal function with accumulation of waste products
  - RISK = Increase in serum Creatinine (sCR) x 1.5 OR GFR drop 25% OR UOP < 0.5 mL/kg/hr for 6 hours
  - INJURY = Increase in sCR x 2 OR GFR drop 50% OR UOP < 0.5 mL/kg/hr x 12 hrs
  - FAILURE = Increase in sCR x 3 OR GFR drop 75% OR UOP < 0.3 mL/kg/hr x 24 hrs OR Anuria x 12 hrs
- AKI is common, up to 5% of all hospitalizations
  - Surgery is the most common cause for inpatient AKI
- Complex spine reconstructions are becoming increasingly common
  - Complications associated with adult spinal deformity (ASD) reconstructions are common
    - 55% Overall complication rate (Sciubba, Spine Deform, 2015)
      - 18.5% Major
      - 15.7% Minor
    - 78% of 3CO patients (Smith et al, JNS Spine, 2017)
- Adult thoracolumbar spine surgeries (degenerative, ASD, etc)
  - 4% Rate of AKI by RIFLE Criteria (Naik, JNS Spine, 2014)
    - R – Risk of renal dysfunction
    - I – Injury to the kidney
    - F – Failure of kidney function
    - L - Loss of kidney function
    - E – End-stage kidney disease
- Why does this matter?
  - Inpatient AKI is associated with high mortality rates
    - 1-30%
    - 80% if renal replacement therapy (RRT, dialysis) is required
  - AKI is associated with developing chronic kidney disease

**PREVENTION**

- Begin by understanding the injury
  - Damage to renal vasculature
  - Damage to renal interstitium
  - Tubular damage (e.g. dye)
    - In ASD, most injuries will be the result of hypoperfusion
    - This causes abnormal renin-angiotensin-aldosterone system behavior
  - <u>RISK FACTORS</u>
    - Male gender
    - Age
    - Diabetes mellitus
    - Smoking
    - Chronic steroid use
    - OBESITY
      - Can be associated with a glomerulopathy
    - Surgery
      - Hypovolemia
      - Duration of surgery
      - Low SVR due to anesthesia
      - Low SVR due to caval compression
      - Anesthesia
        - Inhalational anesthetics historically related to toxic event
        - Perhaps less AKI with use of propofol

- Drugs
  - Combination of nephrotoxic drugs postoperatively should be avoided (ACE-inhibitor + NSAID)
  - Contrast dye

**INDENTIFICATION**

- First identify those at risk
  - Maintain MAP > 60-65mmHg or more if chronic hypertension
  - Intraoperative fluids
    - Balanced crystalloid/colloid improves renal perfusion
    - Monitor UOP
      - Be careful, unlikely to be an adequate proxy for perfusion or volume status
  - Diuretics
    - ONLY to treat hypervolemia
  - Perioperative anemia
    - Low preoperative anemia and blood loss associated with AKI
    - Packed red blood cells may also be a risk factor for AKI
    - Optimize preoperative anemia
    - Use anti-fibrinolytics to minimize intraoperative blood loss
      - Aprotinin associated with AKF and no longer used
  - Vasopressors
    - Norepinephrine reduces renal blood flow
    - Dopamine no longer considered renal protective and not recommended for AKI

**TREATMENT**

- Goal is preservation of renal function
- Careful fluid management
  - Maintenance of renal perfusion without fluid overload
    - (+) Fluid balance associated with AKI
    - Diuretics for (+) fluid balance
- Correction of electrolyte abnormalities
  - May include dietary changes to avoid potassium
  - Restriction of salt
- Indications for dialysis
  - Unable to control fluid balance with diurectics
  - Unable to manage hyperkalemia with medicine
  - Uremia / Severe azotemia
  - Correction of acid-base abnormalities
- Dialysis 3x weekly
- Must continue to follow long term with referral to Nephrology

## Post-Op Pain: In Today's Climate When is it Necessary to Involve a Pain Management Specialist?

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Due to the chronicity of spine-related disease and the associated somatic and neuropathic pain, patients presenting for spine surgery have a high prevalence of chronic opioid use. For spine surgery, 55-71% of patients utilize opioids preoperatively in contrast patients requiring colorectal surgery have a pre-procedure opioid prevalence of 33-44%. Despite surgery a significant percentage of spine surgery patients continue to require long-term opioids, independent of whether they were previously using opioids. A recent study by Brummett et al. showed that after major or minor non-spine surgery, 5.9% to 6.5% of opioid-naïve patients continue to use opioids 90-days after surgery.[1] The aforementioned rates are significantly lower than the chronic opioid prevalence (21-26%) in opioid-naïve spine patients undergoing surgery.[2]

Factors associated with long-term postoperative opioid use include a history of depression and anxiety, alcohol and substance abuse and age greater than 50 years. Preoperative opioid use is a negative predictor of opioid independence. In those who use preoperative opioids, 41% are opioid free at 12 months. In patients who do not use preoperative opioids, 74% are opioid free at 12 months.[2] We also recently demonstrated that preoperative psychosocial factors such as catastrophizing, anxiety and depression can play an important role in postoperative patient reported pain scores and quality of recovery in patients undergoing spine surgery. Patients with higher catastrophizing scores were more likely to have higher maximum pain scores postoperatively [Estimate: 0.03, SE: 0.01, p= 0.02), without increased opioid use [Estimate: 0.44, SE: 0.27, p=0.11). Preoperative anxiety [Estimate: 1.18, SE: 0.65, p= 0.07) and depression scores [Estimate: 1.06, SE: 0.71, p= 0.14) did not correlate with increased postoperative opioid use; however, patients with higher preoperative depression scores have lower quality of recovery after surgery [Estimate: -1.9, SE: 0.56, p < 0.001). Therefore risk stratification based on the aforementioned preoperative factors and the amount of opioids used prior to surgery is important. This will determine which patients can be managed per protocol (as part of a standardized care pathway e.g. Enhanced Recovery After Surgery) and when a pain management specialist should be consulted as part of their management.

Currently there is little data on ERAS pain pathways for deformity correction spine surgery. However a combination of high-risk pre-operative psycho-social factors, as determined by validated scales such as the pain catastrophizing scale or the hospital anxiety-depression scale (HADS), and amount of preoperative opioid use can provide guidance for pathway stratification. We have created an ERAS pain pathway utilizing preoperative daily morphine equivalent (ME) use that is reported below. The aim of this pathway is to standardize perioperative opioid management, with the assistance of the pain service, when appropriate:

A. Low Opioid Use (0-10 mg ME)(Table1)
B. Intermediate Opioid Use (10-100 mg ME) (Table 2)
C. High Opioid Use (> 100mg ME) (Table 3)

Table 1: Low Opioid Use (0-10 mg ME)

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| Gabapentin 600mg PO | Ketamine 5-10mcg/kg/min | Scheduled Tylenol 975mg PO |
| Tylenol 975mg PO | Lidocaine 40mcg/kg/min | Oral oxycodone 5/10/15mg PRN |
| | Methadone 0.1-0.2mg/kg | Opiate Naïve PCA |

Table 2: Intermediate Opioid Use (10-100 mg ME)

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| Gabapentin 600mg PO | Ketamine 5-10mcg/kg/min | Lidocaine (0.5-1.0 mg/min) |
| Tylenol 975mg PO | Lidocaine 40mcg/kg/min | Tylenol 1g IV x1 doses; Tylenol 975mg PO scheduled |
| | Methadone 0.1-0.2mg/kg | Oral oxycodone 5/10/15mg PRN |
| | | (1-30mg MSO4eq) Opiate Naïve PCA (30-100mg MSO4eq) Opiate Tolerant PCA |

Table 3: High Opioid Use (> 100mg ME)

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| Gabapentin 600mg PO | Ketamine 2.5-5.0 mcg/kg/min | Ketamine (2.5-5.0 mcg/kg/min) AND Lidocaine (1mg/min) |
| Tylenol 975mg PO | Lidocaine 40mcg/kg/min | Tylenol 1g IV x1 doses; Tylenol 975mg PO scheduled |
| | Methadone 0.1-0.2mg/kg | Oral oxycodone 5/10/15mg PRN |
| | | Gabapentin 600mg PO |
| | | Opiate Tolerant PCA |
| | | Pain Service |


**Reference:**

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## Proximal Junctional Kyphosis: Strategies to Avoid this Problem


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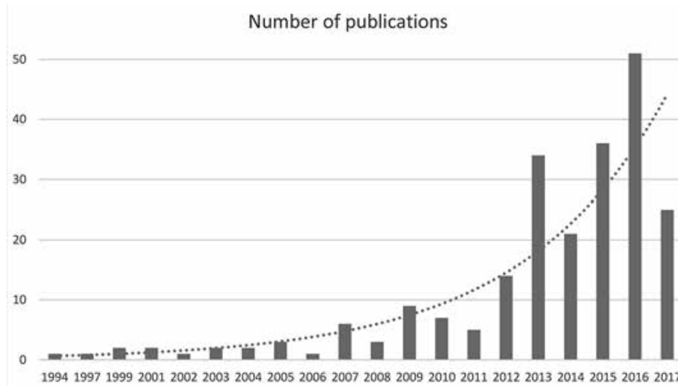
How Much Literature?

- Pub Med search 4/23/2017
- 'proximal junctional kyphosis'
- 226 results

By year




Potential Causes

- Technical surgical issues
- Over/under correction
- Proximal ligamentous disruption
- Muscle disruption
- Cantilever deformity correction mechanics
- Stiffness change between instrumented and adjacent segments

Potential Causes- Host Issues

- Neuromuscular disorders
- Collagen/connective tissue disorders
- Propensity for accelerated disc degeneration
- Osteoporosis
- Attempting to accomplish activities of daily living in the same fashion
- Trying to read
- Smart phones
- Eating
- Others?

What is Necessary to Devise Prevention Strategies?

- To develop meaningful scientific evidence we must be able to 'reasonably' predict the rate
- This requires identifying risk factors
- It requires consistency in surgical technique
- It requires comparisons of interventions to predicted rates
- Highest level of evidence would be an RCT but we are nowhere near ready to appropriately identify the risk factors to make the groups equal

Potential Prevention Strategies

- Pre-op determination of optimal sagittal contour
- Minimizing forces of proximal anchors
- Minimizing tissue disruption for placement of proximal anchors

- Optimizing bone quality pre-op
- Cement augmentation of upper instrumented vertebra and suprajacent vertebra
- Stiffness transitions

## A Multidisciplinary Approach to Global Spine Care Enhanced Recovery After Surgery (ERAS)

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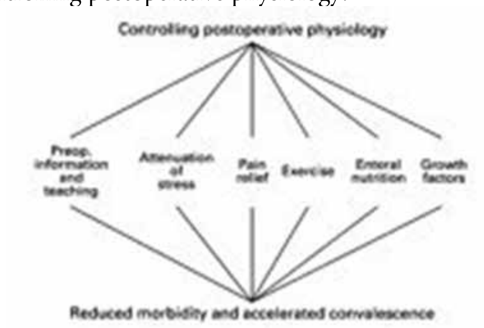
**Synonyms**
Enhanced Recovery After Surgery, fast-track surgery, accelerated surgery, rapid recovery.

**The old dogma of postoperative recovery**
- Slow increase of oral intake of solid foods
- Delayed mobilization
- Nasal tubes and bladder catheters for days
- Postoperative hospitalization 7 to 14 days
- Pain treatment with opioids 4-7 days after surgery

**The Danish dogma of peri-operative recovery**
Introduced by Henrik Kehlet in 1997

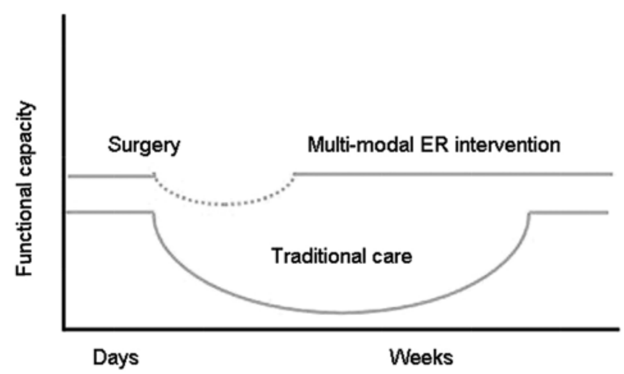
**The new dogma of postoperative recovery**
- Early mobilization
- Early removal of nasal tubes, drains and bladder catheters
- Multi-modal pain treatment:

- Patient information
- Fluid therapy
- Early oral nutrition
- Reduction in blood transfusion
- Controlling postoperative physiology:




**Elements of ERAS**


**ERAS vs. traditional care**




**Conclusion**
There is considerable evidence that ERAS is beneficial in general surgery and hip- and knee replacement. However, a limited number of studies have focused on the benefits of ERAS on complex spine surgery.

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H Kehlet, "Multimodal Approach to Control Postoperative Pathophysiology and Rehabilitation," *Br J Anaesth* 78, no. 5 (1997): 606–17.**cardiopulmonary, infective and thromboembolic complications, cerebral dysfunction, nausea and gastrointestinal paralysis, fatigue and prolonged convalescence. The key pathogenic factor in postoperative morbidity, excluding failures of surgical and anaesthetic technique, is the surgical stress response with subsequent**

**increased demands on organ function. These changes in organ function are thought to be mediated by trauma-induced endocrine metabolic changes and activation of several biological cascade systems (cytokines, complement, arachidonic acid metabolites, nitric oxide, free oxygen radicals, etc**

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Michael Y. Wang, Peng-Yuan Chang, and Jay Grossman, "Development of an Enhanced Recovery After Surgery (ERAS) Approach for Lumbar Spinal Fusion," *Journal of Neurosurgery: Spine* 26, no. April (2016): 1–8.**Enhancing Recovery After Surgery (ERAS**

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## Rapid Recovery Pathway for Adolescent Idiopathic Scoliosis

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1. 'Harms Study Group' Database
   A worldwide cohort of surgeons who perform comprehensive, multi-center prospective research studies focused on pediatric spinal deformity.
2. Harms Study Group's primary focus is multi-center research group for pediatric spinal deformity.
   20 years of research:
   ~150 peer reviewed scientific publications
   ~ 600 scientific meeting presentations
3. Quality Improvement Initiative
   Began 2012
   Simple surgeon specific dashboard created
   Show surgeons how they compare to their peers
   Goal: Reduce variability, improve surgeon performance, improve outcomes
4. Length of Hospitalization
   Variation in Care
   100 % variation in average LOS
   Why?
   Can we do better?
   Encourage a more Rapid Recovery, not an Early Discharge
5. 2013 HSG Quality Improvement Project – Optimize Hospitalization
   Collected AIS Postop order sets
   Special attention to those with shortest LOS
   Meeting of the minds
   Consensus of "Best Practices" agreed
   Implementation across sites (with local modifications)
6. Goal – 4 Day Hospital Stay

| | Percent of Stays ≤ 4 days | | |
|---|---|---|---|
| SURGEON | 2013 | 2014 | 2015 |
| 1 | 25% | 90% | 90% |
| 2 | 27% | 86% | 100% |
| 3 | 28% | 83% | 76% |
| 4 | 48% | 74% | 71% |
| 5 | 27% | 20% | 20% |
| 6 | 21% | 78% | 94% |
| 7 | 0% | 0% | 0% |
| 8 | 88% | 92% | 100% |
| 9 | 10% | 100% | 94% |
| 10 | 81% | 82% | 92% |
| 11 | 6% | 56% | 83% |

7. 2015 Revised Goal to 3 Day Hospital Stay
   Preop
      Gabapentin, CHG wash
   POD 0
      PCA basal + demand
      IV Acetaminophen +/-, expensive
      Clear liquids, chewing gum, Ondansetron/Metoclopramide prn
      Neurontin 300 qHS
   POD 1
      Ketorolac, Gabapentin
      PCA to demand only
      Adv diet as tolerated
      Oral narcotic if tolerating po
      OOB x2 with PT
   POD 2
      Ketorolac, Gabapentin
      D/C PCA
      Adv diet
      Oral narcotic
      OOB x2 with PT
      D/C Foley
      D/C drain if used
   POD 3
      Gabapentin
      Adv diet
      Oral narcotic
      Stairs with PT
      D/C Home
8. Implementation
   Site specific concerns/norms/historical dogma
   Work with Nursing, Anesthesia, Pain Service
   Preop Education

9. Goal: Rapid Recovery for patients
10. Goal is NOT: Early discharge for the hospital

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## Making the Best Use of Inpatient Management Trends: Safely Minimizing Hospital Stay Following Surgery

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❖ **Length of Stay (LOS) for 1,978 spine cases in Jefferson University Hospital in 2016**

- Ortho-spine LOS is generally shorter than Neuro-spine LOS. (3.4d vs. 4.0d)
- LOS has no correlation with the seasons;
- Patients admitted on **Saturday** have the longest LOS;
- Postoperative complications in patients are associated with prolonged hospital stays.
- LOS for fusion except cervical without MCC is comparable among different surgeons.
- LOS after cervical spinal fusion with MCC ranges from 1.6d to 4.4d.
- LOS after cervical spinal fusion without MCC/CC ranges from 1.4d to 3.4d.
- Among top 10 DRGs, **combined anterior/posterior fusion with major complication or comorbidity (MCC)** has the **longest LOS** for **both Neuro-spine and Ortho-spine**.
- Combined anterior/posterior spinal fusion without MCC/CC: LOS ranges from 3.0d to 5.2d.
- Combined anterior/posterior spinal fusion with MCC: LOS ranges from 4.6d to 16.0d.

❖ **Pre-Operative Strategies**

- Expectations should be set through educational handouts regarding what to expect after spinal surgery, including typical Length of Stay after each surgery.
- To identify needs early for post-operative rehabilitation, e.g. the list of *Post-Acute Quality Care Alliance Partners, Skilled Nursing Facilities* in Rothman Institute.

❖ **Post-operative Strategies**

- Clinical Pathways are associated with decreased LOS and reduced in-hospital complication. For example, ACDF Pathway in Jefferson with an estimated LOS of one night was designed not only to improve the patient care, but also to increase the efficiency of our care delivery.[1]
- Early mobilization is encouraged since POD#0, i.e. mobilizing patients in PACU.[2,3]
- Physician directed discharge as opposed to patient directed discharge.
- **Never provide patients with the option to stay an extra day unless medically necessary.**
- **Geographic Placement and Patient-Centered Rounds Model.**[4]
- Minimize **post op imaging** as well as **lab testing** is another important strategy to decrease the LOS: a) Reduce number of multi-sequence studies if possible; b) Eliminate repeat studies on patients transferred in with prior studies c) Plan study as OP when appropriate.
- Unnecessary imaging may do as much harm as good.[5]

❖ **Pain after spine surgery has been a driver of IP LOS**

- According to a random survey of 250 patients after spine surgery, most patients (82%) was in pain for the first few days after surgery.[6]we conducted a national study by using telephone questionnaires. A random sample of 250 adults who had undergone surgical procedures recently in the United States was obtained from National Family Opinion. Patients were asked about the severity of postsurgical pain, treatment, satisfaction with pain medication, patient education, and perceptions about postoperative pain and pain medications. Approximately 80% of patients experienced acute pain after surgery. Of these patients, 86% had moderate, severe, or extreme pain, with more patients experiencing pain after discharge than before discharge. Experiencing postoperative pain was the most common concern (59%
- Patient reported pain does not change much in the past twenty years. The percentages of the patients reporting each category of pain after surgery were comparable among three different surveys in 1995, 2003 and 2012.[7]
- After a prospective cohort study, Archer et.al reported that **early postop fear of movement** (6 weeks) predicted 6-month pain, interference, disability and decreased physical health.[8]
- **Pre-operative opioid usage** can **predict** longer LOS and worse outcome.[9]thoracolumbar, or cervical spine surgery to treat a structural lesion were included in this prospective cohort study. Self-reported preoperative opioid consumption data were obtained at the preoperative visit and were converted to the corresponding daily morphine equivalent amount. Patient-reported outcome measures were assessed at three and twelve months postoperatively via the 12-Item Short-Form Health Survey and the EuroQol-5D questionnaire, as well

as, when appropriate, the Oswestry Disability Index and the Neck Disability Index. Separate multivariable linear regression analyses were then performed. RESULTS: At the preoperative evaluation, of the 583 patients, 56% (326 patients

❖ **Post-operative pain management is essential to optimal healing and recovery of spine surgery**

- Traditionally the mainstay of postoperative analgesia is opioid based, however increasingly more evidence exists to support a multimodal approach or analgesia (MMA) with the intent to reduce opioid side effects and improve outcomes[10,11]a search was performed on English language publications on Medline (PubMed; National Library of Medicine, Bethesda, MD, USA
- Enhanced recovery protocols to reduce LOS in spine surgery are becoming more prevalent and include multimodal opioid sparing regimens as a critical component.
- Pain is multifactorial, therefore treatment should rationally target all components, including nociceptive, visceral, neuropathic, inflammatory and muscle spasm. No single drug can adequately treat each of these components.
- Bohl et al. performed a retrospective study after ACDF, and reported that in comparison with PCA (patient-controlled analgesia), MMA had lower rate of inpatient narcotic consumption, less nausea/vomiting, shorter LOS with no difference in VAS.
- Introduction of General MMA Guideline for MIS spine surgery.[12]
- A prospective RCT on MMA in lumbar decompression surgery showed: a) Total postoperative i.v. morphine requirements in addition to morphine requirements at all predetermined time points were less in patients randomized to receive the MMA regimen. b) Visual analog pain scores were lower at all postoperative time points in patients randomized to receive the MMA regimen. c) Time to solid food was significantly less in the MMA group. [13]
- <u>**The preemptive multimodal analgesic combination in this study appears to be safe and effective after lumbar fusion surgery.**</u> [14]
- Kim et al. recently reported in a prospective RCT (n=80) comparing preemptive MMA with i.v. morphine only group. The preemptive multimodal pharmacologic agents administered were celecoxib (200 mg), pregabalin (75 mg), acetaminophen (500 mg), and extended-release oxycodone (10 mg). MMA group had significantly lower VAS and ODI scores at all time points than those of morphine group, except the ODI on postoperative day 1.[15]

❖ **Tackling LOS reduction also included multidisciplinary cooperation, leadership buy-in, and additional resources to enhance discharge care coordination.**

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# Notes

# HALF-DAY COURSE

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges Medtronic, Orthofix, and Zimmer Biomet for their support of the Half-Day Courses.

# Half Day Courses:
# Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of Life the Cost for a Taller, Straighter Spine?

# MIS Spinal Surgery – An Updated Global Perspective

# Spinal Alignment: Goals, Planning and Pathologies

**September 7, 2017**
**13:30 – 16:30**

Sponsored by the Scoliosis Research Society

# Half-Day Courses

## GROWTH FRIENDLY TECHNIQUES FOR EARLY ONSET SCOLIOSIS (EOS): IS QUALITY OF LIFE THE COST FOR A TALLER, STRAIGHTER SPINE?

Room: Ballroom - Salon A-F

## MIS SPINAL SURGERY – AN UPDATED GLOBAL PERSPECTIVE

Room: Ballroom - Salon HIJ

## SPINAL ALIGNMENT: GOALS, PLANNING AND PATHOLOGIES

Room: Ballroom - Salon GKL

Thursday, September 7th, 2017
13:30 – 16:30
Philadelphia Marriott Downtown
Philadelphia, Pennsylvania, USA

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## TARGET AUDIENCE

Presentations at SRS Annual Meeting & Course will have value for physicians and allied health personnel who treat spinal deformities at all levels and in all ages of patients. Medical students, residents, fellows and researchers with an interest in spinal deformities will also benefit from the materials presented.

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# Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of Life the Cost for a Taller, Straighter Spine?

Room: Ballroom - Salon A-F

Course Chairs:
Suken A. Shah, MD and Muharrem Yazici, MD

Faculty:
Laurel C. Blakemore, MD; Hazem B. El Sebaie, MD, FRCS; John B. Emans, MD; David M. Farrington, MD; Peter G. Gabos, MD; Carol C. Hasler, MD; Charles E. Johnston, MD; A. Noelle Larson, MD; Colin Nnadi, FRCS (Orth); Gregory Redding, MD; James O. Sanders, MD; David L. Skaggs, MD, MMM; Paul D. Sponseller, MD, MBA; Peter F. Sturm, MD; Tetsu Uejima, MD; Michael G. Vitale, MD, MPH; Burt Yaszay, MD

*This course is supported, in part, by a grant from Medtronic.*

# Half Day Courses

Thursday, September 7, 2017

## Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of Life the Cost for a Taller, Straighter Spine?

13:30 – 16:30

| Chairs: Suken A. Shah, MD and Muharrem Yazici, MD | | |
|---|---|---|
| **Time** | **Title** | **Speaker** |
| 13:30-13:32 | Introduction and Objectives | Suken A. Shah, MD |
| 13:32-13:38 | How Are We Doing? Compared to What? Analysis of Outcomes and QoL | Michael G. Vitale, MD, MPH |
| 13:38-13:44 | Repetitive Effect of Anesthetics on the Young Brain | Tetsu (Butch) Uejima MD, MMM, FAAP, CPHRM |
| 13:44-13:50 | Questions / Discussion | |
| 13:50 -13:56 | The Impact of Casting: Spine, Child and Family | James O. Sanders, MD |
| 13:56-14:02 | Post Traumatic Stress During Treatment (Child and Family) | Peter G. Gabos, MD |
| 14:02-14:07 | A Parent's Perspective of Growth Friendly Treatment for EOS | TBD |
| 14:07-14:14 | Questions / Discussion | |
| 14:14-14:19 | Debate: Pro: Magnetically Controlled Growth Rods are A Game Changer | Colin Nnadi, FRCS (Orth) |
| 14:19 -14:24 | Debate: Con: MCGR is a Flash in the Pan…TGR is Here to Stay | Laurel C. Blakemore, MD |
| 14:24 -14:28 | Discussion | |
| 14:28-14:30 | Live Webcast Closing Remarks and Transition to Regular Course | Suken A. Shah, MD |
| 14:30-14:36 | Comparison of Growth Friendly Techniques in Terms of Outcome: Is One Better than the Rest? | John B. Emans, MD |
| 14:36-14:42 | Image Gently: Reduction of Radiation in Kids with EOS | A. Noelle Larson, MD |
| 14:42-14:50 | Cost Analysis of Treatment in EOS | Peter F. Sturm, MD |
| 14:50-14:57 | Questions / Discussion | |
| 14:57-15:04 | Pulmonary Status at the End of Treatment | Gregory Redding, MD |
| 15:04-15:11 | The Fork at the End of the Growth Friendly Road: Final Fusion or Observation? | Paul D. Sponseller, MD, MBA |
| 15:11-15:20 | Questions / Discussion | |
| 15:20-16:20 | Case Presentations with the Expert Panel | Moderator: Muharrem Yazici, MD |
| | A Journey from Childhood to Adolescence with Growth Friendly Surgery: "Yin and Yang" | Charles E. Johnston, MD; Behrooz A. Akbarnia, MD; Burt Yaszay, MD; David M. Farrington, MD; David L. Skaggs, MD, MMM; Hazem B. El Sebaie, MD, FRCS |
| 16:20-16:25 | Questions / Discussion | |
| 16:25-16:30 | Conclusion and Adjourn | Muharrem Yazici, MD |

# Half-Day Courses — Session 1

## Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of Life the Cost for a Taller, Straighter Spine?

**Michael Vitale, MD, MPH**
Children's Hospital of NY Presbyterian
New York, New York, USA

**Why Assess Quality of Life?**
Realization that "technical", "traditional" endpoints have shortcomings
Different, but better?
QOL may be the best endpoint to use when assessing the effect we have on our patients

**Patient-Based Outcomes**
"In the field of scoliosis, there is one rule: keep your eye upon the patient, and not upon the curve."
- Cobb, 1948
"Treat the patient, not the x-rays."
- Blount, 1955

OUTCOMES: Why Treat Children With Scoliosis?
To decrease curve/stop progression curve…
decrease pain or increase function?
for psychosocial reasons?
for cosmetic reasons/self image?
To improve lung function?
<u>To prevent *future* progression and *future* disability</u>

Will QOL measures respond to any of the above?
Disease-Specific and Generic Measures
Are Complementary and ***<u>Both</u>*** Necessary
Burden of Care
I miss work due to my child's health condition.
I am late to work due to my child's health condition.
I miss social events due to my child's health condition.
I am late to social events due to my child's health condition.
Given my child's health condition, I am not able to take care of other family members like I want to.
Intrinsic Difficulties in Pediatric
Quality of Life Assessment
**Developmental** issues -> need for age-based norms
Often need to use **parent** as proxy- **VALID**?
Many procedures in pediatrics are "**prophylactic**"
Long periods of **follow up** needed
**Natural history** of disease unclear
Comorbidities and EOS
**Early Spine Fusion is Associated with Adverse Pulmonary Outcome**
Traditional Endpoints and Patient Based Measures Don't Necessarily Correlate
We need a better ruler to examine HRQOL and responsiveness in EOS
"What is the QOL effect of Repetitive Surgery"
Conclusions
EOS is bad disease
QOL is ONE important outcome measure
We need both disease specific measures and generic QOL measures

## Repetitive Effect of Anesthetics on the Young Brain

**Tetsu (Butch) Uejima MD, MMM, FAAP, CPHRM**
Chairman, Dept of Pediatric Anesthesiology and Perioperative Medicine
Nemours/AI duPont Hospital for Children
Professor of Anesthesiology and Pediatrics
Sidney Kimmel Medical College of Thomas Jefferson University
Wilmington, Delaware, USA

A. What do we know---the basic science
  1. Laboratory studies in animal models show detrimental effects of virtually all commonly used anesthetic agents on the developing brain
  2. First animal study published in 1999
  3. Effects are behavioral and have consistently been demonstrated in many animal models including non-human primates
  4. Investigations of the brains in the these studies demonstrate accelerated neuroapoptosis, i.e., brain cell death
  5. Focus on NMDA (N-methyl-D-aspartate) antagonists and GAGA (gamma-aminobutyric acid) agonists

B. Smart Tots (Strategies for mitigating anesthesia related neurotoxicity in tots) www.smarttots.org
  1. A public (FDA)-private (IARS---international anesthesia research society) partnership
  2. Assess safety of anesthetic drugs
  3. Provide funding and promote research

C. What about human studies?
  1. Many retrospective studies
  2. Three ongoing prospective studies
     a. General anesthesia vs spinal anesthesia (GAS)
     b. Pediatric anesthesia and neurodevelopmental assessment (PANDA)
     c. Mayo anesthesia safety in kids (MASK)
  3. GAS and PANDA studies have both reported preliminary data
     a. Both studies involve single exposure to general anesthesia, not multiple exposures
     b. Both studies report no evidence to neurocognitive deficits

D. The FDA warning
  1. Issued in December of 2016
     *FDA is warning that repeated or lengthy use of general anesthetic and sedation drugs during surgeries or procedures in children younger than 3 years or in pregnant women during their third trimester may affect the development of children's brains*
  2. FDA felt compelled to issue the warning due to the animal evidence
  3. Has generated considerable concern, consternation and debate among pediatric anesthesiologists and pediatric surgeons
  4. Generated a consensus statement from Smarttots

E. What we do not know
  1. Who exactly is at risk?
  2. Does length or frequency of exposure matter?

3. Can this be prevented?
4. Can this be treated?
5. Is there potential medico-legal liability?

F. Practical dilemmas
1. Most procedures in children under the age of 3 yr are not completely elective
2. There is insufficient evidence in the literature to categorically support the age 3 yr warning
3. There is insufficient evidence in the literature to categorically support the 3 hrs anesthetic exposure warning
4. Virtually every anesthetic agent has been implicated however, there may be limited alternatives
5. Lack of national consensus on practical approaches due to disagreement about the risks to humans
   a. Should these potential risks be discussed with every family or only if asked?
   b. How should concerns be addressed?
   c. What, if any, are the anesthetic alternatives?
   d. Should consent forms be changed to address this potential risk?

**Smart Tots Consensus Statement on the Use of Anesthetic and Sedative Drugs in Infants and Toddlers** *October 2015*
Each year, millions of infants and toddlers require anesthesia and/or sedation for surgery, procedures, and tests. Concern has been raised about the safety of the medicines used for anesthesia and sedation in young children. This concern is based on research in animals demonstrating long-term, possibly permanent, injury to the developing brain caused by exposure to these medicines. This injury results in abnormalities in behavior, learning, and memory in animals. The effect of exposure to anesthetic drugs in young children is unknown; however, some but not all studies have suggested that problems similar to those seen in animals could also occur in infants and toddlers. It is important to recognize that the studies in children suggest that similar deficits may occur. These studies in children have limitations that prevent experts from understanding whether the harmful effects were due to the anesthetic drugs or to other factors such as the surgery or related illness. Better research is required to understand whether children are harmed and if so, what alternative medicines might be used to minimize risk from anesthesia.

Because there is not enough information about the effects of anesthetic drugs on the brains of young children, it is not yet possible to know whether use of these medicines poses a risk, and if so, whether the risk is large enough to outweigh the benefit of the planned surgery, procedure, or test. Until further research clarifies the importance of these findings we recommend:

**For healthcare providers**
Answers to questions from parents and caregivers related to these risks should highlight the differences between research findings in animals and children and the uncertainty of any effect in children. It may also be emphasized that because most anesthetic drugs have been shown to cause injury in animal experiments, no specific medications or technique can be chosen that are safer than any other. Clearly, anesthetic drugs are a necessary part of the care of children needing any surgery, procedure, or test that cannot be delayed. Decisions regarding the timing of a procedure requiring anesthesia should be discussed with all members of the care team as well as the family or caregiver before proceeding. The benefits of an elective procedure should always be weighed against all of the risks associated with anesthesia and surgery.

**For parents and caregivers**
Discuss the timing of planned procedures with your child's primary care physician, surgeon/proceduralist and anesthesiologist. Concerns regarding the unknown risk of anesthetic exposure to your child's brain development must be weighed against the potential harm associated with cancelling or delaying a needed procedure. Each child's care must be evaluated individually based on age, type and urgency of the procedure and other health factors. Your child's doctors are best able to provide this advice. If you desire additional information and updates on current research, please go to **smarttots.**

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## Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of Life the Cost for a Taller, Straighter Spine?

**James O. Sanders, MD**
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**QOL and EOS:**
With the advent of a several growth "friendly" techniques, the outcome of early onset scoliosis is no longer inevitably early demise from pulmonary problems or right sided heart failure1. However, several recent reports and presentations have identified decreased quality of life scores in children undergoing treatment for early onset scoliosis compared to other children2, 3. This leads to the question posed by the title, "Is Quality of Life the Cost for a Taller, Straighter Spine? "

**The Childhood Patient Experience:**

Children without chronic diseases rarely experience being a patient except for acute episodes which quickly pass with the child returning to their normal environments. For children with chronic medical conditions, it becomes part of their identity. Frequent procedures, pain, time away from school, peers, and family disrupt their normal development. Children with other chronic diseases such as cystic fibrosis, cancers, juvenile arthritis, sickle cell also experience decreased QOL using standard measures[4]. Nor are their siblings immune. Although they have higher QOL than their ill sibling, the healthy siblings often have lower QOL than their peers attributed to the family's disruption to care for the ill child.

**The Early Onset Scoliosis Patient:**
Because early onset scoliosis is a potentially fatal disorder, surgeons and families will go to extreme means to create a chest with sufficient length to function well as an adult. Whether using something as simple as a brace or as complex as magnetically activated growing instrumentation, the child will necessarily experience disruptions. If they have underlying other diseases such as cardiac, asthma, or neuromuscular disease, these other disorders will have additional effects on their life. Flynn, et al, and Matsumatto, et al, have documented decreased QOL with increased risk for those younger at the age of the index surgery and having a total greater number of surgeries.

From Flynn, et al:25% of patients displayed "clinically significant" neurobehavioral dysfunction, 33% scored "at- risk," and the remaining 42% scored in the normal range. Internalizing problems, including anxiety, depression, and somatization, was the most commonly seen pathology. Matsumoto et al. reported an association between recurrent surgery for EOS and increased incidence of aggression and rule breaking. Auran, et al, have also reported decreased HRQOL associated with serial EDF casting for EOS[5]. Recently, Doany, et al[6], compared the QOL in children undergoing traditional growing rods to those undergoing magnetically controlled rods. Although the scores were better for the latter, the follow up was much longer in the former with a toward convergence with longer follow up.

**What is the natural history?**
While it would be best to compare the QOL of children undergoing treatment to those experiencing the natural history, this is not feasible because of the morbidity and mortality of EOS. We do not have actual QOL data for children with EOS. This is similar to other childhood diseases with a high mortality where treatments evolved before the development of valid childhood HRQOL measures.

**Which domains of QOL are important?**
QOL is complex concept involving many aspects of life. Even the more specific HRQOL is very complex with multiple domains. Our treatments may have very confusing results depending upon which domains are measured and take precedence.

When comparing the natural history to the treatment and even in determining QOL overall, we need to consider which domains can be helped and which harmed by our interventions:

1. Physical:
    a. Breathing? – treatment goal is improvement
    b. Cardiac? – treatment goal is prevention
    c. Activity level? – while the goal is to increase, active treatment decreases this.
    d. Participation? – similar to activity
2. Discomfort:
    a. Pain? – likely worse with treatment
    b. Fear? – likely worse with treatment
3. Psychosocial (can go up or down with treatments and their phases):
    a. Emotional?
    b. Education?
    c. Social?

**Is psychosocial disability inevitable?**
Preventing psychosocial disability should be one of our goals. If our treatments naturally create challenges, we should develop effective counter measures. Social support and socioeconomic status are strongly correlated with QOL in children with chronic disease[7]s.

Resilience or the ability to recover from an insult and continue with normal activity and adaptation is an emerging concept which has become particularly important for children experiencing trauma and other events. The role of resilience is still emerging[8-14], but logically, the ability to provide proper coping mechanisms for children undergoing care must become important to those of us treating children.

Currently, programs would be well served by access to a child psychologist or psychiatrist with an interest in helping children with chronic diseases and their families cope with the challenges of both the disorder and its treatments.

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## Post Traumatic Stress During Growing Rod Treatment

**Peter G. Gabos, MD**
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Philadelphia, Pennsylvania, USA
Co-Director, The Spine and Scoliosis Center of the Nemours/Alfred I. duPont Hospital for Children
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**Introduction:**

Technological advances in the medical sciences are saving increasing numbers of children with illness and injury and allowing novel treatments and outcomes of chronic conditions that were previously unattainable. An emerging area of study, called "Medical Traumatic Stress," has emerged as an important field to investigate and address a national public health concern that is really still in its infancy. In 2001, The National Child Traumatic Stress Network (NCTSN; www.nctsnet.org) was funded by the Substance Abuse and Mental Health Services Administration (SAMHSA) to "raise the standard of care and improve access to services for traumatized children, their families and communities throughout the United States." Most of the work in this area in pediatrics over the past 15 to 20 years has focused on severe medical illness, such as pediatric liver transplantation and cancer, and more recently in the area of traumatic injury including spinal cord injury and severe burns.

**Diagnosing PTSD:**

**I. DSM-IV Criteria for PTSD:**

A. The person has been exposed to a traumatic event in which both of the following have been present:

(1) the person experienced, witnessed, or was confronted with an event or events that involved actual or threatened death or serious injury, or a threat to the physical integrity of self or others (2) the person's response involved intense fear, helplessness, or horror. **Note:** In children, this may be expressed instead by disorganized or agitated behavior.

B. The traumatic event is persistently re-experienced in **one (or more)** of the following ways:

(1) recurrent and intrusive distressing recollections of the event, including images, thoughts, or perceptions. **Note:** In young children, repetitive play may occur in which themes or aspects of the trauma are expressed.

(2) recurrent distressing dreams of the event. **Note:** In children, there may be frightening dreams without recognizable content.

(3) acting or feeling as if the traumatic event were recurring (includes a sense of reliving the experience, illusions, hallucinations, and dissociative flashback episodes, including those that occur upon awakening or when intoxicated).**Note:** In young children, trauma-specific reenactment may occur.

(4) intense psychological distress at exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event.

(5) physiological reactivity on exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event.

C. Persistent avoidance of stimuli associated with the trauma and numbing of general responsiveness (not present before the trauma), as indicated by **three (or more)** of the following:

(1) efforts to avoid thoughts, feelings, or conversations associated with the trauma

(2) efforts to avoid activities, places, or people that arouse recollections of the trauma

(3) inability to recall an important aspect of the trauma

(4) markedly diminished interest or participation in significant activities

(5) feeling of detachment or estrangement from others

(6) restricted range of affect (e.g., unable to have loving feelings)

(7) sense of a foreshortened future (e.g., does not expect to have a career, marriage, children, or a normal life span)

D. Persistent symptoms of increased arousal (not present before the trauma), as indicated by **two (or more)** of the following:

(1) difficulty falling or staying asleep

(2) irritability or outbursts of anger

(3) difficulty concentrating

(4) hypervigilance

(5) exaggerated startle response

E. Duration of the disturbance (symptoms in Criteria B, C, and D) is more than one month.

F. The disturbance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.

*Specify if:*
Acute: if duration of symptoms is less than 3 months
Chronic: if duration of symptoms is 3 months or more

*Specify if:*
With Delayed Onset: if onset of symptoms is at least 6 months after the stressor

**II. ICD-10 Criteria for diagnosing PTSD (F43.1)** (*Geneva, WHO, 1992*)**:**
A. Exposure to a stressful event or situation (either short or long lasting) of exceptionally threatening or catastrophic nature, which is likely to cause pervasive distress in almost anyone.

B. Persistent remembering or "reliving" the stressor by intrusive flash backs, vivid memories, recurring dreams, **or** by experiencing distress when exposed to circumstances resembling or associated with the stressor.

C. Actual or preferred avoidance of circumstances resembling or associated with the stressor (not present before exposure to the stressor).

D. Either (1) or (2):

(1) Inability to recall, either partially or completely, some important aspects of the period of exposure to the stressor

(2) Persistent symptoms of increased psychological sensitivity and arousal (not present before exposure to the stressor) shown by any **two of the following**:

a) difficulty in falling or staying asleep;

b) irritability or outbursts of anger;

c) difficulty in concentrating;

d) hyper-vigilance;

e) exaggerated startle response

E. Criteria B, C (For some purposes, onset delayed more than six months may be included but this should be clearly specified separately).

**III. The major differences between the ICD-10 and DSM-IV criteria:**

| | **DSM-IV** | **ICD-10** |
|---|---|---|
| Stressor: | yes | yes |
| Subjective: | yes | no |
| Re-experiencing: | 1+ (B, 1-5) | 1 (B) |
| Avoidance: | 3+ (C, 1-7) | 1 (C) |
| Hyper-Arousal: | 2+ (D, 1-5) | D1 or 2+ (D2, a-e) |
| Onset/Duration: | >1 month duration | Onset within 6 months |

**Literature Review Specific to Growing Rod Treatment:**
No published peer-reviewed studies specifically examine PTSD in children undergoing multiple spinal surgeries. **Flynn et al (2012)** evaluated 12 patients with EOS who underwent rib-based growing rod surgery (RBGRS) utilizing the Behavioral Assessment System for Children (BASC-2) tool between 1.5 and 3 years from the index surgery. The authors found that 25% of the patients scored in a clinically significant range on at least 1 scale, 33% scored in an at-risk range on at least 1 scale, and 42% had a normal range for all scales. Younger age and greater total number of surgeries correlated with lower scores. **Matsumoto et al (2014)** evaluated 34 EOS patients utilizing the Child Behavioral Checklist (CBCL) and the Strength and Difficulties Questionnaire and correlated domain scores with age at first scoliosis surgery, total number of operative procedures and total number of growing instrumentation surgeries. A higher prevalence of abnormal psychosocial scores was found in multiple domains in multi-operated EOS patients as compared with national norms. EOS patients with abnormal psychosocial scores were younger at the time of index surgery. The number of repetitive surgeries also correlated positively with 3 behavioral problem scores. Interestingly, healthier scores were found in 1 positive behavioral domain in more operated children, suggesting the potential for "post-traumatic growth." **Doany et al (2017)** evaluated health-related quality of life (HRQL) in 44 matched EOS patients using the EOSQ-24 and compared domain scores between traditional growing rods (TGR) and magnetically-controlled growing rods (MCGR). The authors found that superior outcomes were noted in the overall satisfaction and financial burden domains in the MCGR, but that these improvements diminished when controlled for length of follow-up. **Sewell et al** (2017) compared 30 braced and 30 GR EOS patients using the Activities Scale for Kids performance version (ASKp) questionnaire. The GR group demonstrated a reduction in activity and participation compared to the braced group. Pain was the most important factor affecting activity and participation in both groups.

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### Growth Friendly Techniques for Early Onset Scoliosis (EOS): Is Quality of life the cost for a Taller, Straighter Spine?

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**DEBATE: Pro** – Magnetically Controlled Growth Rods are A Game Changer

The Magnetic Growing Rod in my opinion is one of the most innovative and life changing devices to emerge on the spinal implant market in the last 20 years.

In the last century the turning point for scoliosis surgery was with the introduction of the Harrington rods. The next major landmark was in the 1980's with the Cotrel-Dubousset instrumentation which took Luque's segmental instrumentation concept one step further with a system which allowed 3 dimensional correction of the spinal deformity. Dr Suk in 1994 presented the first results of thoracic pedicle screw fixation here at the SRS meeting. The binding factor with all these developments has been a change in thinking and behaviour driven by Game Changing individuals.

What is a Game Changer?

The Oxford dictionaries define the phrase as "An event, idea, or procedure that effects a significant shift in the current way of doing or thinking about something'

History is littered with Game Changing individuals from Politicians, scientists, Sports personalities, artists and even within our very own spinal community! All of these individuals have driven a seismic shift in the way we do things. They stand out and are prepared to buck the trend and garner a re-think about process.

Historically, Early Onset Scoliosis was a problematic condition affecting "little children" which could be addressed with the same treatment ideology as adolescents. We now know differently and in recent years there have been huge strides in our understanding of the condition and its treatment as well as the consequences of some of the existing treatment interventions.

These interventions have come at a cost in terms of psychosocial burden, high complication rates and increased financial demands on the health economy. Traditional Growing Rods have served us well but have laboured under the burden of adversity and inevitability. The high failure rates have been accepted due to a lack of a viable alternative. Children were regularly subjected to multiple anaesthetics through out the course of treatment. School days were missed, work schedules were disrupted and multiple stays in hospital were required to facilitate successful treatment. Some children develop a morbid fear of hospitals and clinicians because of their experiences. Akbarnia et al in their paper titled ' Complications of Growing Rod Treatment for Early Onset Scoliosis' report a 24% complication risk increase for every additional surgical procedure. There are also recent concerns about the effect of repetitive anaesthesia on behavioural and cognitive development in children.

With these controversies in mind the Magnetically Controlled Growing Rods (MCGR) were developed and first used in the UK in 2009 at the Royal National Orthopaedic Hospital in London. The device was designed to allow non-invasive lengthening of the rods after initial implantation in order to maximize growth potential of the child as well as control the spinal deformity.

The MCGRs have generated huge debate around efficacy, cost and complication rates. A recent query of the Medline and Embase databases using the search terms magnet and scoliosis revealed 99 articles between 2012 and 2017. Very rarely does a device generate such amount of widespread interest. In the UK, the device has been through multiple levels of clinical regulatory evaluation culminating in approval by NICE (**N**ational **I**nstitute for Health and **C**are **E**xcellence) in 2014 and by the FDA shortly thereafter. Despite regulatory approval controversy still seems to surround the MCGR.

Recent reports would suggest that the main economic and clinical advantages are in the primary cases when longevity of the instrumentation has been achieved whilst concerns remain around metallosis and failed distraction. The impact on the quality of life of these children and their families can be in no doubt but there are still looming questions about failure rates, wear debris generation and long term effects as well as cost.

The MCGR has changed our thinking about treatment of EOS. It has opened a door of opportunities. The ability to apply controlled incremental distraction to the rod means we can now think about how, when and what is necessary to maintain spinal growth and deformity control. Successful treatment does not mean Cobb angle control alone but also progression of growth parameters such as weight and height in a proportionate and appropriate manner for a particular child. No longer are we applying a 'one size fits all' approach to growth rod lengthening. Treatment is now individualized and tailored to meet the specific needs of the child. Most importantly, this is a lifestyle choice of treatment that is more palatable to family units. It is not as disruptive to the lives of these children and their families. If a child has a Traditional Growth Rod inserted at the age of 6 it would mean a minimum of 11 further surgeries by the age of 12. This does not include revisions for complications. I do not believe this position is sustainable.

The concerns about metallosis are justified but stricter control of indications for surgery, patient selection and surgical expertise are required to ensure optimal outcomes. Case entry into spine registries/databases should be the standard rather than voluntary.

I believe it is imperative upon the surgical community to make non-invasive lengthening technology for the treatment of EOS work; as a return to our old ways, in my view, will not provide the much needed solutions to this very complex condition.

In my view MCGR represents a welcome shift towards non-invasive technology in the battle against Early Onset Scoliosis in a very vulnerable section of the population. It is not only a Game Changer but is also providing a magic moment in the quest for better quality of life for our patients.

**KEY FACTS**

- Magnetic Growth Rods are approved by the FDA (USA) and NICE (UK) for treatment of EOS
- Age Indications is 2 – 10 years
- Minimum acceptable patient weight is 11.4kg
- Maximum acceptable patient BMI is 25
- Do not insert rods under tension
- Not every EOS case is suitable

APPENDIX

Further Reading:


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## MCGR is a Flash in the Pan…TGR is Here to Stay

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The term '**flash in the pan**' originated sometime during the late 17th century, when flintlock muskets were used. An attempt to fire a musket that resulted in gunpowder flaring up but no ball firing was referred to as a **flash in the pan.**

**Sometimes MCGR feels like there's no ball firing!**

**1. Too Small**

- Esp very small kyphotic patient
- Need 70mm of "flat space" for the actuator
- Options:
  - Domino TGR
  - Sliding End Fixed Apex construct
  - 

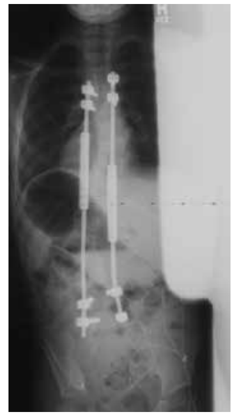
**2. Too stiff**

- How much kyphosis is too much?
- How much Cobb angle is too much?
  - Very high Cobb angle → more discrepancy between programmed and achieved length
- Upasani *Spine J 2016*
  - Risk factors for complications in TGR were young age and high kyphosis- true for MCGR also?
- Cheung J Orthop Surg 2015
  - Special update from a large group of MCGR users
  - "…congenital scoliosis patients with unsegmented bars and adolescent idiopathic scoliosis patients who are older and larger also have increased incidence of distraction failure, as the MCGR may not be able to impart enough force to allow for lengthening."

**3. Too Late**

- Conversions: How long was original TGR in place?
  - If diminishing returns already occurring
- Jain *#17 ICEOS 2016*
  - Length achieved same for conversions (23 mo avg)
- Rolton , Keskinen *Eur J Spine 2016*
  - less achieved length conversions vs. primary
- Hosseini *Spine 2016*
  - 23 pts with 2 yr f/u, 8 conversions
  - conversion group *lost* T1-S1 (4.2 mm) height at 2 yrs

**4. Conversions?**

- Choi *JPO 2016*
  - higher rate of rod breakage in revisions
- Sawyer *#30 ICEOS 2016*
  - Higher complication rate for conversions (44% vs 26%)
- So when considering conversions, weigh the risks and benefits
- 

**5. Too Much Going On**

- Not a safety concern but still an imaging issue
- Intraspinal pathology, malignancy
- Skaggs et al FP#2 ICEOS 2016
  - 0% ability to interpret TL spine
  - Also non MRI-compatible pacemakers
  - If compatible must be switched to tonic mode for each lengthening
  - Tan *JPO 2016*

**6. Too Big**

- > 4 cm deep
- Consider alternatives
- 


**7. Why you might get more length than you think**

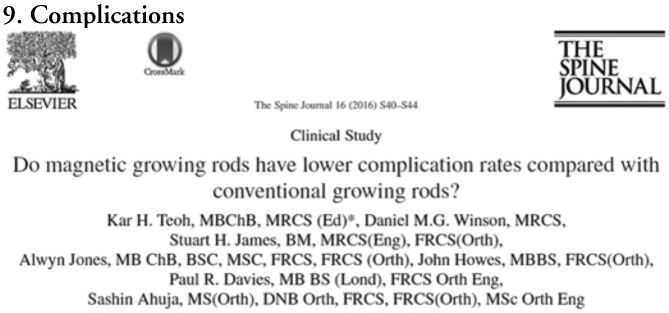
- Cross Talk
  - Both actuators are lengthened
  - Avoid by placing in standard and offset configuration
  - > 4mm separation
  - Cheating ERC laterally
- Discrepancy between US and XR
  - Cheung *Spine J 2016*
  - The mean distracted length per 6 months was 5.7 mm on XR and 5.2 mm on US for the concave rod, and 6.1 mm on XR and 5.9 mm on US for the convex rod.
  - SO, because of discrepancy, or by overshooting to account for true/programmed length gained, could you over-lengthen over time if you rely on US?
  - Probably need to check radiographs periodically.
    - 6 mo, annually?
- Failure of Distraction
  - Cheung paper #22 ICEOS 2015
    - 11/23 patients (42.3%) required reoperation within 17 months

- 5 due to failure of distraction
- Cheung *J Orthop 2015*
  - Group 1 14 pts (every 1 week-2 months), and Group 2 16 pts (every 3 months-6 months).
  - Higher rate of failure of lengthening (71% vs 25%) and a higher incidence of PJK(21% vs 13%)
  - Causes:
    - Technical
    - Bending to close to actuator
    - Inserting in wrong direction
    - Mechanical
    - Bone around actuator
    - Dislodged housing pin
    - Clunking
      - Distinct feeling of bucking- more common offset rod
      - Palpable and audible clunk
- Lengthening to Max
  - Lengthening at longer increases risk of PJK in preliminary studies (Cheung IMAST 2015).
    - May increase risk of distraction failure
  - Lengthening to clunk: unknown if further lengthening occurs
    - Short intervals, lengthening to max→? overlengthening
  - What about syndromic patients?
    - Skaggs *JBJS 2008*
    - Marfan's pt, acute cardiac failure after 2 cm lengthening TGR
    - Could occur in theory with MGR if lengthening to max

**8. Social/Societal Issues and Cost**

- Yaczici #20 ICEOS 2016
  - MCGR shows EOSQ 24 benefits in financial burden and patient satisfaction
- Families that can't return to clinic for frequent MCGR lengthenings ?
  - Self-lengthening constructs may be better options
    - Fixed apex sliding ends, modified Luque trolley
  - Short duration may not be worth it!
    - cost neutral at year 2, cost benefit year 3 (Polly 2015)

**9. Complications**


ELSEVIER

The Spine Journal 16 (2016) S40–S44

THE SPINE JOURNAL

Clinical Study

Do magnetic growing rods have lower complication rates compared with conventional growing rods?

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- Retrospective case control series, 10 MCGR vs 27 TGR
- MCGR : 0.32 complication/patient/year vs. 0.15 for TGR
- Less infections but more implant complications in this series

**In Summary:**

- MCGR has definitely been a game changing addition to our armamentarium
  - **BUT**
- TGR still have a role as best indications for newer techniques are defined and technology improves

## Comparison of Growth Friendly Techniques in Terms of Outcome: Is One Better than the Rest?

**John B. Emans, MD**
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1. **Outcomes in EOS – a difficult question – see prior talks!**
   a. What/How to measure outcomes?
      i. Spine and chest deformity angles?
      ii. Spine length and chest dimensions?
      iii. Chest mobility and pulmonary function?
      iv. Spine mobility?
      v. Overall function? Aerobic capacity?
      vi. Self image?
      vii. QOL? Cost? QALY?
   b. How well did we meet our standard goals of EOS Rx? – everyone still has TIS after treatment!
      i. Maximum spine length, residual mobility
      ii. Maximum chest size/function
      iii. Minimum surgeries, hospitalizations
      iv. Minimum complications
   c. Compared to what?
      i. Normals
      ii. Natural history without treatment
      iii. Dimensions by age
      iv. Pelvic-width based dimensions
      v. Others with same diagnosis
   d. Outcome confounders:
      i. Multiple diagnostic etiologies
      ii. Changes with age, variable growth rates
      iii. Comorbidities
      iv. Physician variation: indications, timing, technique execution
2. **So how can we compare growth-friendly surgical techniques?**
   a. Common techniques available: (and politically correct terms)
      i. Spine-based distraction (traditional dual growing rods) = **TGR**
      ii. Rib-based distraction +/- expansion thoracostomy (V...R) = **RBD**
      iii. Magnetically controlled spine based distraction (M…C) = **MCGR**
      iv. Growth guidance with apical fusion and sliding screws (S….A) = **GGS**
      v. One-time fusion in early adolescence – one and done = **1&D**
   ***b.*** We have the most experience with and greatest variance in:
      i. Number of operations

ii. Complications
iii. Need for final fusion

**GF techniques compared:**

| Consider: | TGR | RBD | MCGR | GGS | 1&D |
|---|---|---|---|---|---|
| Procedure complexity | | Med | | High | High |
| **Multiple operations** | Y | Y | | No | No |
| **Complications** | Early fusion | Chest wall stiff-ness | Early fusion | Metal-losis | |
| **Law of diminishing returns?** | Yes | Yes | Yes! | ? | |
| **Final fusion needed?** | Some | Some | All | Most | |
| **Final fusion complex-ity/severity?** | Hard | Medium | Hard | Messy | Hard |
| **OK for very small child?** | Yes | Yes | No way | Yes | |
| **OK for upper thoracic kyphosis** | Yes | No | Yes | ? | Yes |
| **Diagnostic MR com-patible?** | Yes | Yes | No | +/- | |
| **Ok for thoracogenic deformity/rib fusions** | No | Yes | No | | |
| OK for myelokyphosis? | | Yes | | | |
| **OK for SMA/collaps-ing?** | Yes | Yes | Yes! | No | |
| **OK for stiff congenital curves?** | Yes | Yes | No | No | |
| **OK for revisions of prior surgery?** | Yes | Yes | No | Yes | |
| **OK for very thin child?** | Yes | Yes | No | No | |
| **OK for severe complex deformity?** | Yes | Yes | No | No | |

3. **The best technique in terms of outcome depends on:**
   i. Diagnosis, etiology
   ii. Deformity type, severity
   b. Choose the GF technique best for that situation –
      i. **individualize the technique** choice to the disease and deformity
      ii. **individualize the timing** of the first surgical intervention:
         1. Early surgery= early complication/spontaneous fusion/growth arrest
         2. Chest–based decision to start GF surgery – operate for chest deformity, not the Cobb angle
         3. But don't wait so long as to miss the beneficial effect of GF surgery on chest deformity and spine growth.
4. **Conclusion**
   a. Hard to compare outcomes across groups
   b. Each technique has advantages/disadvantages specific to different diagnoses
   c. Some specific best outcomes by GF technique:
      i. Best outcomes for ***SMA, collapsing deformity – MCGR***
      ii. Best outcomes for ***very small children, complex deformity, revisions, stiff deformity – TGR***
      iii. Best outcomes for ***thorcogenic, rib fusions – RBD =/- MCGR***
      iv. Best outcomes for ***normally segmented moderate deformity = MCGR***
      v. Best outcomes for ***moderate juvenile idiopathic – No GF surgery - brace, then one and done fusion***

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## Image Gently: Reduction of Radiation in Kids with EOS

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**Introduction**

Children may be more sensitive to radiation than adults, due to multiplying cells (Kleinerman, Ped Rad, 2006). Medical radiation → Stochastic risk

**Radiation Terminology**

Radiation: energy transmitted in waves or particles
Order of increasing energy: visible light < ultraviolet < x-rays < gamma rays < cosmic rays
Various radiation exposures represent different types of energy

- Hiroshima/Nagasaki atomic bomb – gamma/neutron
- Radiation therapy – alpha, beta, gamma
- Orthopedics – X-ray
- Airplane travel – UV, some cosmic

**Radiation Measurements**

Radioactivity – Curie, Becquerel – how many atoms decay over time
Exposure – Roentgen, coulomb/kg – how much radiation travels through air, can measure with a monitor
Absorbed dose: How much radiation is absorbed by a person or object

Organ dose – milliGray – measures amount of radiation absorbed by a specific organ
– 1 Gy = 100 rad

Skin entrance dose – dose to skin, does not measure dose absorbed by internal organs, etc.

Effective dose– milliSieverts – measures effect of radiation on entire body
– 1 Sv = 100 rem

**ICRP workplace recommendations**

- Limit exposure to < 50 mSv annually or 100 mSv total within 5 years for occupational radiation workers
- 1 mSv per year to the general public allowable (not including natural background radiation, occupational exposure or medical exposure) (i.e., visiting a hospital, nuclear plant exposure to a neighboring town)
- Annual natural background radiation ~ 3 mSv (300 mrem); chest x-ray 0.1 mSv
- Cancer treatment ~ 100 mSv (Wrixon, J Radiol Prot. 2008)

**General Population**

- Australian population-based study
  - Childhood CT, estimated at 5 mSv, 24% increased rate of developing a cancer
  - Mathews, Forsythe et al., BMJ 2013.
- BEIR VII Phase II, based on Hiroshima/Nagasaki survivors
  - 100 mGy at age 10, resulted in 1.3 more cancers per 100 males and 2.5 more cancers per 100 females
- CT exams represent 24% of US population exposure to radiation.
- Hendee and O'Connor (2012) argue these epidemiologic studies are flawed (use a linear model to predict a nonlinear relationship) and that medical radiation is likely very low risk.

**AIS Population**

- Historic data, increased risk of breast and thyroid cancer in scoliosis patients
  - Doody, Lonstein, Stovall, US Scoliosis Cohort, Spine 2000; Ronckers, Land, Miller, Radiation Research, 2010.
    - 5,466 women treated for scoliosis from 1912-1965, estimated 109 mGy dose to breasts, 74 mGy to thyroid; patients had on average 25 x-rays.
    - 77 breast cancer deaths compared to 45.6 deaths expected; 8% increase in cancer mortality
  - Simony et al., ESJ 2016
    - 215 patients treated between 1983-1990, 16 radiographs per patient at 0.8-1.4 mSv per radiograph ~ 16 mSv exposure
    - At 25 years follow-up, 3 breast and 6 endometrial cancers or 4.8X higher than normal Danish population

**EOS Population**

- Little information on cancer risk for EOS patients, but high level of exposure
- Radiation measurements performed often performed on teenager/adult-sized phantoms, may differ for small patients

- Cannon, Sawyer JPO 2014. 24 rib-based growing construct patients over a 4 year period.
  - Mean 40 imaging studies/patient. Cumulative radiation dose was 86.7 mSv, with mean of 34 mSv exposure per year.
  - 41% exposure from fluoro, 49% x-ray, 10% CT scans
  - Estimated: Spine x-ray 1.5 mSv, Chest x-ray 0.1 mSv, spine CT 6 mSv
- Mundis et al., Sp Def 2015.
  - 24 growing rod patients, spine x-rays.
  - Estimated: Spine x-ray 1.5 mSv; Chest x-ray 0.1 mSv, Thoracic/Lumbar spine CT, 2mSv
  - 9 patients with spinal fusion had 36.5 mSv total, overall annual 7.2 mSv (84% xray, 11% CT)
  - Most radiation prior to index surgery, and 7 mSv per year thereafter.

**Practical Suggestions**

- Ensure preop CTs are obtained using 'pediatric dosing program'
- Carefully consider role of bone scans
- Avoid oblique lumbar spine films (can be as much radiation as limited lumbar CT)
- If using CT guided navigation, use **low dose** protocol, not manufacturer settings.
  - Sarwahi Spine 2017, Ultra low dose (120 kV, 39 mAs), as accurate as regular CT to detect screw malposition in cadavers
  - Abul-Kasim J Sp Dis Tech 2012 (80 kV, 80 mAs), pig spine study
  - Su, Luo et al. JPO – One low dose scan (80 kV, 80 mAs ) is ~ 0.65 mSv or 85 seconds of intraoperative fluoroscopy; feasible in clinical practices
    - Manufacturer setting (120 kV, 160 mAs) calculated at 4.65 mSv per scan
  - Richerand et al., JPO 2016 Low dose protocol mean 1.48 mSv exposure with navigation (settings adjusted based on patient's weight and body size, for instance 50 kg child, 70 kV/63 mAs) vs. 0.34 mSv with fluoroscopy
- Radiography:
  - Minimize number of lateral x-rays (lateral is more radiation than PA)
  - Minimize intraoperative use of x-rays (0.82 mSv for 2-view T-spine)
- Biplanar Slot Scanning (EOS):
  - Damet et al, Med Phys, 2014. EOS AP and lateral together 0.29 mSv for adult-sized phantom
  - Luo et al., Sp Deformity 2015. Cumulative radiation in AIS patients using standard EOS was 2.66 mSv vs. 5.38 mSv with standard radiographs
    - Mean 21 x-rays per patient.
    - EOS PA 0.069 mSv; EOS AP 0.121; EOS lateral 0.121
    - Digital PA 0.215 mSv, digital lateral 0.295
    - Surgical patients received most radiation because the high number of lateral radiographs obtained.
  - Always PA for standard radiography and standard EOS; for EOS microdose may not be significant difference between PA and AP
  - Bending films, false profile pelvis films, traction films using biplanar slot scanning if possible

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### Is Quality of Life the Cost for a Taller, Straighter Spine?

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NEED TO DISCUSS TREATMENT IN LIGHT OF NATURAL HISTORY

EOS is a potentially fatal condition.

Severe Pulmonary consequences

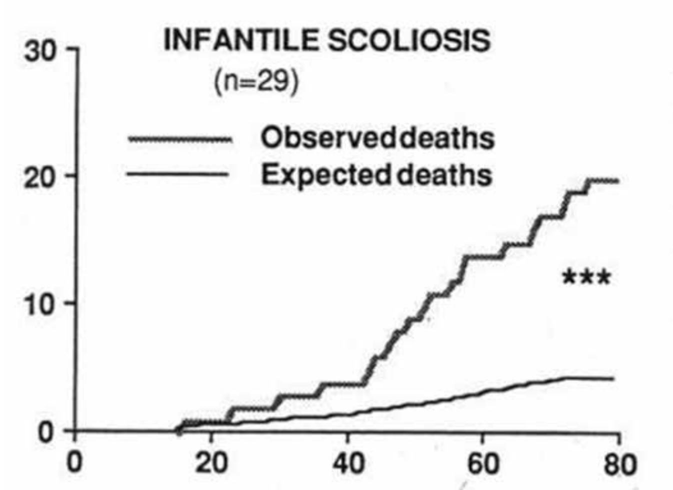
Davies and Reed Archives of Disease in Childhood (1971)

- Decreased alveoli
- Decreased small blood vessels
- Atrophy pulmonary parenchyma
- Increased work breathing
- Abnormal V/P ratio

Branthwaite British Journal of Diseases of the Chest (1986)

- CURVE DIAGNOSED BEFORE AGE 5
    - 11/15 CARDIORESPIRATORY DISEASE
- CURVE DIAGNOSED AFTER AGE 11
    - 6/28 CARDIORESPIRATORY DISEASE
    - 5/6 OTHER CAUSES

Pehrsson Spine (1992)




EARLY FUSION

Goldberg Spine (2002)

SURGERY AFTER AGE 10
- FEV1 79%
- FVC 68.3%

- EARLY SURGERY (AVG. 4 YEARS)
    - FEV1 41%
    - FVC 40.8%

Karol JBJS (2008)

FVC CORRELATED WITH EXTENT OF FUSION
- FUSION TO T1 OR T2 PREDICTIVE OF DIMINISHED PULMONARY FUNCTION

Vitale Spine (2008)

QOL Among the lowest observed in Kids
JRA/Heart Transplant/Asthma
High Emotional Burden on Caregivers

EFFECT OF TREATMENT ON QOL

Matsumoto ICEOS (2012).
Early-Onset Scoliosis 24 item Questionnaire (EOSQ-24) demonstrated improvements in multiple domains of health-related quality of life after growth friendly surgery in 68 patients with an average age of 6.2 years (range 0 -11 years)

Matsumoto JPO (2016)
Improved HRQOL in patients with Neuromuscular EOS
Diminished HRQOL in idiopathic EOS

Johnston JBJS (2017)

SRS-30 results (4.1 of a possible 5 points) indicate a slightly lower level of function compared with that reported for patients with adolescent idiopathic scoliosis undergoing surgical correction. Lowest scores in the functional/activity domain and exercise-tolerance testing. Possibly secondary to underlying condition. Highest-scored domain was mental health, suggesting that the patients have adapted psychologically very well to their residual deformity and the rigorous treatment protocol that they had undergone.

Doany (Spine 2017)

Improved QOL with MGR as compared to TGR

CONCLUSIONS

Increased Burden of Care on Care Givers

Less Trips to OR with MGR or growth guidance system may mean better QOL versus TGR

Natural History of Untreated Early Onset or Early Definitive Fusion is Dismal

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Johnston,CE, Tran,DP,McClungA: Functional and Radiographic Outcomes Following Growth-Sparing Management of Early-Onset Scoliosis JBJS 99(12):1036–1042, JUN 2017

Michael E Doany, Z Deniz Olgun, Gizem Irem Kinikli, Senol Bekmez, Aykut Kocyigit, Gokhan Demirkiran, A Ergun Karaagaoglu, Muharrem Yazici :**Treated Surgically: EOSQ scores in Traditional Growing Rod vs. Magnetically-Controlled Growing Rods. Spine (2017)**


## Postgraduate Course: Growth Friendly Techniques for Early Onset Scoliosis: Is Quality of Life the Cost for a Taller, Straighter Spine? Pulmonary Status at Maturity and Thereafter


**Gregory Redding, MD**

Seattle Children's Hospital

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Among children with spine and thoracic deformities, there is a wide spectrum of pulmonary disability and lung function impairment. Since the era of growth friendly constructs began, several case series have described the range of lung functions among children with Early Onset Scoliosis (EOS) at some point during therapy. (1-4) Forced vital capacity in older children ranges between 58+/-24%. (); in younger children under anesthesia, vital capacity averaged 77% of normal. (4) Children with EOS usually receive non-surgical and/or surgical treatment over time, including use of growth friendly devices. Due to the "law of diminishing returns" with repeated (invasive) expansions, casting and/or bracing are used initially to control the spine deformity and delay surgical treatment. Between ages 5 and 10 years of age, if the coronal curve has not improved, spine distraction or growth guidance systems are used to reduce coronal and sagittal curves and promote spine growth and height. Sometime after 10 years of age, fusion is considered, although it is not inevitable as growing constructs can be left in place in some patients.

Changes in lung function during treatment with distraction devices have been reported in two series. In both reports which followed children for an average of 6 years, vital capacity as a percent of predicted norms fell by 19-28% despite improvements in Cobb angles.(4,5) Lung function improvement over time has been reported in 24% of young children receiving long-term oxygen or mechanical ventilation pre-operatively.(6) Lung function changes before and after spine fusion in AIS are technique dependent but associated with a loss of function for 6 months to 2 years with a gradual return to pre-operative levels. (7.8) Changes in lung functions after spine fusion in older children with EOS have not been reported.

The pulmonary status of adults depends on their best lung function at the end of lung function growth, which occurs at 17 years in girls and 18 years in boys. Pulmonary status "at maturity" means after pulmonary function growth and spine growth are complete. Lung function then declines gradually as a result of aging in adulthood. (9) In a report of adults with scoliosis diagnosed before 10 years of age EOS treated with bracing and/or surgery with lung functions before surgery and 25 years later, lung function impairment as adults was related to lung function prior to spine fusion. (10) In a long-term follow-up study of children diagnosed with scoliosis before age 4 years of age, Goldberg et al found that lung function at 20 years of age was worse in those children with EOS who required surgical intervention before 10 years of age. (11)

Danielsson et al described the decline in lung function during adulthood relative to age-matched norms in 30-40 year olds with EOS diagnosed before 10 years of age and found the rate of decline to be similar. (10) This may not be true in children with EOS that require surgical intervention before adolescence. These findings are superimposed upon factors at birth and during childhood that determine lung function in adults. These include birth weight, premature birth, and social class at birth and sitting height (as a proportion of adult height) at 7 years of age. (12, 13) Additional risks after spine fusion in adulthood that accelerate lung function decline include smoking, occupational exposures, and severe respiratory infections, e.g. Influenza. (12)

So how can we achieve the best lung function outcome at skeletal maturity? Close monitoring of lung function as part of surgical care before and during spine treatment should be standard of care. Loss of lung function must be attributed (or not) to the spine and chest wall deformity and not to other co-morbid conditions, e.g. progressive neuromuscular weakness.  Loss of lung function should prompt a re-examination of an individual patients' spine treatment plan. Surgical strategies that reduce the rate of decline must be developed. The timing of growth friendly instrumentation remains controversial.  The timing of spine fusion relative to further spine and thoracic cage growth also is controversial. Respiratory management of residual lung impairment, which includes non-invasive positive pressure ventilation at night, is now considered part of comprehensive care. Finally, ways to transition care of older adolescents to adult specialists that are expert in chronic restrictive chest wall disease must be developed.

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## The Fork at the End of the Growth Friendly Road: Final Fusion or Observation?

**Paul D. Sponseller, MD, MBA**
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Baltimore, Maryland, USA

**Outline / Key Points:**

Theoretical vs actual Growth Friendly Course are different

Several options exist at maturity

Plan how to position for best result.

**I. Implications of Growth Friendly Surgery for Maturity**

If final fusion performed, there may be new scars, stiff spine, Obscured landmarks, Implants needing removal, drifted anchors

Fusion at "graduation": Many required osteotomies; most gained <50% correction

**III. 3 Scenarios/ Strategies at maturity**

1. Straight, not stiff

2. Not Straight (unacceptable/unbalanced)

3. Straight and stiff

**1. Straight but not Stiff**

Evidence: Recent rod breakage, Lots of laxity at last distraction; Patient with a connective tissue disorder

Treatment at Maturity: Add anchors + graft

**2. Not Straight (Unacceptable)**

Mutual assessment of patient and surgeon

Treatment: Osteotomies or discectomies needed; VCR if high DAR

Re-check anchors; don't assume screws are safe

**3. Straight and Stiff**

If no rod breakage past 2 years, limited gain at last distraction, near maturity

-No final fusion is an option

**Final Fusion is not always Final**

**IV. Conclusion**

**Growth-Friendly surgery**

Can be an incremental process

Preventing and managing deformities in safe steps

Avoiding need for higher-risk surgery

**Implications:**

Need to focus not only on minimizing procedures, but: not allowing deformity to progress to need for riskier surgery

Avoid Progressive 2-plane deformity or uncontrolled junctional deformity

**V. References:**

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# Notes

# MIS Spinal Surgery – An Updated Global Perspective

Room: Ballroom - Salon HIJ

Course Chairs:
Praveen V. Mummaneni, MD & Gregory M. Mundis Jr.

Neel Anand, MD; Dean Chou, MD; Robert K. Eastlack, MD; Richard G. Fessler, MD, PhD; Kai-Ming G. Fu, MD, PhD; Regis Haid, MD; Virginie Lafage, PhD; Ronald A. Lehman, Jr., MD; Frank La Marca, MD; Pierce D. Nunley, MD; Paul Park, MD; Khoi D. Than, MD; Juan S. Uribe, MD; Alexander R. Vaccaro, III, MD, PhD, MBA

*This course is supported, in part, by a grant from Orthofix.*

# Half Day Courses

Thursday, September 7, 2017

## MIS Spinal Surgery – An Updated Global Perspective

13:30 – 16:30

| Chairs: Praveen V. Mummaneni, MD & Gregory M. Mundis, Jr., MD | | |
|---|---|---|
| Time | Title | Speaker |
| **13:30-15:10** | **Section I** | **Moderator: Gregory M. Mundis, Jr., MD** |
| 13:30-13:38 | Minimally Invasive Spine Surgery: MISDEF Algorithm | Praveen V. Mummaneni, MD |
| 13:38-13:46 | How Do We Define MIS in 2017 | Gregory M. Mundis, Jr., MD |
| 13:46-13:54 | Spinal Balance- Do These Concepts Apply to MIS Deformity? | Virginie Lafage, PhD |
| 13:54-14:00 | Discussion | |
| 14:00-14:08 | MIS Approach Selection: When to Use LLIF? | Neel Anand, MD |
| 14:08-14:16 | MIS Approach Selection: When to Use TLIF? | Pierce D. Nunley, MD |
| 14:16-14:24 | MIS Approach Selection: When are MIS Screws Appropriate and When Open? | Dean Chou, MD |
| 14:24-14:30 | Discussion | |
| 14:30-14:38 | Pitfalls of Flatback Creation with MIS Deformity Surgery | Khoi D. Than, MD |
| 14:38-14:46 | What Impact Do MIS Techniques Have on PJK in Deformity Surgery | Paul Park, MD |
| 14:46-14:54 | What Are the Limits of MIS Surgery in 2017 | Kai-Ming G. Fu, MD, PhD |
| 14:54-15:02 | What Are the Challenges to Adopting MIS Surgery in a Deformity Practice? | Frank La Marca, MD |
| 15:02-15:10 | Discussion | |
| **15:10-15:35** | **Section II: DEBATE: 35 Degree Degenerative Scoliosis** | **Moderator: Praveen V. Mummaneni, MD** |
| 15:10-15:20 | Open Techniques are Best | Alexander R. Vaccaro, III, MD, PhD, MBA |
| 15:20-15:30 | MIS Techniques are Superior | Juan S. Uribe, MD |
| 15:30-15:35 | Discussion | |
| **15:35-16:30** | **Section III: Techniques and Complications** (education with video) | |
| 15:35-15:42 | Lateral Lumbar Interbody Fusion | Robert K. Eastlack, MD |
| 15:42-15:49 | MIS Anterior Lumbar Interbody Fusion | Regis Haid, MD |
| 15:49-15:55 | Oblique Lateral Interbody Fusion | Ronald A. Lehman, Jr., MD |
| 15:55-16:05 | Discussion | |
| 16:05-16:15 | Complications of MIS Anterior/Lateral Approaches | Gregory M. Mundis, Jr., MD |
| 16:15-16:25 | Complications of MIS Posterior Approaches | Richard G. Fessler, MD, PhD |
| 16:25-16:30 | Discussion | |
| 16:30 | Adjourn | |

## Minimally Invasive Spinal Surgery: MISDEF Algorithm

**Praveen V. Mummaneni, MD**
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Dept. of Neurosurgery
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MIS-ISSG

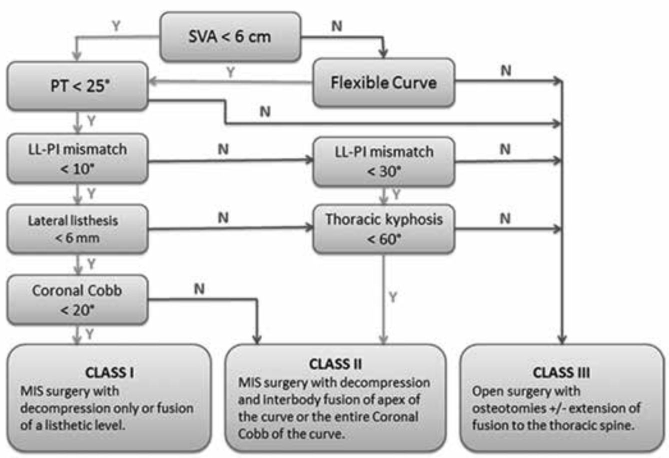
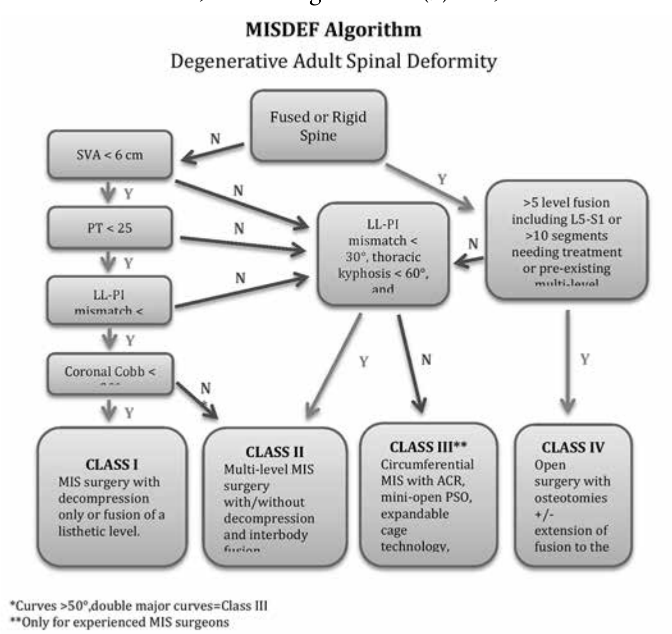



Fig. 1. Minimally invasive spinal deformity algorithm for decision making when considering less invasive correction techniques. N = no; Y = yes.

Mummaneni et. al., Neurosurg Focus 36(5): E6, 2014




Mummaneni et. al., UNPUBLISHED, 2017

## How Do We Define MIS in 2017?

**Gregory M. Mundis, Jr., MD**
Scripps Clinic Department of Orthopedic Surgery
San Diego, California, USA

1. Historical Perspective:
   a. Lessons learned from General surgery
   b. Lessons learned from our orthopedic colleagues
2. Is it MIS? Is this a binary question?
   a. YES or NO
   b. Vs. a continuum
3. Muscle damage
   a. Preservation of muscle tissue
      i. Kim DY, Lee SH et al- Improved trunk muscle strength
      ii. Stevens et al. Appearance of multifidus on MRI Is normal in MIS vs. OPEN TLIF
      iii. Hyun et al. Effect of Wiltse approach compared to OPEN…favorable for MIS
   b. Elevation of inflammatory markers persists in OPEN v MIS (Kim KT, Lee SH et al., Baggiolini M, Dewald B et al., Hirano T et al, Igonin AA et al)
4. Preservation of the Bone Ligament Complex
   a. Removing the BLC results in increased instability
      i. Facets (Abumi K et al)
      ii. Laminectomy with Supra-/Inter-spinous, ligamentum flavum and lamina. (Tuite GF et al, Johnsson KE et al)
      iii. Bilateral MIS decompression yields good results (Palmer S et al, Guiot et al)
      iv. Standard midline release reveals higher level of instability (Fessler et al)
5. Skin incision size does not matter, it's what happens beneath the skin
6. Invasiveness as a continuum.

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## Spinal Balance: Do These Concepts Apply To MIS Deformity?

**Virginie Lafage PhD,**
**Jessica Andres-Bergos PhD,**
**Frank Schwab, MD**
Hospital for Special Surgery
New York, New York, USA

### SAGITTAL ALIGNMENT: QUICK OVERVIEW OF KEY PRINCIPLES

While the analysis of the sagittal alignment can sometimes be perceived as a complex academic exercise, a pragmatic approach for clinical environment consists of focusing on the key parameters proven to correlate with patient reported outcomes:

1. Relation between Pelvic Incidence and Lumbar lordosis
2. Truncal Inclination
3. Pelvic retroversion

**Pelvic incidence vs. lumbar lordosis**

In asymptomatic subjects, pelvic incidence (PI), a morphological parameter representative of the orientation of the sacrum within the iliac, has a direct impact on the amount, shape (i.e. apex), and number of lordotic segments.

| | Low PI | Average PI | High PI |
|---|---|---|---|
| Amount of Lordosis | LL < PI by ~10° | LL ~ PI | LL > PI by ~10° |
| Apex of Lordosis (Rousoully) | L4-L5 | L4 | L3 |
| Segments with focal lordosis > 10° | L4-S1 (i.e. 2 discs) | L3-S1 (i.e. 3 discs) | L2-S1 (i.e. 4 discs) |

**Truncal Inclination and Pelvic Retroversion**

Truncal inclination and pelvic retroversion, two key components of the sagittal evaluation, must be quantified together. From a pragmatic point of view, events associated with sagittal plane malalignment can be described as follows:

1. Modifications of sagittal curvatures such as loss of lordosis or increase kyphosis “leads” to a positive sagittal malalignment (i.e. anterior truncal inclination, increased SVA)
2. Since the spine “sits” on the pelvis, one of the most effective way to counter-balance an anterior truncal inclination is to increase the pelvic tilt (i.e. posterior rotation of the pelvis)

This simple explanation illustrates the interplay of these parameters and why it is important to evaluate them together.

### SAGITTAL MALALIGNMENT: IS THAT A COMMON PROBEM AND SHOULD IT GET CORRECTED?

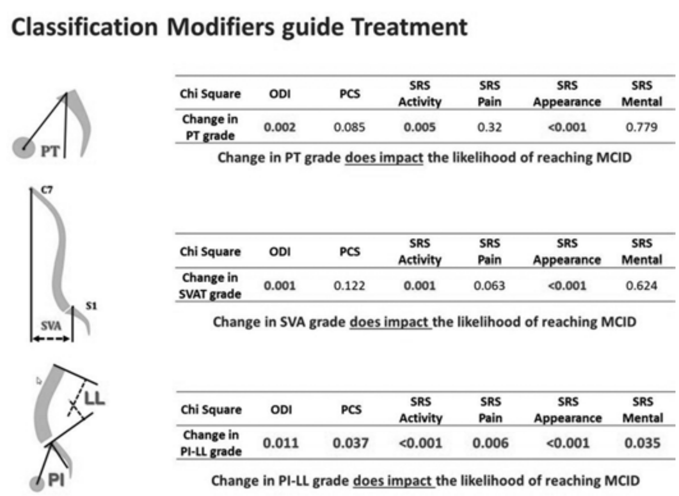
**Sagittal malalignment, a cross-pathologies issue**

While sagittal deformity is quite common in the setting of adult spinal deformity (i.e. >60% of the patients), one should keep in mind that this is in fact a cross-pathologies issue. For example, a comparison of 654 patients with lumbar degenerative spondylolisthesis with 709 asymptomatic subjects (Ferrero, Guigui) demonstrated that 62% of the patients presented with pelvic retroversion and 24% with an anterior spino-pelvic inclination. In a smaller series of 34 surgical patients with low grade isthmic spondylolisthesis (Bourghli), the authors concluded that all patients with good outcomes had a reduction of SVA, while the 4 with poor outcomes had an anterior SVA post-surgery.

**Sagittal alignment and clinical outcomes**

The clinical relevance of sagittal alignment has been demonstrated over the past decade from a patient reported outcome’s (PROs) point of view. The 3 keys parameters previously described all correlate with PROs in the setting of adult spinal deformity patients. These findings are the foundation of the SRS-Schwab classification. Additionaly, our team demonstrated that surgical correction of these parameters is associated with an increased likelihood of reaching MCID.

The clinical relevance of sagittal malalignment has also clearly been demonstrated in the setting of 1 to 3 levels surgery for degenerative conditions: Rothenfluh & al, have recently reported that patients who remained malaligned post-operatively after short fusion exhibited a 10-time higher risk of revision surgery than controls patients.




### SPINAL BALANCE- DO THESE CONCEPTS APPLY TO MIS DEFORMITY?

The question of the applicability of “Spinal Balance” concepts to MIS deformity is an easy one to address. The literature on sagittal malalignment is quite clear: while sagittal deformity is not by itself a new indication for surgery, iatrogenic deformity is detrimental to the patient. In other words, sagittal malalignment matters as soon as a fusion is contemplated. This is, of course, independent of the surgical technique (i.e. open or MIS).

**A more relevant (and challenging) question would be: Can MIS Surgery correct sagittal deformity?**

To date, data reported in the scientific literature are limited. There seems to be consensus regarding the effectiveness of MIS surgery in the setting of mild sagittal deformity, but not in the case for severe sagittal malalignment.

## When to Use Lateral Lumbar Interbody Fusion

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**Fusion Indications:**
1. Concurrent frank instability,
2. Axial back pain
3. Deformity about the level of their stenosis
4. Intervertebral disc height loss translating to foraminal height loss
5. Additionally, the use of interbody fusion is often favored over posterolateral fusion due to its decreased rate of pseudoarthrosis.

**Advantages of LLIF:**
1. Minimally invasive approach to Indirect decompression - The space for the thecal sac and exiting nerve roots is enlarged indirectly through restoring disc height and using ligamentotaxis of the anterior longitudinal ligament (ALL) and posterior longitudinal ligament (PLL) This mechanism of anatomic restoration, originally introduced in 1995 by Chen et al., has also proven itself to be an effective means of managing spondylolisthesis and degenerative scoliosis.
2. This technique allows for greater disc removal than any other approach to the lumbar intervertebral space.
3. It also avoids direct exposure of the neural elements while also facilitating the placement of a cage with a large footprint. This in turn increases fusion potential while also decreasing the risk of cage subsidence.
4. Ideal procedure for patients with a large pannus or special comorbidities that contraindicate prone positioning.

**Approach**

First introduced in 2001 lateral interbody fusion has taken on many other forms and names. Today, the lateral interbody fusion can be performed either directly anterior to the psoas muscle (antepsoas), or through it (transpsoas). Each approach to has its own advantages and disadvantages.

**Indications and Patient Selection**
1. Indirect decompression for management of patients with lumbar stenosis resistant to non-operative management, and who may also benefit from fusion.
2. All lumbar levels that are considered for fusion from L1 to L5

**Ideal Candidates:**
1. Lack of facet fusion on CT,
2. Absence of a free disc fragment or compressive facet joint cyst on MRI,
3. Absence of frank osteoporosis (i.e. a Z score -2.5 or less),
4. Lack of a congenital and/or severe spinal stenosis on MRI (defined as a complete lack of CSF signal on T2-weighted MRI),
5. Bony lateral recess stenosis and calcified disc or PLL as potential contraindications.

**Contraindications**
1. High grade spondylolisthesis is considered a contraindication to transpsoas approaches due to the displacement of the lumbar plexus into the operative field.
2. Epidural fibrosis from previous surgery and facet hypertrophy are not considered contraindications.
3. Retroperitoneal Scarring from prior abdominal surgery
4. Anomalous Vascular Anatomy
5. Access to L5-S1- depending on the experience of the surgeon performing the approach, an ALIF can still be performed with the patient in the lateral decubitus position with an oblique approach in the lateral position

**Patient Positioning**
1. Lateral decubitus position on a table capable of flexing.
2. The table is flexed minimally in order to gain lateral access between the ribs and iliac crest.
3. The patient is secured in place with tape.
4. The operative disc spaces are identified and marked on the patient's skin using orthogonal fluoroscopic imaging.
5. The spine is typically approached from the left side. This helps to avoid any mass effect from the liver and errs the surgeon towards the aorta rather than the more fragile inferior vena cava (IVC). Approaching from the side of concavity is sometimes favored to minimize the number of incisions needed.

**Incision**
1. Transpsoas approach - incision directly over the traced disc space. This will typically be about an inch long.
2. Antepsoas approach - incision should occur about 2 cm anterior to the anterior limit of the drawn disc space.
3. If multiple levels - then a single incision is typically used to access 2 levels.
4. Oblique rather than a vertical incision - In order to avoid injury to the traversing the abdominal muscle wall is preferred.

**Trans-Psoas Access**
1. The externus fascia is divided sharply and the muscle and fascial layers deep to it are divided bluntly.
2. Retroperitoneal space entered by sweeping abdominal contents posterior to anterior
3. The psoas is directly palpated over the spine
4. Dilator is guided down to the disc space along the surgeon's finger.
5. Fluoroscopy confirms the location of the dilator about the anterior third of the disc
6. Sequential dilators are placed, followed by a retractor that allows visualization of the operative corridor.
7. Dilator and retractor placement is guided by the use of intraoperative electromyography (EMG). This provides a means of detecting and avoiding nerve injury that may affect the quadriceps, hamstrings and ankle plantar and dorsiflexors.[22] Injury to sensory nerves however cannot be detected using this method.

**Ante-psoas Access**

1. Anterior Oblique Incision an inch long
2. Retroperitoneal space created similar fashion
3. Retractor placed anteriorly to directly visualize psoas through the incision
4. Anterior border of psoas identified under direct vision
5. Initial dilator docked on anterior third of disc space under direct vision anterior to the psoas
6. During an antepsoas approach, the use of neuromonitoring is not as essential - The antepsoas approach not only avoids introducing the lumbar plexus into the operative field, but it preserves the psoas muscle as well. If the retractor position is challenged by local anatomy such as a rib, a pin may be placed to anchor the retractor to the vertebral body. Preoperative review of the patient's MRI is critical.

**Discectomy**

1. A scalpel is used to perform an annulotomy.
2. Cobbs, curettes, rasps and pituitaries are then used to remove disc material and endplate cartilage.
3. Care is taken to avoid injury to the anterior longitudinal ligament and to
4. Avoid inadvertent passage of an instrument into the spinal canal by appropriate flouroscopy.
5. The disc space is then templated with different sizes of potential implants.

**Implant Placement**

1. Ideal placement of the cage is within the anterior third of the disc space, spanning from the apophyseal ring on one side to the other.
2. Lordotic cages have been shown to help increase local segmental lordosis when compared to parallel cages, while still achieving similar degrees of indirect decompression.
3. The standard implant material for the lateral interbody fusion is polyetheretherketone (PEEK).
4. Rectangular cage is filled with any combination of allograft, autograft, bone graft substitute or other osteoinductive material.
5. Use of recombinant human bone morphogenic protein 2 (rh-BMP2) for example has been shown to be associated with a fusion rate as high as 100% when used in a standalone fashion.[27]

**Stabilization**

1. Additional lateral or posterior fixation.
2. Pedicle screw and rod fixation - significantly stronger and resistant to segmental motion, while also providing superior maintenance of the decompression achieved by the interbody device.
3. Authors - prefer to use percutaneously placed pedicle screws and rods.
4. If multiple levels are being simultaneously addressed with lateral interbody devices, then posterior instrumentation can be placed during a second stage procedure on a separate day.
5. This allows the patient to mobilize between stages and test the effect of their indirect decompression.
6. If symptoms persist after their first stage, a repeat MRI can be performed and a decompression can be added to their second stage surgery.
7. This technique has been described by Anand et al (2017) in an approach to managing adult spinal deformity with circumferential minimally invasive techniques.[8]

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### When to Use TLIF?

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**Approach Choices**

ALIF
Lateral
TLIF

| PROS | | |
|---|---|---|
| ALIF | Lateral | TLIF |
| Large Surface Area Implant | Large Surface Area Implant | More Room for Graft |
| Relatively easy to get correction | Easiest to get Coronal Correction | Excellent coronal correction but requires specific technique |
| lowest chance of subsidence | Low chance of subsidence | |
| | | All from Posterior – No other incisions or positions |
| | | One approach/ operation |

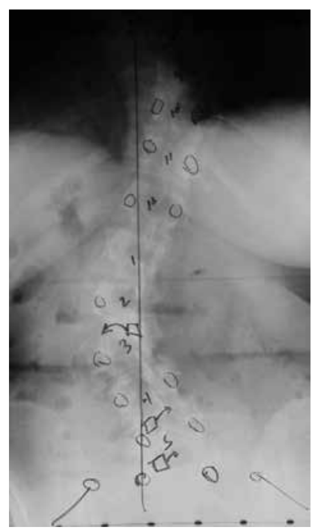
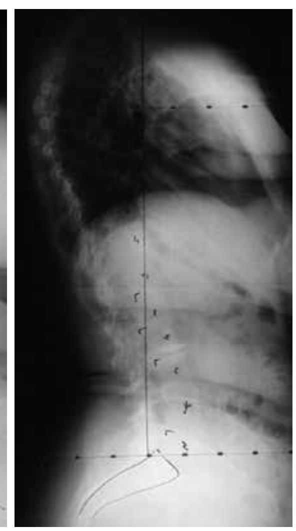
| CONS | | |
|---|---|---|
| ALIF | Lateral | TLIF |
| Requires anterior approach – 2 surgeries, frequently staged | Requires lateral app – 2 surgeries, frequently staged | Most Difficult to perform well |
| Longer hospital stay | Longer hospital stay | Increased Blood Loss |
| Requires another surgeon | May require another surgeon | Potential Nerve Injury |
| | | Increased chance for Epidural Fibrosis |

TLIF is equivalent or better to ALIF/LLIF when:

1. There is a contraindication to anterior surgery
   a. Previous retroperitoneal surgery
   b. Only one viable kidney on approach side
   c. Multiple abdominal surgeries
   d. Morbid obesity (ALIF)
   e. Previous serious pelvic or retroperitoneal infection
2. One or two levels at the apex need release on the concave side of the curve
3. Access surgeon not available or surgeon not trained in ALIF/ LLIF
4. Surgeon skill and preference

Tips and Tricks

1. Patient positioning – optimize lumbar lordosis on Jackson Frame – Hips almost extended.
2. Neuromonitoring
3. Pedicle Screws
   a. Largest diameter that will fit
   b. Longest
   c. Converge to anterior center of the vertebral body
   d. Use Many – every level is preferable
   e. Augment with cement when needed
4. TLIF
   a. Selectively distract on Concave side and 'release'.
   b. COMPLETE discectomy and endplate preparation – Take time!
   c. Pack ENTIRE disc space with graft
   d. Cage Placement
      i. For Apex of Curve - Place cage preferentially on concave and anteriolateral position – Fulcrum effect to help with deformity correction.
      ii. For L4/5 and L5/S1 to build a base – Place cage anterior and pack bone behind it.


## MIS Approach Selection: When are MIS Screws Appropriate and When Open?

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General rules for MIS Screws:

- -- No need for neural decompression or only need limited decompression (1-2 levels)
- -- No need for posterior column osteotomies
- -- Interbody grafts present
- -- Major correction done from anterior surgery already
- -- Foraminal stenosis already treated with interbody graft
- -- Relying mainly on interbody grafts for arthrodesis

When to use open screws:

- -- Multi-level decompression needed
- -- Need for multiple posterior column osteotomies
- -- Need major corrective forces applied posteriorly
- -- Almost all 3 column osteotomies (mini-open PSO exception)
- -- Need extensive posterior fusion surface for arthrodesis

## Pitfalls of Flatback Creation with MIS Deformity Surgery

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**OVERVIEW**

- How important are sagittal balance and lumbar lordosis in MIS?
- What are the workhorse MIS techniques?
- Do these techniques promote lordosis?
- Pearls to avoid creating flatback with MIS
- More advanced techniques

**HOW IMPORTANT ARE SAGITTAL BALANCE AND LUMBAR LORDOSIS IN MIS?**

- Very!
- Literature shows that patients who do best after MIS deformity surgery have normal SVA (< 5 cm) and a PI-LL mismatch ~10 degrees.

**WHAT ARE THE WORKHORSE MIS TECHNIQUES?**

- MIS TLIF
- MIS LLIF

**DO THESE TECHNIQUES PROMOTE LORDOSIS?**

- MIS TLIF
  - Yes, but not much.
- MIS LLIF
  - Yes, but not much.
- Expandable implants do not seem to be superior to static cages.
- Curvilinear (banana) implants do not seem to be superior to straight ones.

**PEARLS TO AVOID CREATING FLATBACK WITH MIS**

- MIS TLIF
  - Large facetectomy
  - Thorough discectomy
  - Place shorter length implant to allow for compression
- MIS LLIF
  - Thorough discectomy
  - Release annulus bilaterally
  - Place most lordotic implant that disc space will allow

**MORE ADVANCED TECHNIQUES**

- Posterior
  - Minimally invasive Smith-Peterson osteotomy
  - Mini-open pedicle subtraction osteotomy
- Lateral
  - Anterior column release
    - Average LL induced per level of ACR = 13-15 degrees

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## What Impact do MIS Techniques Have on PJK in Deformity Surgery?

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Proximal Junctional Kyphosis (PJK)
1. A type of adjacent segment pathology
2. Originally defined by >10° angulation between the UIV and UIV+2 and >10° then preop
   - a number of different definitions in the literature
3. Symptomatic PJK often leads to operative intervention
   - "Bane" of deformity of surgery
4. Incidence
   - Radiographic incidence 17-39% in adult deformity
     – Symptomatic PJK is less frequent
   - Typically occurs within 1 year of index surgery for adult deformity
     – Longer development interval in adolescent
5. Risk Factors for PJK
   - Surgically related
     – Anterior/posterior surgery
     – UIV at upper vs lower thoracic/lumbar spine
     – Pelvic fixation
     – Type of instrumentation
     – thoracoplasty
     – Integrity of the PLC
   - Radiographic related
     – Preop SVA
     – Sagittal sacral vertical line
     – Pelvic incidence
     – Magnitude of correction
   - Patient related
     – Age
     – Osteoporosis
6. PJK Etiology
   - No one factor has been shown to be the main driver
     – Likely multi-factorial
   - Can any of these potential causes be modified??
7. Impact of MIS on spinal surgery
   - Minimally invasive approaches
     – Short segment fusions for degenerative disease have been shown to produce outcomes equivalent to traditional open surgery
     – Added benefit of decreased exposure related morbidity
     – ↓bleeding, ↓LOS, ↓post-op pain, faster recovery
     – Relatively good evidence with longer term follow-up
8. Impact of MIS on deformity
   - What about in deformity surgery?
     – Early evidence suggest outcomes are good in patients with modest deformity
     – Less impactful with significant sagittal imbalance
       - ACR is a newer technique that significantly improves sagittal alignment
9. Impact of MIS on PJK
   - Have to think about what a traditional open approach does to the surrounding tissues
   - Two terms come to mind
     – Carpet bombing
     – Collateral damage
     – Open Spine Exposure = Carpet Bombing
     – Collateral damage = paraspinal muscles, ligaments, joints
10. MIS PJK Study: "Does Minimally Invasive Percutaneous Posterior Instrumentation Reduce Risk of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery? A Propensity-Matched Cohort Analysis."
   - Retrospective study comparing two groups who underwent deformity surgery
     – cMIS – LLIF followed by percutaneous instrumentation (no muscle "stripping")
     – HYB – hybrid LLIF followed by open posterior surgery with instrumentation
     – After propensity-matching and adjusting for levels instrumented
       - 13 (48.1%) cMIS and 14 HYB (53.8%) had radiographic PJK ($p = 0.68$)
       - 3 (11.1%) cMIS patients and 5 (19.2%) HYB patients required revision surgery for PJK ($p = 0.41$)
       - Sample size too small to detect difference??
11. Conclusion
   - PJK is likely multi-factorial
   - MIS approaches minimize one potential cause for PJK

### What Are the Limits of MIS Surgery in 2017?

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The Opportunity for Minimally Invasive Techniques in Spinal Deformity Surgery

- Spinal deformity is a recognized source of morbidity in the adult and elderly population
- A significant number of elderly patients have deformity
- Deformity correction techniques have improved, but most open operations entail significant morbidity
- Complication rates, especially in the elderly, are extremely high
- Some patients may not be candidates for spinal reconstruction and are left without operative options

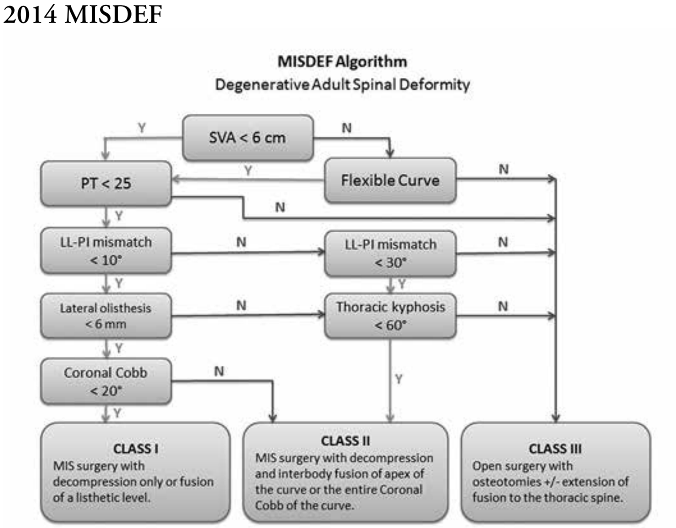
The Barriers for Implementing MIS in Spinal Deformity Surgery

- Techniques can be difficult to apply to long segment reconstructions
- Sagittal Plane Deformity often requires osteotomies
- Surgeon comfort with techniques
- Achieving arthrodesis

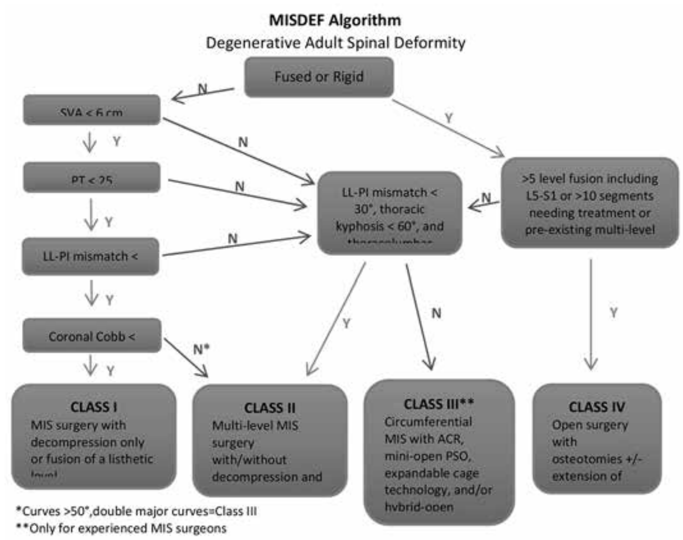
Indications for MIS in Deformity Surgery Continue to Expand

- Certain deformity more amenable to treatment with MIS techniques
- Prior attempts at decision making focused on patient with degenerative disease and moderate at worst deformity

**2014 MISDEF**




**2017 MISDEF**




What has Changed?

- Advances in techniques
  - Hybrid techniques
  - ACR
  - Less invasive osteotomies
- Pendulum swing in elderly SVA objectives

Limits in 2017

- Goals of treatment
- Sagittal plane correction
- Comfort with techniques
- Current state of instrumentation for MIS

### What are the Challenges to Adopting MIS Surgery in a Deformity Practice?

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The benefits of minimally invasive surgical (MIS) techniques for the treatment of spinal degenerative disease has been demonstrated in the literature (less blood loss, shorter hospital stays, less injury to paraspinal soft tissues) with fusion rates and outcome measures comparable to classic open techniques (1 ). The introduction of better instrumentation and more aggressive techniques in allowing mobilization of the thoracolumbar spine via MIS has allowed for a broader application to operations that were commonly considered possible only via open surgery. Similar advantages of MIS techniques in deformity surgery as described for degenerative spinal surgery are yet to be fully proven but there has been evidence that in a preselect group of patients these advantages are real (2).

This poses the question as to how to adapt a classic deformity practice so as to include these treatment option for patients.

There are several key points that require particular consideration.

Understanding the indications for MIS and its current limitations:

- Amount of correction attainable has been shown to have a ceiling effect that limits the type of deformity that can appropriately be corrected with MIS techniques (3).
- Limitations of the the screw/bone interface
- Patient limitations: (Fixed deformity, Osteoporosis)

Introducing new surgical techniques in to an established practice algorithm requires overcoming the learning curve so as to become comfortable with the different MIS techniques available:

- MIS can be difficult because of loss of visual cues
- Curvature and rotation of the deformed spine increases the difficulty
- Decreased Radiologic visualization in older osteopenic patients
- Image guidance is crucial to replace visual cues
- Fluoroscopy most commonly used
- Mini osteotomy techniques through tubular retractors
- Use and limitations of expandable interbody technology and lordotic implants
- New Intraop Imaging/Navigation Applications for MIS Deformity

However, the particular risks associated with complex MIS techniques also need to be understood:

- ALL release presents more benefits in deformity correction but also presents higher associated surgical risks (4).
- Re-operation rates as they apply to different surgical techniques chosen (5).

Addressing the cost benefit with hospital administration and third party payers:

- Higher cost but lower complication rates in MIS surgery in particular for what regards infection rates (Table 1) and length of hospital stay
- The overall cost expenditure per patient treated within a population seems to support initial higher implant cost for long term cost saving for MIS techniques as compared to classic open (Table 2)
- Willingness to explore and understand other cost savings that offset the increase in initial capital expenditure (robotics and neuronaviagational technology capable of eliminating k wire guided cannulated implants).

**Table 1** Summary of all MIS and open-TLIF cohorts in the literature to date assessing incidence of post-TLIF infection.

| MIS TLIF Series | Cohort Size | Post-op Wound Infections | Infection Incidence (%) | Open TLIF Series | Cohort Size | Post-op Wound Infections | Infection Incidence (%) |
|---|---|---|---|---|---|---|---|
| Peng 2009 [11] | 29 | 0 | 0.0 | Peng 2009 [11] | 29 | 1 | 3.4 |
| Dhall 2008 [12] | 21 | 0 | 0.0 | Dhall 2008 [12] | 21 | 0 | 0.0 |
| Villavicencio 2005 [23] | 73 | 2 | 2.7 | Villavicencio 2005 [23] | 51 | 0 | 0.0 |
| Kim 2009 [24] | 46 | 0 | 0.0 | Lowe 2002 [25] | 40 | 1 | 2.5 |
| Starkweather 2008 [26] | 17 | 0 | 0.0 | Grob 2009 [27] | 63 | 1 | 1.6 |
| Deutsch 2006 [28] | 34 | 0 | 0.0 | Lauber 2006 [29] | 39 | 1 | 2.6 |
| Schwender 2005 [30] | 49 | 0 | 0.0 | Hsieh 2007 [31] | 25 | 2 | 8.0 |
| Selznick 2009 [32] | 43 | 0 | 0.0 | Faundez 2009 [33] | 65 | 6 | 9.2 |
| Lee 2008 [34] | 27 | 0 | 0.0 | Rodriguez 2008 [35] | 20 | 3 | 15.0 |
| Jang 2005 [36] | 23 | 0 | 0.0 | Humphreys 2001 [37] | 40 | 0 | 0.0 |
| | | | | Hee 2001 [38] | 111 | 5 | 4.5 |
| | | | | Hackenberg 2005 [10] | 52 | 1 | 1.9 |
| | | | | Potter 2005 [39] | 100 | 2 | 2.0 |
| | | | | Houten 2006 [40] | 33 | 1 | 3.0 |
| | | | | Taneichi 2006 [41] | 92 | 1 | 1.1 |
| | | | | Rosenberg 2001 [42] | 22 | 2 | 9.1 |
| | | | | Chastain 2007 [43] | 40 | 5 | 12.5 |
| | | | | Crandall 2009 [44] | 20 | 1 | 5.0 |
| | | | | Carter 2009 [45] | 20 | 1 | 5.0 |
| | | | | Rihn 2009 [46] | 130 | 5 | 3.8 |
| | | | | Parker 2010 | 120 | 6 | 5.0 |
| **all series** | **n=362** | **n=2** | **0.6%** | **all series** | **n=1133** | **n=45** | **4.0%** |

Table 2: The ability to commit to capital investment to support the increasing advancements in Technology (robot, navigation)

Average Cost Comparison of MIS vs. Open TLIF

| | MIS | Open | p Value |
|---|---|---|---|
| 1-level | $29,187 +/- 461 | $29,947 +/- 269 | P=0.55 |
| 2-levels | $33,879 +/- 521 | $35,984 +/-269 | P=0.002 |


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## Why Open Surgery Is Better Than MIS in Deformity? (Previously: Open Techniques are Best)


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- ❖ **The Trends in Spine Surgery**
  - To become more cost-effective and to focus on reducing complications and length of stay while maximizing outcomes – which ultimately increases the value proposition of a particular intervention
  - Evidence-based practice
- ❖ **Foundational questions about MIS**
  - What is MIS?
  - Access aid or surgical care philosophy?
  - Is the cost difference justified by outcomes?
  - Is patient safety compromised by MIS?
- ❖ **Goals of Surgical Spine Management: Nihil Nocere.**
  - "To do no harm" reads nice but does work in the real

world unless harm is **clearly defined**, as was in Christopher Duntsch's case

- **Characteristics of Lumbar Degenerative Scoliosis:**
  - Adult onset of deformity (de novo);
  - Adult sequelae of AIS
  - Degenerative changes within the deformity include spinal stenosis, spondylolisthesis, rotatory subluxation, lumbar hypolordosis, and osteoporosis.
- **The Goal of Care for Lumbar Degenerative Scoliosis**
  - To improve Self-Assessment of Quality of Life, to decompress neural compression, to improve back pain, and sagittal and coronal alignment.
  - When degenerative scoliosis becomes symptomatic, the main goal of treatment is to reduce pain and/or any accompanying neurologic symptoms. Treatment does not tend to focus on correcting the curve because that is typically not the cause of pain, nor is the curve likely to progress enough to cause a deformity.
  - The surgical options for degenerative scoliosis tend to fall into two general categories:
    - Decompression surgery (e.g. lumbar laminectomy).
    - Decompression with fusion surgery. More commonly, the decompression surgery mentioned above is combined with a fusion to create certain stability.
    - Anterior/Posterior Open, Posterior only, With Interbody fusion, Posterior only with Osteotomies, With or without interbody fusion, Minimally or Lesser Invasive options, Transpsoas- LLIF/direct lateral interbody device, etc., MIS TLIF, L5/S1 ALF, Percutaneous internal fixation and Combination Open and MIS.
- **Defining Characteristics of MIS**[1]
  - Minimally invasive posterior lumbar surgery is performed with table-mounted tubular retractors that focus the surgical dissection to a narrow corridor directly over the surgical target site.
  - The path of the surgical corridor is chosen based on anatomic planes, specifically avoiding injury to the musculotendinous complex and the neurovascular bundle.
  - However, minimally invasive surgical techniques remains technically demanding, and a significant complication rate has been reported during a surgeon's initial learning curve for the procedures.
  - Improvements in surgeon training along with long-term prospective studies will be needed for advancements in this area of spine surgery.
- **Alternatives to the open approach have significant requirements before they can be considered a reasonable:_ Long-term follow-up, Cost-efficacy, Value**
- **Complications have always been the major concern to any treatment modality in ASD, and have very commonly been defined as a major parameter in decision-making.**
  - When treatment complications are evaluated, most care providers and decision-makers think of the complications of surgical treatment. As can be seen, there is a very wide variance in the incidences reported, especially with regard to pseudoarthrosis and implant failures (ranging between 0.5% and 54.0%).
  - Any treatment in ASD is prone to complications, and complications can affect surgical outcomes adversely. Patients with complications have a decreased likelihood of getting better compared to those with no complications, and they carry a heavier burden of the disease; potentially even heavier than their baseline status.
  - Surgical treatment of ASD is prone to complications (31.7%). These complications affect the clinical outcomes of treatment. Further, complications are associated with a heavier disease burden. All controlled and non-controlled studies on the treatment of ASD uniformly suggest that at this point in time, surgical treatment may provide better chances of improvement when compared with non-surgical treatment.
- **Safety Issue of MIS procedures**
  - Many of the maneuvers involved in minimally invasive surgery are not intuitive, and the dearth of anatomical landmarks can lead to a high rate of intraoperative errors.
  - Manipulation through tubular dilator retractors can result in higher rates of neurological injuries, as well as inadequate decompression. Problems with intervertebral cage sizing and placement, insufficient preparation of the fusion bed, and misplacement of transpedicular screws are all likely to be more common with minimal access approaches.
  - Overall, there were 13 (59.1%) approach-related complications in the Direct lateral interbody device group and 3 (14.3%) in the OLIF group. In the Direct lateral interbody device group, 3 (45.6%) were classified as persistent, however, there was no persistent complication in the OLIF group.[2]
  - Direct lateral interbody fusion significantly improves segmental, regional, and global coronal plane alignment in patients with degenerative lumbar disease. Although Direct lateral interbody device increases the segmental sagittal Cobb angle at the level of instrumentation, it does not improve regional lumbar lordosis or global sagittal alignment.[3]
- **Clinical outcomes seem similar between the MIS and open, but outcomes depend on the surgeon's skill level and patient selection.**
  - A wide range of literature exists showing minimally invasive techniques can have equal or better outcomes than open techniques, but outcomes often depend on the surgeon's skill level and patient selection.
  - Minimally invasive techniques require a steep learning curve and surgeons with more experience are likely to achieve better outcomes.
- **New MIS techniques still need evidence-based backing.**
  - High-level data supporting new minimally invasive techniques, such as lateral spine surgery and disc replacements, has been published over the past few years.

- Studies comparing the effectiveness of lateral procedures for spine surgery to other techniques and open surgery show the approach is effective for various procedures. NuVasive initially launched the eXtreme Lateral Interbody Fusion system more than 10 years ago, but several other device companies over the past few years have launched lateral systems as well.

❖ **Radiation exposure higher for MIS procedures, although new innovations coming.**
- Most minimally invasive spine surgical techniques use fluoroscopic guidance which increases surgeon and patient radiation exposure. Radiation exposure is one of the top reasons he has not adopted minimally invasive techniques.
- A 2013 study published in Spine found that spine surgeons performing percutaneous endoscopic lumbar discectomy procedures reach the limit of allowable radiation exposure without a lead apron after 219 lumbar spinal discectomies per year.
- Another study from 2011 published in Spine found that surgeons performing minimally invasive lumbar microdiscectomy were exposed to significantly more radiation than surgeons performing open microdiscectomy. Exposure to high dose of radiation may increase the risk of health complications for spine surgeons.

❖ **Goals of open spine surgery remain the gold standard.**
- Although more spine surgeons are moving toward minimally invasive techniques, but the outcomes achieved with open spine surgery remain the gold standard. Residents and fellows continue to learn the open procedures first and then focus on less invasive techniques.
- Fellowship and residency programs are struggling to ensure their faculty and trainees have enough experience with both minimally invasive and open techniques for proficiency.
- Axial lumbar interbody fusion is a novel minimally invasive approach for fusion of L4-5 and L5-S1. This technique uses the pre-sacral space for percutaneous access to the anterior sacrum. A total of 68 patients underwent MIS lumbo-sacral interbody fusion device surgery, with an average follow-up time of 34 months. Sixteen patients (23.5%) experienced a total of 18 complications (26.5%); this group included 8 men and 8 women (mean age 52.1 years). These complications included pseudarthrosis (8.8%), superficial infection (5.9%), sacral fracture (2.9%), pelvic hematoma (2.9%), failure of wound closure (1.5%), transient nerve root irritation (1.5%), and rectal perforation (2.9%).

❖ **Conclusion:**
- "Minimally invasive surgery demonstrated reduced costs, blood loss, and hospital stays whereas open surgery exhibited greater improvement in VAS scores, deformity correction, and sagittal balance.
- Adult lumbar degenerative scoliosis with spinal stenosis is treated most reliably and optimally with an open approach including the entire measured curve.

❖ **Future**
- We need to keep on working on new surgical technologies that would improve patient safety and decrease complications.
- The priority may be developing new fusion and implant technologies as the rates of mechanical failure are still unacceptably high in ASD.
- Studies are needed analyzing the economic impact of minimally invasive spine surgery.
- Future studies are necessary to confirm the durability and further define indications for minimally invasive lumbar spine procedures.

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## MIS Techniques are Superior

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The past decade has seen a revolution in minimally invasive techniques to improve surgical outcomes, including minimally invasive spine surgery (MIS). Whereas traditional open techniques have their indications, procedural necessities including large openings, muscle attachment takedown, copious retraction, and increased operative times often stand in the way of the goals of MIS surgery. To circumvent these obstacles, MIS has emerged as an alternative form of surgical treatment, with innovations directed at restoring each of the objectives lost in large traditional operations.

Specific advancements in the field have included the development of unique methods of nerve monitoring and tissue retraction. Intraoperative nerve monitoring has offered improvements in operative safety in small corridors by avoiding direct damage or retraction injury of non-visualized neural elements(1). The virtually universal use of tubular self-retaining retractors that allow for muscle fiber spreading, rather than muscle takedown, are widely believed to be a major source of the decreased pain, reduced blood loss, earlier mobilization, and improved outcomes seen in numerous studies (2).

In some cases, these tubular retractors have offered completely new corridors of surgical approach—for example, the lateral approach to the thoracic and lumbar spine. This has eliminated the widespread use of comparably morbid thoracotomies and large lumbar incisions in the effort to gain surgical access to these segments of the spine.

Furthermore, the development of specialized drills, delivery cannulas, and instrumentation platforms allow for safe performance of spinal decompression, as well as instrumented fusion through percutaneous placement of vertebral interbody devices, pedicle screws, fixation rods, augmenting cement, and numerous other therapeutic measures.

These rapid advances in techniques, instruments, and indications have led to the successful implementation of MIS for the treatment of a diverse group of pathologies. Indeed, MIS procedures are now applied to all arenas of surgical disease including the treatment of trauma, spinal deformity, tumor, and degenerative disease.

Patient selection is an important factor when electing to use an MIS approach, because not all patients are candidates for this approach due to the extent of deformity. The MIS decision-making process includes a thorough analysis of clinical and radiographic parameters to establish benchmark surgical objectives for neural decompression, restoration, and maintenance of spinal balance in a similar fashion to traditional open techniques. (4)

Minimally invasive surgery (MIS) approaches have the potential to reduce procedure-related morbidity when compared with traditional approaches. However, the magnitude of radiographic correction and degree of clinical improvement with MIS techniques for adult spinal deformity remain undefined.

For the patient with uncompensated and minimal sagittal and coronal imbalance (green subgroup), our outcomes show that a stand-alone or limited segmental lateral interbody fusion with posterior fixation at the curve apex should be adequate. For the yellow subgroup (moderate deformity), correction of sagittal imbalance can be achieved through some combination of lateral ALL release with or without MIS facetectomy with posterior xation. For more severe deformity (red subgroup, sagittally unbalanced with rigid deformity curves), a hybrid MIS–open procedure will likely be needed. (4, 5)

Work remains to be done in producing more robust studies with longer follow up to determine durability of correction, subsidence rates, and improvement of quality of life. To make concrete claims about the efficacy of MIS treatment of deformity, studies with control groups treated with traditional deformity surgery are necessary. Consistent use of CT scans for assessment of fusion is needed because this is the main purpose of these surgical procedures. In addition, further study is needed to delineate the role of advanced techniques such as anterior longitudinal ligament release and use of hyperlordotic cages. Finally, given that adult degenerative scoliosis affects predominantly elderly patients, more data with larger cohorts fitting this demographic are needed to assess if MIS techniques reduce the incidence of age-related complications in patients undergoing spine surgery (5).

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## Technical Considerations of the Lateral Approach in ASD

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PRE-OP PLANNING

1. Utilize axial sequences of CT/MRI to scrutinize the visceral/vascular structures around the ventral spine.

- Vessels--need to consider ipsilateral and contralateral aspects of the approach. Annular release contralaterally is done without gross visualization, and vascular structures (vein if approaching from the left side of patient) can be in position of danger. Review for aberrant segmental vasculature.
- Renal—evaluate position of kidneys and any unusual location; typically fall ventral or mobile when in standard locations.
- Bowel---review position of bowel, although typically mobile, and specifically, history of retroperitoneal processes (prior surgery, prior significant retroperitoneal/diverticular infections, endometriosis, etc)
- Liver—usually feasible to work behind/dorsal, but hepatomegaly/abnormal positioning may affect access to upper lumbar/thoracolumbar levels
- Location of psoas muscle---proxy to lumbar plexus position; beware transitional lumbosacral anatomy (Figure 1), as significant ventrally positioned psoas musculature results in limited/absence of adequate safe window between vasculature (ventral) and lumbar plexus (dorsal)

2. Review radiographs/advanced imaging for guidance on best side of approach
    a. L4-5 tilt will often dictate side of approach---concavity typically, but whichever side is more cephalic and often gives a coaxial approach over the ilium into the disk space (Figure 2)
    b. Concavity more common choice---allows for a single retractor incision that can address all levels (up to T12-L5)
    c. Severe lateral listhesis with obliteration of intervertebral interval on one side may also influence choice to approach from the other side.
    d. Anterolisthesis greater than grade 2 on the SUPINE preoperative imaging disallows safe/adequate window of passage between vasculature and lumbar plexus
    e. Severe segmental rotation that would force a marked ventral to posterior vector of the approach to remain perpendicular to the anteroposterior axis of the segment may be obstructed by viscera/peritoneal contents. In such a case, coming from the contralateral side with a more dorsal to ventral vector can be more tenable. The degree of rotation should be most ideally evaluated on the relaxed supine advanced imaging via axial sequences.

INTRAOPERATIVE MANAGEMENT

1. Positioning
    a. Place patient in perceived lateral position and provisionally tape/secure.
    b. Goal is to keep the fluoroscopy in orthogonal position relative to floor and the operative table in the lateral and AP planes respectively to avoid errant positioning/visualization, and thus improper vector of lateral cage preparation/implantation
    c. Fluoro imaging assessment of the most cephalad and caudad levels in the anteroposterior plane to ensure the c-arm can achieve the positioning required (wagging) to properly visualize true AP views of the target disk space.
    d. Fluoro imaging assessment of the most rotated of the segments to ensure that the bed rotation can accommodate bringing these particular segments into adequate anteroposterior view of those segments.
    e. Now fully secure the patient with taping to prevent intraoperative 'rolling'/'motion' of the torso/legs.
    f. Once secured, move to Fluoro imaging assessment in the lateral view of the most cephalad and caudad segments to be addressed in order to ensure the bed Trendelenberg/reverse Trendelenberg excursion can accommodate providing perfect lateral views of the segments being reconstructed
    g. Mark the mid disk space point, or the full AP length of the disk space on the flank skin for each level. This requires resetting the bed rotation and AP position of each level, so do one at a time, restarting at each level with the AP view of that segment, and then resetting the lateral view for that segment before skin marking.
    h. Once all disk spaces to be addressed have been given an associated skin target location, the skin incisions can be planned.
    i. The lateral incision can often be ideally placed at the midpoint between lowest palpable rib in the midaxillary line and the ilium, and in a transverse fashion. Approaching in the concavity will allow for reasonable approach to all levels in the lumbar spine (above L5-S1) through a single incision (with the strategy discussed below). If there is no coronal deformity and more than 3 levels of lateral approach are being employed for sagittal correction, a vertical extensile incision or multiple lateral incisions may be necessary. Alternatively, a longer transverse skin incision can be employed, with skin mobilization to accommodate more than one underlying muscular/fascial approach. There may be need to 'break' the table slightly to create room between the rib and ilium in some cases, but it is generally not necessary to break the table for the purpose of disk space access.
    j. For the two incision approach, make the counter (posterior) incision in the softest spot bordered by the $12^{th}$ rib, the ilium and the paraspinal musculature, but also within finger reach externally to the planned lateral incision.
2. Surgical Approach
    a. Unless the L4-5 tilt is dramatic and results in the upper lumbar disk spaced/endplates being relatively neutral to the pelvis, start at the upper levels first and work down. This approach prevents the act of 'building the spine away or cephalad' to the lateral incision, and reducing or eliminating the ability to access all disk levels through a single lateral retractor incision.
    b. If there is a marked L4 tilt (as with a lateral listhesis and concomitant severe asymmetric collapse on the side of the fractional curve, and correcting the angular deformity of that segment brings the upper levels into a more favorable coaxial position relative to the lateral incision, then reconstruct L4-5 first; AND THEN go to the most cephalad level and work down level by level.
    c. Use separate psoas muscle dilations and neural mapping at each level, and use the table controls to RESET perfect AP and LATERAL segmental views to be addressed. This will require table rotation and fluoroscopic 'wagging' when taking the AP view, and then Trendelenberg table adjustments when taking the lateral views at each successive segment being reconstructed. If there is considerable segmental rotation present that disallows good AP views of both vertebra being addressed, more commonly position the bed/patient such that the caudal vertebra is in the ideal anteroposterior position.
    d. The cephalad levels, typically above L2, may require an angled approach to allow access to the disk space. If angled instrumentation is not available, skin/fascial incision planning will need to accommodate a coaxial approach to these levels, which may include passage between ribs. Be prepared to address violation of the pleural space in a safe and reparative manner (discussed separately), if so.
    e. Likewise, if L4-5 is not tilted in a manner that favors a coaxial approach from the lateral incision, the use of

angled instrumentation is recommended, with the alternative option of additional table break.

f. Protect the endplates with great care while delaminating the disk from them, and if the angle of approach makes this difficult when employing the Cobbs, utilize the softer side of the Cobb to 'glance' off at-risk endplates. (Figure 4) This is preferred over engaging the endplates in a manner that risks violation and structural compromise of them.

g. Release the segment both ipsilaterally and contralaterally with annulatomy and Cobb passage through each annular-endplate junction, respectively. A thorough ipsilateral and contralateral annular release allows for better correction and derotation of that segment when introducing the intervertebral devices.

h. If there is a concave collapse and/or osteophytic obstruction to disk space access, utilize a Cobb or osteotome to gain access, preferably using image guidance in order to avoid errant penetration of the vertebral bodies or damage to the endplates. Ipsilateral osteophytectomy can also be performed to gain access to the disk space with other typical instruments.

3. Closure

a. Close each available muscle/fascial layer before skin closure—prevents potential hernia occurrence

b. When working between ribs, assess for violation of pleural space. If violation has occurred, evacuate the pleural space with catheter placed in pleural cavity and large end external to wound submerged in saline bowl, while preparing a purse-string closure. Valsalva/deep ventilation by Anesthesiology is undertaken until bubbling/evacuation of any air in the pleural cavity has ceased, and then closure of the wound during withdrawal of the catheter is completed. Chest radiographs should be obtained (ideally intraoperatively), and a chest tube can be placed if a significant pneumothorax remains.

c. Drains are optional in the retroperitoneal space.


Figure 1.


Figure. 2


Figure 3


Figure 4

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## MIS Anterior Lumbar Interbody Fusion (ALIF)

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1. ADVANTAGES:

a. Optimal preservation or restoration of lumbar lordosis
b. "Harmonious" correction of Lumbar lordosis
c. Most applicable at L4-S1 (Majority of lordosis)
d. Complete sectioning of ALL, for optimal "release."
e. Large graft surface area, under compression,
f. High rates of fusion
g. Allograft, Peek, Titanium
h. FDA clear used with Ti and BMP
i. Indirect foramina decompression
j. "Stand alone," or with Posterior Stabilization (Open or Perc)
k. Restoration of disc height
l. Compared to posterior, less risk of nerve injury, infection, CSF leak
m. Large implants, available in "hyper-lordotic" up to 30 degrees.

2. DISADVANTAGES

a. Risk of visceral / vascular injuries
b. Higher risk of ileus
c. May require an "access surgeon."
d. NOTE: in cases with PRIOR posterior decompression, an ALIF is such a powerful mechanical distraction maneuver, "over-distraction " may cause stretch root injury, palsy and neuropathic pain.
e. THUS, in these patients with prior posterior decompression (and fibrosis), AVOID "over distraction " of disc space.
f. Retrograde ejaculation in 4-8 %. Studies not clear on role of BMP. I still use BMP, in lower doses.

3. HISTORICAL

a. Originally described for Pott's disease, started greater utility for degenerative conditions with Femoral Ring Allograft (FRA), threaded cortical bone dowels, Ti cages ( Ray, BAK, and threaded lordotic cages / LT), later more anatomical spacers that preserved endplates (PEEK and Titanium.)
b. rh-BMP FDA cleared for L5-S1 LT Ti threaded lordotic cages; also used with laparoscope.
c. Laparoscopic approaches cleared the way for current "mini-open " techniques. (no significant difference in outcome between lap and mini-open)
d. Gaining widespread usage to optimize Spinal Pelvic Parameters, Lumbar Lordosis in both degenerative and deformity condition.
e. In "non-fixed " deformities, creates a more HARMONIOUS lordosis, most critical at the L4-S1 levels, compared with posterior PSOs, which are more angular in correction, and typically performed at a higher lumbar level.
f. NOTE: PSOs still utilized for fixed deformities.
g. Recently, decreased number of cases for PSOs, with increased volume of ALIF (and lateral retroperitoneal approaches).

4. PRE OP EVALUATION

a. MRI (disc hydration, neuro compression). NOTE: Analogous to cervical spine, a herniated disc may be removed via an ALIF, with or without an anterior foraminotomy (kerrisons, similar to an ACDF). Also assess vascular anatomy.
b. CT often used to assess facet joints, air in disc (thus, disc is more "movable" with implants), osteophytes
c. Lumbar spine series with weight and non-weight bearing flexion extension
d. Measurement of Spino-Pelvic Parameters

5. ALIF vs TLIF, POSTERIOR -LATERAL FUSIONS, AND LATERAL FUSIONS

a. ALIF, in multiple studies, has the highest, most reproducible ability to restore lordosis.
i. Hsieh, Koski, Ondra et al.:
ALIF: 6.2 degree increase lordosis; 18.5% increase in foramina height
TLIF: 2.1 degree decrease lordosis; -0.4% decrease foramina height
Later correspondence: with bilateral Smith-Pete osteotomies, anterior graft placement, and compression: TLIF 5.7 degree increase in lordosis.
ii. Kim, et al:
ALIF: segmental lordosis increased 8.6 degrees
TLIF (MIS): segmental lordosis increased 2.5 degrees
iii. Dorward et al: Long segment scoliosis:
ALIF: 5.6 degrees
TLIF: -1.7 degrees
iv. Dimar, et al:
Compared : ALIF with LT tapered lordotic threaded cages, posterior-lateral fusions, TLIF, block ALIF spacer placed posterior disc space with post screws:
LT lordotic cage was superior in Lordosis.
Authors did not dote the "carpentry" of the TLIF procedure.
v.Shaffrey, Smith, et al:
Excellent lordosis correction with TLIF technique.
Single surgeon : Shaffrey
Close to lordosis achieved by ALIF
However, technique demanded open bilateral SP facetectomies, interbody distraction with "disc jack," pedicle screws maintaining

kyphosis until ANTERIOR TLIF deformity cage rotated into the anterior third of the disc space, followed by screw compression.
vi. Arlet, et al:
ALIF with HYPER LORDOTIC cases for deformity
Very successful restoration of lumbar lordosis with anterior posterior deformity.
Also demonstrated that in cases of prior pedicle screws, an ALIF may further distract , open up and improve lordosis (in the presence of screws).

6. TECHNIQUE

a. Mini-open
b. Midline or paramedian
c. Retro-peritoneal (most applicable at L5-S1). Less ileum.
d. Trans-peritoneal (all levels, including L3-4)
e. At L5-S1, retraction of left iliac vein. Clip mid sacral artery and vein; does NOT denote midline
f. At L4-L5, often need to ligate, clip left olio-lumbar vein (do not stretch,,, look for it).
g. Blunt retraction of soft tissue with kittner to diminish injury to plexus (decrease retrograde ejaculation)
h. Avoid cautery (diminish thermal injury to plexus)
i. May place bolster under lumbar junction to increase lordosis
j. 5000 units heparin SQ to decrease DVT and PE. Continue BID-TID until patient ambulating. Also use sequential compression stockings.
k. Wide retraction of veins to optimize Anterior Longitudinal Ligament (ALL) section.
l. Look for Sympathetic nerve chain laterally; this is most lateral aspect of ALL section.
m. #10 scape to cut disc, use large Cobb to remove disc. Do NOT violate endplate.
n. Continual removal of disc with rongeurs, Cobb, pituitary.
o. Proceed until PLL.
q. May do foraminotomy with kerrison; may open PLL to remove HNP if needed.
r. SEQUENTIALLY distract with templates.
s. Maintain posterior disc height to maintain neural foramen. Minimum 6 mm height; 8-10 optimal.
t. Optimize lordosis. "trail and error" to see what height and lordosis FITS the best.
u. Select implant with allograft (+/- BMP); clean endplate, place implant.
v. Lateral flouro as needed. Alway check graft placement prior to closure.

7. POST OP

a. OOB, Ambulate same day if smaller procedure.
b. Clear liquids and advance as tolerated.
c. With multi level ALIFs (L3-S1) , start peripheral IV hypo-alimentation.
d. May give Metaclopramide for GI motility.
e. May give (methylnaltrexone) to block narcotic receptors in gut, decreasing opioid induced constipation.
f. For osteoporosis / smokers, multi level, etc, may use Forteo ( teriparatide) to aid fusion.

8. IMPLANT MATERIALS

a. Allograft. Good fusion rates with posterior fixation in supplementation. Not good fusion in Stand alone.
b. PEEK
i. Radiolucent to assess fusion
ii. Theoretical good MOE
iii. May form "biofilms," with higher rates of pseudoarthrosis
iv. Easily revisable , may Drill out.
c. Titanium
i. Not radiolucent (more difficult to assess fusion)
ii. MUST preserve endplate
iii. Higher affinity than PEEK for bone and Fusion
iv. Thought trends towards higher rates of fusion with Titanium than PEEK.
v. Optimal fusion with BMP (BMP "acts" differently with Allograft, PEEK and Ti)
vi. HYPERLORDOTIC CAGES allow optimal preservation / restoration of lumbar lordosis, notably L5-S1 and L4-5.

9. BIOMECHANICS

a. In pathology, differentiate "axial instability' (Collapsed disc, Modic changes, foramina stenosis), with "translational instability," (Spondylolisthesis; AND: difference between degenerative Spondy and Isthmic Spondy).
b. The greater the instability , the poorer the quality of bone, and more co-morbiditites (DM, smoking, etc), ..the greater the need for posterior supplemental fixation.
c. Integrated screws in ALIF device enhance stability.
d. In biomechanics studies, no advantage of 4 screws vs 3 screws; thus, 3 screws in integrated device will suffice.

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## OLIF: Join the Revolution

**Ronald A. Lehman, Jr., MD**
Professor of Orthopedic Surgery
Columbia University Medical Center
The Spine Hospital
New York Presbyterian/The Allen Hospital
New York, New York, USA

**Advantage of OLIF**

- •1 Position from L2-S1
- •Outside the psoas
    - –Decrease Femoral Nerve
    - –Decrease genitofemoral Nerve
- •No Neuromonitoring
    - –$800-$5000 (bundling)
- •3 ways to get L4-5
    - –Bifurcation
    - –Lateral to vessels
    - –Direct lateral incision
- •OLIF 5-1; ALIF in Lateral position

**How do We Achieve Sagittal Correction**

- •Anesthesia
- •Positioning
- •Facetectomies
- •Osteotomies
- •Interbody
    - –ALIF
    - –TLIF
    - –Transpsoas
    - –Antepsoas

**OLIF Access**

- •No approach-surgeon required
- •Avoids Neural Elements – Optional Neuromonitoring
- •Ante-Psoas
- •Less direct risk to anterior vascular structures
- •Ability to access L4-L5
- •Ability to Access L5-S1
- •All from the lateral position

**Summary**

- •Understanding sagittal alignment relationships= key!
- •Various approaches to achieve Sagittal Correction
    - –Do what works best for you

–Consider all the options
•Understand:
–Preop Assessment – what you are starting with
–Surgical Goals – where do you need to get to
–Maximize Interbody Space – everyone can do this
•Ante-Psoas Avoids Neurological Structures Within the Psoas
•Vascular Injury Equivalent to L5/S1 ALIF
•Temporary Sympathetic Nerve Injury
•Historical Retroperitoneal Corridor
•Avoids Psoas – Less Complaints
•Avoids Neural Elements – Optional Neuromonitoring
•Consistent Access to L4/L5 – Avoids Crest
•Antepsoas approach allows access from L1-sacrum in the lateral position

### Complications of MIS Anterior/Lateral Approaches

**Gregory M. Mundis, Jr., MD**
Scripps Clinic Department of Orthopedic Surgery
San Diego, California, USA

A. Vascular
   a. Venous
      i. Vena Cava
      ii. Iliac vessels
      iii. Ascending Iliolumbar
      iv. Segmental vessels
   b. Arterial
      i. Aorta
      ii. Iliac Vessels
      iii. Segmental
   c. Tips and trick for management
B. Neurologic
   a. Sensory
   b. Motor
   c. Plexopathy
   d. Sympathetic Dysfunction
   e. Retrograde Ejaculation
   f. Tips and tricks for management
C. Retroperitoneal organ injury
   a. Ureteral injury
   b. Kidney
   c. Bowel
   d. Tips and tricks for management
D. Musculoskeletal
   a. Incidental ALL release with anterior graft dislodgement
   b, Subsidence
   c. Vertebral body fracture
   d. Pseudoarthrosis
   e. Persistent psoas weakness
   f. Tips and tricks to management
E. Post operative Infection

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### Complications in MIS Correction of Scoliosis

**Richard Fessler, MD, PhD**
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GENRES OF COMPLICATIONS

EVALUATION AND PLANNING
ACCESS TO ADEQUATE EQUIPMENT
EXPERIENCE
- SCOLIOSIS
- MIS

INTRA-OPERATIVE
POST-OPERATIVE
- SHORT TERM
- LONG TERM

INTRA-OPERATIVE

LATERAL
- Thoracic
- Thoraco-lumbar
- Lumbar

Posterior
- Pedicle screws
- TLIF
- Facet fusion

LATERAL: THORACIC

POOR EXPOSURE OF LATERAL VERTEBRAL BODY
- Not enough rib removed
- Lung is in the way

LATERAL: THORACIC

SPINAL CORD INJURY
- Know your anatomy
- Know how to recognize location through imaging
- Be perfectly, and absolutely LATERAL

LATERAL: THORACIC

RADICULAR ARTERY HEMORRHAGE
- Long bipolars
- Endo clips

PNEUMOTHORAX
LUNG INJURY
PNEUMONIA

LATERAL: THORACOLUMBAR

DIAPHRAGMATIC INCOMPETENCE
- Approach T 12, L1 from above diaphragm
- Approach L 2 from below diaphragm
- Sew muscles directly
- Re-attach insertion to vertebral body with "spiral" endo-suture

LATERAL: THORACOLUMBAR

CHYLOTHORAX
- Thoracic duct should not be an issue with direct lateral approach

LATERAL: LUMBAR

ABDOMINAL WALL PARALYSIS
PATIENT THINKS IT'S A HERNIA
- Associated with burning groin pain
- Nerve to oblique muscles runs in interfascial plane between transversalis and internal oblique
  - Can injure with
    - Bovie or Metz
      - "Spread" muscles, don't cut
    - Sutures
      - Know what you are suturing

LATERAL: LUMBAR

Anatomy
- External Oblique
  - Thoracoabdominal Nerve (7-11)
  - Subcostal Nerve (T 12)
- Internal Oblique
  - Thoracoabdominal Nerve (T 7-11)
  - Subcostal Nerve (T 12)
  - Iliohypogastric (L 1)
  - Ilioinguinal (L 1)
- Transversalis
  - Iliohypogastric (L 1)
  - Ilioinguinal (L 1)

LATERAL: LUMBAR

ABDOMINAL ORGAN INJURY
- URETER
- KIDNEY
- BOWEL
- RADICULAR ARTERY

LATERAL: LUMBAR

NEUROLOGIC INJURY
- LUMBOSACRAL PLEXUS
- GENITOFEMORAL NERVE

LATERAL: LUMBAR

POORLY POSITIONED CAGE
- Especially L 4/5

POSTEIOR: PEDICLE SCREWS

Adequate Pedicle Targeting
- Place AP & lateral films on view box to help with orientation
- Place targeted vertebrae in the middle of image
- Vertebral endplates parallel
  - Avoid parallax inaccuracy
- Line up spinous process
  - Be aware of patients with scoliotic curves and compensate

AP View

Lateral View

FLUOROSCOPIC APPROACH COMPLICATIONS

POSTERIOR: PEDICLE SCREWS

K-WIRE
- Pushing K-Wire through vertebral body
- Pulling K-Wire out of pathway
- Bending K-Wire
- Breaking K-Wire

Always Maintain Control of K-wire

POSTERIOR: PEDICLE SCREWS
MISPLACED PEDICLE SCREW
POSTERIOR: PEDICLE SCREWS
SCREW HEAD POORLY POSITIONED FOR RECEIVING ROD
- Careful intra-op placement

SCREW PULL OUT
- Osteoporosis

PEDICLE FRACTURE
- Over-correction

POSTERIOR: TLIF/PSO/SPO
NERVE ROOT INJURY
- Retraction
- Compression
- Laceration/avulsion

NEUROLOGIC INJURY:
NERVE ROOT

Prevention of retraction injury
- Adequate bone removal laterally
- Special attention when stenosis co-exists with disc herniation
- Use less medial bone resection to limit retraction

NEUROLOGIC INJURY:
ROOT INJURY

Compressive root injury
- Reduction of curve without adequate decompresson
- Excessive amount of surgicel
  - Remove after hemostasis is achieved
- Compression by cage or trial
  - Direct visualization
  - Confirm with fluoroscopy

NEUROLOGIC INJURY
SCI/CAUDA EQUINA SYNDROME

Reduction of curve
- MEP/SSEP monitoring

Reduction of listhesis
- Foot drop
  - Stretch injury
  - Vascular compromise

POSTERIOR: TLIF/PSO/SPO

Cerebrospinal fluid leak
- Cutaneous cerebrospinal fluid leak
- Pseudomeningocoele

Open reported 1-3 %

MED reported 4-5 %

Open TLIF (Rivet, 2004) 20 %

Mini-TLIF (Fessler) 1 %

POSTERIOR: TLIF/PSO/SPO

COLLAPSE INTO VERTEBRAL BODY
- Osteoporosis
- Small cages at L5/S1

HEMORRHAGE
- Direct correlation to complications

PSEUDOARTHROSIS
- In MIS-primarily at L5/S1
- ALIF or Iliac screws salvage

POST-OPERATIVE

DVT/PE
ILEUS
PNEUMONIA
UTI
REACTION TO BMP
- ALLERGIC
- HYPEROSTOSIS

REACTION TO DERMABOND
SCREW PULL OUT
ADJACENT LEVEL DISEASE
POOR SAGITTAL OR CORONAL BALANCE
NEW NEUROLOGIC DEFICIT

Factors Predictive of Perioperataive Morbidity and Mortality After Spinal Deformity Surgery in Patients 75Years and Older. (O'Shaughnassy et al., SRS, 2009)

Demographics

| | |
|---|---|
| Ave age | 77 yrs |
| Mean F/U | 41.2 mo |
| Ave levels fused | 10.5 |

Factors Predictive of Perioperataive Morbidity and Mortality After Spinal Deformity Surgery in Patients 75Years and Older. (O'Shaughnessy et al., SRS, 2009)

Complication rate

| | |
|---|---|
| At least one complication | 71 % |
| At least one major complication | 38 % |

- Age positively correlated with complication rate
- Hypertension only co-morbidity which was predictive of complications (p = .02)

Risk-Benefit Assessment of Surgery for Adult Scoliosis: An Analysis Based on Patient Age. Smith et al. SRS, 2009.

Demographics
- 206/453 pts with 2 yr follow up
- ODI, SF-12 SRS-22
- Age
  - 25-44=47
  - 45-64=121
  - 65-85=38
- Cobb angle > 35 degrees

Complications
Smith et al, 2009

EBL AND TRANSFUSION
OR TIME
COMPLICATIONS
MIS vs HYBRID TECHNIQUE

MIS

| | |
|---|---|
| Levels fused | 6.5 |
| EBL | 877 cc |
| OR time | 635 min |
| Total Cx | 9 (22.5 %) |
| Intra-op | 0 |

HYBRID

| | |
|---|---|
| Levels fused | 8 |
| EBL | 2061 cc |
| OR time | 905 min |
| Total Cx | 35 (75 %) |
| Intra-op | 6 |

MIS vs HYBRID COMPLICATIONS

MIS-major = 15 %

| | |
|---|---|
| Implant failure | 2 |
| Neuro deficit | 1 |
| Wound dehis | 1 |
| PJK | 1 |
| ICH (unrel) | 1 |

HYBRID-major = 50 %

| | |
|---|---|
| Implant failure | 1 |
| Neuro deficit | 7 |
| Wound dehis | 1 |
| PJK | 2 |
| DVT | 4 |
| PE | 3 |
| Deep infection | 1 |

Strategies to Avoid MIS-SCOLIOSIS Complications

Training
- learning new skills (parallel surgery, anatomy with fewer "cues", working through tube, techniques of curve correction)

Patient selection
- Avoid previous abdominal surgery, Start with easy lumbar curves

Complete & Repetitive OR Setup

Adequate access and visualization
- Direct and fluoroscopic

Keep level you are working on in perfect AP or lateral position
- Tilt patient if necessary
- Work perpendicular to floor

Know anatomy in your "mind's eye"

If you even think there is a problem, there IS a problem
- REASSESS OR START OVER.
  - e.g. k-wire becomes dislodged, not sure where you are

# Notes

# Spinal Alignment: Goals, Planning and Pathologies

Room: Ballroom - Salon GKL

Course Chairs:
Sigurd H. Berven, MD and Cristina Sacramento Dominguez, MD, PhD

Faculty:
Christopher P. Ames, MD; Patrick J. Cahill, MD; Theodore J. Choma, MD; Daniel H. Chopin, MD; Vedat Deviren, MD; Jean Dubousset, MD; Richard H. Gross, MD; Munish C. Gupta, MD; Serena S. Hu, MD; Han Jo Kim, MD; Eric O. Kleinberg, MD; S. Rajasekaran, MD, FRCS, MCh, PhD; K. Daniel Riew, MD; Pierre Roussouly, MD; Rick C. Sasso, MD; Frank J. Schwab, MD; Mitsuru Yagi, MD, PhD

*This course is supported, in part, by a grant from Zimmer Biomet.*

# Half-Day Courses — Session 3

## Spinal Alignment: Goals, Planning and Pathologies

September 7, 2017

13:30 – 16:30

| **Chairs:** | | |
|---|---|---|
| **Time** | **Title** | **Speaker** |
| 13:30-13:32 | **Section I Introduction:**<br>**Spinal Alignment – Why is it important?**<br>**Impact on Health Status and Goal of Surgical Planning** | Sigurd H. Berven, MD |
| 13:32-13:40 | Changes in Alignment with Age- From Pediatric to Adult | Jean Dubousset, MD |
| 13:40-13:48 | Normal variation of Spinopelvic Balance and Association with Degenerative Pathologies- Including Hip Pathology | Pierre Roussouly, MD |
| 13:48-13:56 | Thoracolumbar alignment- What measures are important and Why? | Frank J. Schwab, MD |
| 13:56-14:04 | Looking Beyond C7- Cervical Alignment | Christopher P. Ames, MD |
| 14:04-14:12 | Sagittal Deformity in the Cervical Spine- Etiologies and Presentations. Surgical planning. | Rick Sasso, MD |
| 14:12-14:20 | Thoracolumbar and Cervico-thoracic deformity: Which to treat first? | Eric O. Klineberg, MD |
| 14:20-14:35 | DISCUSSION | |
| 14:35-14:37 | **Section 2 Introduction: Junctional Pathologies and Sagittal Alignment** | Cristina Sacramento Dominguez, MD, PhD |
| 14:37-14:45 | Sagittal Alignment and Junctional Pathology; PJK, PJF | Mitsuru Yagi, MD, PhD |
| 14:45-14:53 | Biomechanics of PJK | Richard H. Gross, MD |
| 14:53-15:01 | Influence of Cervical and head Alignment on development of PJK | Han Jo Kim, MD |
| 15:01-15:15 | DISCUSSION | |
| 15:15-15:23 | Influence of bone Quality on the development of PJF. How to improve bone biology? | Serena S. Hu, MD |
| 15:23-15:31 | Influence of Muscle and Neuromuscular Disease on PJK<br>Role of Exercise and PT | Daniel H. Chopin, MD |
| 15:31-15:38 | Vertebral Augmentation and PJK | Theodore J. Choma, MD |
| 15:38-15:45 | The decrease of the transition forces at the end of the construction of the instrumentation. | Patrick J. Cahill, MD |
| 15:45-15:53 | Can the technology replace the extensor muscles of the spine? Is it possible to make a back strap? | Vedat Deviren, MD |
| 15:53-16:08 | DISCUSSION | |
| 16:08-16:12 | Case Presentation | Munish Gupta, MD |
| 16:12-16:19 | Discussion | |
| 16:19-16:23 | Case Presentation | Sigurd Berven, MD |
| 16:23-16:30 | Discussion | |

## Sagittal Alignment in Adults: How to Diagnose Deformity & Develop an Appropriate Surgical Plan

**Sigurd Berven, MD**
Professor in Orthopaedic Surgery
UC San Francisco, California, USA

**I. <u>Causes of Sagittal Plane Malalignment in the Adult</u>**

- Congenital anomaly
- Ankylosing spondylitis
- Iatrogenic:
  - Flatback Syndrome
  - Kyphotic Decompensation Syndrome
  - Adjacent segment pathology
- Degenerative
- Post-traumatic
- Infectious
- Neoplastic
- Osteoporotic Compression Fractures

**II. <u>Clinical Assessment of Spinal Imbalance</u>**

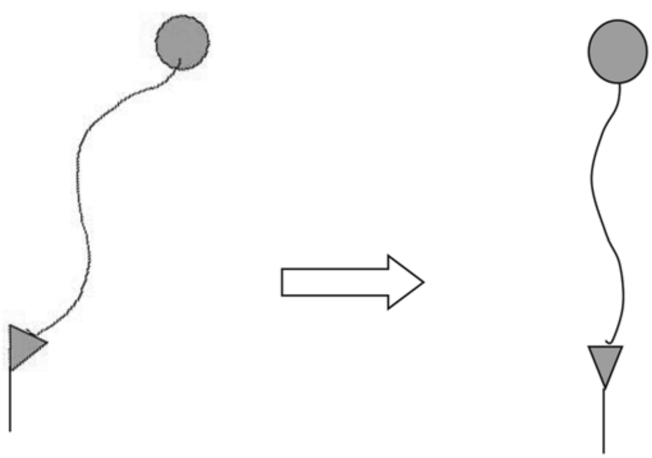
Location of the Deformity:

The localization of spinal deformity requires clinical and radiographic assessment.

*Clinical Assessment of Deformity:*

1) Sagittal Plane:

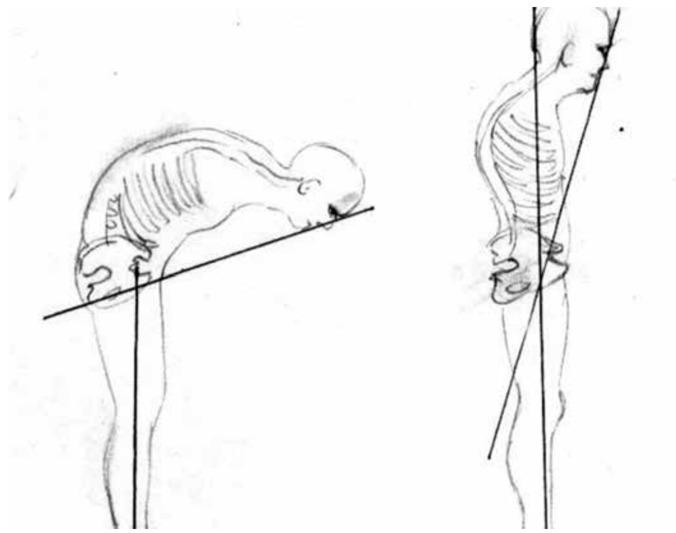
a. Pelvic-femoral axis/Lumbosacral Spine/Cervicothoracic Spine:
Contractures at the hips may contribute significantly to global imbalance of the spine without any change in the regional or segmental shape of the spine (Figure 1). Flexion of the knees may compensate for sagittal malalignment and therefore care must be taken to examine the patient with knees fully extended.



In the sagittal plane, the influence of a hip flexion contracture may be eliminated by examining the patient in the sitting position. A differentiation between spinal deformity that is primarily from the lumbosacral region and deformity primarily from the cervicothoracic region may be made by examining the patient in the supine position. Patients with primary lumbosacral deformity may be able to lie with shoulders flat due to retroversion of the pelvis. In contrast, in the patient with a primary cervicothoracic deformity, the shoulders will remain elevated from the table even in the supine position.

b. Chin-Brow to Vertical Axis:
An assessment of horizontal gaze and the position of the chin-brow axis to the vertical line is an important functional parameter in the clinical assessment of the patient with fixed sagittal plane deformity.

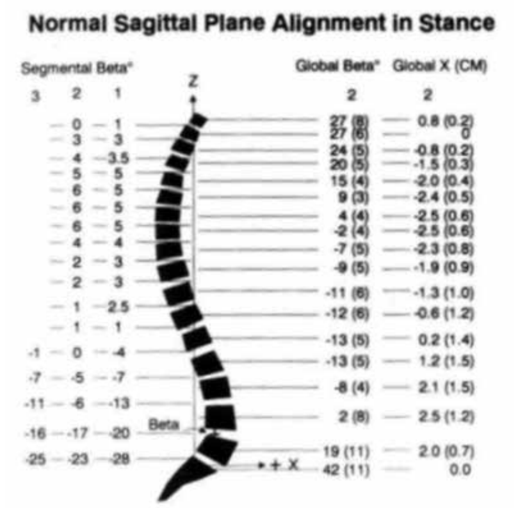
c. Rib-Pelvis Relationship:
The position of the ribs relative to the pelvis is a final consideration in the patient with fixed sagittal plane deformity. Approximation of the ribs and pelvis is an important cause of pain and respiratory and gastrointestinal dysfunction in patients with severe fixed sagittal plane deformity.



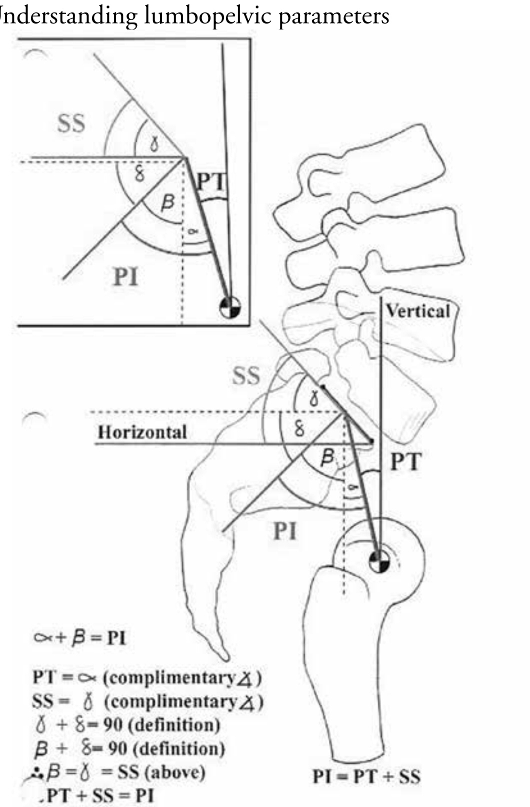
*Radiographic Assessment of Deformity:*

Standing 36” PA and Lateral radiographs of the spine are the most important tool in measuring spinal alignment. The patient position is an important consideration in standardizing radiographic measures. The recommended position for an assessment of coronal deformity is a standing film with feet at shoulder width apart, arms at the side and the pelvis level. For the assessment of sagittal alignment, radiographs most accurately and reproducibly reflect sagittal balance with the hips and knees fully extended and the arms at 30degrees forward flexion and the PIP joint in the clavicular fossa.

1) Global Balance:
Global balance of the spine is measured using a plumb line technique to assess the position of the center of C7 to the pelvis. Global balance is influenced by the contour of the spine as well as extraspinal considerations including pelvic obliquity and hip and knee flexion.



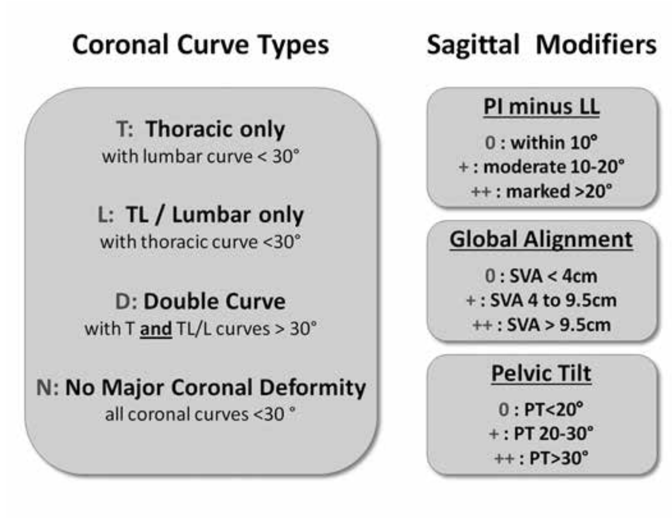

2) Regional Balance:
Regional balance is measured as the contour of the spine over several segments. Specific regional balance may be defined for the cervical, thoracic, thoracolumbar and lumbar regions. Measurement of regional balance permits a localization of deformity within the spine.
3) Segmental Balance
Segmental balance is measured as the angle between adjacent segments, and is not influenced by compensation in other areas of the spine. Measurement of segmental balance is most useful in post-traumatic deformity, and short/sharp curves.
4) Understanding lumbopelvic parameters

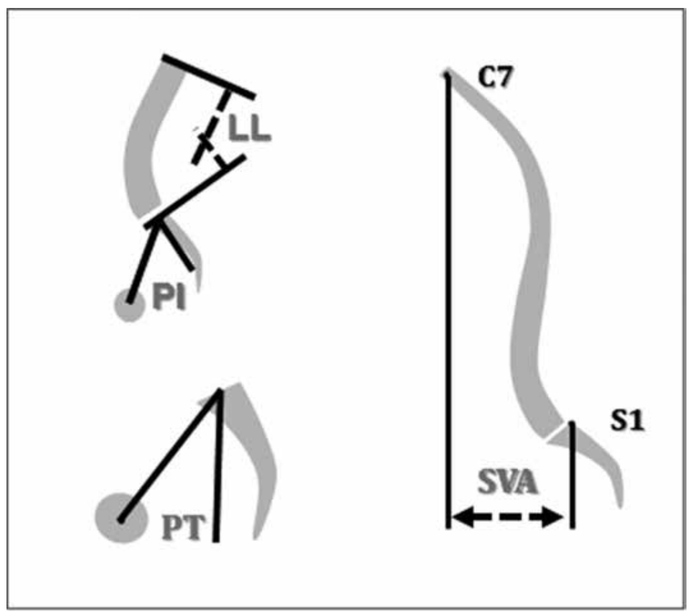



III. <u>Impact of Deformity on HRQoL</u>

**Correlation of radiographic parameters and clinical symptoms in adult scoliosis.**
Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR.
Spine (Phila Pa 1976). 2005 Mar 15;30(6):682-8.
**CONCLUSIONS:** This study suggests that restoration of a more normal sagittal balance is the critical goal for any reconstructive spine surgery. The study suggests that magnitude of coronal deformity and extent of coronal correction are less critical parameters.

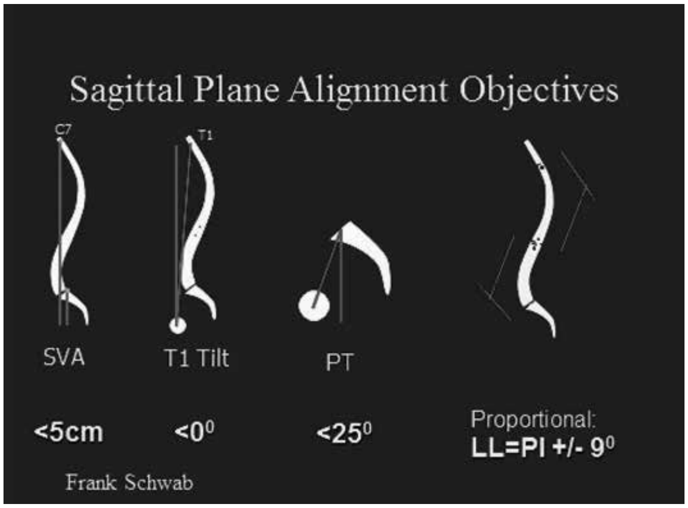
Impact Classification of Spinal Deformity- Schwab/SRS




**<u>How Much Correction is Needed?</u>**
The amount of correction needed is determined by the goals of deformity correction. Measurable goals in planning correction of deformity include:

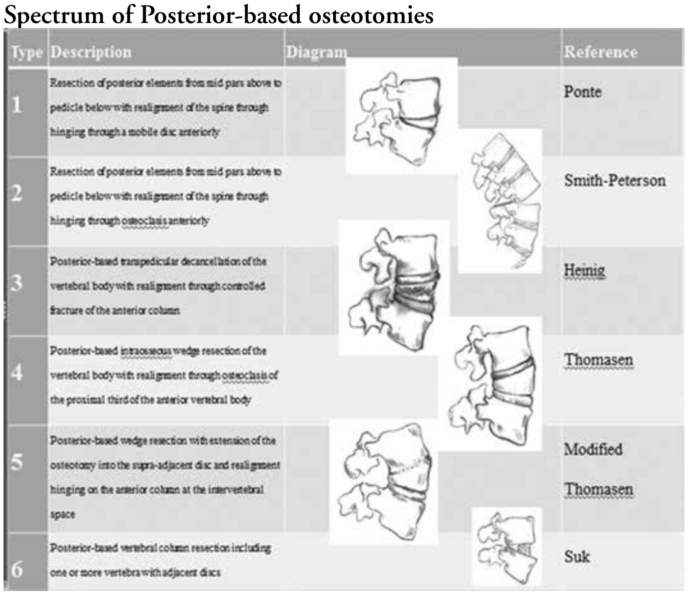
1) Restoration of Global Balance
2) Restoration of segmental anatomy (intervertebral disc trapezoidal deformity)
3) Correction of Chin-brow to vertical angle
4) Shift of Line of Weight-bearing posterior to the osteotomy sites.




<u>**Pre-operative Planning:**</u>

1) Assess rigidity of deformity:
    a. Supine Bending Films
    b. Push Prone Films
    c. Extension over a bolster
2) Determine level of intended ostetomies:
    a. Apex of the deformity
    b. Position of the Conus
    a. Preserving at least 3 caudad points of fixation
2) Trigonometric Method:
3) Modeling and Computer-assisted planning:

**Spectrum of Posterior-based osteotomies**



| Type | Description | Diagram | Reference |
|---|---|---|---|
| 1 | Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly | | Ponte |
| 2 | Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through osteoclasis anteriorly | | Smith-Peterson |
| 3 | Posterior-based transpedicular decancellation of the vertebral body with realignment through controlled fracture of the anterior column | | Heinig |
| 4 | Posterior-based intraosseous wedge resection of the vertebral body with realignment through osteoclasis of the proximal third of the anterior vertebral body | | Thomasen |
| 5 | Posterior-based wedge resection with extension of the osteotomy into the supra-adjacent disc and realignment hinging on the anterior column at the intervertebral space | | Modified Thomasen |
| 6 | Posterior-based vertebral column resection including one or more vertebra with adjacent discs | | Suk |

**Guidelines for Deformity Correction**

| | |
|---|---|
| Ponte Osteotomy | 8-10 degrees per osteotomy<br>1 degree/mm of posterior resection |
| Smith-Peterson Osteotomy | 10-30 degrees- dependent upon anterior column osteoclasis |
| Transpedicular wedge resection osteotomy: | 25-45 degrees per osteotomy |
| Vertebral Column Resection | 60+ degrees and trunk translation |

## Changes in Alignment with Age-From Pediatric to Adult

**Jean Dubousset, MD**
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**4 basic concepts must be understood & accepted in 3D at any age**

*To Study Spinal Biomechanics Segmental Masses are more important than Angles

* The chain of the alignment is made with a piling up of globally 28 masses with variable sizes & weight, based on the cephalic & pelvic vertebra concepts

*Do not confuse Alignment which is static and Balance which is Dynamic

* The concept of "Cone of Economy" explain the concept of Compensation

**Anthropology help us to understand the relation between Alignment and erect posture acquired progressively during the 10 or 15 months of life.**

*At the cephalic vertebra level with the goal of horizontal gaze

*At the pelvic vertebra level with the relationship between the pelvic parameters (especially the incidence angle) described by Mme Duval Beaupère( 1) and the amount of lumbar lordosis & thoracic kyphosis .

In utero and at birth the alignment of the spine is in kyphosis with a small incidence angle, but it was found also very variable angles even in embryo demonstrating the reality of a genetic factor but also the influence of the hip flexion on the shape of the pelvis .

With the acquisition of the erect posture the incidence angle increase as the lumbar lordosis establish and increase also .The pelvic version or pelvic tilt, postural parameter, evolve according the formula Pelvic Incidence = Sacral slope +Pelvic tilt, doing so we can postulate that the pelvic incidence organize the sagittal alignment of the spine .

**The erect posture in human is the result of:**

An harmonious bones and joints alignment lasting during motion thanks to a neurological input-automatic-reflex- modulated- voluntary - it is Balance.

**Biomechanical & neurological organization of alignment from birth to adult**

From Birth to 14 months the organization is descending with in first the cervical lordosis followed by stabilization of the pelvis obtained after 2 months of free standing posture. Up to 6 y old, the organization is ascending from the stable hips, Head & Shoulders function are « en bloc ». Within 7/8 years old Descending organization of the balance with a vestibular dominance, the Head in the space recover its own motion regarding the shoulders. From 8 to 13 y old, the organization works in both directions close to the adult one with a complete dissociation Head – Trunk.

**The concept of the Human Erect Posture with the chain of Alignment and Balance is accepted:** Cervical lordosis, Thoracic kyphosis, Lumbar lordosis, Pelvis as an intercalary bone between trunk and lower limbs with a particular importance of the hips joints extension reserve .This concept when understood within a dynamic aspect drive directly to the Cone of Economy one.

**The cone of economy concept**, described initially on a clinical point of view start to be biomechanically measured confirming the importance of the sagittal sway and its regulation through the glutei muscles and the extensors spinae muscles well demonstrated when comparing normal adults with those with a degenerative spine disorders .( I Liebermann)( 2)

**The Alignment of the Bones, Joints and Soft Tissues of the Spine will develop simultaneously as for Growth and Maturation:** With its specific velocity and the noticeable Growth Spurt ,with also the development of the thoracic cage and lungs volumes continuing in width for 2 years after end of standing growth in height .

**Spinal alignment change from early childhood to adolescence & adult**

***Because morphological reasons**

**For the cervical spine** and head posture between 3y old to adult the protraction of the head decrease .C2-C7 lordosis decrease.O-C2 and C1C2 increase, with a maximum of lordosis in C1/C2. **For the thoracic and lumbar spine** following the pelvic morphology the incidence angle varies from 22° to 86° and the subsequent sagittal shape according the Pierre Roussouly (3)classification follow the rule small incidence = small lumbar lordosis and thoracic kyphosis with the Type 1 & 2 and large incidence = large lumbar lordosis and thoracic kyphosis with the type 3 & 4. Most of the final alignment is acquired by age 9 or 10 y old with some adjustment at the growth spurt period. **Then from adult to Aging**, pelvic incidence & subsequent spinal alignment increase also slowly especially after 65 y old ( Guigui (2003)(4), Legaye (2014)(5),, K. Hazegawa (2016)(6).This demonstrate the plasticity of the SI joint as it was already proven after change in the incidence angle secondary to a spine fusion for scoliosis at the thoracic level ( LIV above L2)in 50% of an adolescent female group**. *Because postural reasons**

**Ante-version & retro-version of the pelvic vertebra** demonstrate the major role of the pelvic vertebra in the compensation mechanisms for the posture, with a special attention to the motion of the hips joints especially thanks to the "hip joint reserve in extension" described by Isvan Hovorka( 7) .

**Aging touch also all spinal structures as for bone as for & soft tissues leading to 3D change in the Alignment & Balance.** Osteoporosis often results in global or localized kyphosis, But more frequently the weakness of active extension of the hip joint create a pelvic retroversion to compensate with a subsequent knee flexion to achieve balance ; Compensation is the "magic word " for posture. The common influence of pelvic & cephalic vertebrae with ageing was well described by Yoshida in 2014 with the Protraction/retraction of the head combined with the pelvic retroversion.

**What is needed about successive balance for a simple movement as climbing 3 stairs:**

***Mechanical requirements:-**a proper mobility of the joints, within a safe alignment chain in space

***Tensegrity of aponeurosis, ligaments, the "White structures " surrounding muscles and giving an "Energy release factor"**

***Muscles agonist & antagonist requirements:** with their strength, Power, Relaxation, Modulation, Speed, Acceleration, Braking, …

***Neurological requirements**, Afferents inputs - Vision ENT, Vestibulum, Proprioception Modulation, Coordination, Automatism, Double task, Cognition, Effectors outputs : Order, speed of transmission, Time of reaction…

**Creating a composite ordered chain in the space.**

**Subsequently: Alignment in 3D results from Genetic & Biomechanics with various shape, size, height, weight and a common factor: Harmony!:**

"Harmony of the movement is the right distribution of the masses of the body cephalic, thoracic, abdominal, pelvic, hanging above the lower limbs on the move".

**"Harmony is the sister of Economy"** (Paul Bellugue)( 8)

Finally any adjacent pathology (paralytic, congenital, dystrophic, idiopathic, ect ) will add its own changes in the alignment but all together will follow the previous general rules expressed in this presentation.

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## Normal Variation of Spino-Pelvic Balance and Association with Degenerative Pathologies.


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Since Hippocrates, spinal curvatures orientations are designed as convex forward in lumbar area and concave forward in thoracic area. Later these curvatures were respectively named Lordosis and Kyphosis. This anatomical segmentation of spinal curvatures still remains and classically Lumbar Lordosis (LL) is between S1 plateau and T12 and the Thoracic Kyphosis (TK) is between T1 and T12. Recently Berthonnaud and Dimnet gave a different segmentation, describing the Inflexion Point (IP)where the Lordosis transitions in Kyphosis, changing the spinal orientation, and independently of the vertebral level. Until now, wherever IP positioning, we kept the appellation LL and TK with a confusion regarding the anatomical limits. For this reason we think it is necessary to use different names for Lordosis and Kyphosis bounded by IP. We propose to call Lower Spinal Lordosis (LSL) the distal part of the spine in extension between S1 plateau and IP, Spinal Kyphosis (SK), the part of the spine between IP and the upper Inflexion Point, and Upper Spinal Lordosis (USL), the Lordosis in the cervico-thoracic area.

**Coronal Spinal segmentation and curvature geometry.**
Following Berthonnaud and Dimnet, the spinal curvatures may approximated by successive arcs of circle. Using the Inflexion Point described previously, they divided Thoracic and Lumbar spine in two different orientations we may call today LSL and SK. The horizontal line issuing from the apex divides each curve in two arcs of circle. LSL is divided in a lower arc between the sacral plateau and the apex and an upper arc between the apex and IP. TK has the same construct. By this geometrical construct we deduce that the lower arc of LSL is equal to the Sacral Slope (SS) and the upper arc of LSL is equal to the lower arc of TK. When SS is small (<35°), there are two geometrical options: the lower arc is very small with a low positioning of the apex, or the lower arc is very flat with a large radius. The more SS increases, the more the lower arc increases with a higher LSL.

From this construct we extracted four types of LSL according to SS:

SS<35°:

-Type 1: the lower arc is short, the apex of LSL is down, LSL does not exceed 3 levels vertebrae, and generally there is a thoraco-lumbar kyphosis (TLK).

-Type 2: The lower arc is flat, LSL is flat. The length of LSL is 4 level or more.

35°<SS<45°

-Type 3: The lower arc increases following SS. This is the average type

SS>45°

-Type 4: This is the type with the greater LSL. Due to the large values of SS the LSL has to compensate by increasing the lordosis effect by bigger angles and or longer LSL.

Regarding the close relation between PI and SS, we may associate low PI (<50°) with low SS with Type 1 and 2, and higher PI (>50°) with high SS and Type 3 and 4. We described a situation of low PI and high SS due to an anteverted pelvis inducing the association of low PI with anteverted Type 3.

**Forces distribution on a vertebral unit:**
The contact force acting at each level of the spine is an addition of Gravity force and counter acting posterior muscles forces. The orientation of the vertebral unit determines the impact positioning of the force and its resultants distribution.

In a hyper lordosis, vertebral unit is in extension, the pressure is maximal on the posterior facets, and the intervertebral disc is discharged. At the extremities of the lordosis the vertebral units are much tilted. Due to this local tilt, the contact force distribution increases the sliding effect.

In a vertical or kyphotic column, vertebrae are parallel with horizontal intervertebral disc, or flexed forward. Forces are acting forward, increasing the disc pressure.

**Effect of the spinal shape on degeneration using the Lordosis classification:**
*Type 1:* There are two places for hyper stress in Type 1: TLK and distal Hyper lordosis.

-In TL area between T10 and L3, the kyphosis shape induces hyper pressure on the discs and disc degeneration. The important posterior tilt between L2 and L3 may induce a local retrolisthesis.

-In the distal lumbar area, the short hyper lordosis preserves the discs from degeneration. Facets are in hyper extension with hyper pressure inducing a risk of facet's degeneration. Distal foramen may be closed in standing position with possibility of nerve root compression

*Type 2:* The flat hypo lordosis furthers disc hyper pressure and early disc degeneration and or multi-level discs degeneration. Early disc herniations are possible, and stenosis so. Numerous de novo degenerative scoliosis have a small PI and a Type 2 shape. This could explain the high level of spinal disc degeneration in this scoliosis.

*Look out !* As type 1 and 2 are always associated with small PI, there is a small ability of compensation of forward unbalance by pelvic retroversion.

*Anteverted Type 3:* This disposition is due to the lumbar hyper lordosis. Facets hyper pressure is the rule, with associated back pain. Rehabilitation trying to restore a more retroverted pelvis is not efficient. In very painful cases a lumbar arthrodesis reducing the lordosis may be efficient.

*Type 3:* As average shape, no relevant degenerative evolution may be mechanically explained by this shape.

*Type 4:* Following a high SS, LSL is high with a risk of over stress on the facets. At the very beginning it may be only painful, mainly in standing position where the extension reaches its maximum. This permanent posterior hyper pressure stress may progressively induce a posterior facets' arthritis with foramen stenosis.

At that time the posterior arthritis is at its maximum on L4L5. A local loosening of the facets may occur producing a degenerative spondylolisthesis. Sometime the patient spontaneously tries to decrease the posterior stress by decreasing the lordosis. In this situation the sress is displaced from posterior to anterior on the discs and induces discopathies. The lack of height due to the discs degeneration induces a lack of lordosis, mainly if the more distal discs are affected. To compensate the loss of lordosis, the pelvis spontaneously retroverses, with increasing PT. This compensation is frequently associated to an active decrease of Thoracic Kyphosis. As PI is high in Type 4, the ability of increasing PT with knee flexion is very important.

*Anteverted Type 3:* This situation is always due to a mismatched hyper lordosis with a low PI. The posterior hyper stress may produce back pain, as for Type 4 .

**Conclusion:**
Many factors may contribute to the degenerative evolution of the spine. The different shapes and orientation of the spine found in an asymptomatic population, privilege probably specific degenerations of discs and, or facets. These mechanism allow a better understanding of back pain production.

## Thoracolumbar Alignment – What Measures are Important and Why?

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**Introduction**
Thoracolumbar alignment is an important parameter to take into consideration when analyzing a patient's clinical presentation, and is of particular use during preoperative planning. Indeed, the loss of lumbar lordosis caused by degenerative lumbar disc diseases is very common and leads to sagittal alignment changes that can be clinically relevant. Accordingly, sagittal malalignment may be poorly tolerated by patients, as they struggle to keep their head above their pelvis and maintain a horizontal gaze while utilizing different compensatory mechanisms.

There are several radiographic parameters to be taken into account when analyzing patients' sagittal balance. Here are the most important ones.

**Measures**
- Basic measures
  - Pelvic parameters (Fig.1):
    - Pelvic incidence (PI)
    - Pelvic tilt (PT)
    - Sacral slope (SS)

**PI = SS + PT**

PI is a fixed morphologic parameter, whereas PT and SS are dynamic parameters that reflect the compensatory changes to maintain upright posture [1].

**SRS-Schwab classification modifier:**
- **0 : PT < 20°**
- **+ : 20°< PT < 30°**
- **++ : PT > 30°**

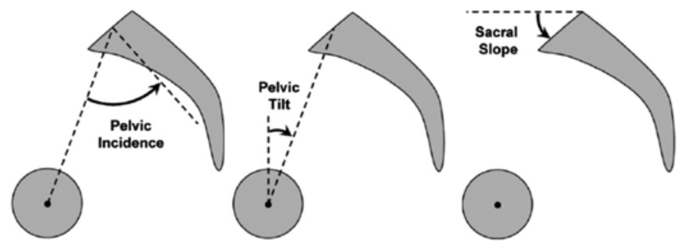



*Figure 1: Pelvic parameters (PI, PT and SS), Bess et al.*

- Spinal parameters *(Fig.2)*:
  - Lumbar lordosis (LL)
  - Thoracic kyphosis (TK)

TK and LL are correlated: the greater the LL, the larger the TK, following approximately a 2:3 ratio.

**TK ≈ 2/3 LL**

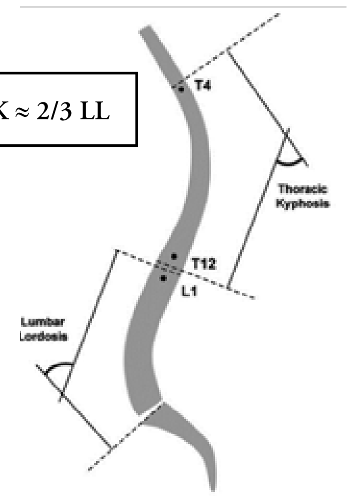
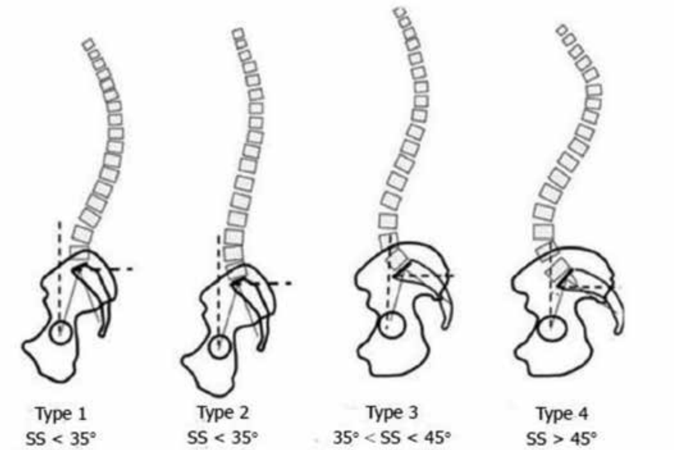



*Figure 2: Spinal parameters, Schwab et al.*

- Alignment analysis
  - PI-LL mismatch:

Sagittal malalignment is, in most cases, due to decreased lumbar lordosis caused by degeneration of lumbar disks [2]either C7 plumb line and sacral plateau, the position of the pelvis rotation by the pelvic tilt, and a description of the position of the lower limbs. Those three parameters have been taken into account by the newly described method called full balance integrated (FBI. Consequently, the loss of lumbar lordosis can be the first marker of sagittal malalignment. There is no universal LL value, as it is correlated to pelvic parameters. Roussouly described 4 types of sagittal alignment depending on parameters of the lumbar spine and pelvis *(Fig.3)* [3]. Small PI/SS patients have Small LL and TK, and Large PI/SS patients have large LL and TK.




**LL ≈ PI ± 10°**

**SRS-Schwab classification modifier:**
- **0 : SVA < 4cm**
- **+ : 4< SVA < 9.5 cm**
- **++ : SVA>9.5cm**

*Figure 3: Roussouly's classification*

- Sagittal Vertical Axis (SVA):

SVA is defined as the horizontal offset from a plumb line dropped from the C7 vertebral body to the postero-superior corner of the sacral plate [4] *(Fig.4)*. SVA is quickly and easily measured, but is dependent on the patient's position and pelvic rotation. As such, SVA may appear normal for patients who compensate for malalignment by retroverting their pelvis.

**SRS-Schwab classification modifier:**
- **0 : SVA < 4cm**
- **+ : 4 < SVA < 9.5cm**
- **++ : SVA>9.5cm**

- T1 Spino-Pelvic Inclination (T1SPi) and T9SPi:

T1 and T9SPi reflect the overall spino-pelvic alignment. These angles are formed by the vertical axis and the T1 (or T9) – femoral heads line *(Fig.4)* [5]. These parameters are affected by a patient's position and pelvic rotation. However, they do not require calibrated X-Rays.

- Spino-sacral angle (SSA):

Unlike SVA and T1-T9SPi, SSA is neither affected by pelvic rotation nor a patient's position. Consequently, this parameter is independent of a compensatory, retroverted pelvis. SSA is defined as the angle between the C7/S1 line and the sacral inclination [6] *(Fig.5)*.

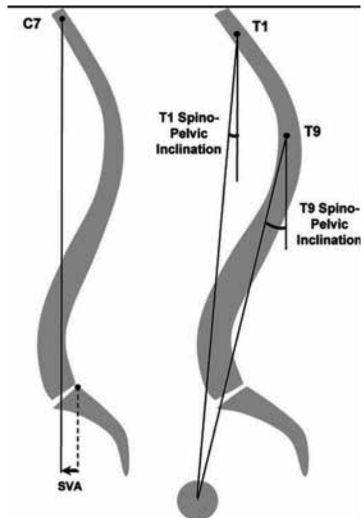



*Figure 4: SVA, T1SPi and T9SPi*

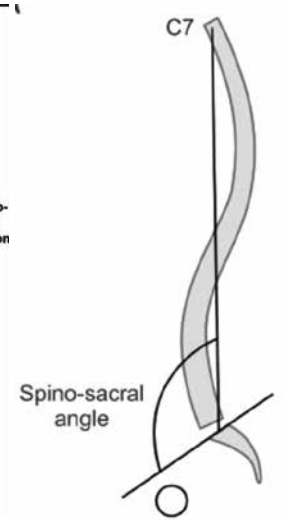



*Figure 5: SSA, Lee et al. [6]*

- T1-pelvic angle (TPA):

This is the most recent parameter of global alignment. It is defined as the angle subtended by a line from the femoral heads to the center of the sacral endplate, and a line from the femoral heads to the center of the sacral plate *(Fig.6)*. Similar to SSA, the TPA is, advantageously, independent of a patient's position. Further, TPA correlates with SVA, PT and PI-LL [7].

**TPA = T1Spi + PT**

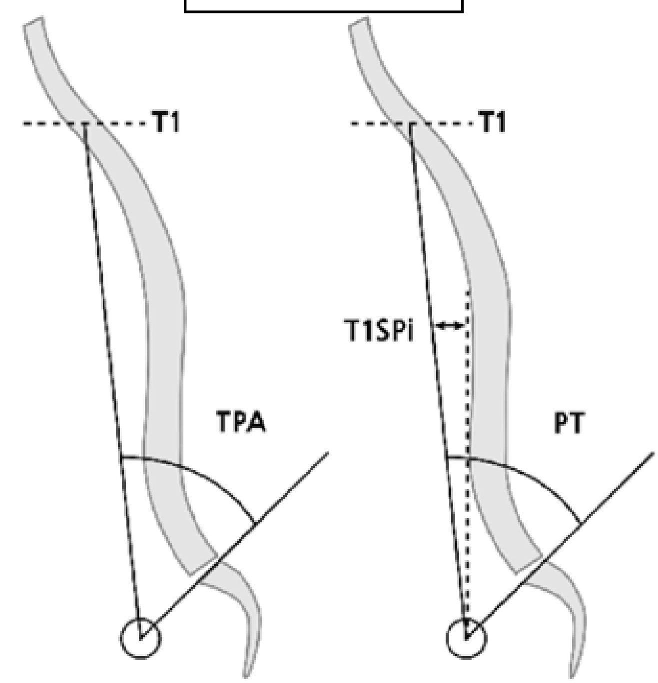



*Figure 6: TPA, Lee et al.*

- Compensatory mechanisms

Many compensatory mechanisms exist within the spine itself but also in the pelvis and the lower limbs. As the degree of malalignment increases, more mechanisms are employed to shift from a decompensated state to a compensated malalignment [2]either

C7 plumb line and sacral plateau, the position of the pelvis rotation by the pelvic tilt, and a description of the position of the lower limbs. Those three parameters have been taken into account by the newly described method called full balance integrated (FBI. An understanding of these different compensatory mechanisms is vital in order to distinguish a global aligned spine from a compensated, malaligned spine. These mechanisms are (Fig.7):

- Increased cervical lordosis
- Thoracic spine flattening: **TK ↓**
- Pelvic shift
- Hyperextension of the adjacent healthy disc spaces
- Increased pelvic tilt / Hip extension: **PT ↑ & SS ↓**
- Knee flexion
- Ankle dorsiflexion

All these mechanisms aim to restore an upright position with a horizontal gaze, which are also the postoperative goals after surgery for sagittal correction.

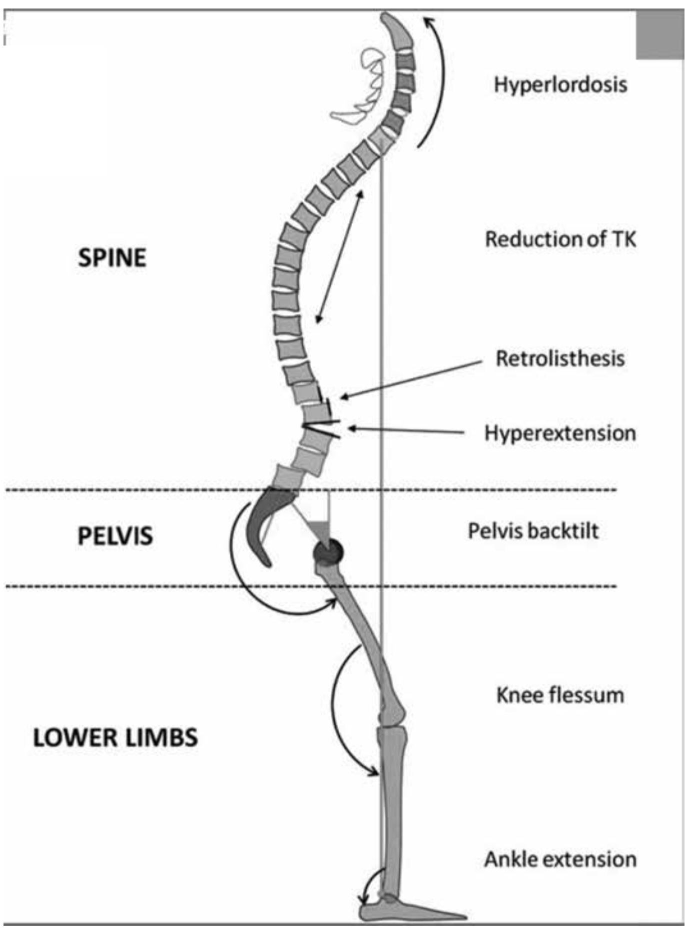



*Figure 7: Compensatory mechanisms in the sagittal plan, K. Abelin-Genevois*

**Conclusion**

Sagittal malalignment is common in older patients and generates fatigue, pain, and disability. Analyzing global alignment is essential in the prompt treatment of spinal disorders. Many parameters can be used (SVA, SSA, T1SPi, T9SPi, TPA, PI-LL) and must be handled with knowledge of their characteristics. Sagittal alignment analysis cannot be dissociated from knowledge of the compensatory mechanisms that take place in order to counterbalance malalignment.

These parameters are intended to guide surgeons' treatment decisions. However, we don't operate on X-rays, and these parameters should not overtake the clinical evidence dictated by patients' symptoms, expectations and general condition.

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## Beyond C7: Cervical Deformity

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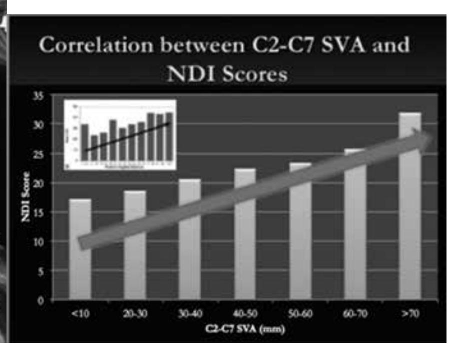
**Radiographic Assessment in Cervical Deformity**

I. Radiographic Assessment of Cervical Alignment
   a. What is normal alignment of the cervical spine?
   b. Cervical alignment in the setting of subjacent spinal pelvic alignment
   c. Importance of assessing cervical alignment on standing 3 foot scoliosis films
      i. AP and lateral
      ii. UT scoliosis
      iii. Shoulder balance for coronal deformities

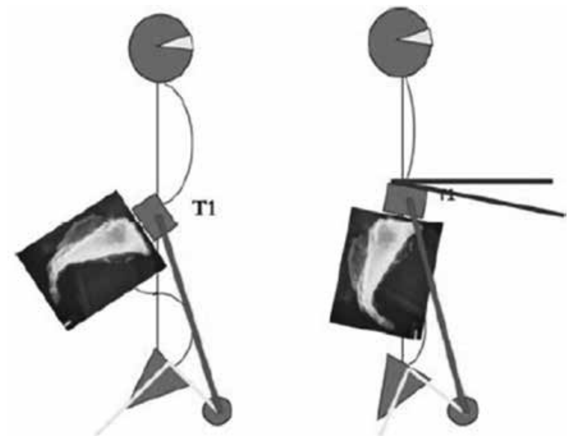
II. Why does cervical sagittal mal-alignment cause pain?
   a. Cantilever forces at cervical thoracic junction
   b. Why would cervical sagittal mal-alignment contribute to myelopathy

MJOA Correlations to Cervical SVA

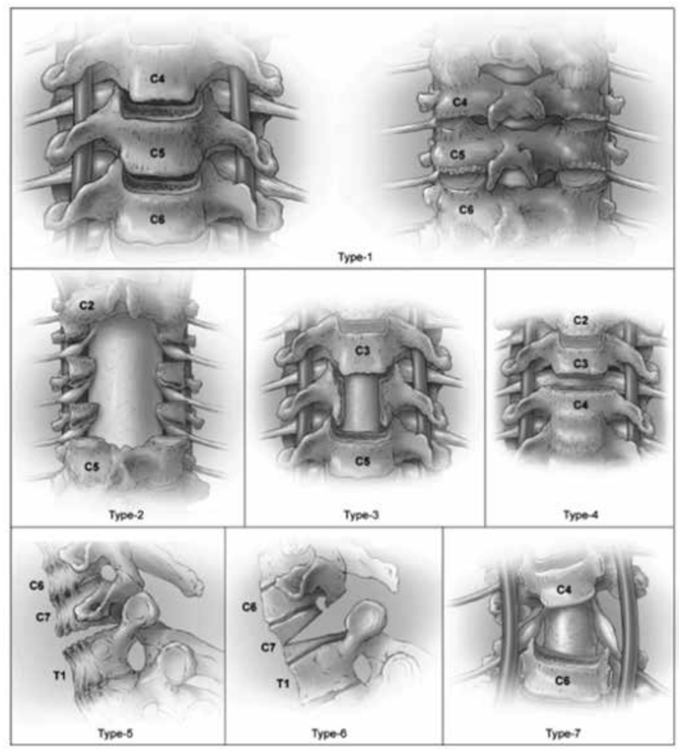
III. Plain radiographic parameters important in the assessment of cervical alignment
   a. C2-C7 cSVA

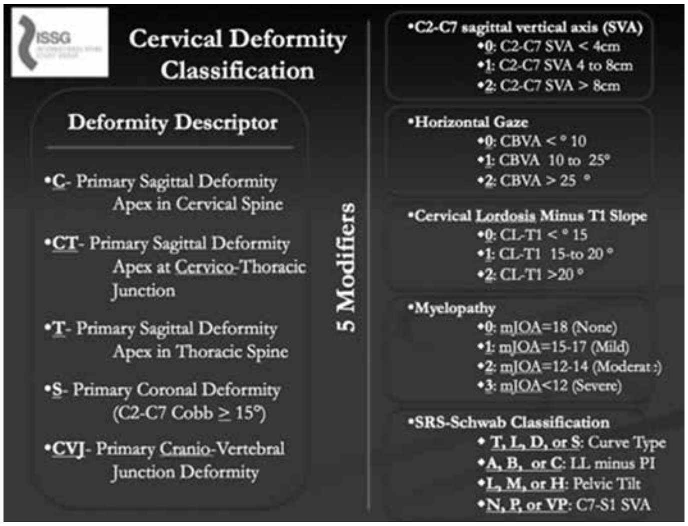

   b. C1-2 lordosis (PT of cervical spine)
   c. T1 slope (a moving target PI for the c spine)




   d. Cervical Lordosis
   e. CL-T1 slope
   f. Upper thoracic kyphosis T1-T4
   g. PI-LL, SVA, PT
   h. ROM on flexion and extension films
   i. Traction Films




IV. Realignment planning
   a. Towards a radiographic clinical impact classification for cervical deformity
   b. Realignment targets

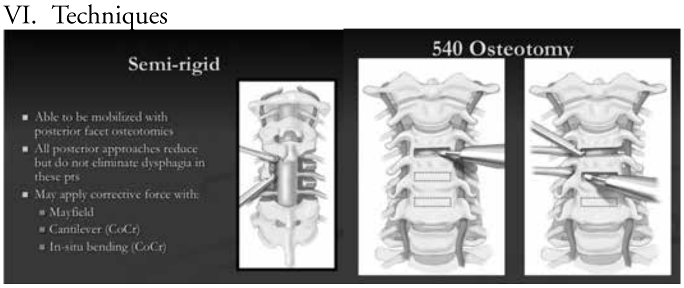



Apex Location:
C2 slope high T1 slope Low---Cervical Apex
C2 slope normal T1 slope high ---Thoracic /Lumbar Apex
C2 slope and T1 slope High ---Double Apex

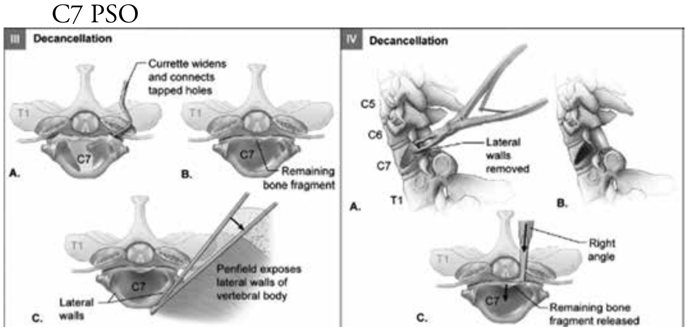
V. Metal Selection

Titanium Rod Deformation

VI. Techniques




C7 PSO

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## Sagittal Deformity in the Cervical Spine- Etiologies and Presentations, Surgical Planning

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**Etiology:**
- Fixed
  - Ankylosing spondylitis
  - DISH
  - Post laminectomy
  - Trauma
  - XRT
  - Structural deformity
- Supple
  - Dropped Head Deformity
    - Myopathy
    - Neuromuscular disease
    - Myasthenia gravis
    - ALS
    - Polyneuropathy
    - Polymyositis
    - Parkinson disease
    - Inflammatory myositis
    - Dystonia
    - XRT
    - Botulinum toxin
    - Peripheral neuropathy
    - MS
  - Post laminectomy
  - Trauma
  - Non-structural deformity

**Presentation:**
- Chin-on-Chest deformity
- Forward Gaze deficits
- Swallowing difficulty
- Myelopathy
- Radiculopathy
- Neck pain

**Surgical planning:**
- Cervical Sagittal Balance
  - C2-C7 Cobb angle
  - C2 SVA (C2-C7 sagittal vertical axis)
  - Chin-Brow vertical angle
  - T1 slope
  - K-line Tilt
- Traction?
  - Pre-op
  - Intra-op
- Approach
  - Anterior
    - Prior surgery? Approach opposite side? ENT evaluation
  - Posterior
  - Ant-Post
    - 3-stage 540
- Osteotomy
  - Smith-Peterson
  - PSO
  - VCR
  - Site-C7 or apex of deformity?
- Provisional rod?
- Vertebral artery
- Position
  - Sitting
    - Awake?
  - Prone
- Slight reverse Trendelenburg
- Neuromonitoring
- Keep MAP 80-90mmHg
- Unscrubbed surgeon assess proper position of head before definitive rod fixed
- Intraoperative Navigation
- Osteoporosis evaluation

**Postoperative**
- Esophageal dysfunction
- Respiratory compromise
- Immobilization?

## Thoracolumbar and Cervico-Thoracic Deformity: Which to Treat First?

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Outline:

Spinal alignment
- Global
- Regional
  - Cervical
  - Thoracic
  - Lumbar

Clinical scenario:

We know that sagittal alignment is critical
- LL, PI, PT, cSVA, SVA

What about cervical deformity

Data:

Is it really a problem?
- Cervical deformity is highly prevalent (53%) in adult TL

deformity. C7-S1SVA, PT, and PI-LL modifiers are associated with cervical deformity prevalence.

**Prevalence and type of cervical deformity among 470 adults with thoracolumbar deformity.** Smith JS, Lafage V, Schwab FJ, Shaffrey CI, Protopsaltis T, Klineberg E, Gupta M, Scheer JK, Fu KM, Mundis G, Hostin R, Deviren V, Hart R, Burton DC, Bess S, Ames CP; International Spine Study Group. Spine (Phila Pa 1976). 2014 Aug 1;39(17):E1001-9.

Deformity is critical

Neck affects the back and vice versa

Changes in cervical lordosis correlate to HRQOL improvements in thoracolumbar deformity patients at 2-year follow-up.

Regional cervical sagittal parameters such as CL and C2-7 SVA are correlated with clinical measures of regional disability and health status in patients with adult thoracolumbar scoliosis.

**How the neck affects the back: changes in regional cervical sagittal alignment correlate to HRQOL improvement in adult thoracolumbar deformity patients at 2-year follow-up.** Protopsaltis TS, Scheer JK, Terran JS, Smith JS, Hamilton DK, Kim HJ, Mundis GM Jr, Hart RA, McCarthy IM, Klineberg E, Lafage V, Bess S, Schwab F, Shaffrey CI3, Ames CP; International Spine Study Group. J Neurosurg Spine. 2015 Aug;23(2):153-8.

Which to fix first?

Deformity is not the only problem

Stenosis, central vs. foraminal

The answer does not lie in XR alone

Need clinical determination

Major driver of complaint, neurology

Myelopathy = cervical

Anticipate reciprocal changes

Lumbar and thoracic PSO resection leads to reciprocal changes in unfused segments and requires consideration beyond focal corrections.

**Acute reciprocal changes distant from the site of spinal osteotomies affect global postoperative alignment.** Klineberg E, Schwab F, Ames C, Hostin R, Bess S, Smith JS, Gupta MC, Boachie O, Hart RA, Akbarnia BA, Burton DC, Lafage V. Adv Orthop. 2011;2011:415946.

Significant postoperative alignment changes can occur through unfused thoracic spinal segments after lumbar PSO. Unfavorable RC may limit optimal correction and lead to clinical failures. Risk factors for unfavorable thoracic RC include older patients, larger preoperative PI and PT, and worse preoperative T1SPI and are not simply due to junctional failure.

**Changes in thoracic kyphosis negatively impact sagittal alignment after lumbar pedicle subtraction osteotomy: a comprehensive radiographic analysis.** Lafage V, Ames C, Schwab F, Klineberg E, Akbarnia B, Smith J, Boachie-Adjei O, Burton D, Hart R, Hostin R, Shaffrey C, Wood K, Bess S; International Spine Study Group. Spine (Phila Pa 1976). 2012 Feb 1;37(3):E180-7.

With Appropriate lumbar correction the cervical spine can achieve acceptable alignment

Surgical correction of spinopelvic malalignment can result in compensatory changes in spinal alignment outside of the fused spinal segments.

Adults with positive sagittal spinopelvic malalignment compensate with abnormally increased cervical lordosis in an effort to maintain horizontal gaze. Surgical correction of sagittal malalignment results in improvement of the abnormal cervical hyperlordosis through reciprocal changes.

**Spontaneous improvement of cervical alignment after correction of global sagittal balance following pedicle subtraction osteotomy.** Smith JS, Shaffrey CI, Lafage V, Blondel B, Schwab F, Hostin R, Hart R, O'Shaughnessy B, Bess S, Hu SS, Deviren V, Ames CP; International Spine Study Group. J Neurosurg Spine. 2012 Oct;17(4):300-7.

But Cervical deformity can also be created with thoraco-lumbar procedure…

A total of 47.7% of patients without preoperative CD developed new onset postoperative CD after thoracolumbar surgery. Independent predictors of new onset CD at 2 years included diabetes, higher preoperative T1 slope minus cervical lordosis, and ending instrumentation above T4. Significant improvements in health-related quality of life scores occurred despite the development of postoperative CD.

**Postoperative cervical deformity in 215 thoracolumbar patients with adult spinal deformity: prevalence, risk factors, and impact on patient-reported outcome and satisfaction at 2-year follow-up.** Passias PG, Soroceanu A, Smith J, Boniello A, Yang S, Scheer JK, Schwab F, Shaffrey C, Kim HJ, Protopsaltis T, Mundis G, Gupta M, Klineberg E, Lafage V, Ames C; International Spine Study Group. Spine (Phila Pa 1976). 2015 Mar 1;40(5):283-91.

Patients with TL deformity and CD deformity do worse, even with the same TL deformity correction

Patients with thoracolumbar deformity without preoperative CD are likely to have greater improvements in HRQOL after surgery than patients with concomitant preoperative CD.

Cervical positive sagittal alignment in adult patients with thoracolumbar deformity is strongly associated with inferior outcomes and failure to reach MCID at 2-year follow-up despite having similar baseline HRQOL to patients without CD.

**Association between preoperative cervical sagittal deformity and inferior outcomes at 2-year follow-up in patients with adult thoracolumbar deformity: analysis of**

**182 patients.** Scheer JK, Passias PG, Sorocean AM, Boniello AJ, Mundis GM Jr, Klineberg E, Kim HJ, Protopsaltis TS, Gupta M, Bess S, Shaffrey CI7, Schwab F, Lafage V, Smith JS, Ames CP; International Spine Study Group. J Neurosurg Spine. 2016 Jan;24(1):108-15.

Clinical Conclusion

Conclusion:

Cervical deformity and thoracolumbar deformity are linked.

Fix the deformity with the greatest neurology or dysfunction

Anticipate reciprocal changes

CD and TL deformity patients tend to do worse, and may need additional operation

## Sagittal Alignment and Junctional Pathology; PJK, PJF

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**Introduction**

- The essential goals of corrective surgery are maintaining both coronal and sagittal balance in addition to achieving an optimal curve correction and solid arthrodesis.
- Proximal junctional kyphosis (PJK) is a well-recognized postoperative phenomenon in adults and adolescents after scoliosis surgery. A uniform and consistent phenomenon is the increased junctional stress concentration that causes soft tissue and ligamentous failure, bone failure, and bone implant interface failure.
- Despite recent reports, the prevention of PJK is still challenging. The aims of this study are to review the existing reports for the sagittal alignment of PJK/PJF.

**Definition of PJK and PJF**

**PJK (Proximal Junctional Kyphosis)**
PJ angle>10deg. and at least 10 deg. progression
**PJF (Proximal Junctional Failure)**
Any type of symptomatic PJK requiring revision surgery

**PJK/PJF classifications**

Yagi et al. Spine 2013

| **Type** | |
|---|---|
| Type 1 | Disc and ligamentous failure |
| Type 2 | Bone failure |
| Type 3 | Implant/bone interface failure |
| **Grade** | |
| Grade A | Proximal junctional angle increase 10°-19° |
| Grade B | Proximal junctional angle increase 20°-29° |
| Grade C | Proximal junctional angle increase 30°- |
| **Spondylolisthesis** | |
| N | No obvious spondylolisthesis above UIV |
| S | spondylolisthesis above UIV |

**Sagittal alignment and surgical correction as a risk for PJK/PJF**

| Author | Age (y/o) | Sample size | Findings | Year and journal |
|---|---|---|---|---|
| Kim et al. | 45.2 | 161 | Greater decrease in TK<br>Larger preop TK | 2008, Spine |
| Yagi et al. | 46.9 | 157 | Larger preop SVA<br>Larger SVA change | 2011, 2012 Spine |
| Mendoza-Lattes et al. | 59.3 | 54 | Postop TK>LL | 2011, Iowa Orthop J |
| Maruo et al. | 64.5 | 90 | Change in LL > 30 °<br>Preop PJ angle > 10 °<br>PI> 55 ° | 2013, Spine |
| Kim et al. | 52.2 | 206 | Larger postop LL<br>Larger SVA change | 2014, Spine |
| Smith J et al. | 57.2 | 510 | Large preop SVA, PT, PI-LL | 2016, Spine |

- Both large amount of LL or SVA correction and inappropriate TK, LL, PI balance can be the risk for developing PJK/PJF.

**Pre-op alignment and PJF**

Nicholls et al. Spine 2017
**Method**
Retrospective analysis of surgically treated 440 ASDs.
Comparisons of pre- and post-op alignment and PJK/PJF
**Results**
Incidence of PJK: 36% PJF 15%
Large pre-op PT, and post-op TK are the risk for PJK.
Younger patients with greater SVA and PJA had revision surgery.
Type2S highest risk for revision surgery (OR 5.1)
**TK and PT are important indicators of overall rigidity and ability to compensate for sagittal plane deformity.**

**UIV inclination**

Lafage R et al. Spine 2017
**Method**
Retrospective analysis of surgically treated 252 ASDs (LIV pelvis).
Comparisons of UIV slope and inclination of the proximal-end rod of the construct between PJK and non PJK.
**Results**
Incidence of PJK: 56% at 2yrs post-op (UIV: UT 49%, LT 64%)
Large UIV slope and proximal-end rod inclination
**PJK may develop in response to excessive spinal realignment**

**Different risk factor of PJK and PJF**

Park SJ et al. Neurosurgery 2016
**Method**
Retrospective analysis of surgically treated 160 ASDs (LIV pelvis).
Multiple regression analysis of risks for PJK and PJF
**Results**
Incidence of **PJK: 16% and PJF 17%** at 3months post-op
Higher BMI is the risk factor for PJK (HR:1.2)

Older age, osteoporosis, UIV (T11-L1), and Large SVA is risk factor only for PJF (HR:1.1, 6.5, 5.2, 1.0 respectively)
**PJK and PJF may develop in different mechanisms**

**Age-matched alignment and PJK**

Lafage R et al. Spine 2017
**Method**
Retrospective analysis of surgically treated 679ASDs.
Comparisons between 1-year post-op alignment and age-specific alignment target
Age-specific target

| Age group | PT (°) | PI-LL (°) | SVA (mm) |
|---|---|---|---|
| <35 | 11 | -10.5 | -30.5 |
| 35-44 | 15.4 | -4.6 | -5.5 |
| 45-54 | 18.8 | 0.5 | 15.1 |
| 55-64 | 22 | 5.8 | 35.8 |
| 65-74 | 25.1 | 10.5 | 54.5 |
| 74> | 28.8 | 17.0 | 79.3 |

Stratified into 3 groups
Young adult (YA<40yrs)
Middle aged (MA: 40-65yrs)
Elderly (ED>65yrs)
**Results**
PJK vs non PJK;
PI-LL offset; MA: -1 vs 4°, ED: -11 vs-2°
SVA offset; MA: -3 vs 10mm, ED: -18 vs -6mm
**PJK PATIENTS WERE OVER-CORRECTED when compared to age-adjusted alignment goals**

**Virtual modeling**

Lafage R et al. Spine 2017
**Method**
Retrospective analysis of surgically treated 458 ASDs.
Comparisons of virtual alignment and real alignment between PJK and non PJK patients.
VIRTUAL: post-op alignment of instrumented segment and pre-op alignment of the unfused vertebrae
REAL: actual alignment at 2yrs post-op.
**Results**
PJK patients:
REAL alignment: smaller PI-LL and large TK but similar SVA and PT
VIRTUAL alignment: smaller PI-LL, PT, and SVA
**PJK may develop partially as a compensatory mechanism** to the over-correction of sagittal deformities.

**Predictive model**

Scheer et al. Spine 2016
**Method**
Retrospective analysis of surgically treated 510 ASDs.
**Create the predictive model;**
An ensemble of decision trees based on the possible risk factors.
**Variables;**
Demographics, surgical factor, and baseline sagittal radiographs.
**Results**
7 strongest predictors were:
Age, LIV, pre-op SVA, UIV implant type, UIV, pre-op PT, and PI-LL.
The overall model accuracy was 86.3% with an AUC of 0.89.
**This model can set the groundwork for risk stratification, and the need for prophylactic strategies for ASDs undergoing surgery.**

**Summary**

- PJF is a multifactorial phenomenon.
- PJK and PJF may develop in different mechanisms
- PJF can be predict from the baseline risk factors
- Age –adjusted restoration of spinal alignment may reduce the development of PJF

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### Biomechanics of PJK

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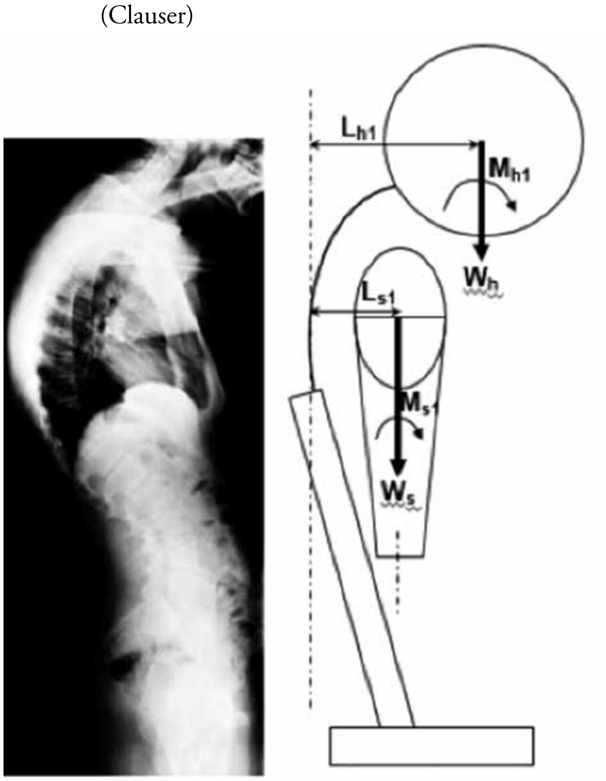
1. (yes, this is a request) Sit in military posture – shoulders back, eyes straight ahead
2. Sit “slouched”, rest forearms on thighs, head looking down. Feel the difference in you cervicothoracic spine
3. Effect of head and shoulder position on thoracic spine –
   a. Head – 7.1% body weight; shoulders and arms – 10.4% (Clauser)




4. Practical example

**Acute proximal junctional failure in patients with preoperative sagittal imbalance**

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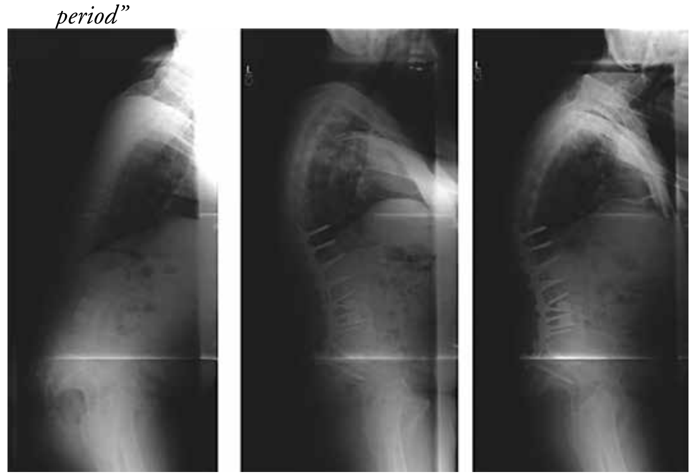
Received 13 May 2014; revised 15 April 2015; accepted 19 May 2015

-Acute PJF in 60/173 patients
-Complete correction of sagittal balance associated with a HIGHER incidence of APJF
“*the large change in sagittal alignment from significant imbalance to normal may result in significant anterior column loading as the patient remains forward leaning in the postoperative period*”



preop immediate postop followup

my comment –immediate postop radiograph not representative of sitting posture; with time, continuing deforming forces from head and shoulder position have an effect

further comment – radiograph may not be accurate depiction of actual status


actual kyphosis is about 180°

5. A postulate -
   Clinical photos might be valuable documentation in addition to radiographs
6. What about ligaments
   a. Supraspinous and infraspinous ligaments added a marginally significant 6.59% loss of flexion stiffness (Anderson)

b. Spinous process shorter in kyphosis – increased stress on posterior ligaments with flexion (Beaubien)
7. Experience with pig surgery
   a. Ligamentous failure lumbar spine - ?comparable to upperthoracic PJK in humans
8. Countermeasures to prevent upper thoracic PJK
   a. Hooks
   b. Preserve ligaments
   c. Sublaminar bands (I have no experience with these)
   d. Transition rods
   e. etc
9. Biomechanical advantage of rib construct
10. Improvement in spinal sagittal alignment with scapulopexy
11. Illustration – if shoulder protraction is flexible, physical therapy can be helpful
12. Other current measures – posterior tethers, "transition" rods, hooks instead of screws on UIV
13. Summary
    a. do not totally rely on radiographs – physical exam important
    b. goal is to minimize percentage of anteriorly displaced body weight proximal to your UIV.

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## Influence of Cervical and Head Alignment on Development of PJK


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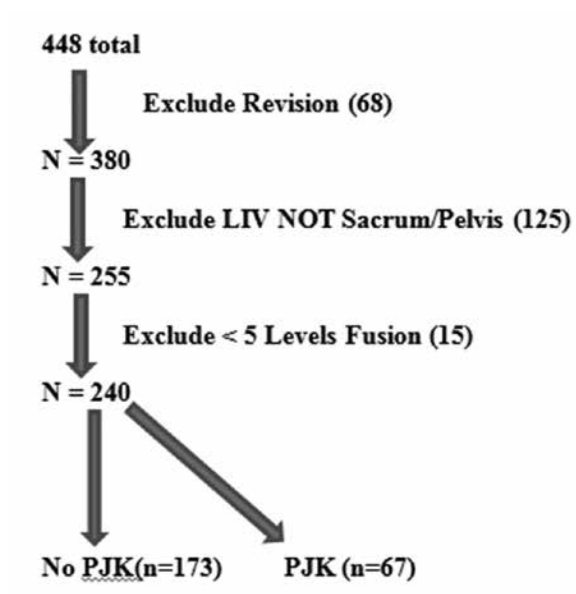
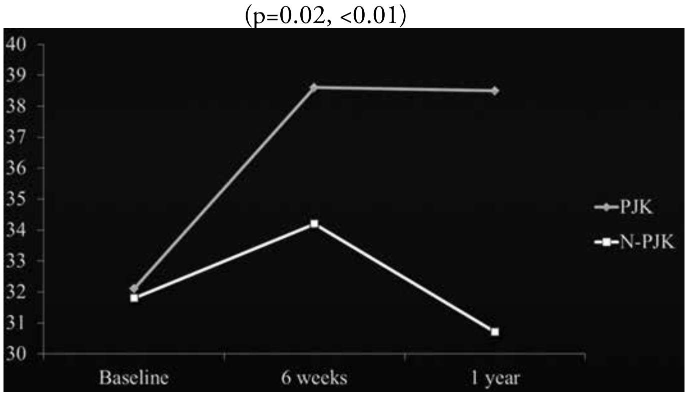
1. **Proximal Junctional Kyphosis**
   a. Incidence approximately 40%
   b. Etiology unknown but many factors
      i. Age
      ii. Posterior Tension Band
      iii. Over-Correction
      iv. Bone quality
      v. Deformity
      vi. Patient Factors (Poor Soft-Tissue, "fraility")
      vii. Underlying Neurologic Disorders (i.e Parkinson's, etc.)
      viii. Instrumentation Types at the UIV (Hooks vs. Screws vs. other)
      ix. Level of the UIV
      x. Rod Contour
2. **Radiographic Risk Factors have been described**
   a. Excessive Lordosis
   b. Large SVA Corrections (>9cm = 80%)
3. **Can Reciprocal Changes in the Cervical Spine after Adult Spinal Reconstruction predict PJK?**
   a. Cervical Deformity Parameters such as
      i. C2-7 SVA
         1. Pre-op and post-op
      ii. C2-T3 SVA
         1. Pre-op and post-op
      iii. Cervical Lordosis to T1S Mismatch
         1. High mismatch post-op might be an indicator for increased stresses at the UIV
   b. Theoretically, the Head is a bowling ball, and if constantly forward, will create proximal stress at the UIV
      i. What can drive head to move forward?
         1. Neurologic conditions?
         2. Excessive Corrections?
4. **Data Analysis to Study this in 448 ADS patients:**
   a.




   b. 190 with complete data for Analysis
      i. PJK Group (n-57)
      ii. Non-PJK Group (n=133)

iii. All stats performed with a Bonferroni Correction (very conservative)

c. PJK incidence 30%
   i. No differences in demographics
   ii. PJK Group
      1. Higher post-op C2-7 SVA immediately post-op
         a. 38.6 mm (Δ8.0) vs. 34.5 mm (Δ1.2) (p=0.14, 0.01)
      2. AND @ 1 year
         a. 38.5 mm (Δ7.4) vs. 30.7 mm (Δ-0.7) (p=0.02, <0.01)




5. **Recurrent PJK Data also consistent with these earlier findings**
   a. Revision PJK Rates 50-60%!
      i. C2-T3 SVA high indicator for recurrence
         1. Should be a radiographic marker for the type of revision surgery planned
         2.
6. **Key Facts – to be discussed at the Course!**

## The Influence of Bone Quality on the Development of PJF: How to Improve Bone Biology

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Bone quality

Osteoporosis is one of the most significant risk factors for PJK/PJF:

Mechanisms of PJK/PJF
Screw pullout or loosening
Fracture at UIV or UIV+1

At risk patients should be tested for bone density:

1. post menopausal females
2. males > age 50
3. history of prior low energy fracture (wrist, spine, hip, humerus)
4. family history of osteoporosis
5. medication
   a. glucocorticoids
   b. anticonvulsants
   c. chemotherapy
   d. serotonin reuptake inhibitors (antidepressants)
6. EtOH use
7. Smoking history
8. Endocrine disorders (DM, hyperPTH, Cushing's, hyperthyroid)
9. Nutritional (malabsorption, anorexia)
10. Organ transplant patients (immune suppression)
11. Immobilization
12. Neuromuscular conditions
13. Systemic illness, malignancy

Osteoporosis:

- T score < -2.5
- Prior fragility fracture
- FRAX score

Treatment options

- Ca 500 mg/d
- Vit D: deficiency interferes with Ca absorption, can occur with low sunlight, poor absorption or metabolism
- Antiresorptive
  – Bisphosphonates:
    - binds to crystals in bone, and slows resorption
    - increases osteoclast apoptosis.
    - Poor GI absorption
    - GFR > 35 required: renal toxicity has been seen with IV infusion, also hypocalcemia.
    - Occasional muscle aches to, Rx Tylenol, NSAI.
    - Can be resumed after acute fracture
  – Alendronate
  – Risedronate
  – Ibandronate
  – Zolendronate, Pamidronate: IV, fracture data only with zolendronate, maintains suppression 12 m or more
    - Should not start for 6-8 weeks after fracture.
  – Rare complications: osteonecrosis of jaw, mostly associated with cancer patients receiving v high doses of IV bisphosphonate.
    - Atypical femur fractures: tension side, bilateral 20
    - Prevented many more fractures than caused. Drug holiday.
      ~ Stop BP, check Vit D, metabolic bone work up
  – RANK-L inhibitor: OPG effect
    - Denosumab: 60 mg SQ q 6m.
      ~ reduced fracture risk at 3 years
      ~ Serious AE: hypocalcemic (more if poor renal function during dialysis. ON jaw in cancer study, infection, atypical femur fracture in GCT trial
  – Calcitonin: 200U/day nasally
    - Analgesic effect in some sacral fractures.
    - Only vertebral fracture prevention, not hip fx.
    - Off market in Europe due to slight increase cancer risk ~1% or so. FDA reviewed and did not change recs
  – Raloxifene
    - antiestrogen with bone augmentation effects.

- Estrogen: 25 mcg/day patches.
    - No fracture studies.
- Strontium: mineral found in seawater and soil, similar to calcium.
    - Approved in Europe for treatment and prevention of osteoporosis but not in US.
    - Available forms in US are <u>not</u> tested for bone health use.
    - May be taken off the market in Europe due to serious side effects (MI, VTE, skin reactions, liver inflammation, seizures)
- Stimulate bone formation
    - Teriparatide: 20 mcg SQ daily x 2 years.
        - Increased bone formation of all bone surfaces. Increased DEXA.
        - Spine BMD increases at 6-12 months, hip BMD increased delayed 18-24 mon, may see dip at 12 mon.
        - follow treatment with BP, denosumab, or SERM.
        - Indicated with bone mass decline on other agents, fracture on other Rx. GC-induced. < -3.0 BMD.
        - Indicated for severe osteoporosis, severe fracture, bad bone builders. Rats given 50x dose developed osteosarcoma.
        - Contraindicated for high bone turnover states eg Paget's, radiation (chronic osteitis)
    - Abaloperitide (injectable approved).
        - Modified human PTH related molecule.
        - Designed to increase anabolic function.
        - 86% reduction in new vertebral fractures at 18 mon, 43% reduction non-vert
        - does not require refrigeration.
        - Post menopausal indication only. Still no longer than 2 year total for PTH/PTHhP.
        - Dose dependent increase in OS in rates. Avoid in high turnover states.

Remember stages of bone healing

1. fracture (decortication)
2. hematoma
3. inflammation (cell infiltration) **inhibited by NSAIs**
4. osteoclastogenesis (remove bony debris, remodeling) **inhibited by anti-resorptives**
5. angiogenesis
6. mesenchymal stem cell migration/proliferation/differentiation

→ primary callus
→ secondary callus

Vitamin D

- deficiency common in spine patients
- optimization of Vit D can result in fracture healing in deficient patients. Can this help our spine patients?

PTH and fracture healing

- anabolic treatment for osteoporosis
- stimulated mesenchymal stem cell recruitment and osteoblast differentiation
- stimulate VEGF expression
- Animal studies

Other drugs under investigation

- Wnt pathway modulators: anabolic, in trial
- DKK-1a antibody
- Anti-sclerostin antibody: Romosozumab: completed clinical trial awaiting FDA.)

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## The Influence of Muscle and Neuromuscular Diseases

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During the past 20y, we had a dramatic increasing knowledge about the analysis and measurement of different parameters defining the economical standing posture of a particular patient.

Including global, regional, segmental and pelvic parameters, they allow to analyze and understand the pathological situations, understanding the primary and compensatory components of an umbalanced status, in order to define the objectives of a comprehensive optimal correction.

**Static evaluation**
Parameters are all defined from a long standing sagittal Xray ideally with EOS system.

In most of the cases a degenerative lumbar evolution leads to an anterior column shortening with loss of lumbar lordosis. To maintain gravity line between the 2 feet , the pelvis rotates backward (increasing pelvic tilt) and then next adaptation is with flexion of the knees.

In the simulation of correction (including various types of osteotomies or cages to fulfill the objectives), the Pelvic Incidence is the fixed reference parameter for a paticular patient. Studies had defined the « ideal » pelvic tilt and lumbar lordosis.

In the amount of correction of LL, <u>restoration of PT has to be included</u> to avoid under correction. But also, as important, restoration of <u>the 2/3 of this lordosis around the lombo-sacral area</u> for an **harmonious** correction (and consecutive restoration of « normal PT according to PI).

Higher lumbar correction, despite restoration of the SVA , provides a dysharmonious one with overstress on the upper junctional zone (PJK), and more correction on the upper part and less or no correction on the pelvis.

**Active compensatory mechanisms**
Retroversion of the pelvis around femoral heads, is one of the compensatory mechanisms .

It could be active with increasing activity of pelvic retrovertors. With posterior translation, the opposite moment arm of the weight of the upper part of the trunck diminishes.

On the opposite, anterior positioning of the trunk increases the tension and lever arm of these muscles .

Diminution of thoracic kyphosis even thoracic lordisis is the « in-spine « compensatory mechanism. It is the traduction of a good quality thoracic muscles activity and neuro central control of the balance.

Adequate restoration of the balance of the lombo-pelvic segment leads to spontaneous correction of a mobile thoracic segment with restoration of an harmonious Kyphosis.

**Dynamic changes**
All the previous items are evaluated from the standing posture. Dynamic may enhance imbalance situation.

1. Walking :
   a. Gait analysis :
      i. Increased forward bending to find some extension of the hip for progression.
         1. With persistant retroversion (activity of hip extensors) gravity line close to femoral head.
         2. With anteversion of the pelvis. Gravity line far anterior to femoral head (increasing moment arm and tension of hip extensors)
         3. Role of PI
      ii. Increased forward bending with time (fatigue)
   b. New Xray standing evaluation after 10 min walk. (impact of fatigue)
2. Clinical evaluation of active muscle strength :
   a. Supine on the table active extension of the thoracic area Thoraco TL extensors )
   b. Hip extensors ( Prone position, elevation of lower limbs outside of the table)

**MRI evaluation of paravertebral muscles**
Different levels corresponding to intervertebral disc:
Lumbo-sacral L5S1
Thoraco-lumbar T12-L1
Thoracic T8-T9

- Qualitative evaluation :
  Fatty infiltration with constant muscle volume (myopathic)
  Atrophy and fatty infiltration less extensive and close to posterior arch ( lumbar degenerative)
  Neurogenic (volume normal or reduced but density of tissue normal)
- Quantitative evaluation: cross sectional area

They may be indicators about the ability or not to control unfused thoracic segment .

**Etiology**
In an imbalanced adult spinal deformity 3 mains factors could be involved:

1. Degeneratives changes in the lumbar spine with schortening of the anterior column due to disc collapse, vertebral body cuneiformization. Could be more or less rigid with synostosis.
2. Muscles function.
3. Neurologic control .

As patients are refered to spine surgeons for the first item the 2 followings have to be search and evaluated considering that they are not exclusive and could be intricated.

Muscular origin :

1. Idiopathic primary axial myopathy (Laroche 1991)
   Stricly localized on paravertebral muscles in elderly , progressive, no associated signs . MRI large fatty infiltration with normal volume
2. Secondary bent syndrom with muscular disorders :
   - FSH Dystrophy, Limb Girdle Dystrphy,
   - Myotonic MD, Steinert
   - Inflammatory
   - Endocrine – metabolic : Hypothyroidism, Osteomalacia, steroid induced, Amyloidosis
   - Mitochondrial myopathies

   Laboratory examinations, MRI, muscle biopsy of paravertebral muscles

Neurogenic origin :
Lesion and dysfunction of the basal ganglion :
Parkinson's Disease
« Parkinson plus Syndromes »
Bent syndrom and Parkinson : specific form

- Prevalence 3 to 12%
- Long duration of Parkinson, but may be associated with discrete signs of PD
- Progression in one year sometimes 2-3 monthes
- Bent syndrom doesn't respond to levodopa.
- Gait disturbance
- If spine surgery decided,Importance of restoration of the sagittal balance with long instrumentation

Complete analysis of the **static and dynamic** muscle components of a sagittal imbalance are mandantory to reach an optimal post-operative functional status of a particular patient.

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## Vertebral Augmentation and Proximal Junctional Failure


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**PJF and Osteoporosis**

- PJK/PJF reported at rates of 20-40% [1]
- Osteopenia / osteoporosis implicated as a risk factor for PJK in New York [2]
  - Osteoporosis and independent risk for PJF in retrospective series of 160 patients in Korea[3]
  - Osteoporosis and independent risk factor in retrospective series or 98 patients from China [4]
  - BMD noted to be strongly associated with presence of PJK in 49 patients in Korea [5]

**Medical prophylaxis**

- Teriparatide seems to substantially reduce PJK due to fracture [6]

**Polyxial vs. Monoaxial screws at the UIV**

- No benefit based on retrospective review of 242 patients from China [7]

**Vertebroplasty Kyphoplasty as prophylaxis**

- Aydogan reported on 36 patients who received V-ploasty at every instrumented level and UIV+1 and reported no PJK in their 2- year followup [8]
- Case report of fx- subluxation at UIV despite v-splasty [9]
- Kebaish suggested that v-plasty at UIV and UIV+1 could prophylax against PJK in cadaveric model[10]
- Use of K-plasty / V-plasty at UIV and UIV+1 associated with significant reduction in revision for PJF at UCSF in retrospective cohort of 51 patients [11]
- Retrospective case – control study of 85 patients (38 with v-plasty at UIV and UIV+1) showed lower incidence of PJK with v-plasty ( 23%) vs. no cement (36%) [12]

**Other forms of screw augmentation**

- Via screw fenestratuions or cement placed in pilot hole
  - No clear clinical evidence at this point

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## Implant Strategies for Decreasing PJK in Pediatric Spinal Deformity


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I. Biomechanical Contributions to PJK
   a. Contribution of the PLC
   b. Relative stresses with variations in metallurgy
II. Implant strategies for other spine applications
   a. "Topping off" in degenerative surgery
   b. Rod long/fuse short in trauma applications
III. Pediatric Strategies
   a. Protect the soft tissues
   ★ Technique Tip: Dissect away from the midline at the top level
   ⊙ Study Results: Impact of damaged supraspinous and intraspinous ligaments
      1. Increased disk pressure: 32%
      2. Increase flexion ROM: 29%
   b. MacEwen strategy – decorticate and graft one level proximal to instrumentation
      ✚ Application: Osteogenesis Imperfecta
   c. Unilateral proximal constructs (aka Clements Constructs)
      ✚ Application: structural proximal thoracic curves
      ⊙ Study Results: V. Khatri et al.
         -Similar PJK, shoulder balance, surgical time
   d. Transition Rods
      ⊙ Study Result: Finite Element Analysis of Transition Rod
         1. intra-disc pressure: >50%
         2. pathologic flexion at the level above the construct: 19%
         3. implant stress: 60%
   e. Is it the Anchors?
      i. Hooks may avoid midline dissection
         ⊙ Study Results:
            1. Helgeson et al.
               a. PJK rate varied by construct type
                  i. All hooks – 0%

ii. Hybrid mix of hooks and screws – 2.3%
iii. All screws – 8.1%
iv. Note: global kyphosis is decreased with all screws

2. Pahys et al.
   a. 1.4 degrees less kyphosis at level above construct with hooks (v. screws)
   b. No decrease in catastrophic PJK (15 degrees or more)

f. Make it More Kyphotic!
   i. Increase thoracic kyphosis from pre-op
      ⊙ Study Results: reversal of cervical kyphosis Hwang et al.
         ★ key tip: any increase in kyphosis over pre-op helps!

## Can the Technology Replace the Extensor Muscles of Spine?

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While the North American population ages, demands for an active lifestyle continue to increase. In this context, surgical intervention for patients with adult spinal deformity is becoming increasingly more commonplace. Surgical intervention is indicated for spinal deformity patients presenting with coronal or sagittal plane malalignment, neurologic compromise and back pain recalcitrant to non-operative modalities. Surgery for correction of spinal deformity has been demonstrated to reliably result in not only radiographic but also clinical improvements in pain and function. Nonetheless, perioperative complications continue to occur at a significant rate, reported at between 10 and 45%.

While the use of rigid, third generation pedicle screw construct enables the modern spine surgeon to effectively treat a growing number of patients, the syndrome of 'adjacent segment disease' has become an increasingly recognized phenomenon. Adjacent segment disease encompasses a variety of pathologies, all occurring immediately caudal or cephalad to rigidly instrumented spinal fusions. Proximal junctional kyphosis (PJK) is a frequently observed form of adjacent segment disease wherein the vertebral body immediately cephalad to a construct will demonstrate ten or more degrees of incremental kyphosis over the subjacent level on serial radiographs. The prevalence of PJK in adult patients undergoing long instrumented posterior spinal fusions has been reported as between 5.8% and 59%. The presence of PJK alone does not constitute an absolute indication for revision, and despite its high incidence, revision surgery rates are reported at as low as 13 and up to 47.4%. When undertaken, revision surgery for PJK carries a significant social and economic burden, with an average associated cost in excess of 77,000 USD.

Prevention of proximal junctional failure and subsequent sagittal plane decompensation may hold the key to reducing the need for revision surgery in these complex patients. In recent years, an increasing amount of research into the rates, mechanisms and treatment strategies for PJK has seen publication. Despite the widespread interest of the surgical community, formal, widely accepted indications for revision surgery have yet to be established. In order to delineate these indications and to guide future investigation, we have undertaken a comprehensive radiographic review of the initial surgical strategies as well as the pre- and post-operative radiographic parameters associated with revision surgery for PJK in patients presenting to a specialized spinal deformity center over the last ten years.

Several surgical adjuncts have been proposed for the prevention of PJK, including the use of hooks at the upper instrumented vertebrae (UIV), augmentation with sublaminar wiring and the use of vertebroplasty at the UIV and UIV+1. Both the use of hooks at the UIV and the use of sublaminar wires for augmentation of the construct were found to lower the rate of PJK in this series. Contrarily, the use of wires as a primary form of fixation was not proven to be protective against the development of PJK. While vertebroplasty has been proposed as a mechanism for prevention of PJK due to fracture at the UIV or UIV+1, this did not hold true in the current study. This may be due to apparent low volumes of cement injected in the current case series. As vertebroplasty was adopted for prevention of PJK at the study center, and not simply for augmentation of screw fixation, a greater volume of cement has been employed. Comparison of more recent cases may in fact yield different results.

Ligament augmentation represents a novel modality for PJK prevention that provides additional strength to the junction between the UIV and UIV+1. The ligament suture used in this procedure is strong and durable, yet flexible. The augmentation process itself is straightforward, safe, and does not significantly increase operative time, thus making it a valuable adjunct for PJK prevention in adult spinal deformity. The goal of ligament augmentation is to provide strength to the UIV, UIV+1, and UIV-1 along with decreasing junctional stress at those levels. A matchstick burr is used to drill through the center of the spinous process and a soft sublaminar cable is looped through these holes in a mirrored fashion. Two cables are used (one on each side), then pulled tightly by hand to allow for the desired tension. The cables are then locked onto the rod under tension using supplied connectors. Spinous processes at these levels are loaded in slight extension to resist flexion at the terminal construct.

Compared to historical controls from a single institution, we provide data illustrating a dramatic reduction in PJK/PJK associated with the use of ligament augmentation in adult patients undergoing spinal deformity surgery. These results provide compelling rationale for the implementation of ligament augmentation, but also stress the importance of standardized metrics for reporting PJK/PFJ (Table 1).

Strategies for decreasing rates of PJK will be essential moving forward. We present surgical techniques that are safe and add minimal operative time. Vertebroplasty provides strength to constructs terminating at the thoracolumbar junction, where failure is often due to fracture. Transverse process hooks are valuable for constructs terminating in the upper thoracic spine since they provide a softer stress transition to the UIV and can be applied with minimal muscular dissection and preservation of the facets. Our technique for terminal rod bending prevents additional loading and has the potential to minimize forces causing screw pullout or junctional stress. Ligament augmentation provides strength to the upper construct and reinforces the ligamentous complex, which is a common site of failure at these levels. It also allows for the upper construct to be placed in slight extension to help resist flexion forces. In addition to reducing PJK/PJF, these techniques, when used together in appropriately selected high-risk patients, have the potential to improve safety and reduce the cost and morbidity of surgery for adult spinal deformity.

PJK prevention strategies represent a critical area for improvement in surgery for adult spinal deformity. Surgical adjuncts that can prevent PJK/PJF and abrogate the need for readmission and revision surgeries are necessary to reduce both cost and morbidity. We present a summary of techniques that are safe and add minimal operative time. These techniques warrant future investigation in a thoughtful, prospective manner, but are supported by existing data and compelling biomechanical rationale. Our hope is that these strategies can be applied, particularly in high-risk patients, to help reduce rates of PJK.

Table 1. Comparison of ligament augmentation to control cohort

| Variable | Ligament augmentation cohort N=100 | **Control cohort N=100** | **p value** |
|---|---|---|---|
| Age (years) | 66 | 62 | 0.014 |
| Gender | | | |
| Male | 33 | 29 | 0.541 |
| Female | 67 | 71 | |
| Indication for surgery | | | |
| Scoliosis | 49 | 43 | 0.395 |
| Sagittal imbalance | 43 | 42 | 0.886 |
| Flat back | 34 | 22 | 0.059 |
| Adjacent segment disease | 14 | 18 | 0.440 |
| Proximal junctional kyphosis | 7 | 5 | 0.552 |
| Degenerative disease | 3 | 8 | 0.121 |
| Revision surgery | 49 | 58 | 0.202 |
| Combined anterior/lateral and posterior | 38 | 36 | 0.771 |
| Number of levels fused | 11 | 10 | 0.029 |
| Three-column osteotomy | 40 | 47 | 0.318 |
| Upper instrumented level | | | 0.021 |
| Cervical | 1 | 1 | |
| Upper thoracic* | 42 | 32 | |
| Lower thoracic§ | 56 | 56 | |
| Lumbar | 1 | 11 | |
| Hook fixation at UIV | 42 | 18 | <0.001 |
| Vertebroplasty | 48 | 25 | 0.001 |
| Fracture at UIV | 9 | 9 | 1.000 |
| Change in PJA | 6° | 14° | <0.001 |
| Proximal junctional failure | 4 | 18 | 0.002 |
| Other causes for reoperation | | | |
| Pseudarthrosis | 3 | 14 | 0.005 |
| Iliac bolt removal | 4 | 2 | 0.407 |
| Wound complications | 3 | 7 | 0.194 |
| Progression of deformity | 1 | 6 | 0.054 |
| Distal junctional failure | 0 | 2 | 0.115 |
| Osteotomy correction | 2 | 2 | 1.000 |
| Other | 2 | 0 | 0.155 |

# Notes

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# CASE DISCUSSION & LUNCHTIME SYMPOSIA PROGRAM

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

Case Discussion & Lunchtime Symposia Program

The Scoliosis Research Society gratefully acknowledges Medtronic for their support of the Pre-Meeting Course, E-Poster Kiosks, Charging Station, Ribbon Display, Beverage Break, Welcome Reception, Half-Day Courses and Webcast.

# CASE DISCUSSION PROGRAM

## WEDNESDAY, SEPTEMBER 6, 2017

16:45 - 17:45
These sessions are open to all Annual Meeting delegates. Pre-registration is not required and no additional fee applies.

The Case Discussion sessions allow an opportunity to present unique and challenging clinical cases to the SRS with a panel of experts present to review and discuss each case and the clinical issues that are highlighted, as well as answer questions from audience participants. The panels will also prepare case studies for presentation and discussion, as time allows.

### Case Discussion 1: Innovative Solutions

Ballroom - Salon A-F
*Moderators: Munish C. Gupta, MD and David S. Marks, FRCS*

**16:45-17:00** **1A: 3D Printed, Patient Specific Drill Guides Represent an Alternative Form of Intraoperative Navigation in Complex Spinal Reconstruction Surgery**
*George A. Frey*

**17:00-17:15** **1B: The Role of Magnetically-controlled Growing Rods as a Temporary Internal Brace for Treatment of Adolescent Idiopathic Scoliosis with Failed Bracing**
*Jason Pui Yin Cheung, MBBS (HK); Kenny Kwan, BMBCh(Oxon), FRCSEd; Kenneth MC Cheung, MD*

**17:15-17:30** **1C: Temporary Internal Distraction Facilitates Surgical Reduction of High Grade Spondylolisthesis.**
*Harry L. Shufflebarger, MD; Jahangir K. Asghar, MD*

**17:30-17:45** **1D: 20 Screws in The Treatment of 4 Patients – Decision Making and Surgical Strategies in Resource Limited Countries**
*Kin C. Mak, BSc, MBBS, FRCS; Kenneth MC Cheung, MD*

### Case Discussion 2: Tumor & Syndromic Spine

Room: Ballroom - Salon GKL
*Moderators: John Dormans, MD and Ibrahim Obeid, MD*

**16:45-17:00** **2A: Two Cases of Paralysis Secondary to Aneurysmal Bone Cysts (ABC) with Complete Neurologic Recovery**
*Aaron Beck, MD; David L. Skaggs, MD, MMM; Erin Kiehna, MD; Lindsay M. Andras, MD*

**17:00-17:15** **2B: Gorham's Disease of Dorsolumbar Spine – Can we Predict Prognosis?**
*Hardik Suthar; Pramod Sudarshan, MS; Vamsi Krishna Varma Penumatsa; Appaji Krishnan; Sajan Hegde, MD*

**2C: Kyphoscoliosis in Metatropic Dysplasia Treated with Staged Anterior Release and Magnetically Controlled Growing Rods (MCGR)**
*Jennifer M. Bauer, MD; William G. Mackenzie, MD*

**17:30-17:45** **2D: Ten-Year Follow-Up of Jarcho-Levin Syndrome with Thoracic Insufficiency Treated by Prosthetic Rib/Rib Based Construct-Magnetically Controlled Growing Rod Hybrid**
*Kenny Kwan, BMBCh(Oxon), FRCSEd; Jason Pui Yin Cheung, MBBS (HK); Kenneth MC Cheung, MD*

### Case Discussion 3: Unusual Conditions

Room: Ballroom - Salon HIJ
*Moderators: Vedat Deviren, MD and David M. Farrington, MD*

**16:45-17:00** **3A: Management of the Most Severe Dystrophic Cervical Kyphosis (140 degrees) in Neurofibromatosis Type 1**
*Yat Wa Wong, MD; Jason Pui Yin Cheung, MBBS (HK); Keith D K Luk, MD; Kenneth MC Cheung, MD*

**17:00-17:15** **3B: U-type Sacral Fracture and Hardware Failure After Posterior Spinal Corrective Surgery Using S2-Alar-Iliac (S2AI) Fixation in a Patient with Osteoporosis.**
*Scott S. Russo, Jr., MD; Matthew W. Wilkening, MD; Jordan, R Nester, MS4*

**17:15-17:30** **3C: Late Atraumatic Fusion Mass Fractures Occurring Between Non-bridged Constructs in Patients Requiring Fusions Distal to AIS Fusions**
*Stephen J. Lewis, MD, MSc, FRCSC; Tan Chen, MD; Mohammed Obeidat; Anupreet Bassi, MD; So Kato, MD*

**17:30-17:45** **3D: Vascularized Clavicle Graft Rotated into an Anterior Cervical Defect on a Sternocleidomastoid Pedicle: Case Report**
*Michael Bohl, MD; Jay D. Turner, MD; Udaya K. Kakarla, MD; Randall Porter, MD*

# Educational Program

Pre-registration is required for all of the following sessions and space is limited. There is an additional registration fee of $50 for the Hibbs Society Program. The Hibbs Society Program is not eligible for CME credit. Lunchtime Symposia registration is included in the Annual Meeting base registration fee.

## TUESDAY, SEPTEMBER 5, 2017 – HIBBS SOCIETY PROGRAM

*An additional registration fee of $50 applies for the Hibbs Society Program.*

13:00 - 18:15
Room: Ballroom - Salon HIJ
Over the years, the Russell A. Hibbs Society, a group formed in 1947 as an international travel club for continuing medical education and furthering orthopaedic knowledge, has held an educational meeting at the SRS Annual Meeting. These meetings address difficult and complex issues that do not lend themselves to the usual kind of scientific presentations. The meeting encourages interaction among international participants and new ideas, new concepts and reports on personal experience.

13:00-13:05 **Introduction: Hibbs and the Hibbs Program**
*Robert W. Gaines, Jr., MD*

13:05-14:45 **Complications in Early Onset Scoliosis Surgery**
*Moderator: Brice Ilharreborde, MD, PhD*

- 13:05-13:15 **Limits of Serial Casting in EOS: What to Look Out For**
  *Noriaki Kawakami, MD, DMSc*
- 13:15-13:25 Bad Indication for Growth Sparing Techniques in EOS
  *Jean Dubousset, MD*
- 13:25-13:35 Incidence and Management of Unplanned Surgeries in Growth Sparing Techniques
  *Behrooz A. Akbarnia, MD*
- 13:35-13:50 Discussion
- 13:50-14:00 How to Avoid PJK in Growth Sparing Techniques?
  *David L. Skaggs, MD, MMM*
- 14:00-14:10 Transition from Growth Sparing Techniques to Definitive Fusion
  *Hilali H. Noordeen, FRCS*
- 14:10-14:20 Failures of the Tethering Techniques; How and Why?
  *Amer F. Samdani, MD*
- 14:20-14:40 Discussion

14:40-14:55 **Break**

14:55-16:30 **Complications in AIS surgery**
*Moderator: Kota Watanabe, MD, PhD*

- 14:55-15:10 The Evidence Base for the Prognosis and Treatment of Adolescent Idiopathic Scoliosis
  *Stuart L. Weinstein, MD*
- 15:10-15:20 Severe Neglected AIS, is VCR Needed?
  *Lawrence G. Lenke, MD*
- 15:20-15:30 Severe Neglected AIS, Anterior Fusion Better?
  *Hee-Kit Wong, MD*
- 15:30-15:45 Discussion
- 15:45-15:55 What to Achieve in AIS Surgery: The Fusion Block Concept
  *Keith DK Luk, MD*
- 15:55 -16:05 Failure of Selecting UIV, Unbalanced Shoulder
  *Mun Keong Kwan, MBBS, MS Orth*
- 16:05-16:15 Failure of Selection LIV in Selective Thoracic Fusion
  *Morio Matsumoto, MD*
- 16:15-16:30 Discussion

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| 16:30-16:45 | **Break** | |
| 16:45- 18:15 | **Complications in Adult Deformity Surgery from Cervical to Lumbar Spine**<br>*Moderator: Bangping Qian, MD* | |
| | 16:45-16:55 | Complications in Cervical Osteotomy<br>*Daniel Riew, MD* |
| | 16:55-17:05 | Latest Concepts in Treating Cervical Deformity<br>*Todd J. Albert, MD* |
| | 17:05-17:15 | Discussion |
| | 17:15-17:25 | Adult Spine Deformity Surgery: Measuring Outcomes and Development of a Core Outcome Set<br>*Marius de Kleuver, MD, PhD* |
| | 17:25-17:35 | Preoperative Convex Imbalance: A Risk Factor for Postoperative Coronal Decompensation in Adult Scoliosis<br>*Yong Qiu, MD* |
| | 17:35-17:45 | Neurological Comorbidities Predict Proximal Junctional Failure<br>*Steve D. Glassman, MD* |
| | 17:45-17:55 | How to Recognize Factors that Could Lead to Postoperative Radiculopathy when Inducing Lordosis<br>*Ronald A. Lehman, Jr., MD* |
| | 17:55-18:15 | Discussion |
| **18:15** | **Adjourn** | |

## WEDNESDAY, SEPTEMBER 6, 2017 – LUNCHTIME SYMPOSIA

12:35 - 13:35
Room: Ballroom - Salon GKL

### Developing Your Academic Footprint

Session focusing on the education of both young and more experienced researchers on how to produce better quality studies and scientific works.

*Chairs: Olavo B. Letaif, MD, MSc & David W. Polly, Jr. MD*

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|---|---|
| 12:35 - 12:43 | Starting a Deformity Study: 1. Asking a Good Research Question. 2. Collecting Outcomes Data – *Steven D. Glassman, MD* |
| 12:43 - 12:50 | Researching Tools: Internet/Database Searches, Tools for Radiographic Analysis, Helpful Software – *Charla R. Fischer, MD* |
| 12:50 - 12:58 | Assembling the Researching Environment: 1. Researching Team. 2. Study Groups. 3. Institutional Facilities – *Leah Y. Carreon, MD, MSc* |
| 12:58 - 13:06 | Organizing the Data, the Protocols and the Follow Up – *A. Noelle Larson, MD* |
| 13:06 - 13:13 | Choosing the Appropriate Journal or Meeting for Your Paper – *Paul D. Sponseller, MD, MBA* |
| 13:13 - 13:20 | Reviewer Perspective of the Most Common Mistakes and Flaws in a Paper – *Ferran Pellisé, MD, PhD* |
| 13:20 - 13:27 | Pearls and Tips to Write a Good Paper and Abstract – *John E. Lonstein, MD* |
| 13:27 - 13:35 | Closing remarks, Discussion, and Questions – *Olavo Letaif, MD, MSc; David W. Polly, Jr., MD* |

## WEDNESDAY, SEPTEMBER 6, 2017 – LUNCHTIME SYMPOSIA

12:35 - 13:35

### Intraspinal Anomalies and Spine Deformity

Room: BallRoom - Salon A-F

This symposium will focus on the management of spinal deformity patients who harbor an intraspinal anomaly. Through a case based approach, the topics covered will include those patients with Chiari malformation, tethered cord, and split cord malformation. We will also explore the role of spinal column shortening in these patients.

*Chairs: Amer F. Samdani, MD & Ahmet Alanay, MD*

12:35 - 12:40 Welcome and Introduction – *Amer F. Samdani, MD*

12:40 - 12:50 Most Common Intraspinal Anomlies – *Steven W. Hwang, MD*

12:50 - 13:00 Chiari/Syrinx and Scoliosis: Management Strategies – *Daniel J. Sucato, MD, MS*

13:00 - 13:10 Split Cord Malformation: When to Remove Prior to Deformity Correction – *Muharrem Yazici, MD*

13:10 - 13:20 Severe Deformity and Intraspinal Anomaly: Role of VCR – *Amer F. Samdani, MD*

13:20 - 13:35 Panel Case Discussion

### Non-Operative Treatment of Adult Spinal Deformity

Room: Ballroom - Salon HIJ

The symposium will focus on multidisciplinary evaluation and treatment of the symptomatic adult spinal deformity patient and will include an evidence based review of non-operative treatment options.

*Chairs: Richard Hostin, Jr., MD & Frank J. Schwab, MD*

12:35 - 12:45 Where Does the Literature Stand on Non-operative Treatment Modalities of Adult Spinal Deformity in 2017? – *Richard Hostin, Jr., MD*

12:45 - 12:55 Review of Recent Multicenter Non-operative Data from Prospective Multicenter Database / Where is Future Research Headed? – *Frank J. Schwab, MD*

12:55 - 13:05 Physical Therapy Evaluation and Treatment Options for the Adult Spinal Deformity Patient – *Pamela R. Morrison, MS, PT, BS, DHS*

13:05 - 13:15 Interventional and Non-interventional Pain Management Options for the Adult Spinal Deformity Patient – *Allen S. Chen, MD, MPH*

13:15 - 13:35 Case Panel and Discussion – *Richard Hostin, Jr., MD*

## FRIDAY, SEPTEMBER 8, 2017 – LUNCHTIME SYMPOSIA

12:00 - *13*:00

Room: Ballroom - Salon HIJ

### SRS GOP Mission Trips. How to be Effective and Safe at a Reduced Cost

During this lunch symposium you will hear from members of the Global Outreach Committee and representatives from SRS-GOP Endorsed Sites about tips and tools that can help us all to make care effective and safe at a reduced cost in GOP Missions and Activities. If you have ever thought about volunteering your skills and knowledge in another country, then you will find this symposium informative. If you have already been involved in GOP activity, this symposium will be an excellent opportunity to network and learn how to increase safety and cost-effectiveness in your next GOP activity.

*Chairs: Ferran Pellisé, MD, PhD; J. Michael Wattenbarger, MD*

12:00 - 12:05 Introduction *Ferran Pellisé, MD, PhD*

12:05 - 12:13 What It Means to Get Involved in GOP. People's Experiences of Their "First Trip" – *Kenneth J. Paonessa, MD*

12:13 - 12:21 How to Build a Sustainable Outreach Site from the Ground-Up – *Gregory M. Mundis, Jr., MD*

12:21 - 12:29 Pearls to Minimize Clinical Safety Challenges in a SRS Outreach Site – *Anthony S. Rinella, MD*

12:29 - 12:37 The Challenge of Severe Neglected Deformities. How to Be Effective and Safe with Low Resources – *W. Fred Hess, MD*

12:37 - 12:45 Pearls for the Treatment of Early Onset Scoliosis in Underserved Areas – *Francisco Javier Sanchez Perez-Grueso, MD*

12:45 - 13:00 Discussion

## FRIDAY, SEPTEMBER 8, 2017 – LUNCHTIME SYMPOSIA

### Research Grant Outcomes

Room: Ballroom - Salon GKL

The SRS Research Grant Committee presents a Lunchtime Symposium giving recent grant recipients an opportunity to present and discuss the fruits of their labors. After presenting their final results, each project will be discussed in detail. There will also be an opportunity to discuss the grant funding application process with the members of the SRS Research Grants Committee

*Patrick J. Cahill, MD*

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| 12:00 - 12:05 | Introduction – *Patrick J. Cahill, MD* |
| 12:05 - 12:12 | SRS Medtronic Research Fellowship Report – *So Kato, MD* |
| 12:12 - 12:19 | Evidence-Based Algorithm for the Surgical Treatment of Lumbosacral Spondylolisthesis – *Jean-Marc Mac-Thiong, MD, PhD* |
| 12:19 - 12:26 | Validation of 3D Ultrasound Measurements with EOS System on Children with AIS – *Edmond H. Lou, PhD, P.Eng* |
| 12:26 - 12:34 | 3D Biomechanical Analysis of the Spontaneous Lumbar Curve Correction After Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis – *Saba Pasha, PhD, MS* |
| 12:34 - 12:41 | Optimization of Implant Density in AIS Instrumentation Using a Computerized Spine Simulator – *Xiaoyu Wang, PhD* |
| 12:41 - 12:49 | How Does SKI-1 Regulate Somitogenesis? – *Jeffrey P. Gorski, PhD* |
| 12:49 - 13:00 | Discussion |

12:00 - 13:00

### Adult Spinal Deformity for Early Career Deformity Surgeons

Room: Ballroom - Salon A-F

The evaluation and management of patients with adult spinal deformity can be a challenging and daunting task for even the most experienced deformity surgeon. Indications, understanding global spinal alignment, risk assessment and patient optimization prior to surgery, surgical options and managing postoperative complications are constantly evolving. This symposium seeks to provide guidance and guidelines to early career deformity surgeons when facing challenging decisions during the care of patients with symptomatic adult spinal deformity.

*Chair: Ripul R. Panchal, DO, FACOS, FACS and Ram Mudiyam, MD, MBA*

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| 12:00 - 12:05 | Introduction – *Ripul R. Panchal, DO, FACOS, FACS and Ram Mudiyam, MD, MBA* |
| 12:05 - 12:15 | Pre-op Patient Assessment, When is it Over My Head and When Do I Ask for Help? – *Rajiv K. Sethi, MD* |
| 12:15 - 12:25 | Assessing Radiographic Parameters, Balancing the Art and Science – *Saumyajit Basu, MD* |
| 12:25 - 12:35 | Role of MIS in ASD Correction – *Neel Anand, MD* |
| 12:35 - 12:45 | Intraoperative - What Keeps Me Out of Trouble and How do I Get Out of it? – *Munish C. Gupta ,MD* |
| 12:45 - 12:55 | Women in Spine – Lessons Learned and Advice to Young Female Spine Surgeons – *Laurel C. Blakemore, MD and Evalina L. Burger, MD* |
| 12:55 - 13:00 | Questions and Discussion |

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# SCIENTIFIC PROGRAM

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges NuVasive for their support of the Pre-Meeting Course, E-Poster USBs, Newsletter, Ribbon Display, and Welcome Reception.

## THURSDAY, SEPTEMBER 7, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 1: Adolescent Idiopathic Scoliosis

07:55 - 09:49

*Moderators: René Castelein, MD, PhD; Peter O. Newton, MD*

07:55 - 08:00 **Welcome & Announcements**

08:00 - 08:04 **Paper #1: Correlation of Lowest Level of Instrumentation to Functional Outcomes and Risk of Further Spine Surgery in AIS with Minimum 40 Year Follow-up**
*Sarah T. Lander, MD; Caroline Thirukumaran; Krista Noble, BS; Ahmed Saleh, MD; Addisu Mesfin, MD; Paul T. Rubery, MD; James O. Sanders, MD*

08:04 - 08:08 **Paper #2: Mean 23 Years Follow-up Study on the Effects of Lumbar Muscular Condition on Curve Progression after Skeletal Maturity in Adolescent Idiopathic Scoliosis**
*Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD; Kazuhiro Hasegawa, MD, PhD*

08:08 - 08:12 **Paper #3: Impact of an Accelerated Discharge Pathway on Early Outcomes and Recovery Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Prospective Comparative Study**
*Nicholas D. Fletcher, MD; Joshua Murphy, MD; Patricia Bush; Heather Guerreso, MPH; Eva Habib, BSc; Michael L. Schmitz, MD; Firoz Miyanji, MD, FRCSC*

08:12 - 08:21 **Discussion**

08:22 - 08:26 **Paper #4: Thoracic-Only Fusions for Double (Type 3) and Triple (Type 4) Major Curves in AIS at a Minimum 5 Year Follow-Up: Are They Possible and Durable?**
*Lawrence G. Lenke, MD; Ronald A. Lehman, MD; Michael P Kelly, MD; Michael Vitale, MD, MPH; Baron Stuart Lonner, MD; Thomas J. Errico, MD; Randal R. Betz, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Peter O. Newton, MD; Kathleen M. Blanke, RN; Harms Study Group*

08:26 - 08:30 **Paper #5: Short Fusion Strategy can Prevent Left Shoulder Elevation with Shorter Fusion Area in Lenke Type 1A Curve in Mid-term Follow Up**
*Soya Kawabata, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Naobumi Hosogane, MD; Narihito Nagoshi, MD, PhD; Osahiko Tsuji, MD, PhD; Ken Ishii, MD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD; Kota Watanabe, MD, PhD; Keio Spine Research Group*

08:30 - 08:34 **Paper #6: Ponte Osteotomies Increase the Risk of Neuromonitoring Changes in Surgery for Adolescent Idiopathic Scoliosis**
*Aaron J. Buckland, MBBS, FRACS; John Moon, BS; Randal R. Betz, MD; Baron Stuart Lonner, MD; Peter O. Newton, MD; Harry L. Shufflebarger, MD; Thomas J. Errico, MD; Harms Study Group*

08:34 - 8:43 **Discussion**

08:44 - 08:48 **Paper #7: New Sagittal Classification For AIS: Optimizing The Surgical Correction**
*Kariman Abelin Genevois, MD, PhD; Pierre Roussouly, MD*

08:48 - 08:52 **Paper #8: Reciprocal Relationship between Thoracic Kyphosis and Lumbo-Sacro-Pelvic Sagittal Alignment in Adolescent Idiopathic Scoliosis**
*Takuya Iimura, MD; Haruki Ueda, MD; Satoshi Inami, MD, PhD; Hiroshi Moridaira, MD; Daisaku Takeuchi, MD; Yo Shiba, MD; Makoto Ohe, MD; Futoshi Asano, MD; Hiromichi Aoki, MD; Yutaka Nohara, MD; Hiroshi Taneichi, MD, PhD*

08:52 - 08:56 **Paper #9: Defining a Core Outcome Set for Adolescent and Young Adult Patients With a Spinal Deformity. A Collaborative Effort for the Nordic Spine Registries**
*Marinus De Kleuver, MD, PhD; Sayf S.A. Faraj, BSc; Roderick Maurits Holewijn, BS; David W. Polly, MD; Miranda L. Van Hooff, MS; Tjitske M. Haanstra, PhD*

08:56 - 09:05 **Discussion**

09:06 - 09:10 **Paper #10: Preoperative SRS Pain Score is the Primary Predictor of Postoperative Back Pain after AIS Surgery**
*Steven W. Hwang, MD; Amer F. Samdani, MD; Tracey P. Bastrom; Peter O. Newton, MD; Baron Stuart Lonner, MD; Joshua M. Pahys, MD*

## THURSDAY, SEPTEMBER 7, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

09:10 - 09:14 **Paper #11: Back Pain and its Change after Surgery in Adolescents and Young Adults wtih Idiopathic Scoliosis**
*Tamas Fulop Fekete, MD; Anne F. Mannion, PhD; Frank S. Kleinstueck, MD; Markus Loibl; Dezsoe J. Jeszenszky, MD, PhD*

09:14 - 09:18 **Paper #12: Expanding AIS Gene Discovery: A Consortium-Based Meta-Analysis**
*Anas M. Khanshour, PhD; John A Herring, MD; Shiro Ikegawa, MD, PhD; Ikuyo Kou; Kota Watanabe, MD, PhD; You-Qiang Song; Keith D K Luk, MD; Kenneth MC Cheung, MD; Nancy Hadley Miller, MD; Erin E. Baschal, PhD; Cristina M Justice, PhD; Carol A. Wise, PhD*

09:18 - 09:27 **Discussion**

09:28 - 09:32 **Paper #13: Intraspinal Pathology(ISP) in Severe Spinal Deformity(SSD): A Ten-year MRI Review**
*Jingming Xie, MD; Ying Zhang, MD; Yingsong Wang, MD; Ni Bi, MD; Zhiyue Shi, MD; Zhi Zhao, MD; Jie Zhang, MD; Tao Li, MD*

09:32 - 09:36 **Paper #14: Prevalence and Characteristics of Scoliosis in Patients Operated for Pectus Excavatum: A Radiographic Study of 326 Patients**
*Sébastien Charosky, MD; Neil Upadhyay, MD; Iria Vazquez Vecilla; Pierre Moreno; Benjemin Moreno*

09:36 - 09:40 **Paper #15: Mental Health and not Deformity Magnitude Correlate to Self Image in Adolescent Idiopathic Scoliosis**
*Michael P Kelly, MD; Tracey P. Bastrom; Lawrence G. Lenke, MD; Michelle Claire Marks, PT, MA; Peter O. Newton, MD; Harms Study Group*

09:40 - 09:49 **Discussion**

09:49 - 10:10 **Break**

### Session 2: Non-Operative Management, Natural History, and Spondylolisthesis

10:10 - 12:30

*Moderators: Firoz Miyanji, MD, FRCSC; Yong Qiu, MD*

10:10 - 10:14 **Paper #16: AIS Bracing Success is Influenced by Time In Brace: Comparative Effectiveness Analysis of BrAIST and ISICO Cohorts**
*Lori A. Dolan, PhD; Sabrina Donzelli, MD; Fabio Zaina, MD; Stefano Negrini, MD; Stuart L. Weinstein, MD*

10:14 - 10:18 **Paper #17: Efficacy of Bracing for Main-lumbar vs Main-thoracic Curves in Patients with Adolescent Idiopathic Scoliosis at Risser 0**
*John Vorhies, MD; Lori Ann Karol, MD; John A Herring, MD*

10:18 - 10:22 **Paper #18: Comparison of Treatment's Effectiveness Between Providence Braces and Boston Braces in Adolescent Idiopathic Scoliosis**
*Julie Joncas, RN, BSc; Stefan Parent, MD, PhD; Marjolaine Roy-Beaudry, MSc; Mathieu Nault; Morris Duhaime, MD; Jean-Marc Mac-Thiong, MD, PhD; Hubert Labelle, MD*

10:22 - 10:31 **Discussion**

10:32 - 10:36 **Paper #19: Risk Factors for Progression of Thoracolumbar/Lumbar Curve with Lumbar Modifier C and Low Back Pain in Non-Operated Patients with Adolescent Idiopathic Scoliosis: Mean 25-Year Follow-Up**
*Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD*

10:36 - 10:40 **Paper #20: Long-Term Results of Compensatory Lumbar Curve in Non-operated Patients with Thoracic Adolescent Idiopathic Scoliosis**
*Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD*

10:40 - 10:44 **Paper #21: Long-Term Back Pain in Patients with Adolescent and Juvenile Idiopathic Scoliosis: A Population-Based Cohort Study**
*Aidin Kashigar; Katherine Lajkosz, MSc; Susan Brogly PhD, MSc, BSc; Ana Johnson; Daniel P. Borschneck, MD, BSc, MSc, FRCSC*

10:44 - 10:53 **Discussion**

## THURSDAY, SEPTEMBER 7, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

10:54 - 10:58 **Paper #22: Biplanar Imaging Unlocks 3D Deformity in a 30-Year Follow-up Cohort of AIS Patients**
*Chenghao Zhang, MD; Charles Gerald T. Ledonio, MD; David W. Polly, MD; Clayton T Cowl; Michael J. Yaszemski, MD, PhD; A. Noelle Larson, MD;*

10:58 - 11:02 **Paper #23: Evaluating Healing Rates of Adolescent Pars Fractures Using Activity Restriction and Rigid Lumbar Brace**
*John W. McClellan, MD; Dorsey Ek, MS; Alec, P Lerner; Michaela Smith*

11:02 - 11:06 **Paper #24: Surgical Treatment of Spondylolisthesis in Adolescents Has a 47% Re-operation Rate: A Multi-Center Retrospective Cohort Study**
*Ena Nielsen, BA; Lindsay M. Andras, MD; Nicole Michael, BA; Sumeet Garg, MD; Michael Paloski DO, MBA; Brian K. Brighton, MD; David L. Skaggs, MD, MMM*

11:06 - 11:15 **Discussion**

11:16 - 11:20 **Paper #25: Guidelines for Surgical Reduction in High-Grade L5-S1 Spondylolisthesis Based on Quality of Life**
*Jean-Marc Mac-Thiong, MD, PhD; Michael T. Hresko, MD; Stefan Parent, MD, PhD; Daniel J. Sucato, MD, MS; Lawrence G. Lenke, MD; Michelle Claire Marks, PT, MA; Hubert Labelle, MD*

11:20 - 11:24 **Paper #26: Clinical Outcomes of Surgically Treated High-Grade Spondylolisthesis and Their Relation to Spinal Deformity Study Group (SDSG) Classification**
*Daniel Bouton, MD; Daniel J. Sucato, MD, MS*

11:24 - 11:28 **Paper #27: The Importance of Proximal Femoral Flexion on the Sagittal Balance and Quality of Life in High-Grade Spondylolisthesis**
*Jean-Marc Mac-Thiong, MD, PhD; Stefan Parent, MD, PhD; Julie Joncas, RN, BSc; Soraya Barchi; Hubert Labelle, MD*

11:28 - 11:37 **Discussion**

11:38 - 11:46 **Introduction of the President**
*Todd J. Albert, MD – President Elect*

11:46 - 12:06 **Presidential Address**
*Kenneth MC Cheung, MD*

12:06 - 12:35 **Presentation of Lifetime Achievement Awards**
*(see page 10-11 for additional information)*

12:35 - 13:30 **Lunch**

13:30 - 16:30 **Half-Day Courses**
*(see page 89 for additional information)*

## FRIDAY, SEPTEMBER 8, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 3A: Hibbs Basic Research Award Nominees

07:55 - 08:43

*Moderators: Charles Johnston, MD; Marinus De Kleuver, MD, PhD*

07:55 - 8:00 **Welcome & Annoucements**

08:00 - 08:04 **Paper #28: Analysis of the Associations of Polymorphism and Bone Mineral Density in Patients with Idiopathic Scoliosis**
*Miao Yu, MD*

08:04 - 08:08 **Paper #29: Intrinsic ß-catenin Overexpression in Osteoblast Could Contribute to Impaired Osteocytogenesis in Adolescent Idiopathic Scoliosis (AIS)**
*Jiajun Zhang, MPhil; Yujia Wang; Huanxiong Chen, MD, PhD; Bobby Kinwah Ng, MD; Tsz-Ping Lam; Jack C.Y. Cheng, MD; Wayne YW Lee, PhD*

08:08 - 08:12 **Paper #30: Detection of Brain Abnormalities by in Vivo MRI May Serve as a Prognostic Test for Acquired Scoliosis in Proprioception-Deficient Animal Model of AIS**
*Inbal Biton, PhD; Eran Assaraf; Yossi Smorgick; Yoram Anekstein; Elazar Zelzer, PhD; Ronen Blecher; Rod J. Oskouian, MD; Jens R. Chapman, MD; David Hanscom, MD; Robert A. Hart, MD*

08:12 - 08:21 **Discussion**

08:22 - 08:26 **Paper #31: Propionibacterium Acnes Survives Only in the Presence of Implants and Causes Late Infection**
*Yuta Shiono; Ken Ishii, MD; Kota Watanabe, MD, PhD; Morio Matsumoto, MD*

08:26 - 08:30 **Paper #32: Can MRSA Biofilm Infections Be Cleared from Pedicle Screws Intraoperatively?**
*Daniel G Meeker, BS; Karen Beenken, PhD; Weston, B Mills, BA; Richard E. McCarthy, MD; Mark S Smeltzer, PhD; David B. Bumpass, MD*

08:30 - 08:34 **Paper #33: Molecular Characterization of Intervertebral Disc Tissue by Next Generation RNA Sequencing**
*Ahmad Nassr, MD; Scott Riester; Lin Cong, MD, PhD; Mohamad Bydon, MD; A. Noelle Larson, MD*

08:34 - 08:43 **Discussion**

### Session 3B: Hibbs Clinical Research Award Nominees

08:43 - 09:48

*Moderators: Kenneth MC Cheung, MD; Muharrem Yazici, MD*

08:43 - 08:47 **Paper #34: Dose-Response Relationship Of Tranexamic Acid In Adolescent Scoliosis Surgery**
*Susan M. Goobie, MD, FRCPC; Michael T. Hresko, MD; Michael P. Glotzbecker, MD; Daniel J. Hedequist, MD; John B. Emans, MD; Lawrence I. Karlin, MD; Mary Ellen Mccann, MD, MPH; Robert, M Brustowicz, MD; Navil F. Sethna, MD; Andres Navedo, MD; Elisabeth Dwyer, BSN; Xiayi Huang, BS; Luis Periera, PhD*

08:47 - 08:51 **Paper #35: Calcium and Vitamin D for Adolescent Idiopathic Scoliosis – A Further In-depth Review Using Finite Element Analysis (FEA) for a Randomized Double-blinded Placebo-controlled Trial**
*Tsz-Ping Lam; Benjamin Hon Kei Yip, PhD; Elisa M. S. Tam, PhD; Gene Chi Wai Man, PhD; Wayne YW Lee, PhD; Kwong Man Lee; Wai Ping Fiona Yu, MPH, BSc(Advanced); Yong Qiu, MD; Bobby Kinwah Ng, MD; Jack C.Y. Cheng, MD*

08:51 - 08:55 **Paper #36: Disc Degeneration at Distal Unfused Segments after Posterior Spinal Fusion in Patients with Adolescent Idiopathic Scoliosis Lenke Type 1 or 2: A 20-Year Follow-up Study**
*Kazuki Kawakami, B.Kin; Ayato Nohara, MD; Toshiki Saito, MD; Ryoji Tauchi; Tesuya Ohara, MD; Noriaki Kawakami, MD, DMSc*

08:55 - 09:04 **Discussion**

09:05 - 09:09 **Paper #37: Minimally Invasive Lateral Lumbar Interbody Fusion for Adult Spinal Deformity: Clinical and Radiological Efficacy**
*Kee-Yong Ha; Jae-Won Lee, MD; Sang-il Kim, MD; Young-Hoon Kim; Jin-Woo Lee, MD; Hyung-Youl Park; Joo-Hyun Ahn, Fellow; Dong-Gune Chang, MD, PhD*

09:09 - 09:13 **Paper #38: An Analysis of the Relative Incidence and Outcomes of Minor vs. Major Neurological Decline after Complex Adult Spinal Deformity Surgery: A Sub-analysis of Scoli-RISK-1 Study**
*So Kato, MD; Michael G. Fehlings, MD, PhD, FRCSC FACS; Stephen J. Lewis, MD, MSc, FRCSC; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Kenneth MC Cheung, MD; Leah Yacat Carreon, MD, MSc; Mark*

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| | *B. Dekutoski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Khaled Kebaish, MD; Christopher P. Ames, MD; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Hossein Mehdian, MD, FRCS(Ed); Ferran Pellisé, MD, PhD; Sigurd H. Berven, MD* |
| 09:13 - 09:17 | **Paper #39: Clinical Results and Surgery Tactics of Spinal Osteotomy for Ankylosing Spondylitis Kyphosis: Experience with 448 Patients**<br>*Yan Wang, MD; Guoquan Zheng; Zheng Wang, MD; XueSong Zhang, MD* |
| 09:17 - 09:26 | **Discussion** |
| 09:27 - 09:31 | **Paper #40: Long-Term Outcome of Untreated Scheuermann's Kyphosis**<br>*Enrique Garrido, MD, EBOT, MRCS; Andrew David Duckworth, BSc, MBChB, MSc, FRCSEd(Tr&Orth), PhD; Joseph V J Fournier* |
| 09:31 - 09:35 | **Paper #41: A Dedicated Pediatric Spine Deformity Team Significantly Reduces Surgical Time and Cost**<br>*John M. Flynn, MD; Brendan Striano; Wallis, T Muhly, MD; Wudbhav N. Sankar, MD; Blair Kraus, RN, MSN, MBE; Vaidehi Mehta, MS, MPH; Michael Blum, RN, BSN, CNOR; Barbara DeZayas, MS, MSN, CRNA; Ron Keren, MD, MPH; Jeffrey Feldman* |
| 09:35 - 09:39 | **Paper #42: Development of a Risk Severity Score Predicting Surgical Site Infection in Early Onset Scoliosis**<br>*Hiroko Matsumoto, MA; Anas A. Minkara, BHS; Nicholas Feinberg; John T. Smith, MD; Amer F. Samdani, MD; Michael P. Glotzbecker, MD; Jeffrey R. Sawyer, MD; David L. Skaggs, MD, MMM; David Price Roye, MD; Michael Vitale, MD, MPH; Growing Spine Study Group; Children's Spine Study Group* |
| 09:39 - 09:48 | **Discussion** |
| 9:48 - 10:08 | **Break** |

### Session 4: Innovative Methods

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| 10:08 - 11:48 | |
| | *Moderators: Gregory Mundis, MD; Stefan Parent, MD, PhD* |
| 10:08 - 10:12 | **Paper #43: Anterior Spinal Growth Tethering Leads to Asymmetric Growth of the Apical Vertebra**<br>*Yi Yang, MD; Peter O. Newton, MD; Megan Jeffords, MS; Tracey P. Bastrom; Carrie E. Bartley, MA; Fredrick Reighard; Burt Yaszay, MD* |
| 10:12 - 10:16 | **Paper #44: Immediate Tridimensional Changes Following Anterior Vertebral Body Tethering in Adolescents with Idiopathic Scoliosis**<br>*Olivier Turcot; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Christian Bellefleur, MSc; Stefan Parent, MD, PhD* |
| 10:16 - 10:20 | **Paper #45: Isolated Posterior Ligamentous Reinforcement does not Decrease Proximal Junctional Kyphosis in Adult Spinal Deformity**<br>*Sravisht Iyer, MD; Francis Lovecchio, MD; Jonathan Charles Elysée, BS; Renaud Lafage; Frank J. Schwab, MD; Virginie LaFage, PhD; Han Jo Kim, MD* |
| 10:20 - 10:29 | **Discussion** |
| 10:30 - 10:34 | **Paper #46: Two Birds, One Stone: A Change in Hand Positioning for Low Dose Stereoradiography AIS Imaging Allows Concurrent, Reliable Sander's Scoring**<br>*Taylor Jackson; Daniel J Miller, MD; Susan Nelson, MD, MPH; Patrick J. Cahill, MD; John M. Flynn, MD* |
| 10:34 - 10:38 | **Paper #47: 3D Printing Innovation in the Surgical Management of Adolescent Idiopathic Scoliosis Patients**<br>*Alpaslan Senkoylu, MD; Mehmet Cetinkaya; Ali Eren, MD; Ismail Daldal; Erdem Aktas, Orthopaedic Surgeon; Dino Samartzis, DSc; Elsan Necefov, MD* |
| 10:38 - 10:42 | **Paper #48: Patient Specific Navigation Yields Accurate Pedicle Screw Placement across Surgeons of Varying Experience**<br>*Kyle Walker, MD; Joel Kolmodin; Michael, P Silverstein, MD; Eric, J Rodriguez, BS; Brandon L. Raudenbush, DO; David P. Gurd, MD* |
| 10:42 - 10:51 | **Discussion** |

## FRIDAY, SEPTEMBER 8, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

10:52 - 10:56 **Paper #49: Development of a Software Estimates Spinal Alignment Utilizing Artificial Intelligence for Scoliosis Screening**
*Kota Watanbe, MD, PhD; Ran Choi, MD; Nobuyuki Fujita, MD, PhD; Yoji Ogura; Satoru Demura, MD; Toshiaki Kotani, MD, PhD; Kanichiro Wada, MD; Masashi Miyazaki, MD; Hideki Shigematsu, MD; Yoshimitsu Aoki, MD; Morio Matsumoto, MD*

10:56 - 11:00 **Paper #50: Temporary Magnetic Controlled Growing Rods (MCGR) for the Treatment of Severe Scoliosis Provides Maximum Curve Correction and Spinal Height Restoration: A 6 Years Experience from First to Latest Case**
*Heiko Koller; Axel Hempfing, MD; Aiman Tateen, MD; Michael Mayer, MD, PhD*

11:00 - 11:04 **Paper #51: Posterolateral Diskectomies for Pediatric Spinal Deformities: Indications, Outcomes, and Comparison with Anteroposterior Spinal Arthrodesis**
*Amit Jain, MD; Brian T. Sullivan, BS; Hamid Hassanzadeh, MD; Paul D. Sponseller, MD, MBA*

11:04 - 11:13 **Discussion**

11:14 - 11:17 **2018 IMAST Preview**

11:17 - 11:20 **2018 Annual Meeting Preview**

11:20 - 11:23 **Worldwide Conferences Preview**

11:23 - 11:28 **Harrington Lecture Introduction**

11:28 - 11:48 **Harrington Lecture**
*(see page 10 for additional information)*

11:48 - 12:05 **Break**

12:05 - 13:05 **Lunchtime Symposia**
*(see page 165-167 for additional information)*

13:05 - 13:15 **Break**

### Session 5: Early Onset Scoliosis (Runs Concurrenltly with Session 6)

13:15 - 15:04
*Moderators: Laurel C. Blakemore, MD; Kota Watanabe, MD, PhD*

13:15 - 13:19 **Paper #52: Building the Case for Optimal Prophylaxis for Growth-Friendly Surgery for Non-Idiopathic Scoliosis: Using Vancomycin and Aminoglycosides**
*Anas A. Minkara, BHS; Michael Vitale, MD, MPH; Hiroko Matsumoto, MA; Michael P. Glotzbecker, MD; John M. Flynn, MD; John T. Smith, MD; Amer F. Samdani, MD; Lisa Saiman, MD, MPH; Children's Spine Study Group*

13:19 - 13:23 **Paper #53: Deep Surgical Site Infections (SSIs) Following Growth-Friendly Procedures in Children with Non-idiopathic Scoliosis Requiring Repetitive Surgery: Per Patient Risk 6-Fold Higher than Per Procedure Risk**
*Anas A. Minkara, BHS; Michael Vitale, MD, MPH; Hiroko Matsumoto, MA; Michael P. Glotzbecker, MD; John M. Flynn, MD; John T. Smith, MD; Amer F. Samdani, MD; Lisa Saiman, MD, MPH; Children's Spine Study Group*

13:23 - 13:27 **Paper #54: Analysis of Explanted Magnetically Controlled Growing Rods from 7 UK Spinal Centers**
*Thomas J Joyce; Simon L Smith; Paul RP Rushton; Andrew J Bowey, MB ChB MRCS(Glasg) FRCS (Tr&Orth); Michael J Gibson*

13:27 - 13:36 **Discussion**

13:37 - 13:41 **Paper #55: Continued Deterioration in Pulmonary Function at Minimum 18-Year Follow-Up from Early Thoracic Fusion in Non-Neuromuscular Scoliosis**
*Daniel Bouton, MD; Lori Ann Karol, MD; Kiley Poppino, BS; Charles E. Johnston, MD*

## FRIDAY, SEPTEMBER 8, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

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|---|---|
| 13:41 - 13:45 | **Paper #56: Improvement of Pulmonary Function Measured by Patient-Reported Outcomes in Patients with Spinal Muscular Atrophy after Growth-Friendly Instrumentation**<br>*Hiroko Matsumoto, MA; John David Mueller, BS; Anas A. Minkara, BHS; Patrick J. Cahill, MD; Peter F. Sturm, MD; John T. Smith, MD; George H. Thompson, MD; Paul D. Sponseller, MD, MBA; David L. Skaggs, MD, MMM; Michael Vitale, MD, MPH; David Price Roye, MD; Growing Spine Study Group; Children's Spine Study Group* |
| 13:45 - 13:49 | **Paper #57: MRI in Early Onset Scoliosis: Is Universal Screening Necessary?**<br>*Scott Herron, MD; Anthony Kouri, MD; Elizabeth, W Hubbard, MD; Vishwas R. Talwalkar, MD; Ryan D. Muchow, MD; Henry J. Iwinski, MD; Cale Jacobs, PhD* |
| 13:49 - 13:58 | **Discussion** |
| 13:59 - 14:03 | **Paper #58: All that Glitters is Not Gold – Serial Casting for EOS Negatively Affects Health-Related Quality of Life even after Discontinuation of Serial Casting: A 2 Year Follow-up**<br>*Hiroko Matsumoto, MA; Emily Auran, BA; Chun Wai Hung, MEng; Peter F. Sturm, MD; Sumeet Garg, MD; James O. Sanders, MD; Matthew E. Oetgen, MD; David Price Roye, MD; Michael Vitale, MD, MPH; Children's Spine Study Group; Growing Spine Study Group* |
| 14:03 - 14:07 | **Paper #59: Results of Casting in Severe Infantile Scoliosis**<br>*Peter J. Stasikelis, MD; Ashley Carpenter, BS* |
| 14:07 - 14:11 | **Paper #60: Does Decompression of Chiari I Malformations Alter the Progression of Early-onset Scoliosis (EOS) -The Importance of Associated Syringomyelia?**<br>*Eric A. Davis; Amanda T. Whitaker; Michael J. Troy, BS; Michael T. Hresko, MD; John B. Emans, MD; Daniel J. Hedequist, MD; Mark Proctor, MD; Brian D. Snyder, MD, PhD; Michael P. Glotzbecker, MD* |
| 14:11 - 14:20 | **Discussion** |
| 14:21 - 14:25 | **Paper #61: Pelvic Obliquity Correction in Distraction-Based Growth Friendly Implants**<br>*Mathew D Schur, BA; Lindsay M. Andras, MD; Nicholas, R Gonsalves, MD; Paul D. Sponseller, MD, MBA; John B. Emans, MD; Michael Vitale, MD, MPH; David L. Skaggs, MD, MMM; Children's Spine Study Group; Growing Spine Study Group* |
| 14:25 - 14:29 | **Paper #62: Hemoglobin Levels Pre- and Post-Treatment as a Surrogate for Disease Severity in Early Onset Scoliosis**<br>*Michael P. Glotzbecker, MD; Alexandra Grzywna, BA; Patricia E. Miller, MS; Michael Vitale, MD, MPH; Jeffrey R. Sawyer, MD; Joshua M. Pahys, MD; Patrick J. Cahill, MD; John B. Emans, MD; Children's Spine Study Group* |
| 14:29 - 14:33 | **Paper #63: Congenital Spine Deformity with Fused Ribs Treated with Proximal Rib- vs. Spine-Based Growing Constructs**<br>*A. Noelle Larson, MD; Tricia St. Hilaire, MPH; Jeff Pawelek; David L. Skaggs, MD, MMM; John B. Emans, MD; Joshua M. Pahys, MD; Children's Spine Study Group; Growing Spine Study Group* |
| 14:33 - 14:42 | **Discussion** |
| 14:43 - 14:47 | **Paper #64: Self Sliding Growth Guidance Technique with Multisegmenter Pedicle Screw Fixation in the Treatment of EOS**<br>*Sinan Kahraman, MD; Cem Sever, MD; Selhan Karadereler, MD; Emel Kaya, MD; Isik Karalok, MD; Tunay Sanli, MA; Meric Enercan, MD; Azmi Hamzaoglu, MD* |
| 14:47 - 14:51 | **Paper #65: Growth Guidance - Evolution of a New Procedure: Rate of Complications in the First Two Years Following Implantation in the First 80 Patients**<br>*Richard E. McCarthy, MD; Frances McCullough, MNSc; David B. Bumpass, MD* |
| 14:51 - 14:55 | **Paper #66: Construct Levels to Anchored Levels Ratio and Rod Diameter are Associated with Implant-Related Complications in Traditional Growing Rods**<br>*Pooria Hosseini, MD; Behrooz A. Akbarnia, MD; Stacie Nguyen, MPH; Jeff Pawelek; John B. Emans, MD; Peter F. Sturm, MD; Paul D. Sponseller, MD, MBA; Growing Spine Study Group* |
| 14:55 - 15:04 | **Discussion** |

## FRIDAY, SEPTEMBER 8, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 6: Etiology/Genetics, Diagnosis, Miscellaneous, and Cervical Deformity (Runs Concurrently with Session 5)

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|---|---|
| 13:15 - 15:04 | *Moderators: Andre Luis Fernandes Andujar, MD; Serena S. Hu, MD* |
| 13:15 - 13:19 | **Paper #67: GWAS-associated Single Nucleotide Polymorphisms are Associated with Curve Progression in Adolescent Idiopathic Scoliosis?**<br>*Gene Chi Wai Man, PhD; Nelson Leung Sang Tang; Ting Fung Chan, PhD, BSc; Bobby Kinwah Ng, MD; Lei-lei Xu, MD; Tsz-Ping Lam, MD; ZeZhang Zhu, MD PhD; Yong Qiu, MD; Jack C.Y. Cheng, MD; Wayne YW Lee, PhD* |
| 13:19 - 13:23 | **Paper #68: A Genetic Predictive Model Estimating the Risk of Developing AIS**<br>*Lei-lei Xu, MD; Xiao-dong Qin, PhD; Weixiang Sun, MD; Weiguo Zhu, MD, PhD; ZeZhang Zhu, MD PhD; Jack C.Y. Cheng, MD; Tsz-Ping Lam; Yong Qiu, MD* |
| 13:23 - 13:27 | **Paper #69: Correlation of the Sanders Skeletal Maturity Stage with Risser Stage in Adolescents with Idiopathic Scoliosis**<br>*Kushagra Verma, MD, MS; Peter G. Gabos, MD; James O. Sanders, MD; Kenneth J. Rogers, PhD, ATC; Suken A. Shah, MD* |
| 13:27 - 13:36 | **Discussion** |
| 13:37 - 13:41 | **Paper #70: Supine Radiographs are Superior to Standing Radiographs in Predicting Surgical Correction in Adult Spinal Deformity**<br>*Jeffrey J Varghese, BS; Tejbir Pannu; Jonathan Charles Elysée, BS; Sebastien Pesenti, MD; Renaud Lafage, MS; Virginie LaFage, PhD; Han Jo Kim, MD* |
| 13:41 - 13:45 | **Paper #71: Ultrasound Imaging Can Reduce Traditional Radiology in the Follow-up of Children with AIS**<br>*Edmond H. Lou, PhD, P.Eng; Rui zheng, PhD; Douglas Leon Hill, MBA; V. James Raso, MASc; Douglas M. Hedden, MD; Marc J. Moreau, MD* |
| 13:45 - 13:49 | **Paper #72: A Consistent Intraoperative Neuromonitoring Team Decreases the Number of Alerts, Stagnara Wake-up Tests, and Aborted Cases**<br>*Amer F. Samdani, MD; David S. Casper, MD; Joshua M. Pahys, MD; Maria Zuccaro, CNIM; James Zuccaro, DABNM; Steven W. Hwang, MD* |
| 13:49 - 13:58 | **Discussion** |
| 13:59 - 14:03 | **Paper #73: A Preliminary Study of Spinal Cord Blood Flow During Posterior Vertebral Column Resection in Severe Rigid Scoliokyphosis Patients**<br>*Tao Li, MD; Jingming Xie, MD; Yingsong Wang, MD; Ni Bi, MD; Ying Zhang, MD; Jie Zhang, MD; Zhiyue Shi, MD; Zhi Zhao, MD* |
| 14:03 - 14:07 | **Paper #74: Sagittal Spinal and Pelvic Parameters in Patients with Scheuermann's Disease**<br>*Saif Aldeen Farhan; Martin Christian Eichler, MD; Xiaobang Hu, PhD, CCRP; Isador H. Lieberman, MD, MBA, FRCSC; Theodore A. Belanger, MD; Arif Pendi; S. Samuel Bederman, MD, PhD, FRCSC* |
| 14:07 - 14:11 | **Paper #75: Does Preserving or Restoring Lumbar Lordosis Influence the Functional Outcome in Lumbosacral Tuberculous Spondylodiscitis?**<br>*Ajoy Prasad Shetty, MS Orth; S. Rajasekaran, MD, DNB, FRCS, MCh, PhD; Aju Bosco, MS, FNB* |
| 14:11 - 14:20 | **Discussion** |
| 14:21 - 14:25 | **Paper #76: Is there an Anatomic Predisposition to Postoperative Total Hip Arthroplasty Dislocation in Patients with Prior Lumbar Fusion?**<br>*Philip J. York; Christopher Chen, MD; Michael Reiter, PGY3; Craig Hogan, MD; Michael Dayton, MD; Evalina Burger, MD; Christopher J. Kleck, MD* |
| 14:25 - 14:29 | **Paper #77: Total Hip Arthroplasty in the Spinal Deformity Population: Does Degree of Deformity Affect Hip Stability?**<br>*Edward M. DelSole, MD; Ran Schwarzkopf, MD; Jonathan Vigdorchik, MD; Thomas J. Errico, MD; Aaron J. Buckland, MBBS, FRACS* |

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

14:29 - 14:33 **Paper #78: The Ecuador Pediatric Spine Deformity Surgery Program Development and Outcomes, 2008-2014**
*Amanda Fletcher; Richard M. Schwend, MD*

14:33 - 14:42 **Discussion**

14:43 - 14:47 **Paper #79: Neurological Complications and Recovery Rates in Adult Cervical Deformity Surgery**
*Han Jo Kim, MD; Hongda Bao, MD, PhD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Michael P Kelly, MD; Munish C Gupta, MD; Todd J. Albert, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Virginie LaFage, PhD; Christopher P. Ames, MD; International Spine Study Group*

14:47 - 14:51 **Paper #80: Prospective Multicenter Assessment of All-Cause Mortality Following Surgery for Adult Cervical Deformity (ACD)**
*Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Renaud Lafage; Gregory M. Mundis, MD; Eric O. Klineberg, MD; Virginie LaFage, PhD; Frank J. Schwab, MD; Justin K. Scheer; Michael P Kelly, MD; D. Kojo Hamilton, MD, FAANS; Munish C Gupta, MD; Vedat Deviren, MD; Richard Hostin, MD; Todd J. Albert, MD; K. Daniel Riew, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group*

14:51 - 14:55 **Paper #81: Establishing the Minimum Clinically Important Difference in NDI and mJOA for Adult Cervical Deformity**
*Alex Soroceanu, MD, MPH; Jeffrey L. Gum, MD; Michael P Kelly, MD; Peter G. Passias, MD; Justin S. Smith, MD, PhD; Themistocles S. Protopsaltis, MD; Virginie LaFage, PhD; Han Jo Kim, MD; Justin K. Scheer; Munish C Gupta, MD; Gregory M. Mundis, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group*

14:55 - 15:04 **Discussion**

15:04 - 15:25 **Break**

## Session 7: Congenital & Neuromuscular

15:25 - 17:14

*Moderators: Noriaki Kawakami, MD, DMSc; Paul D. Sponseller, MD*

15:25 - 15:29 **Paper #82: Surgical Correction of the Rigid Sharp Angular Kyphotic Deformity with Gradual Sequential Posterior Compression and Simultaneous Anterior Column Lengthening Technique After PVCR**
*Selhan Karadereler, MD; Sinan Kahraman, MD; Cem Sever, MD; Emel Kaya, MD; Ayhan Mutlu, MD; Tunay Sanli, MA; Meric Enercan, MD; Azmi Hamzaoglu, MD*

15:29 - 15:33 **Paper #83: SRS-Schwab Grade 4 Osteotomy for Angular Congenital Kyphosis: A Minimum 2-Year Follow-Up Study**
*ZeZhang Zhu, MD PhD; Xu Sun, MD, PhD; Qinghua Zhao, MD; Shifu Sha, MD, PhD; Bangping Qian, MD; Bin Wang, MD; Yang Yu, MD; Yong Qiu, MD*

15:33 - 15:37 **Paper #84: Cluster Analysis Describes Constellations of Cardiac Anomalies Presenting in Spinal Anomaly Patients (Passias)**
*Peter G. Passias, MD; Gregory W Poorman, BA; Dennis Vasquez-Montes, MS; Charles Wang, BS; John Moon, BS; Peter L Zhou, BA; Samantha R. Horn, BA; Bassel G. Diebo, MD; Shaleen Vira, MD*

15:37 - 15:46 **Discussion**

15:47 - 15:51 **Paper #85: Is It Possible to Correct Congenital Spinal Deformity Associated with Tethered Cord without Detethering?**
*Hui-Ren Tao, MD, PhD; Michael S. Chang, MD; Bo-bo Zhang, MD*

15:51 - 15:55 **Paper #86: Does Untreated Intraspinal Anomalies in Congenital Scoliosis Impact the Safety and Efficiency of Corrective Surgery for Scoliosis? A Prospective Case-Control Study**
*Qinghua Zhao, MD; Xu Sun, MD, PhD; Shifu Sha, MD, PhD; Yong Qiu, MD; ZeZhang Zhu, MD PhD*

15:55 - 15:59 **Paper #87: Thoracic Cage Deformities Affected Cardiopulmonary Function in Patients with Congenital Scoliosis**
*Youxi Lin, MD; Xingye Li, MD; Wangshu Yuan; Hui Cong, MD; Haining Tan; Jianxiong Shen, MD*

## FRIDAY, SEPTEMBER 8, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

| | |
|---|---|
| 15:59 - 16:08 | **Discussion** |
| 16:09 - 16:13 | **Paper #88: Maternal Risk Factors for Congenital Spinal Deformity Diagnosed in Infancy**<br>*Hillard T. Spencer, MD; Ming-Sum Lee, MD PhD* |
| 16:13 - 16:17 | **Paper #89: Risk of Surgical Treatment for Idiopathic-like Scoliosis Associated with Chiari 1 Malformation Following Decompression**<br>*Dong-Phuong Tran, MS; Charles E. Johnston, MD; Kaitlyn, E. Brown, MS; John A Herring, MD* |
| 16:17 - 16:21 | **Paper #90: Progression of Scoliosis in Children who Sustained Spinal Cord Injuries at 5 years of Age and Younger**<br>*Jennifer Schottler, MPT; Purnendu Gupta, MD; Kim W. Hammerberg, MD; Erin H. Kelly, PhD; Lawrence C Vogel, MD* |
| 16:21 - 16:30 | **Discussion** |
| 16:31 - 16:35 | **Paper #91: Improving Health Related Quality of Life in Patients with Non-Ambulatory Cerebral Palsy: Who Stands to Gain from Scoliosis Surgery?**<br>*Patrick J. Cahill, MD; Daniel J Miller, MD; John M. Flynn, MD; Saba Pasha; Burt Yaszay, MD; Stefan Parent, MD, PhD; Jahangir K. Asghar, MD; Mark F. Abel, MD; Joshua M. Pahys, MD; Harms Study Group; Paul D. Sponseller, MD, MBA* |
| 16:35 - 16:39 | **Paper #92: Pelvic Fixation in Cerebral Palsy Scoliosis: Differences Evident at 5-Year Follow-Up**<br>*Oussama Abousamra, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Burt Yaszay, MD; Patrick J. Cahill, MD; Peter O. Newton, MD* |
| 16:39 - 16:43 | **Paper #93: Relative Valuation of Interventions for Severe Cerebral Palsy: Spinal Correction Ranked the Most Beneficial, but Below G-tube**<br>*Amit Jain, MD; Paul D. Sponseller, MD, MBA; Brian T. Sullivan, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Unni G. Narayanan, MBBS, MSc, FRCS(C); Peter O. Newton, MD; Michelle Claire Marks, PT, MA; Harms Study Group* |
| 16:43 - 16:52 | **Discussion** |
| 16:53 - 16:57 | **Paper #94: Don't You Wish You Had Fused to the Pelvis the First Time: A Comparison of Reoperation Rate and Correction of Pelvic Obliquity**<br>*Ena Nielsen, BA; Lindsay M. Andras, MD; Laura L. Bellaire, MD; Nicholas D. Fletcher, MD; Anas A. Minkara, BHS; Michael Vitale, MD, MPH; Michael J. Troy, BS; Michael P. Glotzbecker, MD; David L. Skaggs, MD, MMM* |
| 16:57 - 17:01 | **Paper #95: Incidence and Description of Scoliotic Curves in Friedreich Ataxia Patients at Skeletal Maturity**<br>*Jean Meyblum; Anne-Laure Simon, MD; Christophe J. Vidal, MD; Keyvan Mazda, MD, MS; Brice Ilharreborde, MD, PhD* |
| 17:01 - 17:14 | **Discussion** |

## SATURDAY, SEPTEMBER 9, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 8A: Complications

07:55 - 09:05

*Moderators: Ferran Pellisé, MD, PhD; Justin S. Smith, MD, PhD*

7:55 - 8:00 **Welcome & Announcements**

08:00 - 08:04 **Paper #96: Implementing a Multidisciplinary Clinical Pathway Can Reduce the Deep Surgical Site Infection Rate After Posterior Spinal Fusion In High Risk Patients**
*Michael J. Troy, BS; Michael P. Glotzbecker, MD; Patricia E. Miller, MS; Michael T. Hresko, MD; Brian D. Snyder, MD, PhD; Lawrence I. Karlin, MD; Mary Ellen Mccann, MD, MPH; Susan M. Goobie, MD, FRCPC; Robert, M Brustowicz, MD; Andres Navedo, MD; Daniel J. Hedequist, MD; Anne-Laure Simon, MD; Keyvan Mazda*

08:04 - 08:08 **Paper #97: Postoperative Surgical Site Infection after Spine Surgery: An Update from the Scoliosis Research Society (SRS) Morbidity and Mortality Database**
*Jamal Shillingford, MD; Joseph Lawrence Laratta, MD; Alex Ha, MD; Comron Saifi, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD; Charla R. Fischer, MD*

08:08 - 08:12 **Paper #98: Topical Vancomycin Increased the Rate of Superficial Infection Without Impacting Deep Infection**
*Kelly Harms, BA; Benjamin Hooe, MD; Megan Mignemi, MD; Gregory A. Mencio, MD; Jeffrey E. Martus, MD, MS*

08:12 - 08:21 **Discussion**

08:22 - 08:26 **Paper #99: Vertebral Column Resection for the Treatment of Adult Spinal Deformities: Outcomes and Complications with Minimum 2-Year Follow-Up**
*Mostafa H. El Dafrawy, MD; Micheal Raad, MD; Moustafa Abou Areda, BA; Khaled M. Kebaish, MD*

08:26 - 08:30 **Paper #100: Perioperative Complications after Vertebral Column Resection (VCR) for Severe Pediatric Spinal Deformity**
*Lawrence G. Lenke, MD; Munish C Gupta, MD; Brenda Sides, MA; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Suken A. Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Sumeet Garg, MD; Oheneba Boachie-Adjei, MD; Michael P Kelly, MD*

08:30 - 08:34 **Paper #101: Single Stage Multi-Level PVCR for Severe & Rigid Adult Spinal Deformity Associated with Neurologic Deficit: Clinical, Radiological Results and Complications**
*Cem Sever, MD; Selhan Karadereler, MD; Gokce Feride Inan, MD; Emel Kaya, MD; Sezgi Burcin Barlas, MD; Ayhan Mutlu, MD; Yesim Erol, BSc; Tunay Sanli, MA; Sinan Kahraman, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD*

08:34 - 08:42 **Discussion**

08:43 - 08:47 **Paper #102: Postoperative Radiological Predictors for Proximal Junctional Kyphosis: Comparison of Four Radiological Predictive Models**
*Amer Sebaaly; Guillaume Riouallon; Ibrahim Obeid, MD; Maroun Rizkallah, MD; Féthi Laouissat, MD; Yann-Phillippe Charles, MD, PhD; Pierre Roussouly, MD*

08:47 - 08:51 **Paper #103: The Role of Posterior Ligamentous Tension Band in Proximal Junctional Kyphosis**
*Samuel K. Cho, MD; Jun S Kim, MD; John M. Caridi, MD*

08:51 - 08:55 **Paper #104: Recurrent Proximal Junctional Kyphosis: Incidence, Risk Factors, Revision Rates and Outcomes at 2-Year Minimum Follow-Up**
*Han Jo Kim, MD; Shan-Jin Wang, MD; Okezie K. Aguwa, MD; Renaud Lafage, MS; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Munish C Gupta, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Virginie LaFage, PhD; International Spine Study Group*

08:55 - 09:05 **Discussion**

## SATURDAY, SEPTEMBER 9, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 8B: Complications

09:06 - 10:20

*Moderators: Ilkka Helenius, MD, PhD; David W. Polly Jr., MD*

09:06 - 09:10

**Paper #105: Incidence and Risk Factors of Post-Operative Neurological Decline after Complex Adult Spinal Deformity Surgery: Results of the Scoli-RISK-1 Study**
*So Kato, MD; Michael G. Fehlings, MD, PhD, FRCSC, FACS; Stephen J. Lewis, MD, MSc, FRCSC; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Kenneth MC Cheung, MD; Leah Yacat Carreon, MD, MSc; Mark B. Dekutoski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Khaled Kebaish, MD; Christopher P. Ames, MD; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Ferran Pellisé, MD, PhD; Sigurd H. Berven, MD; Niccole M. Germscheid, MSc*

09:10 - 09:14

**Paper #106: Unilateral vs. Bilateral Lower Extremity Motor Deficit Following Complex Adult Spinal Deformity Surgery: Is there a Difference in Recovery Up to 2-Year F/U?**
*Alexander Tuchman, MD; Lawrence G. Lenke, MD; Michael G. Fehlings, MD, PhD, FRCSC FACS; Stephen J. Lewis, MD, MSc, FRCSC; Christopher I. Shaffrey, MD; Kenneth MC Cheung, MD; Leah Yacat Carreon, MD, MSc; Mark B. Dekutoski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Khaled Kebaish, MD; Christopher P. Ames, MD; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Hossein Mehdian, MD, FRCS(Ed); Ferran Pellisé, MD, PhD; Sigurd H. Berven, MD*

09:14 - 09:18

**Paper #107: Visual Loss Following Spine Surgery: What Have We Seen Within the Scoliosis Research Society (SRS) Morbidity and Mortality Database?**
*Jamal Shillingford, MD; Joseph Lawrence Laratta, MD; Nana Sarpong; Ronald A. Lehman, MD; Lawrence G. Lenke, MD; Charla R. Fischer, MD*

09:18 - 09:27

**Discussion**

09:28 - 09:32

**Paper #108: Impact of Resolved Early Major Complications on Two-Year Follow-Up Outcome Following Adult Spinal Deformity Surgery**
*Susana Núñez Pereira, MD, PhD; Alba Vila-Casademunt, MSc; Montse Domingo-Sàbat, PhD; Sleiman Haddad; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Francisco Javier Sanchez Perez-Grueso, MD; Ferran Pellisé, MD, PhD; European Spine Study Group*

09:32 - 09:36

**Paper #109: Impact of Adverse Events on the Readmission Rate, Revision Surgery and Mortality 2 Years After Complex Spine Surgery - a SAVES Follow-Up Study**
*Sven Karstensen, MD; Mathias Dahl Sørensen, BSc; Tanvir Bari, MD; Martin Gehrchen, MD, PhD; John T. Street, MD PhD; Benny T. Dahl, MD, PhD, DMSci*

09:36 - 09:40

**Paper #110: Utilizing the Fracture Risk Assessment Tool (FRAX) to Assess Risk of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery**
*Brian C Goh, BS; Akachimere C Uzosike, BA; Robert J Tamai, BA; Mostafa H. El Dafrawy, MD; Amit Jain, MD; Daniel M. Sciubba, MD; Richard Skolasky, ScD; Khaled Kebaish, MD; Brian J. Neuman, MD*

09:40 - 09:49

**Discussion**

09:50 - 09:54

**Paper #111: Pulmonary Cement Embolism Following Cement Augmented Fenestrated Pedicle Screw Fixation in Adult Spinal Deformity Patients with Severe Osteoporosis (Analysis of 2978 Fenestrated Screws)**
*Isik Karalok, MD; Emel Kaya, MD; Onur Levent Ulusoy, MD; Gokce Feride Inan, MD; Cem Sever, MD; Yesim Erol, BSc; Tunay Sanli, MA; Sinan Kahraman, MD; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD*

09:54 - 09:58

**Paper #112: Topical Vancomycin in Pediatric Spine Surgery Does Not Reduce Surgical Site Infection: A Retrospective Cohort Study**
*Sumeet Garg, MD; Nikki Bloch, BA; Morgan Potter, BA; Claire Palmer, MS; Nicole Michael, BA; Courtney O'Donnell, MD; Mark A. Erickson, MD*

09:58 - 10:02

**Paper #113: The Significance of Clunking in Magnetically Controlled Growing RodDdistractions: A Prospective Analysis of 22 Patients**
*Jason Pui Yin Cheung, MBBS (HK); Karen Kar-lum Yiu, MS; Dino Samartzis, DSc; Kenny Kwan, BMBCh(Oxon), FRCSEd; Kenneth MC Cheung, MD*

## SATURDAY, SEPTEMBER 9, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

10:02 - 10:06 **Paper #114: National Trends and In-Hospital Outcomes of Patients with Solid Organ Transplant Undergoing Spinal Fusion**
*Hiroyuki Yoshihara, MD, PhD; Carl B. Paulino, MD; Daisuke Yoneoka*

10:06 - 10:20 **Discussion**

10:21 - 10:30 **Transfer of Presidency**
*Kenneth MC Cheung, MD & Todd J. Albert, MD*

10:30 - 10:40 **Awards Presentations**

**Russell A. Hibbs Awards**

**Louis A. Goldstein Award**

**John H. Moe Award**
*Muharrem Yazici, MD - Program Comittee Chair*

10:40 - 11:00 **Break**

### Session 9: Adult Deformity

11:00 - 12:49

*Moderators: Todd J. Albert, MD; Ahmet Alanay, MD*

11:00 - 11:04 **Paper #115: Sagittal Realignment Goals Should Be Set to Ideal Proportionate Shape and Alignment Independent of Age**
*Caglar Yilgor, MD; Nuray Sogunmez, MSc; Yasemin Yavuz, PhD; Ibrahim Obeid, MD; Frank S. Kleinstueck, MD; Emre R. Acaroglu, MD; Francisco Javier Sanchez Perez-Grueso, MD; Anne F. Mannion, PhD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; European Spine Study Group*

11:04 - 11:08 **Paper #116: Global Sagittal Angle (GSA) Defines the Fan of Full Body Alignment**
*Bassel G. Diebo, MD; Carl B. Paulino, MD; Vincent Challier, MD; Gregory W Poorman, BA; Samantha R. Horn, BA; Peter L Zhou, BA; Frank A. Segreto, BS; Virginie Lafage, PhD; Peter G. Passias, MD*

11:08 - 11:12 **Paper #117: Description of the Sagittal Alignment of the Degenerative Human Spine According to Roussouly's Classification**
*Amer Sebaaly; Pierre Grobost; Lisa Mallam; Pierre Roussouly, MD*

11:12 - 11:21 **Discussion**

11:22 - 11:26 **Paper #118: Minimum Detectable Change (MDC) and Minimum Clinically Important Difference (MCID) of Health Related Quality of Life Parameters in Adult Spinal Deformity**
*Selcen Yuksel, PhD; Selim Ayhan, MD; Montse Domingo-Sàbat, PhD; Ibrahim Obeid, MD; Francisco Javier Sanchez Perez-Grueso, MD; Frank S. Kleinstueck, MD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; Emre R. Acaroglu, MD; European Spine Study Group*

11:26 - 11:30 **Paper #119: How Much Will I Improve After My Surgery and Will I Be Normal? The Critical Importance of Collecting and Discussing Patient Reported Outcomes Measures (PROMS) With Adult Spinal Deformity (ASD) Patients**
*Shay Bess, MD; Breton G. Line, BSME; Christopher P. Ames, MD; Douglas C. Burton, MD; Virginie LaFage, PhD; Renaud Lafage, MS; Robert A. Hart, MD; Michael P Kelly, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Munish C Gupta, MD; Khaled Kebaish, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group*

11:30 - 11:34 **Paper #120: Cost-Effectiveness of Operative vs Nonoperative Treatment of Adult Symptomatic Lumbar Scoliosis**
*Leah Yacat Carreon, MD, MSc; Keith H. Bridwell, MD; Michael P Kelly, MD; Christine R. Baldus, RN, MHS; Kelly R. Bratcher, RN, CCRP; Charles H. Crawford, MD; Elizabeth L. Yanik, PhD; Steven D. Glassman, MD*

11:34 - 11:43 **Discussion**

11:44 - 11:48 **Paper #121: Preoperative Osteoporosis Treatment in Patients with Lumbar Scoliosis**
*Natalia Morozova, MD; Sergey Kolesov, MD, PhD*

## SATURDAY, SEPTEMBER 9, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

11:48 - 11:52 **Paper #122: Cost Effectiveness of rhBMP-2 Use in Adult Spinal Surgery**
*Amit Jain, MD; Samrat Yeramaneni, MBBS, MS, PhD; Jeffrey L. Gum, MD; Michael P Kelly, MD; Khaled Kebaish, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Hamid Hassanzadeh, MD; Steven D. Glassman, MD; Leah Yacat Carreon, MD, MSc; Shay Bess, MD; Richard Hostin, MD; International Spine Study Group*

11:52 - 11:56 **Paper #123: Association of Degenerative Lumbar Scoliosis with the Genetic Factors in Adolescent Idiopathic Scoliosis and Disc Degeneration**
*Kazuki Takeda, MD; Naobumi Hosogane, MD; Mitsuru Yagi, MD, PhD; Shinjiro Kaneko, MD; Hitoshi Kono, MD; Masayuki Ishikawa, MD; Youhei Takahashi; Takeshi Ikegami; Kenya Nojiri, MD; Eijiro Okada, MD, PhD; Haruki Funao, MD; Kunimasa Okuyama, MD; Takashi Tsuji; Nobuyuki Fujita, MD, PhD; Narihito Nagoshi, MD, PhD; Osahiko Tsuji, MD, PhD; Yoji Ogura; Ken Ishii, MD; Keio Spine Research Group; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD; Kota Watanabe, MD, PhD; Shiro Ikegawa, MD, PhD*

11:56 - 12:05 **Discussion**

12:06 - 12:10 **Paper #124: Fractional Curves in Adult Spinal Deformity: Is it a Driver of or a Compensation for Coronal Malalignment?**
*Nicolas Plais; Hongda Bao, MD PhD; Han Jo Kim, MD; Munish C Gupta, MD; Christopher I. Shaffrey, MD; Jonathan Charles Elysée, BS; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Shay Bess, MD; Frank J. Schwab, MD; Virginie LaFage, PhD; International Spine Study Group*

12:10 - 12:14 **Paper #125: Can We Stop the Long Fusion at L5 for Selected Adult Spinal Deformity Patients with Less Severe Disability, Superior Bone Quality, and Less Complex Deformity?**
*Hiroshi Taneichi, MD, PhD; Satoshi Inami, MD, PhD; Hiroshi Moridaira, MD; Daisaku Takeuchi, MD; Tsuyoshi Sorimachi, MD; Haruki Ueda, MD; Yo Shiba, MD; Futoshi Asano, MD; Hiromichi Aoki, MD*

12:14 - 12:18 **Paper #126: Is the "2/3 Lumbar Lordosis Comes from L4-S1" Rule Predictive of Outcome Among Patients with Sagittal Plane Spinal Deformities**
*Gregory M. Mundis, MD; Renaud Lafage, MS; Robert K. Eastlack, MD; Alex Soroceanu, MD, MPH; Virginie LaFage, PhD; Daniel M. Sciubba, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Frank J. Schwab, MD; International Spine Study Group*

12:18 - 12:27 **Discussion**

12:28 - 12:32 **Paper #127: Intraoperative Neuromonitoring During Adult Spinal Deformity Surgery: Alert Positive Cases in Different Surgical Procedures**
*Go Yoshida; Tomohiko Hasegawa, MD PhD; Yu Yamato, MD, PhD; Sho Kobayashi, MD, PhD; Shin Oe, MD; Hideyuki Arima, MD, PhD; Tatsuya Yasuda, MD; Tomohiro Banno, MD; Yuki Mihara, MD; Hiroki Ushirozako; Daisuke Togawa, MD; Yukihiro Matsuyama, MD, PhD*

12:32 - 12:36 **Paper #128: Does the Use of an Interbody Fusion at the Osteotomy Site Limit the Loss of Correction After 3 Column Osteotomy in Adult Spinal Deformity?**
*Hongda Bao, MD PhD; Jeffrey J Varghese, BS; Han Jo Kim, MD; Munish C Gupta, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Shay Bess, MD; Frank J. Schwab, MD; Virginie LaFage, PhD; International Spine Study Group*

12:36 - 12:40 **Paper #129: Adult Symptomatic Lumbar Scoliosis: Randomized Results from a Dual-Arm Study**
*Michael P Kelly, MD; Elizabeth L. Yanik, PhD; Christopher I. Shaffrey, MD; Steven D. Glassman, MD Leah Yacat Carreon, MD, MSc; Han Jo Kim, MD; Lawrence G. Lenke, MD; Stephen J. Lewis, MD, MSc, FRCSC; Stefan Parent, MD, PhD; Frank J. Schwab, MD; Christine R. Baldus, RN, MHS; Keith H. Bridwell, MD*

12:40 - 12:49 **Discussion**

## SATURDAY, SEPTEMBER 9, 2017

*All abstract presentations, unless otherwise noted, will be presented in Ballroom - Salon A-F. Overflow seating will be available in Salon HIJ.*

### Session 10: Meeting Highlights and Wrap-Up

12:51 - 13:30

*Moderator: Muharrem Yazici, MD*

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|---|---|
| 12:51 - 12:54 | **Session 1 Highlights**<br>*Peter O. Newton, MD* |
| 12:54 - 12:57 | **Session 2 Highlights**<br>*Firoz Miyanji, MD, FRCSC* |
| 12:57 - 13:00 | **Session 3A Highlights**<br>*Charles E. Johnston, MD* |
| 13:00 - 13:03 | **Session 3B Highlights**<br>*Muharrem Yazici, MD* |
| 13:03 - 13:06 | **Session 4 Highlights**<br>*Gregory M. Mundis Jr., MD* |
| 13:06 - 13:09 | **Session 5 Highlights**<br>*Laurel C. Blakemore, MD* |
| 13:09 - 13:12 | **Session 6 Highlights**<br>*Andre Andujar, MD* |
| 13:12 - 13:15 | **Session 7 Highlights**<br>*Paul D. Sponseller, MD* |
| 13:15 - 13:18 | **Session 8A Highlights**<br>*Ferran Pellisé, MD* |
| 13:18 - 13:21 | **Session 8B Highlights**<br>*David W. Polly Jr., MD* |
| 13:21 - 13:24 | **Session 9 Highlights**<br>*Ahmet Alanay, MD* |
| 13:24 - 13:27 | **E-Presentations Highlights**<br>*David H. Clements III, MD* |
| 13:27 - 13:30 | **Education Program Highlights**<br>*Suken A. Shah, MD* |
| 13:30 | **Adjourn** |

# Notes

# PODIUM & CASE DISCUSSION ABSTRACTS

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges Zimmer Biomet for their support of the Annual Meeting & Course Welcome Reception, Half-Day Courses, Charging Station, Printing Station, and Newsletter.

## 1A. 3D Printed, Patient Specific Drill Guides Represent an Alternative Form of Intraoperative Navigation in Complex Spinal Reconstruction Surgery

George A. Frey

**Summary**

The use of pre-surgical planning with 3D analytics along with 3D printed, patient-matched drill guides offered an alternative form of intraoperative navigation in this case that helped reduce intraoperative radiation exposure for the patient and the surgical team while maintaining accurate screw placement.

**Hypothesis**

3D pre-surgical planning would provide an alternative to interoperative navigation.

**Design**

Case Discussion

**Introduction**

A 56 year old male patient with an ASIA-C T4 spinal cord injury presented with autonomic dysreflexia and a kyphotic deformity. He was diagnosed with an unstable Charcot spine. CT scans revealed destruction of T11/T12 as well as large masses of reactive bone and heterotopic ossification. The typical anatomical landmarks were obscured; the distinction between vertebrae difficult. Spinal fusion was recommended for Charcot instability, angular kyphosis and resulting autonomic dysreflexia.

**Methods**

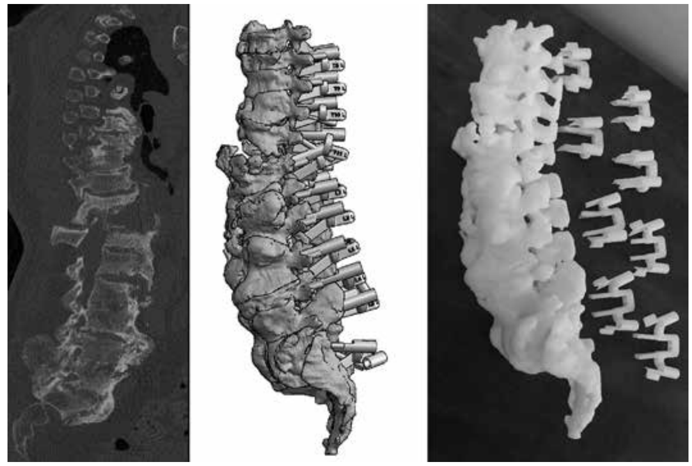
Segmentation and analytics of the CT data was performed. From this virtual 3D modeling, an actual 3D printed, sterilizable bone model was created. Optimal pedicle screw trajectories were defined, and screw specificities for length and diameter were identified. Pedicle screw drill guides corresponding to each vertebrae were then designed and 3D printed for use in the surgery; these function as patient-specific navigation guides that uniquely mate to the patient's individual vertebral anatomy and provide for accurate cannulation of each pedicle. Posterior lumbar spinal fusion from T6 to sacrum along with a posterior extracavitary corpectomy reconstruction of the Charcot defect was performed. Despite difficult anatomy, the use of the bone model and guides avoided the use of imaging for levels identification or screw placement. There were no perioperative complications.

**Results**

Post-operative CT scan was performed. Actual achieved pedicle screw trajectories were compared to the pre-operative planned trajectories. A correlation between the pre-surgically planned versus the achieved trajectories was observed in this case.

**Conclusion**

The use of pre-surgical planning with 3D analytics along with 3D printed, patient-matched drill guides offered an alternative form of intraoperative navigation in this case that helped reduce intraoperative radiation exposure for the patient and the surgical team while maintaining accurate screw placement.



## 1B. The role of magnetically-controlled growing rods as a temporary internal brace for treatment of adolescent idiopathic scoliosis with failed bracing

Jason Pui Yin Cheung, MBBS (HK); Kenny Kwan, BMBCh(Oxon), FRCSEd; Kenneth MC Cheung, MD

**Summary**

A patient with adolescent idiopathic scoliosis (AIS) is treated with dual magnetically controlled growing rods (MCGRs) after failed bracing. At maturity, the rods were removed and the resulting Cobb angle and truncal balance was improved.

**Hypothesis**

MCGRs are a viable option as an internal brace for AIS patients who failed conventional bracing.

**Design**

Case report.

**Introduction**

Bracing is a time-honored treatment to prevent curve progression in AIS. Compliance to bracing is the major obstacle for successful conservative treatment. MCGRs have been shown to be an effective treatment for early onset scoliosis its role as an internal brace for AIS has yet to be determined.

**Methods**

A 10-year-old girl with a major thoracic AIS and truncal imbalance was managed with a Boston brace. Her initial Cobb angle was 31 degrees from T5-12 with good correction in brace down to 9.6 degrees. However, bracing failed due to intolerance and the curve progressed to 40 degrees. Dual MCGRs were inserted as an internal brace.

**Results**

The Cobb angle measured 18 degrees with the dual MCGRs inserted. Seven distractions were performed and the MCGRs were removed when the patient reached skeletal maturity. After removal, the Cobb angle was 32.8 degrees which was better than preoperatively and was well maintained up to 2-years follow-up after removal. The truncal balance was also corrected with the surgery and well-maintained. Scoliosis Research Society 22-item questionnaire (SRS-22) scores were improved in general during MCGR treatment as compared to during bracing.

**Conclusion**
MCGRs are effective as an internal brace for AIS. Removal of rods without fusion at skeletal maturity is possible with improved curve magnitude and truncal balance.

## 1C. Temporary Internal Distraction Facilitates Surgical Reduction of High Grade Spondylolisthesis.

*Harry L. Shufflebarger, MD; Jahangir K. Asghar, MD*

**Summary**
Distraction is a safe and effective method of achieving spondylolisthesis reduction. Multiple methods of distraction have been employed for the past 15 years, most being cumbersome. A novel, effective, and safe method of applying significant distraction force to achieve reduction is reported. This simple technique employs iliac screws (to be retained for final construct) and temporary L3 screws.

**Hypothesis**
Distraction is a safe and effective method to achieve reduction of >50% spondylolisthesis. A novel method of application of distraction during surgery is reported.

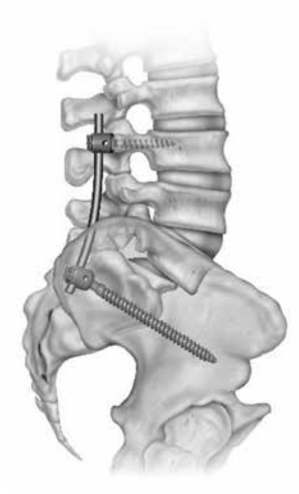
**Design**
A single case report of a new technique.

**Introduction**
Surgical reduction and fuion of high grade (>50%) adolescent spondylolisthesis is greatly facilitated by distraction during the various stages of the procedure (L4 and L5 screw placement, discectomy, sacral dome excision, reduction, and cage placement). Several methods have been employed by the authors, all cumbersome and requiring additional implants in a small space. A novel, unobstrusive technique is reported.

**Methods**
A single 14y/o 100Kg patient with >50% spondylolisthesis is the study subject. After exposure form L4 through the sacrum, bilateral L3 pedicle screws were placed, protecting the L3-4 facet. Bilateral iliac screws were placed. A CoCr rod was inserted between the L3 screw and iliac screw unilaterally, and maximally distracted. See Figure 1.

**Results**
Fluoroscopy demonstrated significant improvement in lumbosacral kyphosis, grade of displacement, and orientation of the L4 and 5 pedicles with distraction. Distraction was increased at several stages during the procedure. The remainder of the procedure proceeded relatively easily, including all additional screw placement, discectomy, sacral dome osteotomy, cage placement, and reduction. TcMEP was unchanged during the procedure. Direct stimulation of L5 root at several stages during the procedure demonstrated 20% improvement in stimulation threshhold. The distraction was removed and compression applied. Complete reduction of the displacement and the lumbosacral kyphosis was obtained. No neurologic deficits ensued. The L3 screws were removed.

**Conclusion**
Distraction is an effective adjunct to reduction of high grade spondylolisthesis. A method of internal temporary distraction, lateral to the surgical area is described.



## 1D. 20 screws in The Treatment of 4 Patients – Decision Making and Surgical Strategies in Resource Limited Countries

*Kin C. Mak, BSc, MBBS, FRCS; Kenneth MC Cheung, MD*

**Summary**
A charitable 2-man spine mission in a developing country (with average daily wage around US$8/day) had to rationalize how best to utilize remaining 20 screws to treat 4 spinal deformity patients near the end of the mission. This was an illustration of how best to utilize available resources, thus maximizing treatment for spinal deformity patients in a developing country.

**Hypothesis**
Spinal deformity surgery in developing areas (especially those with severely limited resources) can be maximized with clear understanding of principles in managing spinal deformity in young patients, and the ability to strategize under changing circumstances.

**Design**
A retrospective case series review of a surgical mission in a single centre.

**Introduction**
While it has been proven that implant density beyond 50% does not improve curve correction and that reduced screw density can help reduce operative time, risk and cost, not much has been said about how the objective of a surgical mission can be maximized without compromising surgical principles for spinal deformity in situations with severely limited resources. Furthermore, anterior approach may resolve pathologies difficult for posterior.

**Methods**
Four consecutive pateints were treated as part of charitable spine mission. Two adolescent idiopathic scoliosis, 1 congenital scoliosis and an old man with TB kyphosis and neurological deficit. Pre and post-operative neurological status and x-rays were taken and noted. The facility had no intraoperative neurmonitoring or ICU. Bending films, MRI, wake up test, fluoroscopy and transfusion were available.

**Results**
The charitable spine mission was a one week endeavor and on the last 2 days 4 patients presented requiring treatment. The 2 AIS patients had Cobb's 65° and 95°. An example after operation is in Figure 1. An 11-year old quadrant hemivertebra received vertebra excision with correction from 90° to within 40°. The TB patient had a "Hong Kong Operation" for T11 kyphosis, obviating need for instrumentation for a posterior approach. There was no neurological deterioration postoperatively.

**Conclusion**
The treatment objectives used in developed countries should be adjusted, sometimes day by day, but without compromising basic principles of spinal deformity surgery, when managing patients in developing nations with severely limited resources. Through this report, we hope these patients will not be abandoned, but even more important is that the number treated can be greatly increased.


## 2A. Two Cases of Paralysis Secondary to Aneurysmal Bone Cysts (ABC) with Complete Neurologic Recovery

*Aaron Beck, MD; David L. Skaggs, MD, MMM; Erin Kiehna, MD; Lindsay M. Andras, MD*

**Summary**
These two cases of paralysis secondary to aneurysmal bone cysts (ABC) demonstrated complete neurologic recovery following decompression and posterior spinal fusion (PSF).

**Hypothesis**
Paralysis associated with ABCs in the pediatric population may have a better outcome following decompression and PSF than predicted.

**Design**
Case report

**Introduction**
n/a

**Methods**
n/a

**Results**
Case 1: A healthy 12 year-old female presented to the ER after 2 weeks of progressive bilateral lower extremity weakness, lower back pain and inability to ambulate. On presentation, she had 0/5 motor function in both lower extremities. She had decreased sensation through dermatomes L5 and S1 and absent sensation in dermatomes L1-L4. Bowel/bladder function were spared. MRI showed a lesion involving the T9 posterior elements with cord compression. She was taken for urgent decompression and biopsy. Pathology confirmed an ABC. She returned to the operating room 1 week later for stabilization with posterior spinal fusion from T6 to T11. Over the proceeding 9 months, she had complete neurologic recovery (Figure 1). Case 2: A healthy 13 year-old female presented to the ER after 4 weeks of progressive lower back pain and 1 week of progressive bilateral lower extremity weakness, inability to ambulate, and loss of bowel/bladder control. She presented with 0/5 motor function and absent sensation throughout her bilateral lower extremities. She had decreased rectal tone. MRI imaging showed a lesion involving the posterior elements of T11 and T12 consistent with an ABC with cord compression. She underwent decompression and stabilization with posterior spinal fusion of T9 to L2. Postoperatively, she quickly regained sensation to her bilateral feet and recovered bowel/bladder function by postoperative day 4. Despite initial presentation as an ASIA A, over the ensuing 6 months, the patient demonstrated complete neurologic recovery.

**Conclusion**
These 2 patients with ABCs and spinal cord compression far exceeded initial expectations of neurologic recovery following decompression and PSF. The gradual development of compression from a tumor etiology may have allowed the cord to be more resilient than with traumatic spinal cord injuries.

## 2B. Gorham's Disease of Dorsolumbar Spine – Can We Predict Prognosis?

Hardik Suthar; Pramod Sudarshan, MS; Vamsi Krishna Varma Penumatsa; Appaji Krishnan; Sajan Hegde, MD

**Summary**
Gorham's disease of spine is an extremely rare disorder of unknown etiology characterized by idiopathic osteolysis of bone. We discussed a case of Gorham's disease in dorsolumbar spine with 7 years followup. Multiple revision surgeries, unpredictable course and significant morbidities impose great financial burden to patient and a challenge to the treating surgeon

**Hypothesis**
Gorham's disease of dorsolumbar spine and prognosis prediction

**Design**
Case report for discussion

**Introduction**
Gorham's disease is a rare disorder characterized by osteolysis and abnormal vascular growth within bones. Etiology is still unclear and no specific treatment is available. Management options include surgery, radiation therapy and medical therapy with bisphosphonate.

**Methods**
A 24 years old patient who presented with chronic mid back pain with both hip weakness was evaluated with radiographs, CT scans, MRI scans. He was operated with posterior stabilisation and anterior reconstruction with tricotical iliac bone grafting and medical treatment with intravenous zoledronate. Biopsy report was consistent with Gorham's disease. We reported difficulty in treating the disease and literature review.

**Results**
The patient had complications with rod breakage twice, staph aureus wound infection and chylothorax during the course. The fusion at the latest followup of 7 years is still questionable and further possibilities for surgery proves to be enigmatous in terms of prognosis.

**Conclusion**
Prediction of course of Gorham disease of spine is difficult. It has high morbidity, mortality and financial burden for the patient, particularly in developing country. Early spinal stabilization before irreversible neuro deficit and regular followup for timely management of complications should be considered.


## 2C. Kyphoscoliosis in Metatropic Dysplasia Treated with Staged Anterior Release and Magnetically Controlled Growing Rods (MCGR)

Jennifer M. Bauer, MD; William G. Mackenzie, MD

**Summary**
An 8-year-old boy with kyphoscoliosis from metatropic dysplasia was treated with staged anterior thoracoscopic release, 4 weeks of halo traction, and subsequent T3-T4 and L3-L4 posterior spinal fusion with MCGR instrumentation. Kyphosis improved from 106* to 43* which was maintained over several years of rod lengthenings. Anterior release and staged placement of MCGR affords correction and accommodation for the severe kyphoscoliosis.

**Hypothesis**
Kyphoscoliosis in metatropic dysplasia treated with staged anterior release and MCGR corrects severe deformity in diseased bone while allowing continued growth.

**Design**
Case Report

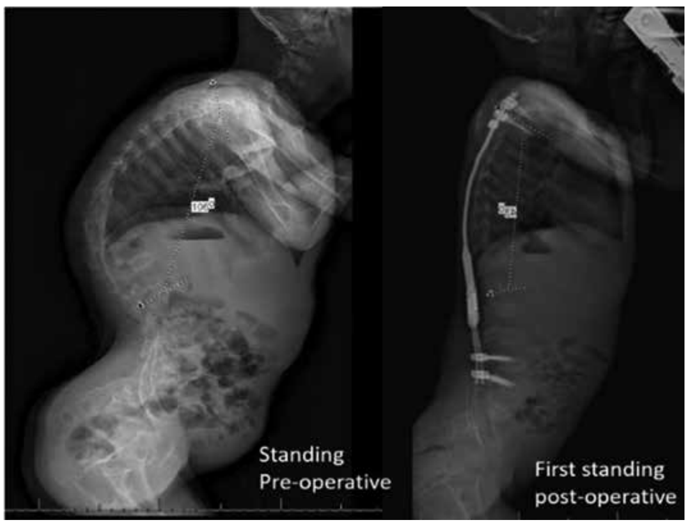
**Introduction**
Metatropic dysplasia is a rare skeletal dysplasia characterized by a short-limbed, short-trunk dysplasia with articular abnormalities and kyphoscoliosis. It is caused by an activating TRVP4 mutation which has an impact on bone growth and development that in the spine leads to severe platyspondyly and vertebral wedging. The vertebral abnormalities cause marked kyphosis which begins in the first year of life and progresses to a stiff, short thorax and restrictive lung disease. Spinal stenosis with a natural history of myelopathy results from the progressive deformity. We present a treatment strategy for a child with severe kyphoscoliosis from metatropic dysplasia, one of several who have been treated successfully in this manner.

**Methods**
An 8-year-old boy with metatropic dysplasia who initially presented at 16 months with a 58* kyphosis returned in follow-up with 106* thoracic kyphosis and 41* scoliosis with restrictive lung disease. He was treated with T7-T12 anterior thoracoscopic release of the anterior annulus and anterior longitudinal ligament without attempt to fuse, and application of halo traction. Four weeks later he returned to the operating room and underwent

T3-T4 and L3-L4 posterior fusion with MCGR spinal growing rod instrumentation.

**Results**
After anterior release and four weeks in halo traction, thoracic kyphosis improved to 50* standing in traction. After MCGR placement, thoracic kyphosis measured 43*. There were no postoperative complications. Lateral radiographs one year later show maintenance of 43* kyphosis, and he continues to do well without complication now 2 years out from index procedure.

**Conclusion**
Severe kyphoscoliosis in metatropic dysplasia can safely be treated with a staged anterior release and placement of MCGR to allow continued spine and thoracic cavity growth. In addition, the morbidity of childhood definitive fusion, as well as frequent return to surgery as with other growing rod systems, can be avoided.




## 2D. Ten-year Follow-up of Jarcho-Levin Syndrome with Thoracic Insufficiency Treated by Prosthetic Rib/Rib Based Construct-Magnetically Controlled Growing Rod Hybrid

*Kenny Kwan, BMBCh(Oxon), FRCSEd; Jason Pui Yin Cheung, MBBS (HK); Kenneth MC Cheung, MD*

**Summary**
Jarcho-Levin syndrome (JLS) results in stunted spine growth due to multiple congenital anomalies and repeated respiratory infections due to insufficient thoracic volume. We report a case with a 10-year follow-up who has been treated by prosthetic rib/rib based construct (PRRC) and magnetically controlled growing rod (MCGR) hybrid. This strategy addressed the thoracic cage deformity, spine deformity and growth, but continued distraction could lead to sagittal imbalance and kyphosis when maximal spinal height was achieved.

**Hypothesis**
A hybrid PRRC-MCGR construct can improve the chest volume and enhance spinal growth in a case of JLS.

**Design**
A case report.

**Introduction**
JLS is characterised by early onset scoliosis (EOS) and thoracic insufficiency syndrome (TIS). The use of PRRC for the treatment of TIS is well-reported. However, continued rib-rib distraction has no effect on spinal height gain. We report the outcome and challenges of a case of JLS treated by PRRC-MCGR hybrid construct.

**Methods**
A boy with short neck and trunk, and developed respiratory distress after delivery, was diagnosed with JLS. He required oxygen supplementation, had frequent respiratory infections, and the diagnosis of TIS was made at aged 2. He underwent right and left PRRC at the age of 38 and 59 months respectively. During this period, there was minimal gain in spinal height, and rib-to-pelvis MCGRs were implanted bilaterally to distract and lengthen the spine when he was aged 8. At aged 12, no further distraction was possible and there was no increase in body height or spinal length. Serial radiographs showed progressive kyphosis, and all implants were removed.

**Results**
At aged 2 when the PRRC constructs were implanted, his computerised tomography (CT) lung volumetry of 197$cm^3$. His lung volume increased by 51% over the course of subsequent three years. He no longer required oxygen supplementation, and was free from chest infections. He underwent 24 MCGR lengthenings on the left and 21 on the right using an external magnet in the outpatient setting. Over a period of four years, there was an increased in body height by 15.3%, lateral spine height by 5%, C7 plumb line-S1 distance by 93%, and thoracic width by 8%. His CT lung volumetry had increased to 640$cm^3$. After removal of all implants, there was an improvement in his sagittal profile.

**Conclusion**
Our case highlights an innovative use of hybrid PRRC-MCGR construct in the management of TIS in in the context of reduced spinal column length. The addition of MCGR can be considered to maximize spinal growth potential in patients suffering from TIS.

### 3A. Management of the Most Severe Dystrophic Cervical Kyphosis (140 degrees) in Neurofibromatosis Type 1

*Yat Wa Wong, MD; Jason Pui Yin Cheung, MBBS (HK); Keith D K Luk, MD; Kenneth MC Cheung, MD*

**Summary**
A severe case of dystrophic cervical kyphosis due to neurofibromatosis is presented. The deformity and neurological deficit was improved by halo traction prior to posterior spinal fusion. Due to extensive vertebral bone loss and presence of plexiform neurofibromata at the head and neck region, a new pillar of bone was created posteriorly using a combination of bone morphogenetic protein 2 (BMP-2), autogenic, and allogenic bone graft to support the skull.

**Hypothesis**
Stable fixation is important for solid fusion. BMP-2 can be used to promote fusion and formation of bony column.

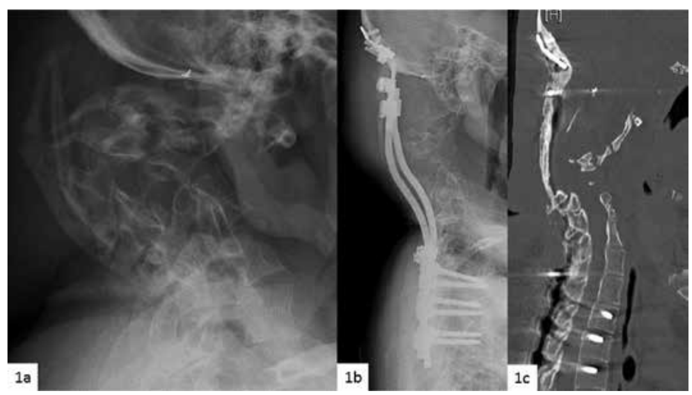
**Design**
Case Report

**Introduction**
Dural ectasia can cause progressive bony erosion, vertebral collapse and neurological deficit. Spinal reconstruction is often difficult due to extensive bone loss.

**Methods**
A 6-years-old boy with Type-1 Neurofibromatosis had an intradural neurofibroma at C1. Tumour excision was performed after C1 posterior arch excision and enlargement of the foramen magnum. He remained functionally and neurologically intact despite progressive cervical kyphosis. At 15 years old, he developed neck pain, right upper limb weakness, and myelopathic hand signs. Subsequent investigations revealed C1/2 instability, cervical kyphosis and C4/5 dislocation. C2-5 laminectomy and C0-T2 posterior fusion were attempted using autogenous rib grafts with postoperative halo-vest immobilization. His neurological status remained unchanged in subsequent 3 years but cervical kyphosis progressively deteriorated. At 18 years old, he developed tetraplegia and a 140-degrees cervical kyphosis (Fig 1a). PET showed no malignant neurofibroma. The kyphosis was reduced to 80 degrees by halo traction with an increasing force from 3 Kg to 24 Kg over a period of 2 months. His neurology normalized after traction. Occiput-to-T7 posterior instrumented fusion using mixture of iliac crest autograft, femoral head allograft and 12mg BMP-2. BMP-2 was used because of prior failure of fusion and extensive bony deficiency. Informed consent of using BMP-2 was obtained.

**Results**
No wound, airway and neurological complication was noted after surgery. The postoperative kyphotic angle was 100 degrees and was maintained at 1 year follow-up (Fig 1b). CT scan demonstrated well-formed posterior bony column (Fig 1c) and PET scan 1-year postoperatively did not reveal malignant transformation of the plexiform neurofibromata.

**Conclusion**
Stable fixation and adequate bone grafting is necessary to reconstruct a dystrophic cervical kyphosis. BMP-II is not contraindicated but clinicians should balance the potential risks.




### 3B. U-type Sacral Fracture and Hardware Failure After Posterior Spinal Corrective Surgery Using S2-Alar-Iliac (S2AI) Fixation in a Patient with Osteoporosis.

*Scott S. Russo, MD; Matthew W Wilkening, MD; Jordan R. Nester*

**Summary**
55 year old female with osteoporosis underwent a T9 to the pelvis instrumented fusion for degenerative scoliosis and developed a U type sacral fracture with S2AI instrumentation failure after multiple low energy falls.

**Hypothesis**
S2AI screws may create a stress riser which requires iliac screw back up in patients with osteoporosis.

**Design**
Case study

**Introduction**
As life expectancy increases, complications related to osteoporosis are becoming more common in spinal deformity patients. We

present a case of progressive painful kyphoscoliosis with significant coronal and sagittal imbalance in a 57-year-old female who had previously undergone bilateral total hip arthroplasty for low energy femoral neck fractures.

**Methods**

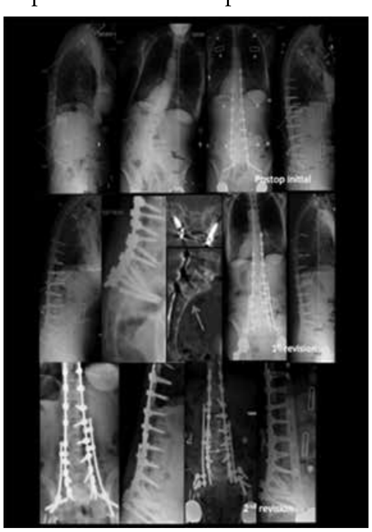
After a year of teriperatide treatment, the patient underwent a T9 to the sacrum staggered (T9 left, T11 right) posterior spinal instrumentation and fusion, with TLIF's placed at L2-3, L3-4 and L5-S1, with a bilateral S2AI screw foundation. Her postoperative course was complicated by a superficial wound infection and multiple ground-level falls. Three months following her index procedure she presented with pain and loss of sagittal balance. X-rays showed bilateral pubic rami fractures, U-type sacral fracture, and bilateral broken S2AI screws. She underwent revision fusion with bilateral iliac screw placement following unilateral extraction of the left S2AI screw. A droplock hinge pantaloon orthosis was prescribed and teriperatide was continued. At 6 months post index procedure, after 2 additional documented falls, she presented again with bilateral broken iliac screws and delayed unions of her pubic rami and sacral U fracture. She underwent a second revision surgery in which the broken left S2AI screw and bilateral iliac bolts were explanted using a novel technique in which the proximal screw threads were burred down until an easy out screw extractor was able to capture the exposed shank and facilitate extraction. She then had placement of 4 new iliac screws as well as an internal bone stimulator. Her posterior sacral fusion mass was augmented using autogenous iliac crest, bone morphogenic protein, and cancellous allograft.

**Results**

Final radiographs showed improved sagittal balance and stability at the fracture site. Postoperative CT scans suggest fracture healing of both the pubic rami and the sacrum. The patient has maintained sagittal balance and decreased pain. Additionally, we identified a technique for the removal of large screws broken deep in the ilium and sacrum.

**Conclusion**

S2AI screws without iliac screw back up may be contraindicated in patients with osteoporosis.



## 3C. Late Atraumatic Fusion Mass Fractures Occurring Between Non-bridged Constructs in Patients Requiring Fusions Distal to AIS Fusions

*Stephen J. Lewis, MD, MSc, FRCSC; Tan Chen; Mohammed Obeidat; Anupreet Bassi; So Kato, MD*

**Summary**

Distal degeneration requiring fusion is a common problem following surgery for AIS. Controversy exists on how best to manage the old implants in the face of a solid fusion mass. Two cases of late fractures through the junctional fusion mass are presented in patients where the new distal implants were not bridged to the original constructs.

**Hypothesis**

Unprotected fusion masses occurring between two spinal constructs are at risk of fracture.

**Design**

A retrospective chart and radiographic review

**Introduction**

Distal degeneration requiring fusion is a common problem following surgery for AIS. Controversy exists on how best to manage the old implants in the face of a solid fusion mass.

**Methods**

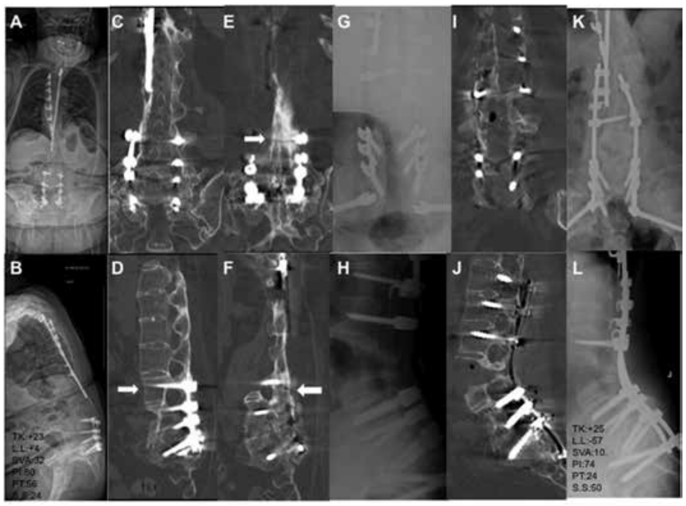
A retrospective chart and radiographic review was performed on two patients sustaining atraumatic fractures in the fusion mass between the original proximal construct and the newly added distal construct.

**Results**

A 57-year-old female underwent a Harrington rod instrumentation at the age of 12 and subsequent L3-S1 fusion for distal segment degeneration at age 40 without connection between the constructs. She presented with a transverse fracture through the pedicles and vertebral body of L3 with kyphosis. The second patient is a 39-year-old female who underwent T5-L1 fusion at age 12, presented 6 months following a T11-L5 revision posterior decompression and fusion without bridging of the constructs. A kyphotic compression fracture at T11 occurred, with resultant severe back pain and loss of alignment. Both patients underwent revision of posterior spinal instrumentation and correction of kyphotic deformity. In the first cases, upon positioning of the patient in extension on the operating room table, significant anterior gapping at the fracture site occurred, leading to full correction of the kyphotic deformity and resulted in significant epidural bleeding with subsequent hematoma requiring evacuation. The distal construct was revised and connected to the Harrington distraction rod through rod to rod side connectors. In the second case, the proximal construct was removed and a new construct was placed from the proximal thoracic region to the pelvis.

**Conclusion**

Unprotected fusion masses between constructs in the revision of old AIS posterior spinal constructs are vulnerable to fracture. This complication is preventable with bridging or overlapping of the original and new constructs. Sagittal malalignment and osteoporosis are likely significant contributors to these fractures. When extending AIS constructs secondary to distal degeneration, protecting the entire fusion mass with the new construct can prevent atraumatic fusion mass fractures.




### 3D. Vascularized Clavicle Graft Rotated into an Anterior Cervical Defect on a Sternocleidomastoid Pedicle: Case Report

*Michael Bohl, MD; Jay D. Turner; Udaya K. Kakarla, MD; Randall Porter*

**Summary**
Pedicled bone grafts afford the benefits of vascularized bone without the added morbidity of free-tissue transfer and vascular anastomosis. The use of vascularized clavicle rotated on a pedicle of sternocleidomastoid muscle for the treatment of anterior cervical deformity is reported.

**Hypothesis**
The use of a vascularized clavicular bone graft rotated into the anterior cervical spine on a pedicle of sternocleidomastoid muscle is a reasonable and technically feasible method of augmenting fusion rates in patients who have failed first-line surgical techniques and are at exceptionally high-risk of pseudoarthrosis.

**Design**
Case Report

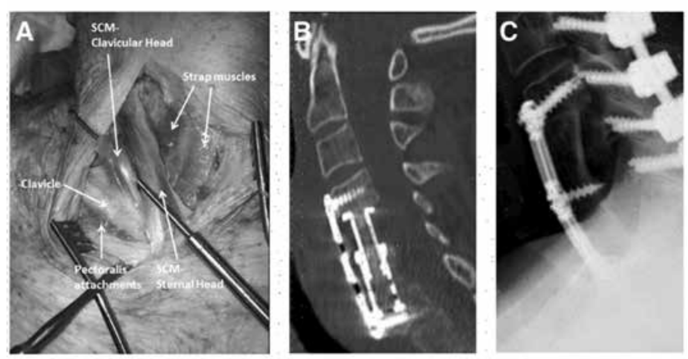
**Introduction**
The use of vascularized free fibula graft is well described for augmenting fusion in the anterior cervical spine, but the added morbidity of free-tissue transfer has precluded the wider use of this method. A vascularized clavicular graft rotated on a pedicle of sternocleidomastoid muscle (SCM) would afford all the benefits of a vascularized bone graft without the added morbidity of free tissue transfer and vascular anastomoses. This surgical technique has yet to be described in the literature.

**Methods**
A 69 year-old woman with cervical myeloradiculopathy underwent a C5-C6 corpectomy, insertion of an expandable cage, and C4-C7 anterior cervical plating for treatment of recurrent stenosis and pseudoarthrosis following a C5-6 ACDF. Two weeks after surgery she had recurrence of her neck pain, and imaging showed collapse of the C7 vertebral body and dislodging of the expandable cage. Given that she would require a third revision procedure and expansion of her corpectomy defect to 3 levels, we consented the patient for anterior cervical reconstruction with a vascularized clavicle graft, followed by posterior cervical fixation from C2-T2.

**Results**
The ipsilateral clavicle was harvested on a pedicle of SCM and implanted into the 3-level anterior cervical corpectomy defect. Care was taken to preserve the periosteum and SCM attachments providing the graft's blood supply. Postoperatively the patient required 1 month of inpatient rehab. At 2 months she developed shoulder pain and was found to have pseudoarthrosis of her clavicular repair. 3-, 6-, and 10-month postoperative imaging show continued clavicular graft hyperdensity with medullary and cortical bone growth (see Figure 1). The patient's neck pain remains well-controlled at 10 months.

**Conclusion**
The pedicled clavicular graft is a feasible technique for patients at exceptionally high risk of pseudoarthrosis. Donor site morbidity is a potential complication which could perhaps be avoided by harvesting split thickness clavicle, thereby leaving the pectoral girdle intact.

Figure 1: Pedicled Vascularized Clavicle Graft




A: Cadaver dissection demonstrating the clavicle graft and SCM pedicle. B: Preoperative CT sagittal showing a dislodged cage and collapsed C7 vertebral body. C: 6-month postoperative lateral XR showing interval growth of medullary and cortical bone in the clavicular graft.

The Russell A. Hibbs Awards are presented to both the best clinical and basic research papers presented at the 52nd Annual Meeting & Course. The nominated abstracts, selected by the Program Committee, are invited to submit manuscripts for consideration. Winners are selected on the basis of mauscripts and podium presentations.

## 1. Correlation of Lowest Level of Instrumentation to Functional Outcomes and Risk of Further Spine Surgery in AIS with Minimum 40 Year Follow-up


*Sarah T. Lander, MD; Caroline Thirukumaran; Krista Noble, BS; Ahmed Saleh, MD; Addisu Mesfin, MD; Paul T. Rubery, MD; James O. Sanders, MD*



**Summary**

In long-term follow up of patients undergoing PSIF with Harrington instrumentation comparing the lowest instrumented level with patient reported outcome measures and the need for additional surgery, patients with more caudal LIV had a higher rate of additional surgery and lower functional outcomes than those with more cephalad LIVs. This could be because of the instrumentation, the fusion, or the nature of curves requiring more caudal instrumentation.


**Hypothesis**

The more caudal the level of instrumentation the more likely the patient is to receive an additional spine surgery and the lower the patient reported functional outcomes.

**Design**

Long-term follow-up

**Introduction**

There is uncertainty in AIS instrumentation and fusion how the long-term outcomes relate to the level of instrumentation including pain and the need for further surgery.

**Methods**

We identified records of 314 patients treated by Louis A. Goldstein with Harrington instrumentation and fusion between 1961 and 1977. A search was performed identifying the patients who were then contacted for various assessments including patient related outcomes. This analysis compares the lowest level of fusion with the Oswestry Disability Index (ODI) and the SRS-7 using bivariate and multivariate analysis.

**Results**

We identified 91 living and 6 deceased patients with follow-up from 40 to 56 years and current patient age from 52 to 71 years old. 81 completed the outcome questionnaires. In those without additional surgery, those with LIV L3 and above had avg ODI of 14.12 and SRS-7 of 23.3 compared to LIV L4 and below having 17.9 and 22.7 respectively. 6/47 or 12.8% with LIV L3 and above had further surgery compared to 13/34 or 38.2% L4 and below. Those with LIV L4 and below had 2.4 times higher odds of receiving additional surgery. Patients receiving additional surgery compared to those who did not had a mean ODI of 22.8 vs 12.8 and SRS-7 of 19.6 vs 23.1. ODI disability comparison comparing those without to those with additional surgery showed 73% vs. 42% min disability, 23% vs. 53% mod disability, and 2% vs. 5% severe disability.

**Conclusion**

In long-term follow up patients with more caudal instrumentation levels had a higher rate of receiving additional surgery and lower functional outcomes than those with more cephalad LIV. Those who received additional surgery had lower functional outcome than those without. There were higher ODI and lower SRS scores in those with LIV L4 or lower compared to L3 and above in patients not receiving additional surgery, but differences were not large or statistically significant

## 2. Mean 23 Years Follow-Up Study on the Effects of Lumbar Muscular Condition on Curve Progression after Skeletal Maturity in Adolescent Idiopathic Scoliosis


*Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD; Kazuhiro Hasegawa, MD, PhD*



**Summary**

Less muscularity and greater fatty degeneration of trunk muscles including the multifidus (MF), erector spinae ES) and psoas major (PM) have significant correlation with thoracolumbar/lumbar (TL/L) curve progression during adulthood in adolescent idiopathic scoliosis (AIS).


**Hypothesis**

Lumbar muscular condition affects scoliosis progression after skeletal maturity in AIS.

**Design**

Long-term follow-up study.

**Introduction**

There is a paucity of studies investigating the relationship between skeletal muscle condition and scoliosis progression after skeletal maturity in AIS.

**Methods**

Inclusion criteria were female gender, AIS with major curve ≥ 30° at skeletal maturity (Risser grade ≥ 4), non-operative treatment, and ≥ 30 years of age at the time of the survey. Seventy-four patients [mean age 40.2 years (30–58)] with a mean follow-up of 23.3 years (12–37) after skeletal maturity were enrolled. Skeletal muscle condition was evaluated using the following parameters: skeletal muscle mass index (SMI), lumbar muscularity (cross-sectional area of muscle-vertebral body ratio×100) and fatty degeneration (signal intensity of muscle-subcutaneous fat ratio×100). SMI was measured using bioelectrical impedance analysis, and the other parameters using axial T2-weighted MR images at L4 level.

**Results**

The mean main thoracic (MT) curve at skeletal maturity and at the survey measured 44.3° (18–82) and 52.3° (23–90), and the mean TL/L curves were 35.0° (14–61) and 41.8° (19–89). The mean progression of MT and TL/L curves were 8.0° (-7–27) and

6.8° (-6–45), respectively. TL/L curve progression showed significant correlations with muscularity of MF and fatty degeneration of MF, ES, and PM (Table). There were no correlations between MT curve progression and lumbar muscle condition.

**Conclusion**

In AIS patients, particularly after skeletal maturity, lumbar muscular condition of the posterior stabilizing muscles affect further TL/L curve progression. Maintenance of trunk muscle strength especially during adulthood might be important in preventing development of the lumbar adult spinal deformity.

Table: Correlations between scoliosis progression and muscle conditions

| | Scoliosis progression [° ] | Correlation coefficient, p value |
|---|---|---|
| Body mass index, mean(SD), [kg/m²]: 20.7 (3.3) | MT curve | $r_s$=-0.062, p=0.5977 |
| | TL/L curve | $r_s$=-0.014, p=0.9049 |
| Skeletal muscle mass index, mean(SD), [kg/m²]: 7.1 (1.5) | MT curve | $r_s$=0.002, p=0.9871 |
| | TL/L curve | $r_s$=-0.042, p=0.7264 |
| Multifidus(MF) CSA, mean(SD), [%]: 23.1 (5.9) | MT curve | $r_s$=-0.106, p=0.4094 |
| | **TL/L curve** | **$r_s$=-0.288, p=0.0257** |
| MF fatty degeneration, mean(SD), [%]: 34.9 (9.8) | MT curve | $r_s$=0.182, p=0.1664 |
| | **TL/L curve** | **$r_s$=0.402, p=0.0022** |
| Erector spinae(ES) CSA, mean(SD), [%]: 79.8 (15.7) | MT curve | $r_s$=-0.136, p=0.3016 |
| | TL/L curve | $r_s$=-0.212, p=0.1071 |
| ES fatty degeneration, mean(SD), [%]: 32.2 (8.1) | MT curve | $r_s$=0.111, p=0.3909 |
| | **TL/L curve** | **$r_s$=0.360, p=0.0053** |
| Psoas major(PM) CSA, mean(SD), [%]: 40.0 (10.2) | MT curve | $r_s$=-0.027, p=0.8337 |
| | TL/L curve | $r_s$=-0.016, p=0.9039 |
| PM fatty degeneration, mean(SD), [%]: 21.3 (5.7) | MT curve | $r_s$=0.153, p=0.2400 |
| | **TL/L curve** | **$r_s$=0.260, p=0.0459** |

Abbreviations: CSA, cross sectional area; SD, standard deviation; MT, main thoracic; TL/L, thoracolumbar/lumbar

## 3. Impact of an Accelerated Discharge Pathway on Early Outcomes and Recovery Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Prospective Comparative Study

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**Summary**

An accelerated discharge pathway for post operative management following PSF for AIS can result in an earlier discharge with no difference in complications and a similar time to return to school.

**Hypothesis**

Use of an accelerated discharge pathway following PSF for AIS would result in similar return to school and postoperative pain as a traditional discharge pathway with no increase in complications.

**Design**

Prospective dual center case-control consecutive series of patients treated with PSF for AIS.

**Introduction**

The early impact on post operative pain and recovery of an accelerated discharge pathway following PSF for AIS have not been well defined.

**Methods**

A prospective evaluation of patients undergoing PSF for AIS at two high volume spine centers was performed with focus on early post operative recovery. One center used the an accelerated discharge (AD) pathway while the other used a traditional discharge (TD) pathway. Post operative quality of recovery as determined using the validated QOR9 instrument, last inpatient VAS score, and return to school when applicable were collected. Patients were matched for curve magnitude and estimated blood loss (EBL).

**Results**

30 patients treated using the AD pathway were matched by EBL and curve magnitude to 33 patients treated with the TD pathway. Length of stay was 2.7 days shorter in the AD group (2.48 ±1.22 days AD vs 5.0±0.83 days TD, p<0.0001). Preoperative demographics including age, curve magnitude (59.2°±10.6° AD vs 58.6°±10.8° TD, p=0.83), number of levels fused (11.4±2.5AD vs 11.2±2.1 TD, p=0.62) and EBL (616±193cc AD vs 669±264cc TD, p=0.38) were similar. TD patients had 30 minutes longer OR time (332±54 min TD vs 302±55min, p=0.03). Pain based on the VAS score at discharge was lower in the AD group (2.6 vs 4.5, p=0.001) and patient based quality of recovery (QOR9) scores were similar at 6 weeks follow up (15.6±2.3 AD vs 15.4±2.4 TD, p=0.80). Days until return to school was similar between groups (21.4±9.0 days AD vs 18.7±5.7 days TD, p =0.28). 1 patient in the TD group and none in the AD group developed a postoperative infection. No patient was readmitted within 90 days of discharge for medical issues.

**Conclusion**

The use of an accelerated discharge pathway resulted in a shorter length of stay with lower pain scores at discharge. No patient required readmission or sustained a wound infection related to early discharge. Quality of recovery and time off of school are likely multifactorial and not as dependent on length of stay.

## 4. Thoracic-Only Fusions for Double (Type 3) and Triple (Type 4) Major Curves in AIS at a Minimum 5 Year Follow-Up: Are They Possible and Durable?

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**Summary**

Pts. with Type 3 (Double Major) & Type 4 (Triple Major) AIS curves with MT:TL/L Cobb & AVT ratios >1.2 may be candidates for thoracic-only fusions, thus avoiding instrumentation/fusion into the lower lumbar region. 26 pts. treated in this manner have maintained satisfactory radiographic alignment & balance at a min. 5 yr FU & none in this series have had revision surgery.

**Hypothesis**

Certain pts. with Double & Triple Major AIS curves can be treated with thoracic-only fusion with successful radiographic results at a min. 5 yr FU.

**Design**

Observational Cohort

**Introduction**

The recommended fusion of Lenke Type 3 (Double Major) & Type 4 (Triple Major) AIS curves includes the structural lumbar curve. However, there is a subset of pts. with greater thoracic vs. lumbar radiographic deformities who are candidates for a thoracic-only fusion, thereby saving lumbar motion segments, but the long-term radiographic results for these pts. are unknown.

**Methods**
A multi-center prospective database was queried for pts. with Lenke Type 3 or 4 curves that had thoracic-only posterior fusions using pedicle screw constructs & a T11 to L1 LIV, thus saving the structural lumbar curve from fusion. Radiographic variables at a min. 5 yr FU were analyzed.

**Results**
There were 26 pts. with Lenke Type 3 or 4 curves (Preop Lumbar modifiers: A: n=2, B: n= 8, C: n= 16) & the LIV at T11 (n=2), T12 (n=10), or L1 (n=14). The preop mean Main Thoracic (MT) Cobb was 69° & 48° for the thoracolumbar/lumbar (TL/L) curve (MT:TL/L Cobb ratio: 1.4), while the MT apical vertebral translation (AVT) was 6.1 cm vs 2.7 cm for TL/L AVT (MT:TL/L AVT ratio: 2.3). Postop, the MT & TL/L Cobb measurements at 5 yr FU were nearly matched at 27 & 25° respectively (p=0.21). Pre- & postop coronal balance (C7-CSVL) was 1.5 & 1.8 cm respectively (p=0.16), thus demonstrating maintenance of overall coronal alignment. In the sagittal plane, the preop T10-L2 Cobb mean was 10.4° & unchanged at 10.5° at 5 yr FU (p=0.97). None of the pts. have required revision surgery at min. 5 yr FU.

**Conclusion**
A select group of pts. with Type 3 (Double major) & 4 (Triple major) AIS curves can successfully undergo a thoracic-only fusion resulting in satisfactory coronal & sagittal alignment. Preop, having a MT:TL/L Cobb ratio of >1.2 (mean 1.4), MT:TL/L AVT ratio of >1.2 (mean 2.3), & a non-structural TL/L kyphosis (T10-L2<20°) is important. The pts. in this series have all avoided fusion into the lower lumbar region thus retaining important lumbar motion segments, while maintaining a balanced spine free of any revision surgery at a min. 5 yr FU.

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## 5. Short Fusion Strategy Can Prevent Left Shoulder Elevation with Shorter Fusion Area in Lenke Type 1A Curve in Mid-Term Follow Up

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**Summary**
We estimated mid-term clinical outcome of short fusion strategy for Lenke type 1A adolescent idiopathic scoliosis (AIS). The short fusion strategy could accomplish equivalent correction of the main thoracic curve and better shoulder balance with less invasiveness compared with those in the conventional method.

**Hypothesis**
The surgical treatment with the short fusion strategy for Lenke type 1A curve can maintain balanced shoulder with shorter fusion area in mid-term follow up.

**Design**
Retrospective comparable study about radiographic outcomes between the short fusion strategy and the conventional surgery in Lenke type 1A curve.

**Introduction**
Recently, we have reported the effectiveness of the short fusion strategy in correction surgery for Lenke type 1; that is, select the upper instrumented vertebra (UIV) at one level below the end vertebra (EV) of the main thoracic curve to obtain balanced shoulder. The purpose of this study was to evaluate mid-term radiographic outcomes of the short fusion strategy for Lenke type 1A in comparison with the conventional method, in which UIV was selected at EV or proximal to EV.

**Methods**
47 patients with Lenke type 1A were included in this study. They were followed up for more than 2 years after surgery. The short fusion strategy group included 26 patients (S group, 3 male, 23 female, mean age 15.4 years), and the conventional method group 21 (C group, 2 male, 19 female, mean age 14.8 years). Radiographic outcomes and perioperative data were compared between the two groups.

**Results**
The preoperative radiographic parameters were similar between the two groups. The mean postoperative Cobb angle was slightly larger in the S group (13.9° vs. 12.4° ) and the mean correction rate was slightly smaller in the S group (73.4% vs. 78.3% ) compared with those in the C group. The number of fused vertebrae was significantly shorter in the S group (8.2 vertebrae vs. 9.7 vertebrae). The mean clavicle angle was smaller in the S group (1.2° vs. 2.0°), and radiographic shoulder height was also smaller in the S group (5.5mm vs. 9.7mm). Furthermore, the mean surgical time was shorter (142 min vs. 193 min), and intraoperative blood loss was smaller (302mL vs. 419mL) in the S group.

**Conclusion**
The short fusion strategy could reduce the left shoulder elevation in mid-term follow up with shorter fusion area and less invasive surgery by reducing the correction of main thoracic curve.

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## 6. Ponte Osteotomies Increase the Risk of Neuromonitoring Changes in Surgery for Adolescent Idiopathic Scoliosis

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**Summary**
A multicenter prospective pediatric spinal surgery registry of patients undergoing surgical AIS correction was analyzed for the use of Ponte osteotomy, reported neurological complications, and neuromonitoring changes. Ponte osteotomies were not found to be a statistically significant risk factor for peri-operative neurological injury. However, Ponte osteotomy and curve magnitude were both found to be independent risk factors for intra-operative neuromonitoring alerts.

**Hypothesis**
There is an increased incidence of neuromonitoring alerts in patients with adolescent idiopathic scoliosis (AIS) following surgical treatment with Ponte osteotomies (PO).

**Design**
Observational cohort study of prospective database registry.

**Introduction**
Despite the widespread use of PO in AIS correction, outcomes and complications in patients treated with this technique have not been well characterized.

**Methods**
A multicenter prospective registry of patients undergoing surgical correction of AIS was queried at 2-year follow up for patient demographics, surgical data, deformity characteristics and peri-operative complications. A neurological complication was defined as perioperative nerve root or spinal cord injury as identified by the surgeon. Patients were divided into those that underwent peri-apical PO and those without, and further stratified by Lenke curve classification into 3 groups (I-types 1 & 2, II- types 3, 4, 6, and III-type 5). Patients with- and without neurological complications were compared with respect to baseline demographics, surgical variables, curve types, fusion construct types (screws vs. hybrid), curve magnitude (coronal and sagittal Cobb), apical vertebral translation, and coronal- deformity angular ratios (C-DAR).

**Results**
Of 2210 patients included in the study, 1611 underwent PO. Peri-operative neurological complications occurred in 7 patients, with 6 in the PO group (0.37%) and 1 in non-PO group (0.17%) though this was not a statistically significant risk factor for peri-operative neurological injury (p = 0.45). Neuromonitoring alerts were recorded in 168 patients (7.6%: 9.3% PO group; 4.2% no-PO group (p <0.001). Multivariate logistic regression analysis found PO and curve magnitude to be independent risk factors for intra-operative neuromonitoring alerts (p < 0.01).

**Conclusion**
PO and curve magnitude were found to be independent risk factors for intra-operative neuromonitoring alerts in surgical AIS correction. The effect of Ponte osteotomy on neurological complications remains unknown due to the low incidence of these complications.

| Demographic Comparison of Ponte & No Ponte Patients (n = 2210) | | | |
|---|---|---|---|
| | Ponte Group | No Ponte Group | *p* value |
| Patients | 1611 | 599 | |
| Sex | 79.9% F | 82.1% F | p = 0.25 |
| Age | 14.6 ± 2.0 | 14.6 ± 2.2 | **p<0.001** |
| BMI | 21.0 ± 14.7 | 20.9 ± 4.67 | p = 0.81 |
| Curve Magnitude | **57.3 ± 13** | **52.4 ± 9.6** | **p<0.001** |
| T5-12 Kyphosis | 22.8 ± 14.3 | 22.8 ± 12.5 | p = 0.91 |
| Neuromonitoring Alerts | **9.82%** | **4.01%** | **p<0.001** |
| Peri-Operative Deficits | 0.37% | 0.17% | p = 0.68 |

## 7. New Sagittal Classification For AIS : Optimizing The Surgical Correction

*Kariman Abelin Genevois, MD, PhD; Pierre Roussouly, MD*

**Summary**
We propose a sagittal classification system for AIS resuming the structural consequences of AIS deformity and reciprocal changes in the cervical spine and thoraco lumbar junction in order to define reproducible guidelines to optimize the surgical correction.

**Hypothesis**
Surgical treatment of AIS aim to correct the coronal and sagittal alignment of the spine. The global alignment of the spine may be normalized through reciprocal changes between the fused and adjacent segments.

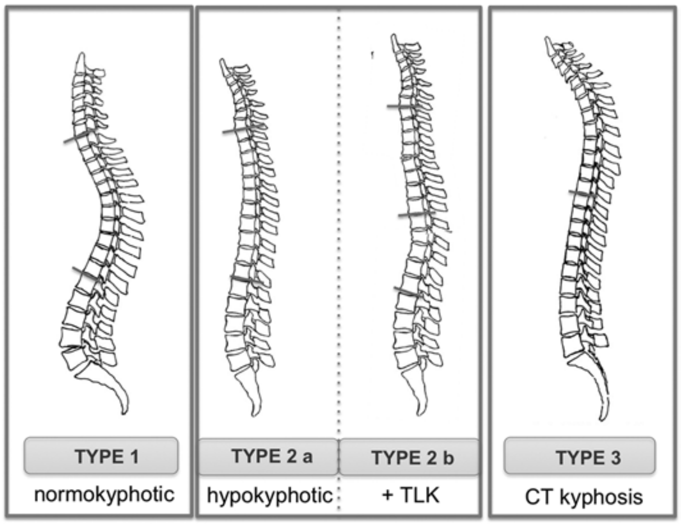
**Design**
Based on a preliminary work (Yu et al. 2013), we proposed a new classification in 3 patterns modified into a 4 types classification system (figure 1).

**Introduction**
The aim of the study is to design a new classification system to describe the global sagittal alignment of AIS as a rationale for the surgical strategy.

**Methods**
We analysed a cohort of 100 consecutive AIS patients aged between 12 and 18 years candidate for spinal fusion. Full-length AP and lateral X rays of the spine were analysed with data management software. Each case was categorized according to the Lenke classification and the new sagittal classification. The following parameters were measured and compared for each groups: - Spino pelvic parameters (PI, SS, PT, SSA) - Magnitude and length of the lumbar lordosis - Magnitude and length of the thoracic kyphosis T1T12 and T4T12 angle - TL junction (T10 L2 angle) - C7 slope, C2C6 angle.

**Results**
Half of the patients had a normal sagittal shape (type 1). Around 40% were type 2. Type 2a were mostly Lenke type 1 or 2 curves. Thoracolumbar kyphosis occurred specifically in double major or TL/L curves. Type 3 (11%) were mainly Lenke 1 curves. Spino pelvic parameters were comparable between the three groups. Three parameters strongly differentiated the three patterns : • thoracic kyphosis • thoraco lumbar junction (T10 L2 angle) • cervical orientation.

**Conclusion**
This new classification allows to resume all the pathological scenarios of the sagittal deformity of AIS into three patterns. In type 1, thoracic kyphosis is normal around 30° with straight or lordotic cervical spine. In type 2, the thoracic spine is flattened. C7 slope is reduced, inducing cervical kyphosis. In type 3, TL junction is hyperextended due to a TL/L curve inducing cervical kyphosis A specific surgical planning can be extrapolated for each of the three patterns : In Type 1 the objective is to preserve the sagittal shape. Surgery should respect the thoracic length and keep TL junction straight. In Type 2 the objective is to restore thoracic kyphosis to induce cervical lordosis. In type 2b, TL junction should be straightened. In Type 3 the objective is to reposition the sagittal thoracic apex and straighten TL junction.




## 8. Reciprocal Relationship Between Thoracic Kyphosis and Lumbo-Sacro-Pelvic Sagittal Alignment in Adolescent Idiopathic Scoliosis

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**Summary**
Analysis of the relationship between thoracic kyphosis and lumbo-sacro-pelvic sagittal alignment in thoracic adolescent idiopathic scoliosis (T-AIS) showed that thoracic sagittal plane alignment of AIS may be affected by lumbar, sacrum and pelvic alignment.

**Hypothesis**
The thoracic sagittal plane alignment of AIS is affected by lumbar, sacrum and pelvic alignment.

**Design**
Retrospective cross-sectional study

**Introduction**
The thoracic sagittal plane alignment in patients with T-AIS is important from the treatment strategy due to the influence on respiratory function. We aimed to clarify reciprocal relationship between thoracic kyphosis and lumbo-sacro-pelvic sagittal alignment in T-AIS.

**Methods**
83 patients (average age, 16 years old; male, 10; female, 73) with T-AIS were enrolled. Radiographic parameters are as follows: thoracic Cobb angle, 41±16 degrees; TK (T5-12), 16±9 degrees; LL, 53±11 degrees; max-LL (Cobb angle at which the maximum lordosis from S1), 56±11 degrees; SVA, −16±4mm; PI, 48±12 degrees; PT, 9±7 degrees; and SS, 39±9 degrees. To determine important factors related to decrease of TK, stepwise logistic regression analysis was conducted. In addition, cluster analysis based on the identified related factors was performed to classify T-AIS according to the characteristics of global sagittal plane alignment.

**Results**
The most important factor associated with decrease of TK was increase of SS ([OR]: 1.16, p=0.0003). Decrease of max-LL ([OR]: 0.89, p=0.0005) was followed. T-AIS can be classified into following types in terms of global sagittal alignment by cluster analysis: Type 1 (low SS low max-LL, n=28); Type 2 (high SS low max-LL, n=22); and Type 3 (high SS high maxLL, n=33). There was statistically significant deference in the average TK in each type of T-AIS: 15 degrees in Type 1; 6 degrees in Type 2; and 23 degrees in Type 3 (p <0.01, Tukey-Kramer HSD).

**Conclusion**
Reciprocal relationship between thoracic kyphosis and lumbo-sacro-pelvic sagittal alignment in adolescent idiopathic scoliosis was clarified. T-AIS with high SS and high max-LL showed normal sagittal profile (TK: 23 degrees). T-AIS with low SS and low max-LL, the thoracic kyphosis was also small, showed flat sagittal profile (TK: 15 degrees). On the contrary, T-AIS with low SS low max-LL compensated for the sagittal plane balance by reducing the thoracic kyphosis (TK: 6 degrees). These were consistent with minus sagittal thoracic modifier of Lenke classification. The thoracic sagittal plane alignment of AIS may be affected by lumbar, sacrum and pelvic alignment.

## 9. Defining a Core Outcome Set for Adolescent and Young Adult Patients With a Spinal Deformity: A Collaborative Effort for the Nordic Spine Registries.

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**Summary**
A core outcome set has been developed for implementation in the five national spine outcome registries of the Nordic countries: Sweden, Norway, Denmark, Finland and the Netherlands. This will subsequently allow for international benchmarking between the five national spine registries.

**Hypothesis**
International consensus can be reached on a core outcome set for spinal deformity surgery.

**Design**
Systematic review and a modified Delphi study

**Introduction**
Routine outcome measurement has been shown to improve performance in several fields of healthcare. National spine outcome registries have been initiated in five Nordic countries. However there is no agreement yet on which outcomes are essential to measure for adolescent and young adult patients with a spinal deformity. The aim of this study was to develop a core outcome set (COS) that will facilitate benchmarking within and between the 5 countries of the Nordic Spinal Deformity Society (NSDS) and other registries worldwide.

**Methods**
The systematic review has included 191 papers, which provided 39 outcome domains, classified within the WHO's International Classification of Functioning, Disability and Health (ICF)

framework. A quality analysis of the 191 papers was performed. From August 2015 to September 2016 seven representatives of the national spine surgery registries from each of NSDS countries participated in a modified Delphi study to reach consensus on which of the 39 potential outcome domains are essential to measure in every patient. After consensus was reached about the "core outcome domains", further consensus was reached on the appropriate instruments to measure these core outcome domains. Four consensus rounds were held; one face to face meeting and three web-based surveys. Consensus was defined as 71% or more agreement. Data were analyzed qualitatively and quantitatively.

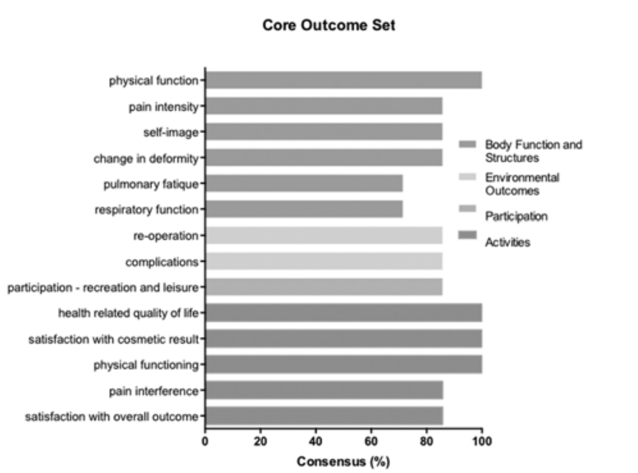
**Results**

Consensus was reached on the inclusion of 14 core outcome domains. Furthermore, existing patient-reported measurement instruments were studied to identify which core outcome domains they measure, how much time is required to complete them, quality metrics and the availability of validated translations in the Nordic languages. Panelists agreed that the SRS-22, EQ-5D and a yet to be developed respiratory questionnaire are the most comprehensive and appropriate set of patient reported measurement instruments that cover the majority of the 14 core outcome domains.

**Conclusion**

To the best of our knowledge this is the first core outcome set that has been developed for a large subgroup of spinal deformity patients. This COS is valid for implementation and validation in the NSDS countries.

**Figure 1.** The core outcome set for the Nordic Spine Registries categorized in four chapters of WHO's International Classification of Function and Disability framework.




## 10. Preoperative SRS Pain Score is the Primary Predictor of Postoperative Back Pain after AIS Surgery

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**Summary**

Back pain after surgical correction of AIS is not uncommon, but factors associated with it remain unclear. We reviewed a prospectively collected registry to identify clinical, radiographic or surgical predictors of back pain. 12% of patients had clinically significant back pain postoperatively (PO) with more frequent pain in Lenke 1 and 2 curve patterns (16%). Preoperative (PreO) SRS pain score was the most common predictor of back pain PO.

**Hypothesis**

Extension of fusions into the lumbar spine may contribute to increased back pain.

**Design**

Review of prospectively collected data

**Introduction**

Back pain has been recognized as increasingly common in PO AIS patients; however, various studies have shown conflicting factors associated with back pain.

**Methods**

We identified AIS patients having undergone surgery with at least 2 years of follow-up. Patients with SRS pain scores ≤ 3 or with a recorded complication of back pain occurring beyond 6 months PO were included in the back pain cohort and compared to the others. Any patient with a concurrent complication (e.g. pseudarthrosis, implant failure) that was associated with pain was excluded from either cohort.

**Results**

1529 patients comprised the no pain (NP) group and 215 the back pain (BP) group. In multivariate analysis of all patients (Table), curve type (16% of Lenke 1/2 curves vs. 10% of Lenke 5/6, p=0.002) and pre-op SRS pain score (NP 4.15±0.67 vs. BP 3.75±0.79 , p<0.001, meeting MCID of 0.2) remained significant. When comparing T2-4 as the UIV in Lenke 1/2 curves, 9% had pain when fused to T2, 13% when the UIV was T3 and 18% when T4 (p=0.002). Upper thoracic curve magnitude, percent correction, LIV, # levels fused, and C7 to CSVL translation were not significant.

**Conclusion**

12% of patients had back pain in our cohort after post-op recovery excluding known complications. For Lenke 1 and 2 curves the incidence decreases with more proximal instrumentation; however, the most consistent predictive factor across curve types was a low pre-op SRS pain score signifying greater pre-op pain.

Table of variables significant in multivariate analysis and odds ratios in parentheses

| ALL | Lenke 1-2 Only | Lenke 3-4 | Lenke 5-6 |
|---|---|---|---|
| **Lenke groups: 5/6 vs 1/2 (0.83)** | **UIV: T2 vs 3 vs 4 (0.48)** | **Pre Disc Angulation below EIV (0.87)** | **PreO SRS pain (0.38)** |
| **PreO PJK (1.04)** | **PreO SRS pain (0.52)** | | |
| **PreO SRS pain (0.50)** | | | |
| **2 yr T10-L2 (0.97)** | | | |

## 11. Back Pain and Its Change After Surgery in Adolescents and Young Adults with Idiopathic Scoliosis

*Tamas Fulop Fekete, MD; Anne F. Mannion, PhD; Frank S. Kleinstueck, MD; Markus Loibl; Dezsoe J. Jeszenszky, MD, PhD*

**Summary**

Surgery for adult idiopathic scoliosis (AIS) aims to prevent curve progression but in some patients it also relieves pain. We

found that, in AIS, young adults more frequently have relevant back pain (≥4/10 on pain scale) and have pain of higher average intensity than do adolescents. In patients with relevant back pain at baseline, surgery is associated with a statistically and clinically significant alleviation of pain, independent of age.

**Hypothesis**
In patients with AIS and notable back pain, surgery is associated with significant pain relief, as much so in adult patients (19-30y) as in adolescents (12-18y).

**Design**
A retrospective analysis of prospectively collected data from patients aged 12-30 y, operated for AIS in our hospital from 2005 to 2014 and registered in our local patient outcomes database linked to EUROSPSINE's Spine Tango Registry.

**Introduction**
The association between back pain and AIS is controversial. Our clinical experience is that a proportion of AIS patients, especially young adults, have relevant back pain. Whether this is related to their deformity and, hence, whether deformity surgery is associated with a relevant reduction in their pain is unclear (1). The influence of age at surgery on back pain relief also remains to be investigated.

**Methods**
Preoperatively and up to 2 years' postoperatively, patients completed the Core Outcome Measures Index, which includes two 0-10 scales for back pain and leg/buttock pain. A score of 4/10 or more is considered "relevant pain" (2).

**Results**
We identified 85 AIS patients (74 (87%) females) fitting the inclusion criteria. Of these, 60 were aged 12-18y (mean 15.5±1.7y) and 25 were 19-30y (mean 22.5±3.1y). There were no significant differences (p>0.05) between the age-groups for coronal Cobb angles of the main curves or Lenke curve types and these curves showed no correlation with pain intensity (p>0.05). Back pain was correlated with age (r=0.31, p=0.004). Preoperatively, 42% patients had a back pain score of ≥4/10 (52% in adults, 38% in adolescents). Just 8% patients had a leg pain score of ≥4/10 (16% in adults, 5% in adolescents). Those with notable back pain showed a significant (p<0.0001) improvement 2 yrs after surgery. There was no significant difference in the extent of improvement in older and younger patients (p=0.22;Figure1)

**Conclusion**
In patients with AIS, back pain is correlated with age. In those with relevant back pain at baseline, surgery is associated with a significant alleviation of pain. Skeletally mature young adults benefit as much as adolescents in terms of back pain relief. 1) Balagué F et al Scoliosis & Spinal Disorders (2016) 11:27 2) Fekete TF et al Spine J 16: S12-18, 2016

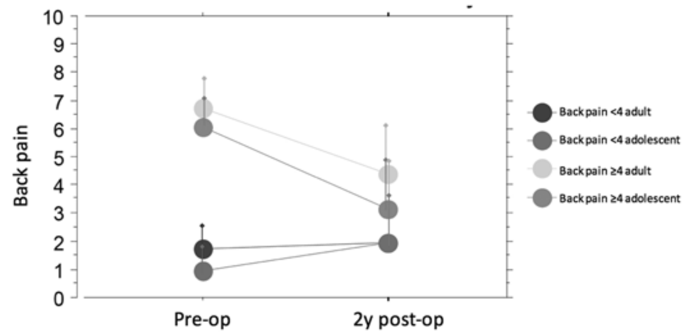


Fig 1. Change in back pain from preop to 2y postop in relation to back pain intensity preoperatively for adult and adolescent patients with AIS

## 12. Expanding AIS Gene Discovery: A Consortium-Based Meta-Analysis

*<u>Anas M. Khanshour, PhD</u>; John A Herring, MD; Shiro Ikegawa, MD, PhD; Ikuyo Kou; Kota Watanabe, MD, PhD; You-Qiang Song; Keith D K Luk, MD; Kenneth MC Cheung, MD; Nancy Hadley Miller, MD; Erin E. Baschal, PhD; Cristina M Justice PhD; Carol A. Wise, PhD*

**Summary**
Adolescent idiopathic scoliosis (AIS) is the most common pediatric spinal deformity, affecting ~3% of children worldwide. The causes of AIS are largely unknown. We performed a meta-analysis of 17,278 participants from four cases/controls discovery studies and found six novel loci potentially representing new AIS risk factors including SOX6 and CHD2 genes.

**Hypothesis**
Combining imputed genomewide association results across studies will identify new genetic risk factors for AIS that are shared between ethnicities.

**Design**
Meta-analysis of 17,278 participants of Japanese, Chinese and non-Hispanic white ancestries from four cases/controls international discovery studies.

**Introduction**
Genome-wide association studies (GWAS) have proven to be one of the most successful for discovering the genetic causes of AIS, the most common pediatric spinal deformity. Analyses of individual GWAS have yielded candidate genetic factors that have been confirmed in other follow-up studies. However, estimates suggest that more than 95% of the genetic contribution to AIS risk awaits discovery.

**Methods**
Quality control procedures, genomewide imputation and logistic regression association were completed for each discovery study separately. A meta-analysis combining all studies was performed by calculating the overall P values of a common set of 2,698,642 single nucleotide polymorphisms (SNPs) using the inverse-variance based method with genomic control correction as implemented in METAL.

**Results**
A total of 197 SNPs in four loci exceeded the genome-wide

significance threshold (P< 5 × 10-8): 10q24.31 (P= 1.2 × 10-44), 20p11.22 (P=3.2 × 10-9), 6q24.1 (P=3.6 × 10-9) and 9p22.2 (2.06 × 10-8). All of these loci were within or near previously associated genes including LBX1, PAX1, GPR126 and BNC2, respectively. In addition, we found six novel loci potentially representing new AIS risk factors. Among these signals near or within the CHD2 (P=2.8 × 10-6, rs58912384) and SOX6 (P=2.6 × 10-6, rs1455114) genes that are known to participate in spinal development.

**Conclusion**
We performed the largest international meta-analysis study for AIS to date. This study has yielded novel AIS genetic discoveries, confirming the utility of multi-ethnic meta-analyses to discover genetic risk factors for AIS.

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## 13. Intraspinal Pathology (ISP) in Severe Spinal Deformity (SSD): A Ten-year MRI Review

*<u>Ying Zhang, MD</u>; Jingming Xie, MD; Yingsong Wang, MD; Ni Bi, MD; Zhiyue Shi, MD; Zhi Zhao, MD; Jie Zhang, MD; Tao Li, MD*

**Summary**
We investigate the incidence of intraspinal pathology ISP and the clinical relevance in severe spinal deformity (SSD) at a single center.

**Hypothesis**
Preoperative whole spine MRI is essential for SSD patients.

**Design**
A cases retrospective research.

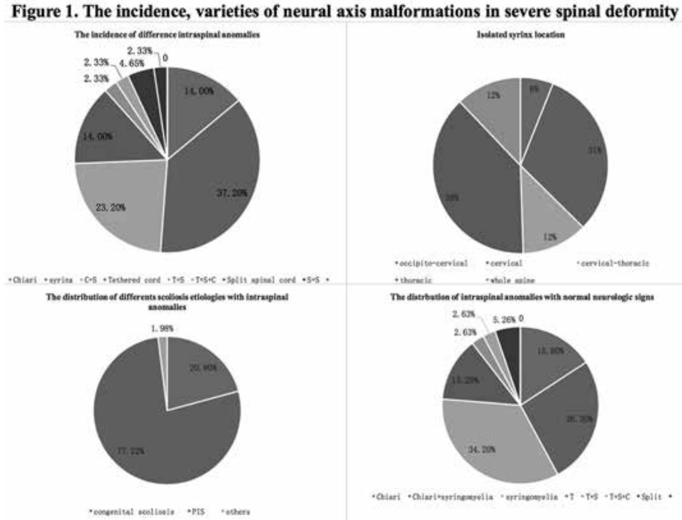
**Introduction**
Documents indicated that the average prevalence of ISP in presumed idiopathic scoliosis (PIS) patients was about 17.7%. However, few study focus on the incidence of ISP in SSD (cobb≥90°).

**Methods**
All the patients with SSD admitted for spinal surgery were evaluated from 2003-2014. Inclusion criteria: patients who present with coronal Cobb over 90° (and/or the sagittal cobb≥90°); patients with whole spine MRI done preoperatively; patients with documented clinical findings preoperatively. Exclusion criteria: ankylosing spondylitis, adult onset scoliosis, scoliosis secondary to bone destruction, spinal dysraphism.

**Results**
101 patients fulfilled the criteria were included. 43 patients were detected with ISP (about 42.6% of the total, 43/101). The most common neural anomaly was isolated-syrinx (S) (16/43, 37.2%). Of which, 43.7% (7/16), 37.5% (6/16), and 18.7% (3/16) were spindle, slit, and swelling types, respectively. Most of them were located in thoracic (6/16, 37.5%) and cervical (5/16, 31.3%) region. MRI revealed Chiari malformation with syringomyelia (C+S) in 10 patients (10/43, 23.2%), isolated Chiari malformation (C) in 6 patients (6/43, 13.9%) and others in 11 patients (11/43, 25.6%). As to the etiology, most patients with ISP were PIS (34/43, 79.1%). For PIS patients with ISP, a higher proportion of flexibility<20% (32/43 74.4%) and Kyphoscoliosis (27/43 62.8%) were present. On clinical examination, 8 of 101 patients (8/101 7.9%) had abnormal neurologic signs. 5 of 8 patients (5/8, 62.5%) with abnormal neurologic signs had ISP on MRI. (Fig. 1)

**Conclusion**
The incidence of ISP in SSD was 42.6%. 88.4% of them presents intact neurologic status. The most common neural anomaly was isolated-syrinx. Preoperative whole spine MRI must be beneficial for SSD even in the absence of neurological findings, especially in PIS (79.1%) who present flexibility<20% and Kyphoscoliosis.

**Figure 1. The incidence, varieties of neural axis malformations in severe spinal deformity**

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## 14. Prevalence and Characteristics of Scoliosis in Patients Operated for Pectus Excavatum: A Radiographic Study of 326 Patients

*<u>Sébastien Charosky, MD</u>; Neil Upadhyay, MD; Iria Vazquez Vecilla; Pierre Moreno; Benjemin Moreno*

**Summary**
Retrospective radiologic study of 326 patients operated for severe Pectus Excavatum ( mean Haller index: 4,8 ). The prevalence of scoliosis in PE patients is higher (27,6%) than rates observed in the normal population. There is a significant correlation between side of the chest deformity and convexity of scoliosis(P<0,02). Severity of PE did not correlate with increased cob angle.

**Hypothesis**
To describe the prevalence of scoliosis in patients with severe PE and characterise chest wall deformity and coronal spinal deformity.

**Design**
Retrospective radiologic study from a single centre database of patients operated on for pectus excavatum (PE).

**Introduction**
Many studies have shown coexistence of PE and scoliosis. No study has looked at the relationship between severity and types of PE and coronal spinal curve characteristics.

**Methods**
326 consecutive patients operated for PE between 2008 and 2016 were included. All patients had a 3D computerized tomography

scan (CT) of the spine and chest. Chest deformity was clinically (Chin) and radiologically (Haller index) analysed. Cobb angle measurements of coronal spinal curves were measured from CT reconstruction images.

**Results**

Mean patient age was 28 years. 60.4% patients male. 27.6% patients had a scoliosis (Cobb angle > 10°); mean Cobb angle 19.5 degrees (range 11 to 55 degrees). 18% of males who underwent surgery for PE had a scoliosis and 41.8% of female patients operated for PE had a scoliosis, which was significant (p<0.00001). Of the 326 patients, 43% (n=143) were classified Chin type I (localized deformity, symmetry of both sides), 14% (n=48) Chin type II (symmetric, more diffuse) and 41% (n=135) Chin type III (unilateral and asymmetrical deformity). Mean Haller index [HI] was 4.8 (normal HI 2.5; severe PE >3.25). A significant correlation was found between asymmetrical PE (Chin type III) and presence of a scoliosis (p<0.0005). In Chin Type III deformities, there was also a significant correlation between side of asymmetrical chest deformity and the convexity of the coronal curve (P<0.02). No correlation was found between the severity of the pectus (Haller index mean 4.8) and the presence of a scoliosis (p=0.19).

**Conclusion**

The prevalence of scoliosis in PE patients is higher than rates observed in the normal population. There is a significant correlation between side of the chest deformity and convexity of scoliosis. Severity of PE did not correlate with increased cob angle.

## 15. Mental Health and Not Deformity Magnitude Correlate to Self Image in Adolescent Idiopathic Scoliosis

*Michael P. Kelly, MD; Tracey P. Bastrom; Lawrence G. Lenke, MD; Michelle Claire Marks, PT, MA; Peter O. Newton, MD; Harms Study Group*

**Summary**

Radiographic and physical examination measurements did not correlate with self-reported Self-Image (SI) at baseline or 2yr FU in surgically treated adolescent idiopathic scoliosis (AIS). Low SI correlated weakly with Mental Health (MH) at baseline and had moderate correlation at 2yr FU. High BMI (>30) and higher Cobb measurements may increase the risk of low SI at baseline. Further examination of environmental and surgical factors related to SI perception and improvement is needed.

**Hypothesis**

Deformity magnitude as measured by physical and radiographic parameters will correlate with SRS-22r Self-Image (SI) and improvement in SI will follow deformity correction following AIS surgery.

**Design**

Observational cohort

**Introduction**

The relationship between SI and measures of deformity in AIS remains elusive. SI improvement is necessary for SRS-22r improvement in AIS.

**Methods**

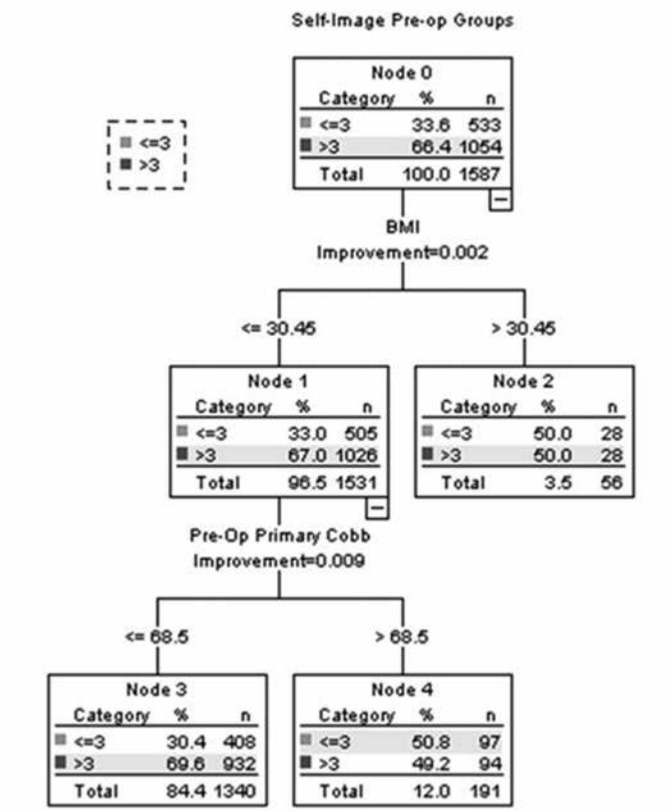
Observational cohort of AIS patients was queried for surgical patients with 2-year follow-up. Spearman rho correlations were performed between SI domain of SRS 22r and radiographic and physical examination measures at enrollment and 2yr F/U, as well as between SI and change in these measures. Poor SI was defined as scores ≤3. Recursive partitioning (CART) was used to determine factors associated with low/normal SI at enrollment and 2yr F/U

**Results**

1587 patients met inclusion. Lenke Type 1 was most common (44.4%) and Lenke 4 the least common (3.7%). At enrollment, 34% (533/1587) of patients were characterized as low SI (<3) and the strongest correlation between SI was with SRS 22r mental health (MH, r=0.38, p<0.001). No correlations were observed with pre-op radiographic or trunk shape measures. At 2 years, 2.5% (39/1587) had SI <3 and similar correlations were observed, with the strongest correlation between SI and MH (r=0.5, p<0.001). The change in deformity magnitude was not correlated to change in SI. The change in MH correlated to the change in SI (r=0.3, p<0.001). CART analysis found a preoperative BMI >30 increased the risk of low SI. For those with BMI < 30, primary Cobb° >68.5 increased the risk of SI < 3. At 2 year followup, no covariates were associated with increased risk of low SI.

**Conclusion**

Low SI is not uncommon prior to surgery. Mental health score correlates most highly with patient self-image. No deformity characteristics, including Cobb magnitude and thoracic prominence, correlated with SI at baseline or 2yr F/U. Analysis indicates that an interaction may exist between BMI and Cobb in their impact on poor self-image prior to surgery. Surgical intervention and environmental factors likely influence perception of SI.




## 16. AIS Bracing Success is Influenced by Time In Brace: Comparative Effectiveness Analysis of BrAIST and ISICO Cohorts

*Lori A. Dolan, PhD; Sabrina Donzelli, MD; Fabio Zaina, MD; Stefano Negrini, MD; Stuart L. Weinstein, MD*

**Summary**
This study corroborates previous work and provide evidence that longer hours of brace wear improve outcomes in high-risk AIS patients.

**Hypothesis**
No difference in outcome between patients treated in BrAIST and with standard care at the Italian Scientific Spine Institute (ISICO).

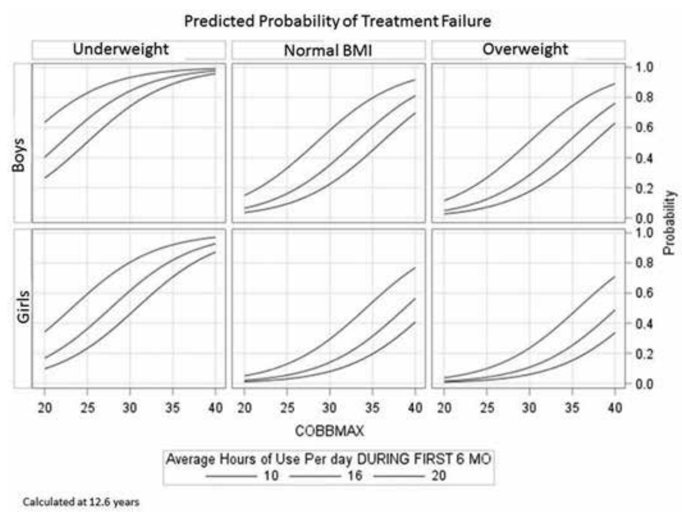
**Design**
Comparative effectiveness

**Introduction**
Studies of bracing in North America have shown worse outcomes than many studies from European centers, possibly due to sample characteristics or treatment approaches.

**Methods**
Sample: Braced patients, age 10-15, Risser< 3, Cobb 20-40°, observed to Cobb ≥40° and/or ≥Risser 4 selected from prospective databases. Comparators: Bracing per BrAIST (TLSO) and ISICO protocol (SPoRT braces with or without SEAS exercises and cognitive-behavioral support). Baseline characteristics (sex, age, BMI, Risser, Cobb, curve type) and average hrs of brace wear/day. Differences in programs (e.g. SEAS, type of brace, weaning protocol) were captured by a variable named "SITE." Outcome: Treatment failure (Cobb≥40 before Risser 4). Statistical analysis: Comparison of baseline characteristics, analyses of risk factors, treatment components and outcomes within and between cohorts using logistic regression.

**Results**
157 BrAIST and 81 ISICO subjects were included. Cohorts were similar at baseline but differed significantly in terms of average hrs of brace wear: 18.31 in the ISICO vs. 11.76 in the BrAIST cohort. 12% of the ISICO and 39% of the BrAIST cohort had failed treatment. Age, Risser, Cobb and a thoracic apex predicted failure in both groups. SITE was related to failure (OR=0.19), indicating lower odds of failure with ISICO vs BrAIST approach. With both SITE and wear time in the model, SITE was no longer a significant predictor. In the final model, the adjusted odds of failure were higher in boys (OR=3.34), and those with lowest BMI (OR=9.83); the odds increased with the Cobb angle (OR=1.23), and decreased with age (OR=0.41) and hours of wear (OR=0.86).

**Conclusion**
Treatment at the ISICO resulted in a lower failure rate, which was primarily explained by longer average hours of brace wear.




## 17. Efficacy of Bracing for Main-Lumbar vs Main-Thoracic Curves in Patients with Adolescent Idiopathic Scoliosis at Risser 0

*John Vorhies, MD; Lori Ann Karol, MD; John A Herring, MD*

**Summary**
Retrospective cohort study of bracing in AIS which demonstrates that brace wear was less effective for thoracic curves than for lumbar curves.

**Hypothesis**
Increasing hours of brace wear will be associated with decreased risk of curve progression.

**Design**
Retrospective cohort

**Introduction**
Prior research supports the efficacy of bracing in preventing curve

progression in AIS, but high quality studies have reached different conclusions about dose responsiveness of curves to bracing. Recent work has demonstrated that compliance, curve morphology, BMI, gender, skeletal maturity and curve magnitude may impact the likelihood of curve progression.

**Methods**

There were 150 thoracic and 43 lumbar curves. For thoracic vs lumbar curves, there was no difference in curve magnitude at brace initiation (32° vs 34° p=0.10), average daily brace wear (10.3 vs 8.9 hours p=0.18), correction in brace (41% vs 39% p=0.58), BMI distribution (p=0.51), rate of open triradiates and initiation (43% vs 42% p=.89), rate of progression (61% vs 58%p=0.71) or surgery (46% vs 47% p=0.95). In multivariable logistic regression, increasing brace wear was significantly associated with decreasing odds of progression of thoracic curves (OR 0.91 95%CI 0.84-0.97 p=0.005) but there was no association with odds of surgery (OR 1.04 95%CI 0.89-1.02 p=0.235) (Figure 1A,B). In lumbar curves, increasing brace wear was associated with decreased odds of progression (OR 0.77 95%CI 0.66-0.95 p=0.034) and surgery (OR 0.79 95%CI 0.66-0.94 p=0.009) (Figure 1C,D).

**Results**

There were 150 thoracic and 43 lumbar curves. For thoracic vs lumbar curves, there was no difference in curve magnitude at brace initiation (32° vs 34° p=0.10), average daily brace wear (10.3 vs 8.9 hours p=0.18), correction in brace (41% vs 39% p=0.58), BMI distribution (p=0.51), rate of open triradiates and initiation (43% vs 42% p=.89), rate of progression (61% vs 58%p=0.71) or surgery (46% vs 47% p=0.95). In multivariable logistic regression, increasing brace wear was significantly associated with decreasing risk of progression of thoracic curves (p=0.005) but there was no association with risk of surgery (p=0.235) (Figure 1A,B). In lumbar curves, increasing brace wear was associated with decreased risk of progression (p=0.034) and surgery (p=0.009) (Figure 1C,D).

**Conclusion**

In patients with AIS initiating treatment at Risser 0, increasing brace wear was associated with decrease risk of progression for thoracic curves but no significant association was found with brace wear and risk of surgery. Lumbar curves respond to bracing with increasing brace wear associated with decreased risk of curve progression and surgery.

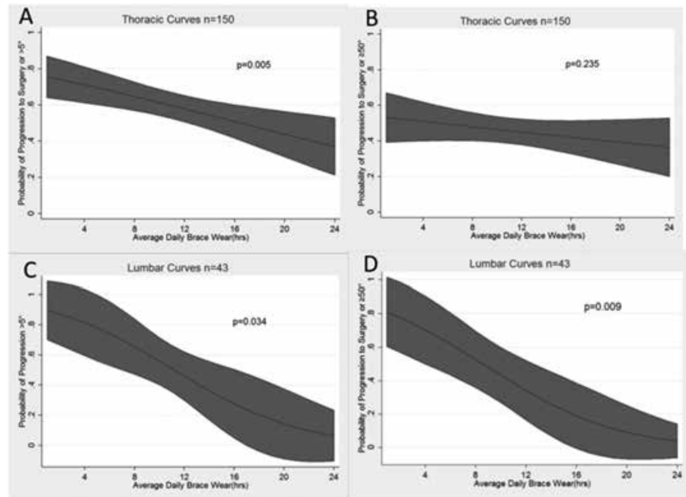



Figure 1: Margins plot with 95% confidence intervals of probability of curve progression or surgery vs average daily brace wear generated from the multivariable logistic regression model.

## 18. Comparison of Treatment's Effectiveness Between Providence Braces and Boston Braces in Adolescent Idiopathic Scoliosis

*Julie Joncas, RN, BSc; Stefan Parent, MD, PhD; Marjolaine Roy-Beaudry, MSc; Mathieu Nault; Morris Duhaime, MD; Jean-Marc Mac-Thiong, MD, PhD; Hubert Labelle, MD*

**Summary**

The aim of this study was to compare the treatment effectiveness on preventing curve progression of the Providence (Pb) and Boston (Bp) brace in AIS patients. This study suggested significant lower final Cobb in Pb treated patients in comparison to Bb patients. Pb over Bb endpoint criteria for surgery was demonstrated in adjusted models for baseline characteristics in our comparison cohort as significant. The benefits of nighttime Pb on compliance improvement and effectiveness should be confirmed in a randomized trial.

**Hypothesis**

Pb is as effective as the Bb in conservative management of AIS.

**Design**

Retrospective comparative cohort study

**Introduction**

The aim of this study was to compare the treatment effectiveness on preventing curve progression of the Pb and Bb in AIS patients.

**Methods**

Two cohorts of patients were identified at a single institution that filled the SRS criteria at the onset of bracing treatment. 51 patients treated with Pb and 122 patients treated with Bb have completed follow-up. Data collection was performed by a single experienced nurse not involved in decision-making for brace treatment nor in data analysis. Sex and age distribution were similar between the two groups. The following endpoint criteria were assessed (minimum Risser 4 with growth <1cm in previous 6 months): 1. ≥6° progression of Cobb angle, 2. exceeding 45° Cobb angle, 3. surgery undertaken or surgery's indication (≥50º Cobb angle). Differences in outcomes were assessed using

MANOVA and logistic regression, with statistical adjustment for baseline characteristics.

**Results**

Patients were more mature in the Pb group and less likely to present thoracic curves, and had smaller initial Cobb (Table). Cobb progression was 2.1±7.6° for the Pb vs 7.8±9.6° for the Bb (p<0.001); Cobb end of treatment was 25.7±7.9° for Pb and 40.0±11.2° for Bb (p<0.001). Significant proportions of patients > 6° progression (31% Pb vs 55% Bb p=0.004); >45° (5% Pb vs 33% Bb p<0.001); referred to surgery (5% Pb vs 28% Bb p<0.001). Adjusted final Cobb model showed significant difference between treatment groups (p<0.001), with initial Cobb as significant predictor. Adjusted logistic regression models on endpoint criteria show a significant difference between treatment groups for surgery (p=0.045).

**Conclusion**

This study suggested significant lower final Cobb angle in Pb treated patients in comparison to Bb patients. Although prescription patterns may differ, when adjusted models for baseline characteristics, Pb patients seemed less likely to be referred for surgery than Bb patients. The benefits of nighttime Pb on compliance improvement and effectiveness should be confirmed in a randomized trial.

Table. Patient characteristics at the onset of bracing treatment and outcome criteria.

| | Providence | | | Boston | | | p[1] | p[2] |
|---|---|---|---|---|---|---|---|---|
| Sex | 8 | males | | 16 | males | | | p=0.410 |
| | 43 | females | | 106 | females | | | |
| Age (y) | 13.4 | ± | 1.1 | 13.0 | ± | 1.2 | p=0.100 | |
| Average initial main Cobb angle (°) | 28 | ± | 5 | 32 | ± | 5 | **p<0.001** | |
| Initial Risser sign | 0 | = | 15 | 0 | = | 73 | | **p=0.001** |
| | 1 | = | 19 | 1 | = | 23 | | |
| | 2 | = | 17 | 2 | = | 26 | | |
| Average final main Cobb angle (°) | 25.7 | ± | 7.9 | 40.0 | ± | 11.2 | **p<0.001** | |
| Average progression (°) | 2.1 | ± | 7.6 | 7.8 | ± | 9.6 | **p<0.001** | |
| ≥6° progression* | 18/51 | | 30% | 67/122 | | 55% | | **p=0.004** |
| Reaching >45°* | 3/51 | | 5% | 40/122 | | 33% | | **p<0.001** |
| Surgery rate* | 3/51 | | 5% | 34/122 | | 28% | | **P=0.001** |

(y) : years
* : Expressed as percentage of patients
p[1] : TTest
p[2] : Chi-Square

## 19. Risk Factors for Progression of Thoracolumbar/Lumbar Curve with Lumbar Modifier C and Low Back Pain in Non-Operated Patients with Adolescent Idiopathic Scoliosis: Mean 25-Year Follow-Up

*Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD*

**Summary**

In non-operated patients with adolescent idiopathic scoliosis (AIS), progression of the thoracolumbar/lumbar (TL/L) curve with lumbar modifier C (Lenke classification) was associated with the level of apex and apical vertebral translation (AVT) at skeletal maturity. Moreover, low back pain (LBP) at middle age was positively correlated with AVT and L4 tilt at skeletal maturity.

**Hypothesis**

Radiographic parameters at skeletal maturity may predict progression of the TL/L curve and LBP at middle age.

**Design**

Long-term follow-up study

**Introduction**

The risk factors at skeletal maturity for progression of the TL/L curve and LBP at middle age remain unclear.

**Methods**

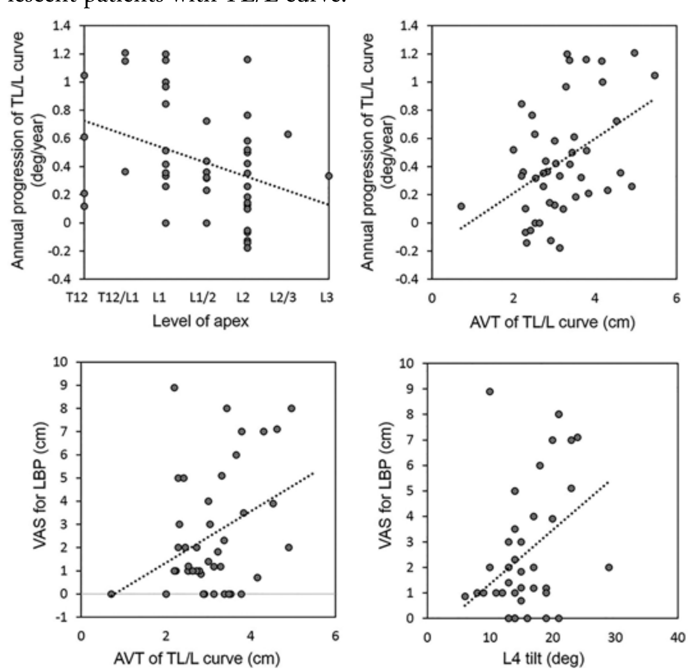
Included subjects had non-operatively treated AIS with TL/L curve (lumbar modifier C) at skeletal maturity and were ≥ 30 years of age at the survey. Of the 168 patients who met the criteria, 45 (43 females; mean age 40 ± 7.3 years) returned for a follow-up evaluation. The curve types at skeletal maturity included double curve in 32 patients and single curve in 13. Correlations between radiographic parameters at skeletal maturity and characteristics at the final follow-up were analyzed.

**Results**

The mean Cobb angle of the TL/L curve significantly increased from 38.3° ± 7.5° to 49.4° ± 13.6° (0.44° ± 0.40° per year). The magnitude and progression of the TL/L curve were not significantly different between double and single curve types. The annual progression of the TL/L curve was correlated with the AVT at skeletal maturity (r = 0.45, p = 0.002) and the level of apex (rs = -0.30, p = 0.02), but not with the Cobb angle or any other parameters. Moreover, the AVT and L4 tilt at skeletal maturity were positively correlated with the visual analogue scale for LBP (AVT/L4 tilt, r = 0.36/0.37, p = 0.02/0.01) and the Oswestry disability index (AVT/L4 tilt, r = 0.30/0.33, p = 0.047/0.03).

**Conclusion**

The AVT, apex level, and L4 tilt were each correlated with either curve progression or LBP at middle age, indicating that they should be considered when selecting treatment methods for adolescent patients with TL/L curve.



## 20. Long-Term Results of Compensatory Lumbar Curve in Non-Operated Patients with Thoracic Adolescent Idiopathic Scoliosis

*Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD. PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD*

**Summary**

In right thoracic adolescent idiopathic scoliosis (AIS) treated non-operatively, the direction of L4 tilt and C7 translation in Lenke's lumbar modifier (LM)-A moved to the right after skeletal maturity, while those in LM-B did not change. L4 tilt to the right and LM-B at skeletal maturity caused lumbar disc degeneration and low back pain (LBP) at middle age.

**Hypothesis**

The long-term results of the compensatory lumbar curve differ according to LM and the direction of the L4 tilt.

**Design**

Long-term follow-up study

**Introduction**

Previous studies have shown long-term results of the structural thoracic curve after non-operative treatment; however, those of the compensatory lumbar curve remain unclear.

**Methods**

Inclusion criteria were ≥ 30° of right thoracic AIS with LM-A or LM-B at skeletal maturity, non-operative treatment, and ≥ 30 years of age at the final follow-up. Of the 147 patients who met the criteria, 35 patients returned for a follow-up evaluation (mean age 40 years (30–52); mean follow-up 26 years (16–39) after skeletal maturity), and were divided into 3 groups based on the radiographic findings at skeletal maturity. Thirteen subjects with LM-A and L4 tilted left were classified as the AL group; 9 subjects with LM-A and L4 tilted right, as the AR group; and 13 with LM-B, as the B group. Twenty-three of the 35 patients also underwent lumbar MRI.

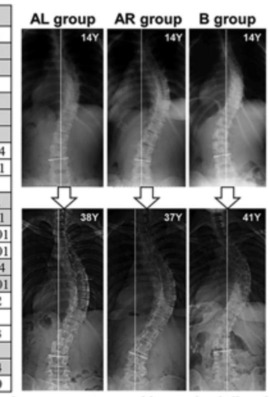
**Results**

The magnitude and progression of the main thoracic curve were not significantly different among groups. The magnitude of the lumbar curve was greatest in the B group, while their progression did not differ among groups. During follow-up, the C7 translation and L4 tilt shifted to the right in the AR and AL groups, while they did not change in the B group. Based on MRI, Pfirrmann disc scores of the lumbar region were higher in the AR and B groups, and L5/S1 disc bulging was likely to occur in the AR group compared with others. The incidence of LBP was higher in the AR and B groups.

**Conclusion**

The AR and B groups at skeletal maturity affected the long-term results of the compensatory lumbar curve. As such, the direction of L4 tilt and LM should be considered when deciding treatment methods for thoracic AIS.

| *Table* | | AL (n = 13) | AR (n = 9) | B (n = 13) | p* |
|---|---|---|---|---|---|
| Sex (male/female) | | 1/12 | 2/7 | 1/12 | 0.50 |
| Age (years) | at maturity | 14 (2) | 15 (1) | 15 (1) | 0.56 |
| | final | 38 (10) | 38 (4) | 43 (2) | 0.36 |
| Follow-up period (years) | | 24 (5) | 24 (4) | 28 (3.5) | 0.21 |
| Main thoracic curve (°) | at maturity | 40 (8) | 44 (5) | 43 (14) | 0.77 |
| | final | 54 (10)† | 56 (16)† | 54 (11)† | 0.87 |
| | Progression | 10 (34) | 12 (40) | 9 (17) | 0.87 |
| Lumbar curve (°) | at maturity | 26 (6) | 22 (9) | 30 (4) | 0.0004 |
| | final | 28 (9) | 25 (11) | 36 (3)† | 0.0021 |
| | Progression | 4 (18) | 3 (23) | 4 (19) | 0.81 |
| C7-CSVL (cm) | at maturity | -0.9 (0.8) | 0.6 (2.3) | -1.2 (1.2) | 0.011 |
| | final | 0 (1.7)† | 2.3 (1.6)† | -0.7 (1.4) | 0.0001 |
| L4 tilt (°) | at maturity | -6 (4) | 6 (5) | -10 (3) | <0.0001 |
| | final | -2 (4)† | 11 (9)† | -9 (7) | <0.0001 |
| L5 tilt (°) | at maturity | -5 (2) | 3 (5) | -6 (4) | 0.0004 |
| | final | -4 (3) | 4 (8)† | -6 (4) | <0.0001 |
| Pfirrmann score | Total Lumbar‡ | 2.4 (0.4) | 3.4 (1.0) | 3.2 (0.3) | 0.012 |
| | L4/5 | 3.3 (1.0) | 4.3 (0.3) | 3.8 (1.3) | 0.12 |
| | L5/S1 | 2.0 (1.7) | 4.0 (0.3) | 3.0 (1.1) | 0.063 |
| Disc bulging (%, cases) | L4/5 | 14.3 (1/7) | 50 (3/6) | 40 (4/10) | 0.36 |
| | L5/S1 | 14.3 (1/7) | 83.3 (5/6) | 20 (2/10) | 0.014 |
| LBP (VAS ≥ 3) (%, cases) | | 7.7% (1) | 55.6% (5) | 23.1% (3) | 0.040 |




Continuous data are shown as median (interquartile range). For radiograph measurements, a positive number indicated either a tilt or translation to the right. *Comparisons between 3 groups ($\chi^2$-test and Kruskal-Wallis test). †P < 0.05, compared to the value at skeletal maturity (Wilcoxon test). ‡The averages of the Pfirrmann disc score from L1/2 to L5/S1.

## 21. Long-Term Back Pain in Patients with Adolescent and Juvenile Idiopathic Scoliosis: A Population-Based Cohort Study

*Aidin Kashigar; Katherine Lajkosz, MSc; Susan Brogly, PhD, MSc, BSc; Ana Johnson; Daniel P. Borschneck, MD, BSc, MSc, FRCSC*

**Summary**

Back pain is frequent in the pediatric population. Previous research has been divided in the long-term effects of adolescent and juvenile idiopathic scoliosis on back pain. This population-based retrospective study shows evidence of adolescent scoliosis patients having more back pain than general pediatric population but with this back pain having less burden on these patients compared to the large number of pediatric patient population with generalized back pain.

**Hypothesis**

Likelihood of a scoliosis patient having back pain is higher than that of the general population. Given the high frequency of back pain in pediatric population, the burden of back pain for scoliosis patient is similar to that of the pediatric population with generalized back pain.

**Design**

Population-based retrospective cohort study

**Introduction**

Back pain is frequent in the pediatric population. Previous research has been divided in the long-term effects of adolescent and juvenile idiopathic scoliosis (AIS/JIS) on back pain. It is important to understand the natural history of back pain in this patient population in order to address potentials for reduced long-term functional abilities.

**Methods**

A province-wide healthcare database was utilized to identify patients diagnosed with scoliosis before age 9 (JIS) and between ages 9 and 16 (AIS). Patients were compared to two reference groups: general population of patients within same age group, and specific sub-set of patients with complaints of back pain with no underlying scoliosis. Scoliosis patients were sub-grouped based on treatment received.

**Results**
A total of 22,676 AIS and 3,520 JIS patients were identified and compared to back pain reference groups of 870,805 and 569,441 patients respectively. The general population group included 3,338,005 patients for AIS and 3,695,387 patients for the JIS comparison group. Average follow-up time was 12.4 years for JIS and 13.2 years for AIS patients. Scoliosis patients were more likely to have back pain compared to the general population. JIS patients were more frequently seen for back pain than pediatric patients with generalized back pain. AIS patients however were less frequently seen for back pain than generalized pediatric back pain population. For both groups, patients who underwent non-surgical managements showed less frequency of visits for back pain than the generalized back pain population.

**Conclusion**
Back pain is common in both general pediatric patient population and patients with scoliosis. In adolescent patient population, scoliosis patients are less affected by back pain than age-matched patients with generalized back pain.

## 22. Biplanar Imaging Unlocks 3D Deformity in a 30-Year Follow-up Cohort of AIS Patients

*Chenghao Zhang, MD; Charles Gerald T. Ledonio, MD; David W. Polly, MD; Clayton T Cowl, MD; Michael J. Yaszemski, MD, PhD; A. Noelle Larson, MD*

**Summary**
Biplanar slot scanning imaging was used to calculate 3D rotational parameters for 36 AIS patients at a mean 30-year follow-up. 3D apical vertebral rotation correlated positively with scoliometer measurements, PFT results, and thoracic hypokyphosis.

**Hypothesis**
We hypothesized that 3D parameters from biplanar reconstructions would correlate with radiographic, pulmonary, and clinical measures.

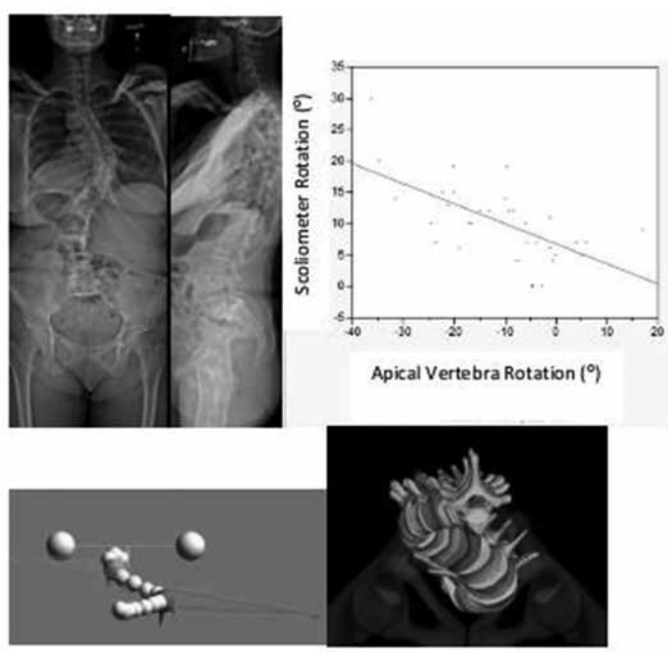
**Design**
Long-term AIS follow-up study.

**Introduction**
Predictors of AIS curve progression in adulthood are lacking. We evaluated 3D biplanar reconstructions from a cohort of US patients treated with bracing or surgery at a minimum of 20-year follow-up. We sought to correlate curve progression and 3D spine parameters with clinical, standard radiographic, and pulmonary function results.

**Methods**
32 patients had current biplanar radiographs, scoliometer reading, HRQL meaures, and pulmonary function testing at a mean of 30 years (range, 20-39). Mean age was 44 years (33-54). Patients had at least a 35 degree AIS curve pattern treated with bracing (16), observation (3), or surgery (17). Utilizing 3D radiograph analyzing software, a model of the spine was constructed based on biplanar PA/lateral films to calculate 3D Cobb angle, kyphosis, rotation of the apical vertebra and plane of the maximal deformity.

**Results**
3D thoracic Cobb and lumbar Cobb correlated well with 2D planar measures ($p<0.0001$, R=0.78, 0.63, respectively). There was a mean 5 degree difference between 3D Cobb and standard Cobb. There was more variation between thoracic 3D Cobb and standard Cobb for patients with increased thoracic scoliometer read ($p=0.037$). Increased thoracic apical vertebral rotation on 3D reconstruction was associated with a higher thoracic scoliometer reading ($p<0.0001$, Rsq=0.4), worse FEV1 ($p=0.0328$) and % FEF ($p=0.023$). Increased thoracic plane of deformity was associated with lower TLC% ($p=0.05$), increased thoracic cobb angle ($p=0.03$), and decreased T4-T12 kyphosis ($p=0.002$, R=0.27). Lumbar scoliometer reading was associated with lumbar curve magnitude ($p=0.0005$, Rsq=0.4), increased plane of deformity for the lumbar curve (Rsq=0.27, $p=0.0072$) and rotation of lumbar apical vertebra (Rsq=0.36, $p<0.0015$). 3D Cobb magnitude varied negatively with TLC% predicted ($p=0.022$), FEV1, and FVC% predicted ($p=0.048$). Only higher thoracic scoliometer reading and thoracic Cobb angle at latest follow-up correlated with curve progression in adulthood.

**Conclusion**
This work validates the use of 3D biplanar imaging parameters as a useful measure for scoliosis deformity at skeletal maturity and describes the complex interplay between pulmonary function, sagittal, coronal and axial plane deformity.




## 23. Evaluating Healing Rates of Adolescent Pars Fractures Using Activity Restriction and Rigid Lumbar Brace

*John W. McClellan, MD; Dorsey Ek, MS; Alec, P Lerner; Michaela Smith*

**Summary**
Pars interarticularis (pars) fractures are increasingly common in the adolescent population. There is evidence that spondylolysis

can progress to spondylolisthesis and pain in adulthood. Our center previously presented a retrospective study demonstrating healing rates of 2% and 25% for bilateral and unilateral adolescent pars fractures after limiting activity for 10 weeks. The current study found healing rates of 50% and 71% for bilateral and unilateral pars fractures after limiting activity and full time rigid lumbar orthosis for 10 weeks.

**Hypothesis**
Activity restriction and full-time rigid lumbar brace wear for 10 weeks will result in increased healing rates of lumbar pars fractures compared to pars fractures treated with activity restriction alone.

**Design**
Retrospective chart review study design.

**Introduction**
The present retrospective study evaluated adolescent lumbar pars interarticularis (pars) fracture healing rates after 10 weeks of full-time rigid lumbar brace wear and limited physical activity. Patients were treated at a single center.

**Methods**
The study population consisted of 79 adolescent patients treated over a 2-year period (2012-2013) for lumbar pars fractures diagnosed by lumbar MRI. After excluding 21 patients due to a lack of post-treatment CT studies, the final study population included 58 adolescent patients. MRI was chosen as the screening tool to avoid excess radiation exposure from CT. Patients were instructed to wear a single piece rigid lumbar brace at all times and restrict physical activity, which included refraining from enrollment in sports or continuing workouts. As in the original study, healing rates were determined by thin cut CT (1.25 mm slice). Patients were re-evaluated after 10 weeks of full-time brace wear and activity restriction using a thin cut CT limited to the fracture location to minimize radiation exposure. All CT studies were reviewed by a single radiologist.

**Results**
Healing rates of 71% for unilateral and 50% for bilateral pars fractures were observed for adolescents treated with activity restriction and full-time bracing. Our previous study presented at the Scoliosis Research Society (SRS) found healing rates of 25% for unilateral and 2% for bilateral lumbar pars fractures treated with activity restriction alone.

**Conclusion**
The considerable increase in healing rates for both unilateral and bilateral lumbar pars fractures observed in the present study, when compared to our earlier study presented at SRS consisting of a similar patient population, suggests that 10 weeks of limited physical activity and full-time rigid lumbar brace wear may be more effective than activity restriction alone.

## 24. Surgical Treatment of Spondylolisthesis in Adolescents Has a 47% Re-Operation Rate: A Multi-Center Retrospective Cohort Study

*Ena Nielsen, BA; Lindsay M. Andras, MD; Nicole Michael, BA; Sumeet Garg, MD; Michael Paloski DO, MBA; Brian K. Brighton, MD; David L. Skaggs, MD, MMM*

**Summary**
Posterior surgical treatment of spondylolisthesis in adolescents was associated with a 47% reoperation rate at 3 high volume spine centers. Addition of a TLIF did not influence the reoperation rate.

**Hypothesis**
Surgical correction of spondylolisthesis has a high complication rate in the adolescent population.

**Design**
Retrospective multicenter

**Introduction**
There is limited information on the complication rate associated with contemporary surgical treatment of adolescent spondylolisthesis. Our objective was to identify risk factors and complications associated with posterior spinal fusion (PSF) of spondylolisthesis.

**Methods**
Patients who underwent PSF for spondylolisthesis between 2004 and 2015 at 3 spine centers, aged 0-21, were included. Exclusion criteria were <2 years of follow-up or anterior approach. Charts and radiographs were reviewed.

**Results**
32 patients had PSF for spondylolisthesis, 11 had PSF alone while 21 had PSF with transforaminal lumbar interbody fusion (TLIF). 15 patients had an attempted reduction. Mean age was 13.8 years (range: 9.6-18.4). Mean follow-up was 4.4 years (range: 2-7.1). Mean spondylolisthesis grade was 2.6 (range I to V). 15/32 patients (47%) underwent reoperation at an average of 2.3 years (range 0-9.3) for the following: implant failure (6), prominent hardware (2), persistent radiculopathy (2), persistent pain (5), infection (2), and pedicle fracture (1). Mean time to reoperation was 2.3 years (range 0-9.3). In addition, there were 10 cases of transient radiculopathy (31%). Reoperation rate was not associated with spondylolisthesis grade (p= 0.35) or addition of a TLIF (PSF= 55%, 6/11; PSF & TLIF= 43%, 9/21, p= 0.84).

**Conclusion**
PSF of spondylolisthesis in the adolescent population was associated with a 47% reoperation rate and high rate of post-operative radiculopathy. Addition of a TLIF did not impact this reoperation rate.

## 25. Guidelines for Surgical Reduction in High-Grade L5-S1 Spondylolisthesis Based on Quality of Life Measures

*Jean-Marc Mac-Thiong, MD, PhD; Michael T. Hresko, MD; Stefan Parent, MD, PhD; Daniel J. Sucato, MD, MS; Lawrence G. Lenke, MD; Michelle Claire Marks, PT, MA; Hubert Labelle, MD*

**Summary**
We prospectively studied 51 young patients undergoing surgery for high-grade L5-S1 spondylolisthesis. Reduction of slip grade and/or lumbosacral angle was not directly associated with the improvement in quality of life (QOL). However, postoperative improvement in QOL is mainly related to a low pelvic tilt, which in turn is strongly correlated with an improved lumbosacral angle. Improving the lumbosacral angle during surgery is therefore recommended in selected patients to decrease the postoperative pelvic tilt and optimize the QOL.

**Hypothesis**
Surgical reduction of slip grade and/or lumbosacral angle is associated with the improvement in quality of life (QOL) of patients with high-grade L5-S1 spondylolisthesis.

**Design**
Multicenter prospective cohort study.

**Introduction**
The guidelines for surgical reduction of slip grade and/or lumbosacral angle in high-grade L5-S1 spondylolisthesis remain unclear. In particular, previous studies have not analyzed the influence of surgical reduction on the quality of life.

**Methods**
A prospective cohort of 51 patients (14.9±3.14 years) with high-grade lumbosacral spondylolisthesis was followed for a minimum of 2 years after surgery. SRS-22 scores, slip grade, lumbosacral angle, pelvic incidence, pelvic tilt and sacral slope were assessed before surgery and at latest follow-up. Statistical analyses were performed for the complete cohort, and also after subdividing the patient based on their pelvic balance (balanced vs. unbalanced), using non-parametric tests and a level of significance of 0.05.

**Results**
Postoperative SRS scores and the improvement in total SRS score were similar between patients with a postoperative slip grade of 1, 2 or greater than 2. Postoperative SRS scores and the improvement in total SRS score were not directly associated with the postoperative value or the improvement in lumbosacral angle. However, a low postoperative pelvic tilt was correlated with increased satisfaction, better function and greater improvement in total SRS score, especially for patients with a preoperative unbalanced pelvis. Postoperative pelvic tilt was mainly associated with postoperative lumbosacral angle.

**Conclusion**
Surgical reduction of slip grade and/or lumbosacral angle in young patients with high-grade spondylolisthesis is not directly associated with an improvement in QOL. However, postoperative improvement in QOL is mainly related to a low pelvic tilt, which in turn is strongly correlated with an improved lumbosacral angle. Therefore, improving the lumbosacral angle during the surgery is recommended in selected patients to decrease pelvic tilt and optimize the QOL.

## 26. Clinical Outcomes of Surgically Treated High-Grade Spondylolisthesis and Their Relation to Spinal Deformity Study Group (SDSG) Classification

*Daniel Bouton, MD; Daniel J. Sucato, MD, MS*

**Summary**
Patients with high-grade spondylolisthesis were classified according to the SDSG system. Patients with a type 4 spondylolisthesis had greater SRS-30 scores at presentation. At two-year follow-up, patients treated with a reduction and fusion had a greater improvement in self-rated appearance with similar complication rates to in-situ fusion.

**Hypothesis**
Clinical outcomes will be affected by the SDSG classification at presentation and the type of surgery performed.

**Design**
Retrospective cohort study

**Introduction**
The Spinal Deformity Study Group (SDSG) classification system was developed in an attempt to guide treatment of spondylolisthesis and emphasized the importance of sagittal spino-pelvic alignment. The goal of this study was to determine if there is an improvement in health-related quality of life (HRQOL) following various surgical treatments for high-grade spondylolisthesis.

**Methods**
Patients with a high-grade lumbosacral spondylolisthesis treated surgically were enrolled at a single institution from 2002 to 2009. SRS-30 questionnaires and radiographic measurements were recorded preoperatively and at a minimum 2-year follow up. Comparisons were made between surgical techniques and SDSG subtypes.

**Results**
Twenty-two patients at average age 13.6 years were included in the study with average follow up of 4.6 years. Ten patients (45%) were treated with a formal reduction of the spondylolisthesis with posterior decompression/arthrodesis. Twelve (55%) were treated with an in-situ arthrodesis. There were 8 SDSG Type 4 (balanced pelvis), 13 type 5 (unbalanced pelvis/balanced spine) and 1 Type 6 (unbalanced pelvis and spine). Compared to SDSG Type 5, patients with an SDSG Type 4 had greater total SRS-30 scores at presentation (3.9 vs 3.4, p=0.019). There was no difference in the magnitude of improvement in SRS-30 scores between different SDSG types. When comparing reduction and in-situ fusion, both groups had improvements in pain (reduction: 3.6 vs. 4.6, p=0.0002; in-situ: 3.1 vs. 4.3, p=0.003) and activity (reduction: 3.5 vs. 4.3, p=0.050; in-situ: 3.2 vs. 4.4, p 0.003); however, only patients in the reduction group had improvement in their self-rated appearance (4.2 vs 3.3, p=0.042). There were no differences in radiographic measurements or complication rates at follow up between the two groups.

**Conclusion**
Patients with an SDSG Type 4 spondylolisthesis have better SRS-30 scores at presentation than patients with Type 5, which may be related to increased clinical severity when the pelvis is unbalanced. Formal reduction and fusion for high-grade spondylolisthesis improves patient appearance scores without increased complications.

## 27. The Importance of Proximal Femoral Flexion on the Sagittal Balance and Quality of Life in High-Grade Spondylolisthesis

*Jean-Marc Mac-Thiong, MD, PhD; Stefan Parent, MD, PhD; Julie Joncas, RN, BSc; Soraya Barchi; Hubert Labelle, MD*

**Summary**
We assessed the proximal femoral flexion angle (PFFA) on 56 normal subjects and 42 subjects with high-grade spondylolisthesis. The PFFA was increased in high-grade spondylolisthesis and increased along with the deterioration in sagittal balance. An increase in PFFA was associated with decreased quality of life. The PFFA is a clinically relevant parameter of sagittal balance, and can be useful in the evaluation and management of patients with high-grade spondylolisthesis.

**Hypothesis**
Increased proximal femoral flexion angle (PFFA) is associated with decreased quality of life (QOL) and deterioration in sagittal balance in high-grade spondylolisthesis (HGS).

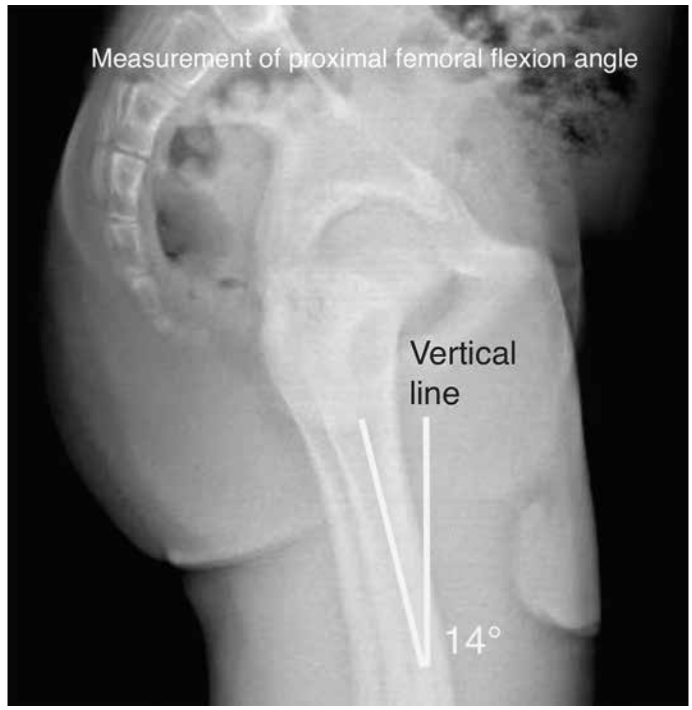
**Design**
Retrospective case-control study.

**Introduction**
Previous studies did not specifically assess the influence of proximal femoral flexion on sagittal balance in spondylolisthesis. In addition, the relationship between proximal femoral flexion and QOL remains unknown.

**Methods**
A retrospective study of 56 normal subjects (13.4±1.8 years) and 42 subjects with HGS (15.7±2.9 years) was performed. For HGS subjects, 17 were type 4 (balanced pelvis), 19 were type 5 (unbalanced pelvis/balanced spine), and 6 were type 6 (unbalanced pelvis/unbalanced spine). PFFA was measured from the orientation of the proximal femurs with respect to the vertical line averaged between the right and left proximal femurs (figure). QOL was assessed from the SRS-22 questionnaire.

**Results**
The PFFA was significantly higher in HGS subjects (8.8±5.9°; range: 2-24°) when compared to normal subjects (3.8±2.0°; range: 0-10°). The PFFA was 6.7±4.2° (range: 2-12°), 9.1±6.4° (range: 2-24°), and 14.0±6.0° (range: 7-23°) in type 4, type 5, and type 6 HGS subjects, respectively. Considering that it is expected that about 95% of normal population will have a PFFA within 2 standard deviations of the mean value observed in the normal cohort, a criteria for abnormal PFFA was set at ≥8° for this study. Abnormal PFFA was more likely in HGS subjects (45.2%) than in normal subjects (5.4%). There were respectively 29.4% (5/17), 47.9% (9/19), and 83.3% (5/6) of HGS subjects with abnormal PFFA in type 4, type 5, and type 6 subgroups. Increased PFFA in HGS subjects was related with decreased SRS scores for pain and self-image domains.

**Conclusion**
The PFFA was increased in high-grade spondylolisthesis and increased along with the deterioration in sagittal balance. An increase in PFFA was associated with decreased QOL. The PFFA is a clinically relevant parameter of sagittal balance, and can be useful in the evaluation and management of patients with high-grade spondylolisthesis.




## †28. Analysis of the Associations of Polymorphism and Bone Mineral Density in Patients with Idiopathic Scoliosis

*Miao Yu, MD*

**Summary**
IS is a serious 3-dimentional deformity which fosters threats on the patients' health. Researches have shown that BMD reduction is detected in the IS patients. Bone markers reflect the functional status of the skeleton. By measuring BMD, bone markers level and gene sequence of the IS patients, the study has discussed the relationship between BMD change, bone markers levels and gene polymorphism, which provides reference for further research on the mechanism of the reduction of BMD of the IS patients.

**Hypothesis**
The gene loci related to BMD(bone mineral density, BMD) reduction and bone markers levels may have effects on IS(Idiopathic Scoliosis, IS) development.

**Design**
Exploratory research method: correlation study had been done to candidate gene loci, BMD and bone markers levels of IS patients.

**Introduction**
Several studies have reported that the occurrence of IS and the

reduction of BMD are affected by genetic factors. Furthermore, a certain number of IS patients have also shown associated symptoms of low bone mass, which indicates that the genetic locus related to the reduction of BMD may also have influence on the occurrence and development of IS. Based on the reports of some highly qualified Genome-wide association studies and and META researches, relevant genetic locus of the reduction of BMD are selected as candidate genetic locus thus to investigate the relationship between the change of BMD, the bone markers levels and the genotype of these genetic locus.

**Methods**
66 IS patients(26 males and 40 females) were enrolled in Peking University Third Hospital. 62 health person(21 males and 41 females) were enrolled as control group. Dual X-ray absorptiometry was applied to detect the BMD. Gene sequencing is conducted under the Sanger method. Measurements of the bone markers levels are conducted and comparison are made between the results and regular indexes.

**Results**
The gene loci rs28377268: chr9-98225056 is related to IS patients' BMD based on linear regression analysis, for there is significant difference: the patient carrying allel G has relatively lower BMD. It is also related to IS patients' osteocalcin based on linear regression analysis, for there is significant difference: the patient carrying allel G has relatively higher osteocalcin.

**Conclusion**
SNP rs28377268 polymorphism influencing on lumbar spine BMD. And the SNP rs28377268 polymorphism was also found to be significantly associated with osteocalcin which helps to determine the mechanism responsible for low bone mass in IS. While, further studies on a larger number of subjects are required.

**Table1 Association of SNPs with IS-related phenotypes**

| Phenotype | SNPs Genotypes | | Phenotype (mean±sd) | Effect Allele | Effect | Pvalue |
|---|---|---|---|---|---|---|
| LSBMD | rs2566752 chr1-68656697 | TT | 0.8365 ± 0.10 | T | 0.05151 | 0.1378 |
| | | TC | 0.8035 ± 0.20 | | | |
| | | CC | 0.732 ± 0.10 | | | |
| | rs6831280 chr4-996165 | AA | NA | A | 0.019 | 0.7769 |
| | | AG | 0.81 ± 0.23 | | | |
| | | GG | 0.79 ± 0.13 | | | |
| | rs28377268 chr9-98225056 | TT | 1.26 ± 0 | T | 0.1313 | 0.006936 |
| | | TG | 0.83 ± 0.08 | | | |
| | | GG | 0.76 ± 0.14 | | | |
| | rs760743075 chr12-48272845 | TT | 0.79 ± 0.10 | T | -0.0384 | 0.3249 |
| | | TC | 0.76 ± 0.17 | | | |
| | | CC | 0.84 ± 0.14 | | | |

**Table 2 Association of SNPs with IS-related phenotypes**

| Phenotype | SNPs Genotypes | | Phenotype (mean±sd) | Effect Allele | Effect | Pvalue |
|---|---|---|---|---|---|---|
| Osteocalcin | rs2566752 chr1-68656697 | TT | 59.44 ± 51.28 | T | -18.26 | 0.197 |
| | | TC | 86.8 ± 55.2 | | | |
| | | CC | 94.33 ± 53.93 | | | |
| | rs6831280 chr4-996165 | AA | NA | A | 9.214 | 0.7592 |
| | | AG | 86.5 ± 73.24 | | | |
| | | GG | 77.29 ± 51.03 | | | |
| | rs28377268 chr9-98225056 | TT | 10 ± 0 | T | -42.89 | 0.02505 |
| | | TG | 48.5 ± 39.44 | | | |
| | | GG | 92.67 ± 52.57 | | | |
| | rs760743075 chr12-48272845 | TT | 97.2 ± 59.12 | T | 24.78 | 0.09009 |
| | | TC | 92.09 ± 55.09 | | | |
| | | CC | 52.22 ± 42.04 | | | |

## †29. Intrinsic β-catenin Overexpression in Osteoblast Could Contribute to Impaired Osteocytogenesis in Adolescent Idiopathic Scoliosis (AIS)

*Jiajun Zhang, MPhil; Yujia Wang; Huanxiong Chen, MD, PhD; Bobby Kinwah Ng, MD; Tsz-Ping Lam, MD; Jack C.Y. Cheng, MD; Wayne YW Lee, PhD*

**Summary**
This study investigated the biological role of β-catenin in AIS osteocytogenesis with a collagen-based 3D osteocyte culture model.

**Hypothesis**
We hypothesized that β-catenin regulating abnormal osteocytogenesis is one of the manifestations of this multifactorial disease.

**Design**
This is an in vitro study.

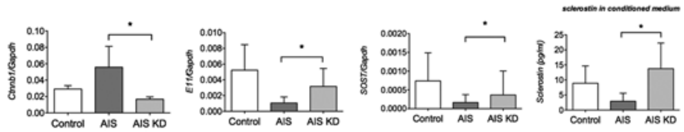
**Introduction**
Adolescent Idiopathic Scoliosis (AIS) is three-dimensional spinal deformity with prevalence of 1-4% in adolescence. 30-38% AIS girls shows systemic low BMD which is a prognostic factor for curve progression. Our group reported the aberrant osteocytes and lacuno-canalicular network in AIS (E-Poster #205 SRS 2015) with state-of-the-art technique. In vitro 3D human osteocytes culture (Paper# 66, SRS 2016) provided a platform revealing defective osteocyte activities in AIS. β-catenin acts on differentiation and metabolism of bone cells.

**Methods**
In this case-control study, primary osteoblasts were isolated from iliac crest trabecular bone biopsies harvested intraoperatively from AIS patients undergoing spinal fusion and from age-matched control subjects undergoing orthopaedic surgery. mRNA and protein level of β-catenin were detected in primary osteoblast culture and in tissue. β-catenin was knock-down in osteoblasts of AIS. Osteocytogenesis in 3D collagen type I gel was validated by co-immunostaining of sclerostin and Alp in temporal sequence. mRNA was isolated with Trizol. mRNA expression and protein secretion of representative osteocyte markers were determined by qPCR and ELISA.

**Results**
Increasing sclerostin and reduced Alp indicated abnormal osteocytogenesis in 3D collagen culture. AIS osteoblasts showed higher cytosolic β-catenin expression in tissue and culture. AIS exhibited lower mRNA expression of E11 and Gja1. In loss of function study, E11 and Sost expression was significantly rescued. ELISA test showed that inhibition of Ctnnb1 improved sclerostin releasing in AIS osteocyte.

**Conclusion**
Reduced E11 and Cx43 indicates abnormal dendrite process and function in AIS osteocyte which are supportive to observed functional defect in osteocyte LCN. Loss-of-function study proves the regulatory role of β-catenin in AIS osteocytogenesis. Reduced sclerostin secreted by AIS osteocytes is speculated to be a positive feedback of abnormal β-catenin signaling in osteoblast. Impaired osteocytogenesis in AIS could be partly explained by inherent β-catenin over-activation. Further study is warranted to

investigate the up-stream factors which may shed light on clinical management for AIS. This project is supported by HK RGC (14116415).




Knock down of β-catenin in AIS osteoblast partially rescued osteoblast and osteocyte activity

## †30. Detection of Brain Abnormalities by in Vivo MRI May Serve as a Prognostic Test for Acquired Scoliosis in Proprioception-Deficient Animal Model of AIS

*Inbal Biton, PhD; Eran Assaraf; Yossi Smorgick; Yoram Anekstein, MD; Elazar Zelzer, PhD; Ronen Blecher; Rod J Oskouian, MD; Jens R Chapman, MD; David Hanscom, MD; Robert A Hart, MD*

**Summary**

Efficient prognostic tools for AIS are currently lacking. Recently, we reported that mutant mice with a primary proprioceptive deficiency display an AIS-like acquired deformity. Here, we test the hypothesis that preceding brain abnormalities could predict the appearance and severity of spinal deformity. Using our animal model of AIS, we show that specific T2 signal brain abnormalities are detected by MRI prior to the development of scoliosis and may thus serve for early diagnosis and prognosis of the disease.

**Hypothesis**

Detection of specific abnormalities of the brain by in vivo MRI may serve as prognostic tests for an AIS-like spinal deformity in an animal model.

**Design**

Animal model study

**Introduction**

The treatment of severe spinal deformities usually consists of major surgery, resulting in considerable aesthetic and functional issues for patients. To date, the diagnosis of the most common form of deformity, Adolescent Idiopathic Scoliosis (AIS), relies on clinical and radiographic examination of the already deformed spine. In recent years, substantial effort has been made to develop currently unavailable prognostic tests for AIS. These would allow early detection of patients at high risk for developing either a severe or a rapidly progressing curve and, in low-risk patients, prevent unnecessary radiation exposure and treatments such as bracing. Previously, we reported that mice lacking key elements in the proprioceptive circuitry developed new-onset, peripubertal spinal deformity in the absence of vertebral anomalies, mimicking AIS. This similarity provides a unique opportunity to explore this animal model for prognostic markers for predicting the development of spinal deformity and its severity.

**Methods**

Brains of mice with either a complete (Runx3-/-) or partial (Egr3-/-) proprioceptive dysfunction were scanned by in-vivo MRI prior to the onset of spinal deformity. Runx3-/- mice were scanned again in maturity to identify possible markers of curve severity. Co-registration (inter- and intra-subject) was applied before the analysis of MRI data. Then, a voxel-by-voxel analysis was performed to identify statistically significant differences in T2 values between mutants and their control.

**Results**

Primary impairments in the proprioceptive pathway resulted in abnormalities localized to the brain and evident in MRI, which preceded the peripubertal appearance of spinal deformity. Furthermore, abnormal T2 signals located at proprioception-related neural tracts were predictive of the development of severe curves.

**Conclusion**

Specific brain abnormalities detected by MRI may serve as prognostic tests in acquired scoliosis.

## †31. Propionibacterium Acnes Survives Only in the Presence of Implants and Causes Late Infection

*Yuta Shiono; Ken Ishii, MD; Kota Watanabe, MD, PhD; Morio Matsumoto, MD*

**Summary**

We proved that Propionibacterium acnes can survive in mouse osteomyelitis model for more than 6 months, and causes delayed surgical site infection. Surprisingly, the presence of implant was quite essential to bacterial survival and development of implant-associated infection.

**Hypothesis**

Establishment of a mouse model of Propionibacterium acnes osteomyelitis using bioluminescence imaging. Clarify whether Propioniacterium acnes could survive in an aerobic environment in vivo and cause Implant assoiated infection or not.

**Design**

Experimental animal study

**Introduction**

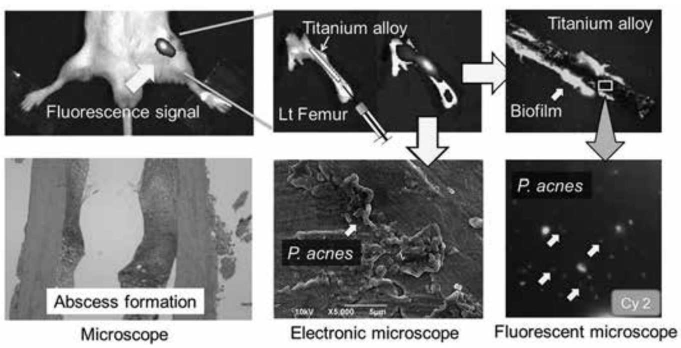
It is recently reported that Propionibacterium Acnes (P. acnes) causes implant-associated infection (IAI) in orthopedic surgeries. We previously reported in this meeting that P. acnes were frequently detected in the intraoperative specimens from the scoliosis surgery. However, no patients developed clinically apparent postoperative infection in our series (2010 SRS 45th annual meeting, Spine 2011). Little is known about the kinetics of P. acnes in vivo. Here we investigated whether P. acnes causes IAI under the presence or absence of titanium implant.

**Methods**

In the model of osteomyelitis, P.acnes (ATCC No. 51277, 1.0E+08 CFU/1µl) were inoculated into the femur of the adult mouse with (implant group, N=12) or without (control group, N=6) 0.5×8mm titan alloy bar. Fluorescent bacterial detection probe which can only detect the living bacteria in vivo was injected intravenously, then P. acnes was tracked using bacterial optical imaging system for 6months. The biofilm formation on the implanted bars and histological tissues were observed under a microscope. Anaerobic culture and PCR of purulent effusion from the infected site in the 6-month mouse was performed.

**Results**
During first 7days, bacterial signal from P. acnes was clearly identified in the infected site in both groups. Afterward, the signal completely disappeared in the control group. Surprisingly, in the implant group, the bacterial signal was maintained over 6months. Microscopic findings showed that P. acnes survived in the biofilm around the implant, and active inflammation and abscess formation were shown over 3months in the implant group, but not in the control group. Moreover, the presence of P. acnes was confirmed in the specimen from the femur of 6month-mice by PCR.

**Conclusion**
We have successfully proved that P. acnes cause delayed IAI over 6 months in the osteomyelitis model. Interestingly, P. acnes could not survive for a long term without implant. To our knowledge, this is the first demonstration of delayed surgical site infection caused by P. acnes.




## †32. Can MRSA Biofilm Infections Be Cleared from Pedicle Screws Intraoperatively?

*Daniel G Meeker, BS; Karen Beenken, Ph.D; Weston, B Mills, BA; Richard E. McCarthy, MD; Mark S Smeltzer, PhD; David B. Bumpass, MD*

**Summary**
Pedicle screws contaminated w/ a virulent strain of biofilm-forming community-acquired methicillin-resistant Staphylococcus aureus (CA-MRSA) can be effectively and easily decontaminated intraoperatively. Avoiding the need to exchange spine implants in deep wound infections (DWI) could result in significant cost savings for these revision procedures.

**Hypothesis**
In an in vitro model of DWI, multiaxial pedicle screws can be effectively decontaminated using common surgical disinfectant solutions conducive to intraoperative use.

**Design**
In vitro microbiologic study

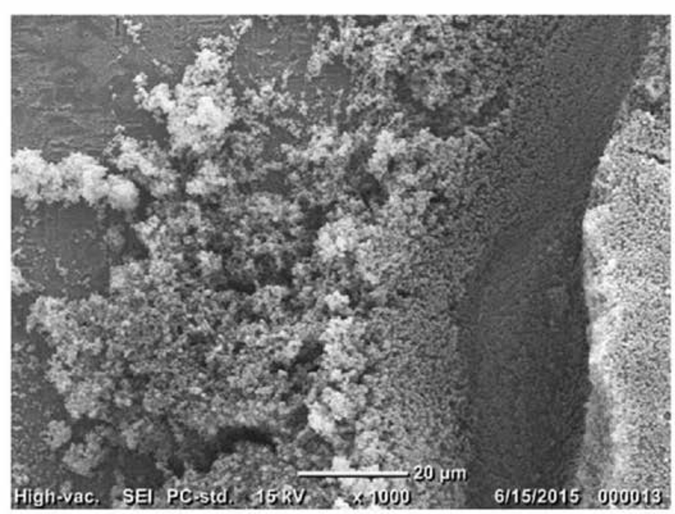
**Introduction**
DWIs after spinal instrumentation are morbid and extremely costly, often requiring implant exchange. Incidence of CA-MRSA surgical infections is increasing; these bacteria form biofilms, further enhancing their antibiotic resistance. Identifying strategies for reducing costs in treating DWIs is crucial as cost-control pressures increase on hospitals and providers.

**Methods**
Multiaxial titanium (T) and stainless steel (SS) pedicle screws were coated in human plasma and colonized w/ the CA-MRSA strain LAC grown in biofilm media. Screws were treated by soaking in various solutions for 30 min. 10 T and 10 SS screws were treated w/ phosphate-buffered saline (PBS) as a negative control. 22 T and 22 SS screws were treated w/ 10% povidone-iodine (PI) solution. 6 T and 6 SS screws were treated w/ 3% hydrogen peroxide solution. After treatment in the disinfectant solution, screws were sonicated to remove remaining bacteria, and viable colony forming units (CFUs) were determined by serial dilutions. Screw sterility was also confirmed by incubating screws in tryptic soy broth following treatment and sonication.

**Results**
As anticipated, all control PBS-treated screws remained fully colonized post-treatment. Overall, PI treatment resulted in a 98% decontamination rate. All of the SS screws were effectively cleared of bacteria in a 30-min PI soak; only 1/22 (5%) T screws remained contaminated after PI treatment, and quantification of the remaining bacterial burden indicated a 10^7 decrease in CFUs on that single screw. Hydrogen peroxide was ineffective at decontaminating any screw, w/ all screws retaining 10^2-10^4 CFUs following treatment.

**Conclusion**
Treating contaminated pedicle screws w/ a 30-min PI soak resulted in a 98% bacterial elimination rate, even despite complex multiaxial screw geometry in the presence of a resistant biofilm-forming MRSA strain. These results suggest that pedicle screws could be removed intraoperatively, sterilized on the surgical field in PI, and reimplanted without risk of continued infection, significantly reducing the cost for revision spine surgery after infection.

Figure 1. Scanning electron micrograph of LAC MRSA biofilm on metallic implant




## †33. Molecular Characterization of Intervertebral Disc Tissue by Next Generation RNA Sequencing

*Ahmad Nassr, MD; Scott Riester; Lin Cong, MD, PhD; Mohamad Bydon, MD; A. Noelle Larson, MD*

**Summary**
RNA expression studies from discarded human disc provide valuable information that can be used to optimize and validate therapeutics and tissue engineering strategies currently under development. Genes associated with NOTCH signaling were enriched in the annulus, while nucleus tissues were enriched in mRNAs associated with proteoglycan extracellular matrix synthesis.

**Hypothesis**
Annulus and nucleus have specific mRNA markers which may be targets for future pharmacologic treatments for degenerative disc disease.

**Design**
High throughput next generation sequencing on human disc samples removed as tissue waste.

**Introduction**
Current therapies cannot regenerate damaged disc tissue, which is a leading cause of back pain and disability. The goal of this investigation is to provide a comprehensive overview of gene expression data in annulus fibrosis and nucleus pulposis tissues to guide ongoing initiatives in tissue engineering, therapeutic drug discovery, and cell-based therapies.

**Methods**
High throughput next generation RNA sequencing was performed on 39 annulus fibrosis and 21 nucleus pulposis samples which were collected from patients undergoing surgical discectomy for the treatment of degenerative disc disease. Tissues were snap frozen in liquid nitrogen prior to RNA extraction and sequencing. Computational methods for weighted gene correlation analysis were used to define gene associations and candidate regulatory networks in spine tissues.

**Results**
We observed statistically significant enrichment of 1399 genes in annulus fibrosis tissue and 373 genes with a statistically significant enrichment in nucleus pulposis tissue (Figure 1). Next generation RNA sequencing studies confirm the expression of known annulus fibrosis and nucleus pulposis specific genes (Figure 2). Studies also identify novel extracellular matrix proteins, and associated transcription factors, and growth factors with potential regulatory functions in spinal disc tissue. Notable genes associated with NOTCH signaling that are enriched in annulus fibrosis tissue include NOTCH 3, NOTCH4, JAG1, JAG2, HEY1, HEYL, CNTN1, DDL1, and MAML3. The nucleus pulposis samples show enrichment in mRNAs associated with proteoglycan extracellular matrix synthesis, including genes associated with the endoplasmic reticulum and golgi apparatus.

**Conclusion**
These findings are consistent with the functional role of the nucleus pulposis as a hydrostatic cushion to reduce pressure and impact between the intervertebral bodies of the spine. Our results also implicate the NOTCH signaling as a potentially important regulatory pathway in annulus fibrosis tissue, which is known to impact cellular adhesion and tissue integrity.

Figure 1. In this heat map clustering scheme, annulus fibrosis and nucleus pulposis samples to preferentially cluster separately.

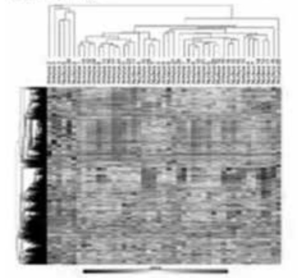
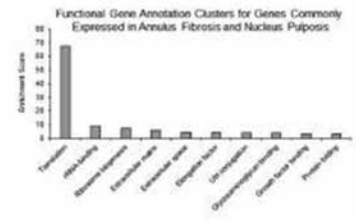


Figure 2. Annulus fibrosis and nucleus pulposis both share common expression of a large number of housekeeping genes as well as a small number of extracellular matrix proteins and growth factor binding associated proteins.




## *34. Dose-Response Relationship Of Tranexamic Acid In Adolescent Scoliosis Surgery

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**Summary**
In this RCT, a tranexamic acid dose-response relationship was established based on a dosing regimen of 50 mg/kg loading dose followed by a 10 mg/kg/hr infusion in adolescent idiopathic scoliosis (AIS) surgery. The target plasma concentration for maximum effectiveness ( significant blood loss reduction) was 73 ug/mL. Based on pharmacokinetic modeling and simulation approach, we recommend a comprehensive dosing regimen of TXA for in AIS surgery.

**Hypothesis**
The primary aim of this portion of a larger prospective, randomized, double-blinded, placebo-controlled trial was to determine the pharmacokinetics (PK) of TXA in AIS surgery. A second aim was to build a pharmacokinetic / pharmacodynamic (PK/PD) model to identify in vivo the ideal therapeutic TXA target concentration.

**Design**
Randomized double-blind placebo-controlled single center prospective trial.

**Introduction**
Tranexamic acid (TXA) has been shown to reduce blood loss in surgery, however, there is no evidence-based dosing regimen in the AIS population. Linking PK with observed blood loss reduction, an evidence-based dosing regimen was developed.

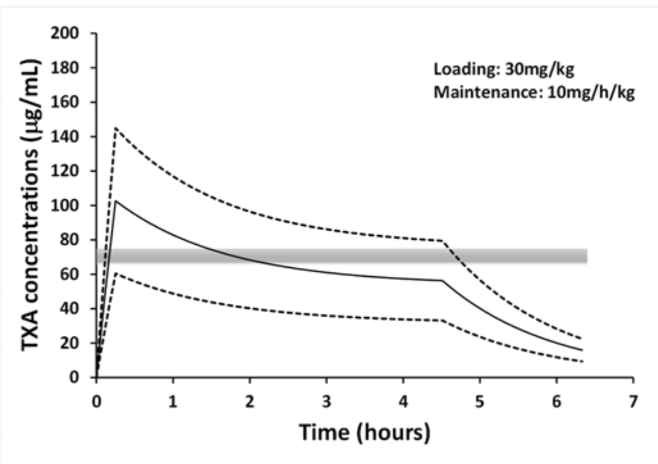
**Methods**
Eighty children, ages 10-21 years, received either placebo or intravenous TXA in a dose of 50 mg.kg-1 loading dose (LD) over 15 minutes and 10 mg.kg-1h-1 maintenance dose (MD) thereafter until wound closure. TXA plasma concentrations were measured throughout the procedure with hourly estimated blood loss (EBL). A PK/PD modeling framework was developed to identify an in-vivo dose-response relationship for TXA.

**Results**
The PK of TXA was described by a two-compartment open model with first order elimination. Body weight was identified as a sig-

nificant covariate for systemic clearance. Cumulative EBL (cEBL) was assessed hourly, compared between placebo and TXA treated patients and the relative difference over time (dEBL) was modeled as the PD variable. The overall average reduction in EBL in the TXA group compared to the placebo group was 27%. A sigmoid-Emax model with baseline effect was fitted to the dEBL data with an estimated half maximal effective plasma concentration (EC50) calculated to be 73ug/mL. Simulations were conducted with the final population PK/PD model to explore competing dosing regimens aiming at this concentration target.

**Conclusion**

TXA was effective in reducing EBL in AIS surgery. A therapeutic plasma steady-state concentration of 70±5 ug/mL was shown to elicit 50-90% of the maximum effect. Based on PK modeling and simulation, and considering the inherent high variability observed with tranexamic acid, a comprehensive dosing regimen in the range of 30 mg/kg LD and 10 mg/kg/h MD can be recommended to achieve that therapeutic target (Figure).




## *35. Calcium and Vitamin D for Adolescent Idiopathic Scoliosis – A Further In-depth Review Using Finite Element Analysis (FEA) for a Randomized Double-Blinded Placebo-Controlled Trial

*Tsz-Ping Lam, MD; Benjamin Hon Kei Yip, PhD; Elisa M. S. Tam, PhD; Gene Chi Wai Man, PhD; Wayne YW Lee, PhD; Kwong Man Lee, PhD; Wai Ping Fiona Yu, MPH, BSc(Advanced); Yong Qiu, MD; Bobby Kinwah Ng, MD; Jack C.Y. Cheng, MD*

**Summary**

Further analysis of our previously reported clinical trial on AIS girls indicated the effects of 2-year treatment with 600mgCa+400/800IUVit-D3/day on preventing curve progression correlated with:(1)increase in FEA parameters, (2)baseline Vit-D level and (3)baseline dietary calcium intake.

**Hypothesis**

Calcium plus Vit-D(Ca+Vit-D) supplement can improve low bone mass and prevent curve progression in AIS.

**Design**

Randomised double-blinded placebo-controlled trial

**Introduction**

This study aimed at evaluating the therapeutic effect and its determinants of Ca+Vit-D supplementation on improving bone strength and preventing curve progression in AIS.

**Methods**

This was a randomized double-blinded placebo-controlled trial on AIS girls (11-14 years old, Tanner stage < IV) with femoral neck bone mineral density Z-score < 0 and Cobb angle ≥ 15°. 330 subjects were randomized to Group1(placebo), Group2(600mgCalcium+400IUVit-D3/day) or Group3(600mg Calcium+800IUVit-D3/day) for 2-year treatment. Investigations were done at baseline and 24-month:(1)FEA on High-resolution Peripheral Quantitative Computed Tomography at distal radius, (2)serum 25(OH)Vit-D assay and (3)dietary calcium intake. The SRS guideline was followed for the Latest Follow-up analysis on curve progression defined as Cobb increase≥6°. Logistic regression analysis was used. P value<0.05 was considered statistically significant.

**Results**

270(81.8%) subjects completed the study. At 24-month, the increases in FEA parameters were significantly greater in the Treatment Group3 than Group1(Fig1). At the Latest Follow-up(N=132), 21·7% in Group3 and 24·4% in Group2 progressed as compared with 46·7% in Group1. Within-group logistic regression analysis showed in Group3, increase in FEA parameters of failure load and apparent modulus were significant protective factors against curve progression(p=0.043 & 0.034 respectively). For those with baseline serum 25(OH)Vit-D≤50nmol/L(N=103), 16.2% progressed in Group3 as compared with 48.6% in Group1(p=0.003). For those with 25(OH)Vit-D>50nmol/L(N=29), no difference on curve progression was noted. For those with baseline dietary calcium intake≤1000mg/day(N=109), 19.0% progressed in Group3 as compared with 54.3% in Group1(p=0.001). For those with calcium intake>1000mg/day (N=23), no difference on curve progression was noted.

**Conclusion**

This study provides strong evidences that the effect of Ca+Vit-D supplementation on preventing curve progression is correlated with increase in FEA parameters, low baseline 25(OH)Vit-D level and low baseline dietary calcium intake. Funding: Pfizer Inc(IIR Grant No. WI 174540)

Fig 1

Proportion of Vit-D insufficiency and mean changes in serum 25(OH)Vit-D and Finite Element Analysis (FEA) parameters from baseline to 24-month time-point for Group 1, Group 2 and Group 3†

| | | Gp 1 N=91 | Gp 2 N=91 | Gp 3 N=88 | p-value Gp 1 Vs Gp 2 | p-value Gp 1 Vs Gp 3 |
|---|---|---|---|---|---|---|
| Proportion with Vit-D insufficiency | Baseline (N=330) # | 74.5% | 70.0% | 75.5% | 0.274 | 0.500 |
| | 24-month time-point (N=270) # | 62.6% | 30.8% | 19.3% | <0.001^ | <0.001^ |
| | p-value for within-group comparison between Baseline Vs 24-month time-point ## | 0.035^ | <0.001^ | <0.001^ | | |
| | | Changes from baseline to 24-month time-point† mean ± SD | | | p | |
| | | Gp 1 N=91 | Gp 2 N=91 | Gp 3 N=88 | Gp 1 Vs Gp 2 | Gp 1 Vs Gp 3 |
| Serum 25(OH)VitD (nmol/L) ### | | 6.3 ± 15.3 | 20.4 ± 19.6 | 28.0 ± 23.3 | <0.001^ | <0.001^ |
| | | Gp 1 N=83 | Gp 2 N=78 | Gp 3 N=72 | | |
| FEA: stiffness (kN/mm) ### | | 13455 ± 4670 | 15786 ± 5701 | 16520 ± 5563 | 0.048^ | 0.001^ |
| FEA: failure load (N) ### | | 533 ± 193 | 622 ± 243 | 658 ± 252 | 0.094 | 0.002^ |
| FEA: apparent modulus (MPa)### | | 465 ± 220 | 591 ± 353 | 588 ± 289 | 0.020^ | 0.028^ |

†: Changes from baseline to 24-month time-point refers to the parameter at 24-month minus that at baseline
#: p-value from Chi-square for between-group comparison
## p-value from McNemar test for within-group comparison on the Vit-D status between baseline and 24-month time-point for the 270 subjects who have completed the 2-year treatment
###: p-value from ANCOVA
^: p-value < 0.05

## *36. Disc Degeneration at Distal Unfused Segments After Posterior Spinal Fusion in Patients with Adolescent Idiopathic Scoliosis Lenke Type 1 or 2: A 20-Year Follow-Up Study

*Kazuki Kawakami, B.Kin; Ayato Nohara, MD; Toshiki Saito, MD; Ryoji Tauchi; Tesuya Ohara, MD; Noriaki Kawakami, MD, DMSc*

**Summary**
This was a retrospective long-term follow-up (FU) study with a FU period of 20y. 32 pts. with adolescent idiopathic scoliosis (AIS) Lenke 1 or 2 (LK1/2) who have undergone posterior fusion with a min. FU period of 15y was compared with an age-matched control group. Disc degeneration (DD) was significantly more common at final FU than in both the pts. 10y data and the control group; however, negative impact on ADL was not seen yet at 20y.

**Hypothesis**
Occurrence rate of DD on distal unfused segments increases and gives negative impacts on ADL in patients with AIS LK1/2 at the time of postop. 20y.

**Design**
Retrospective Cohort Study

**Introduction**
The purpose of this study was to investigate the occurrence of DD in distal unfused segments in patients with AIS during 20y FU period by comparing with an age-matched control cohort.

**Methods**
Out of 64 consecutive pts. with AIS LK1/2, who have undergone corrective fusion at single institution, 32 (FU rate 50%) met following inclusion criteria: 1) > postop. 15y FU, 2) serial lumbar MRI images, 3) coronal and sagittal X-ray Images. These pts. with an age at final FU of 36y were compared with an age-matched control group of 51 volunteers. No significance existed between the cohorts with respect to age (p=0.89) and BMI (p=0.69). Lumbar DD was evaluated according to Pfirrman's grading scale at every 5 years until final FU. Pts. were separated per LIV placement and DD at each placement was also considered. HRQOL using SRS-30 at 10 years postop. and final FU was analyzed per domain.

**Results**
A gradual increase in the number of DD was seen from PO5y to final FU starting at 0.3 at PO5y, 0.8 at PO10y, 1.0 at PO15y and 1.9 at PO20y. Significant difference (p>0.0026) was seen in the number of degenerated discs among the surgical group at PO20y and the control. Severe DD (grade 4) was most common at L5/S in the surgical whereas equal amount of severe DD was seen at L4/S and L5/S in the control along with a lower occurrence rate. Significant loss of correction in Cobb angle (P<0.0001) was seen at PO20y with respect to 10y values. Mean SRS-30 at final FU was 3.8 overall with a lower self-image score than other domains. A significant improvement (p>0.0027) was seen in overall score from PO10y to PO20y. Marital status at PO20y had shown to be significantly correlated (p>0.07) to mental score at PO20y while other domains did not show such correlation.

**Conclusion**
An increase in occurrence of DD during postop. FU period of 20y in pts. with AIS LK1/2 still did not influence on their ADL, while DD occurred more frequently at PO20y in a more severe manner than in the control.

## *37. Minimally Invasive Lateral Lumbar Interbody Fusion for Adult Spinal Deformity: Clinical and Radiological Efficacy

*Kee-Yong Ha; Jae-Won Lee, MD; Sang-il Kim, MD; Young-Hoon Kim; Jin-Woo Lee, MD; Hyung-Youl Park; Joo-Hyun Ahn, Fellow; Dong-Gune Chang, MD, PhD*

**Summary**
Supplementing minimally invasive lateral lumbar interbody fusion (LLIF) might have no additional effect when performed with open posterior instrumented spinal fusion (PSF).

**Hypothesis**
PSF with LLIF might obtain more deformity correction than traditional open PSF due to segmental coronal and sagittal correction effect of LLIF.

**Design**
Retrospective matched cohort study

**Introduction**
There are little reports on direct comparison to the conventional open posterior fusion for adult spinal deformity.

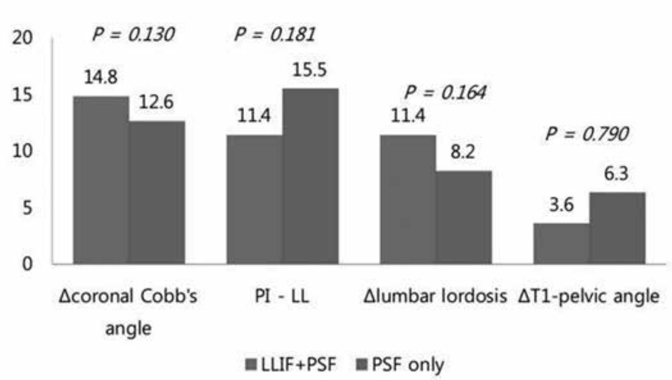
**Methods**
To evaluate the additional advantage of LLIF for adults spinal deformity surgery, patients who had undergone minimally invasive LLIF followed by open posterior spinal fusion (LLIF+PSF group) were compared with patients who had undergone posterior spinal fusion (PSF only group). For assessment of supplementary advantage of LLIF, radiological deformity correction rates and clinical

results were evaluated. In addition, indirect decompression effects of the LLIF were also evaluated cross-sectional area (CSA) and foraminal height (FH) at the index level for the patients who had undergone staged operation.

**Results**
From 2011 Jan. to 2014 Nov. 108 patients who had undergone surgical intervention for spinal stenosis with adult spinal deformity were screened. Preoperative coronal Cobb's angle (CA) >10, sagittal vertical axis deviation (SVA) >7cm), more than 4 levels fusion, and minimal 24 months follow-ups are inclusion criteria. Three column osteotomy or percutaneous pedicle screw fixation were excluded. A total of 77 patients (42 LLIF+PSF group and 35 PSF only group) were enrolled in this study. Mean 2.2 level LLIF was performed for the apex of the deformity. There are no significant differences in clinical outcomes. Supplementary LLIF provided further radiological correction of coronal ( CA: 14.8±6.0 in LLIF+PSF; 12.6±6.6 in PSF only group) and sagittal ( lumbar lordosis: 11.4±10.5; 8.2±9.7) deformity, however, there was no statistical significance (Table 1). LLIF contributed 69.3% in coronal correction and 54.3% in sagittal correction when it is performed with PSF. Significant increase of CSA of spinal canal (10.5%; p=0.000) and FH (8%; p=0.001) at the LLIF level was noted. LLIF+PSF group showed complications; thigh weakness, paresthesia and pain that are specific for LLIF.

**Conclusion**
LLIF showed contribution to correction at certain parts. But, the addition of LLIF to open PSF has no advantages for deformity correction in comparison with PSF only. Furthermore, more complications that are related to LLIF were occurred. Future investigations should aim to more clearly define reasons that warrant the addition of LLIF to PSF.

Table 1. Change of radiographic data




## *38. An Analysis of the Relative Incidence and Outcomes of Minor vs. Major Neurological Decline after Complex Adult Spinal Deformity Surgery: A Sub-analysis of Scoli-RISK-1 Study

*So Kato, MD; Michael G. Fehlings, MD, PhD, FRCSC FACS; Stephen J. Lewis, MD, MSc, FRCSC; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Kenneth MC Cheung, MD Leah Yacat Carreon, MD, MSc; Mark B. Dekutoski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Khaled M. Kebaish, MD; Christopher P. Ames, MD; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Hossein Mehdian, MD, FRCS(Ed); Ferran Pellisé, MD, PhD; Sigurd H. Berven, MD*

**Summary**
This sub-analysis of Scoli-RISK-1 Study reported that 67% of post-operative neurological decline after complex adult spine deformity surgery was minor (<5 LEMS points) decline and 33% was major (≥5 points) decline. A quicker partial and full recovery was seen in the patients with major deficits (77% vs. 56% at 6 weeks). The majority of the recovery occurred in the first 6 months. Severe declines showed a better prognosis for recovery in LEMS compared to minor neurological deficits (94% vs. 77%).

**Hypothesis**
The rate, extent and time course of recovery of neurological deficits related to complex adult spine deformity (ASD) surgery vary based on their severity.

**Design**
A sub-analysis from a prospective, multicenter, international cohort study from 15 sites.

**Introduction**
Post-operative neurological decline has been commonly reported after complex ASD surgeries. The pathologies of these declines include myelopathy, radiculopathy and cauda equina symptoms depending on the surgical technique used and anatomical location of the etiology.

**Methods**
273 patients undergoing complex ASD surgery were prospectively enrolled. Post-operative deterioration in American Spinal Injury Association Lower Extremity Motor Scores (LEMS) compared to pre-operative status was reported, and declines were categorized as "minor" (<5 points loss) vs. "major" (≥5 points loss). Time, rate and quality of recovery in LEMS were investigated for each group.

**Results**
Among the 61 patients with decline in LEMS at discharge, 41 (67%) experienced minor decline and 20 (33%) experienced major decline. Neurological findings were recorded in 58, 59 and 47 patients at 6 weeks, 6 months and 24 months, respectively. For patients with minor decline, 44% of patients showed no recovery at 6 weeks, with the rate decreasing to 21% at 6 months and 23% at 24 months. Full recovery was seen in 49% at 6 weeks, increasing to 69% at 6 months and 67% at 24 months. For patients with major decline, 24% showed no recovery at 6 weeks, decreasing to 5% at 6 months and 6% at 24 months. Full recovery was seen in 24% at 6 weeks, increasing to 65% at 6 months and 24 months.

**Conclusion**

In this series of complex ASD surgeries, a higher incidence of minor vs. major neurological decline was observed. Interestingly, a quicker partial and full recovery was seen in the patients with major deficits. The majority of the recovery occurred in the first 6 months. Patients with severe neurological decline showed a higher likelihood for at least partial recovery as compared to individuals with minor neurological deficits, although the rates of full recovery were equivalent.

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## *39. Clinical Results and Surgery Tactics of Spinal Osteotomy for Ankylosing Spondylitis Kyphosis: Experience with 448 Patients

*Yan Wang, MD; Guoquan Zheng; Zheng Wang, MD; XueSong Zhang, MD*

**Summary**

Spinal osteotomy for ankylosing spondylitis is a technically demanding method, should be reserved for the most experienced spine surgeons. The treatment choices of ankylosing spondylitis kyphosis remain controversial. The lack of a widely accepted consensus contributes to the variation in surgical decision making.

**Hypothesis**

Systematic review of the clinical data of single spine center is help to make surgical decision

**Design**

A retrospective study

**Introduction**

The aim of this study is to report the clinical results and surgical tactics of spinal osteotomy for ankylosing spondylitis (AS) kyphosis based on the experience of single spine center.

**Methods**

From January 2003 to January 2015, totally 448 patients suffering from AS kyphosis who underwent spinal osteotomy in our hospital were reviewed. Among them, Patients were selected to underwent one or two-level transpedicular spinal osteotomy, and the osteotomies were performed range from T12 to L3 according to the apex of kyphosis, type of deformity, and the patient's neurologic conditions. Pre or postoperative radiological parameters were measured. Intraoperative, postoperative, and general complications were recorded.

**Results**

Postoperatively, all patients could walk with horizontal vision and lie on their backs. The chin-brow vertical angle (CBVA) improved from 68.3° to 8.2° (P=0.000) in two-level group and from 46.2° to 4.2° (P=0.000) in one-level group. The mean sagittal imbalance distance improved from 29.4cm to 8 cm (P=0.000) in two-level group and from 18.0cm to 4.3 cm (P=0.000). The mean amount of correction was 27.8° at the superior site of the osteotomy and 42.1° at the inferior site of the osteotomy in two-level group and was 46.2° in one-level group. No major acute complications such as death or complete paralysis occurred. 32 patients suffered one or two complications including: transient neurological deficit (n=3, in two-level group), vascular laceration bleeding (n=1, in two-level group), infections (n=2, 1 in two-level group and 1 in one-level group), postoperatively low back pain (n=5, 2 in two-level group and 3 in one-level group), spinal rod broken (n=3, 2 in two-level group and 1 in one-level group), distally pedicle screws pull out (n=4, 2 in two-level group and 2 in one-level group), non-fusion at osteotomy site (n=4, 3 patients associated with Andersson's lesion preoperatively), and CSF leaks (n=21, 9 in two-level group and 12 in one-level group).

**Conclusion**

Spinal osteotomy can improve the living quality of AS patients largely secondary to the correction of kyphotic deformities. Two-level spinal osteotomy show risk tendency of higher operation-correlated complications.

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## *40. Long-Term Outcome of Untreated Scheuermann's Kyphosis

*Enrique Garrido, MD, EBOT, MRCS; Andrew David Duckworth, BSc, MBChB, MSc, FRCSEd(Tr&Orth), PhD; Joseph VJ Fournier*

**Summary**

There is conflicting evidence regarding the natural history of Scheuermann's Kyphosis (SK)

**Hypothesis**

Untreated SK has an adverse effect on quality of life

**Design**

Retrospective case analysis; mean follow up untreated 27 years

**Introduction**

The effect of SK on health-related quality of life remains unclear. Previous studies have reported reduced self-image, increased back pain and impaired physical status. Little is known of the long term impact of sagittal plane deformity in untreated SK.

**Methods**

A long term cross-sectional study of 113 consecutive untreated patients with SK, obtained from a national service database prior to 2000, when surgical treatment was not recommended. Of 108 patients meeting inclusion criteria, 81 were available for evaluation- 66 (81%) participated and 47 (58%) consented to radiological evaluation. HRQOL was compared to population, age and sex matched normative values. 39 male 27 female. Mean age 45.1 years (31-65), mean follow up 27 years (16-36). 57 patients had thoracic kyphosis and 9 a thoracolumbar deformity.

**Results**

Mean SVA 48 mm(-75 - +99), Pelvic tilt 13.3° (-10 - 28), PI 51° (30-70), C2-7 lordosis 24° (2-51), C2-C7 SVA 35 mm (11-75), T1 slope 38° (8-65), T1 inclination -5° (-12-3), Total kyphosis (TK) mean 78° (50-110), T4-T12 kyphosis 70° (37-97), T11-L1 kyphosis 12° (-10 -43), L1-S1 lordosis 69° (43-96). Kyphosis progressed from a mean 66° at skeletal maturity to 78° ($p<0.001$) after a mean follow-up of 27 years. Rate of progression 0.4° per year. Multilinear regression showed a positive correlation of SVA with ODI (B=0.3; $p<0.01$). There was negative correlation of SVA with SRS-22 pain (B= -0.14; $p<0.001$), SRS-22 function (B=-0.13; $p<0.02$) and SF36 Physical Function (B=-0.4; $p<0.03$). SRS-22 self-image score showed a negative correlation with C2-C7SVA (B=-0.19; $p<0.05$) and TK (B= -0.31; $p<0.01$)

**Conclusion**

The long term rate of progression of untreated SK was 0.4° per year. SRS-22 and SF-36 scores were significantly reduced and ODI was increased in patients with untreated SK compared to normative data. Increasing SVA correlated with a decreasing SF36 physical function, SRS-22 function, SRS-22 pain and a higher ODI. Total kyphosis (TK) and C2-C7 SVA were independent predictors of low SRS-22 Self-image.

| | Untreated SK (66 patients) | Normative values: Population, age and gender matched | Significance |
|---|---|---|---|
| **SRS-22** | | | |
| Function | 3.44 | 4.31 | P<0.01 |
| Pain | 3.44 | 4.39 | P<0.01 |
| Self-Image | 2.84 | 4.23 | P<0.01 |
| Mental Health | 3.28 | 4.17 | P<0.01 |
| **SF-36** | | | |
| Physical functioning | 68.8 | 89.6 | P<0.01 |
| Role limitations physical problem | 65 | 85.23 | P<0.01 |
| Bodily pain | 58 | 82.9 | P<0.01 |
| General health perception | 52.4 | 73.49 | P<0.01 |
| Energy/Vitality | 47.4 | 64.84 | P<0.01 |
| Social functioning | 67.8 | 89.43 | P<0.01 |
| Emotional Role Limitation | 59.8 | 88.37 | P<0.01 |
| Mental Health | 61.5 | 76.52 | P<0.01 |
| **Oswestry Disability Index (ODI)** | | | |
| | 22 | 10.19 | P<0.01 |

## *41. A Dedicated Pediatric Spine Deformity Team Significantly Reduces Surgical Time and Cost

*John M. Flynn, MD; Brendan Striano; Wallis, T Muhly, MD; Wudbhav N. Sankar, MD; Blair Kraus, RN, MSN, MBE; Vaidehi Mehta, MS, MPH; Michael Blum, RN, BSN, CNOR; Barbara DeZayas, MS, MSN, CRNA; Ron Keren, MD, MPH; Jeffrey Feldman*

**Summary**

We created a dedicated spine team to increase efficiency through teamwork and standardization, leading to a consistent, significant and scalable reduction in OR time and cost.

**Hypothesis**

Dedicated surgical teams can increase efficiency and decrease cost of pediatric spine deformity surgery.

**Design**

Retrospective, single center

**Introduction**

Dedicated teams optimize performance in NASCAR and other high risk/high demand endeavors; we investigated a similar approach with similar goals.

**Methods**

In 2015, with hospital support, we assembled a team of improvement advisors and data analysts to build a Dedicated Team (surgery/anesthesia/nursing/techs) with an initial goal of comfortably completing 2 posterior spine fusions (PSF) in a single day/single room of OR block time. The team trained together and designed a standardized anesthetic regimen and standardized teamwork for positioning, prep, drape, imaging, wake-up, and transport. In Phase 1, the Dedicated Team was a single surgeon and a small group of anesthesiologists and RNs. In Phase 2, it was scaled to include most PSFs, a 2nd surgeon, and more anesthesiologists. We studied the effect on surgical time and the cost of OR utilization before (Casual Teams = before training/standardization) and after (Dedicated Teams). Four time periods were analyzed: 1) pre-op time: wheels in to incision; 2) op. time: incision to closure; 3) post-op time: closure to wheels out, and 4) total room time: wheels in to wheels out. Relatively homogeneous Category 1 PSF (7-12 levels, normal BMI, no osteotomies) and more heterogeneous, complex Category 2 PSF (13+ levels, and/or BMI >25, and/or osteotomies) were studied for each surgeon, and in aggregate.

**Results**

167 PSFs (89 Casual Team and 78 Dedicated Team) were studied. The Dedicated Team required significantly less pre-op/op/post-op/ and total room time (p<.05, for all) vs. Casual Team cases. The results remained significant when the project was scaled to a larger group (Phase 2). (Figure 1). For Cat. 1 PSFs, surgical time was reduced by 30% (ave. 112 mins), yielding a cost savings of over $8000 per case; for Cat 2 more complex PSFs, surgical time was reduced by 19% (ave. 78 mins), yielding a cost savings of over $6000 per case.

**Conclusion**

By creating a dedicated team of surgeons, anesthesiologists, RNs and techs promoting teamwork and standardization, our pediatric spine center reduced total surgical time by 30% for standard 7-12 level PSFs (Cat. 1), and 19% for more complex PSFs (Cat. 2). These results were significant, consistent and scalable. Reducing case time by nearly 2 hrs. allowed 2 Cat. 1 PSFs to be comfortably completed in a single day/single room of OR block time.

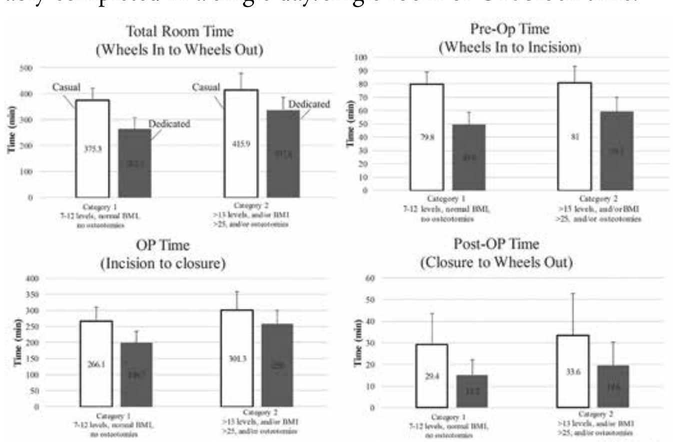



Figure 1: Time reduction for Pre-OP Time, OP Time, Post-OP Time, and Total Room Time for Category 1 and Category 2 cases with dedicated spine surgery team.

□ Casual
■ Dedicated

## *42. Development of a Risk Severity Score Predicting Surgical Site Infection in Early Onset Scoliosis

Hiroko Matsumoto, MA; Anas A. Minkara, BHS; Nicholas Feinberg; John T. Smith, MD; Amer F. Samdani, MD; Michael P. Glotzbecker, MD; Jeffrey R. Sawyer, MD; David L. Skaggs, MD, MMM; David Price Roye, MD; Michael Vitale, MD, MPH; Growing Spine Study Group; Children's Spine Study Group

**Summary**
The Risk Severity Score (RSS) will serve as a useful tool to quantify the risk of SSI when considering operative intervention in patients with early onset scoliosis undergoing spinal surgery. Congenital etiology, syndromic etiology, major coronal curve >70°, hypokyphosis, gastrostomy tube, non-ambulatory status, and pulmonary comorbidity were prognostic of SSI. The RSS will improve shared decision making with patients and families during preoperative counseling and aid policy makers and administrators in determining reliable and valid risk-adjusted outcome measures.

**Hypothesis**
A risk severity score model utilizing patient characteristics can be developed to predict SSI in patients with early onset scoliosis undergoing spinal surgery.

**Design**
Multicenter retrospective cohort study

**Introduction**
Surgical site infections (SSI) in children with early onset scoliosis (EOS) have a major impact on quality of life, caretaker burden, and healthcare expenditure. This study aims to develop a RSS system to predict SSI in EOS patients undergoing spinal surgery.

**Methods**
Pediatric patients who underwent surgery in 15 academic institutions, between November 2002-February 2011, were enrolled. Patients undergoing spinal instrumentation, lengthenings, and fusion with a 5-year follow-up were included. Patient characteristics, preoperative lab values, and clinical data were collected. The CDC's definition of SSI (infection within 90 days of surgery) was used.

**Results**
In total, 171 patients were identified. The average age at surgery was 4.7 years and 55% of patients were female. EOS etiology consisted of: 76 congenital, 45 neuromuscular, 30 syndromic, and 20 idiopathic. The SSI rate was 22.8%. Regression analysis revealed that congenital etiology (OR 2.6), syndromic etiology (1.2), major coronal curve > 70 (2.3), hypokyphosis (OR 1.6), gastrostomy tube (OR 4.3), non-ambulatory status (OR 2.9), and pulmonary comorbidity (OR 1.4) were prognostic of SSI. The RSS predicted an infection risk of 1.1% when no risk factors were present and 65.0% when all risk factors were present. The model's predictive ability was 74.2%, indicating it is a good model in identifying true positives while minimizing false positives.

**Conclusion**
This study revealed a high risk of SSI in patients with EOS (22.8%). The RSS provides a means to predict SSI risk in EOS patients preoperatively. It allows us to provide guidance to patients regarding surgical risks and prepare for high-risk patients. The RSS can facilitate outcome comparisons between hospitals caring for EOS patients. Variables unable to be measured adequately such as perioperative infection prophylaxis likely contribute to SSI and require further investigation.

## 43. Anterior Spinal Growth Tethering Leads to Asymmetric Growth of the Apical Vertebra

Yi Yang, MD; Peter O. Newton, MD; Megan Jeffords, MS; Tracey P. Bastrom; Carrie E. Bartley, MA; Fredrick Reighard, MPH; Burt Yaszay, MD

**Summary**
This study offers convincing 3D radiological evidence that ASGT works to modulate vertebral growth as the mechanism of progressive scoliosis correction.

**Hypothesis**
Anterior spinal growth tethering (ASGT) will result in asymmetrical apical vertebral body growth, leading to scoliosis correction.

**Design**
Retrospective

**Introduction**
ASGT is a relatively new non-fusion method of spinal growth modulation that aims to create asymmetric growth of vertebrae resulting in progressive scoliosis correction during the adolescent growth spurt.

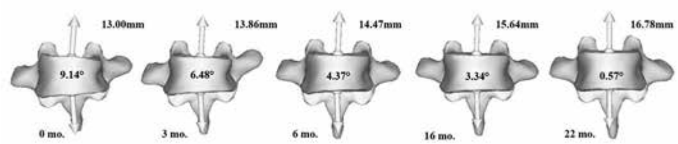
**Methods**
A retrospective review of patients treated with ASGT between 2011 and 2014 was conducted. Patients with >17 months of follow-up and simultaneous bi-planar x-rays were required for inclusion. Patients were excluded if there was evidence of tether breakage prior to 18 months of follow-up. 3D reconstructions based on the bi-planar images were subsequently reconstructed (3D radiograph analyzing software) and various dimensions/angles of each apical vertebra were serially quantified via custom data analyzing software. The rate of change over time in each variable of interest (Cobb angle, apical vertebra body convex and concave side heights, apical vertebra body anterior and posterior heights, apical vertebra coronal plane wedging angle, apical vertebra sagittal plane wedging angle) was calculated for the individual patients and compared between groups utilizing nonparametric statistics: patients with scoliosis correction/improved Cobb angle and those with no correction/continued curve progression.

**Results**
Of 13 subjects included, 9 had progressive improvement in their scoliosis and 4 did not improve or worsened. The average age at tether placement was 11.8±1.8 years with a mean pre-operative scoliosis Cobb angle of 51°±11° (35°-69°). All patients were Risser 0. Follow-up ranged from 17-36 months with 4 to 7 post-operative visits. Following tether placement the FE Cobb angle was reduced to 34°± 8°. Over time, the correction group demonstrated significantly less apical vertebral wedging in the coronal plane, (ave rate of change -0.11°/mo) compared to the no correction group (0.04°/mo, p=0.02). The correction group also showed increased vertebral height over time on the concave

side of the curve (0.11mm/mo), as compared to the no correction group (0.01mm/mo, p=0.005). Figure 1 is a case example of how the apical vertebral wedging decreased and vertebral height on the concave side increased over 22 months.

**Conclusion**
ASGT in immature patients with thoracic scoliosis has the potential to asymmetrically modulate the growth of the apical vertebra. Greater concave sided growth was associated with greater degrees of overall Cobb angle correction.

**Figure 1:** Apical vertebral wedging and concave vertebral height changing over 22 months follow-up.




## 44. Immediate Tridimensional Changes Following Anterior Vertebral Body Tethering in Adolescents with Idiopathic Scoliosis

*Olivier Turcot; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Christian Bellefleur, MSc; Stefan Parent, MD, PhD*

**Summary**
Preoperative and immediate postoperative clinical and radiological data of anterior vertebral body tethering(AVBT) was evaluated. AVBT is a safe technique that offers a significant correction in the coronal and transverse planes at the first erect visit. Although the correction was achieved through an anterior compression approach, the procedure was not found to be kyphogenic. This may be due to the coupling effect of derotation and coronal correction minimizing the impact on the sagittal plane.

**Hypothesis**
3D correction can be achieved without significant changes in the sagittal plane.

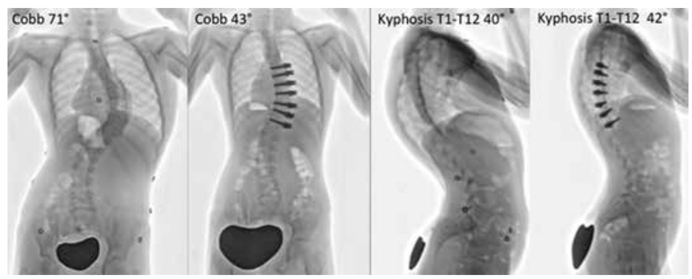
**Design**
Prospective developmental study

**Introduction**
Anterior Vertebral Body Tethering (AVBT) aims to gradually correct scoliosis, using the patient's growth, while preserving spine motion. One of the concerns is the risk of creating kyphosis. The first objective was to evaluate the 3D correction of scoliosis immediately after surgery to determine if 3D correction was achieved. The second objective was to characterize and analyse perioperative data.

**Methods**
We reviewed the clinical, perioperative and radiological prospectively collected data of the first 53 patients who received the AVBT at our institution. The preoperative and 1st erect visit (FE) data were analyzed. Computerized measurements were done on reconstructed 3D spines radiographs. Means, standard deviation and paired t test of specific parameters were calculated.

**Results**
All 53 patients were skeletally immature (mean age 11.9 yo). Mean operative time was 179 min with an EBL of 217.9 ml. Tethering was done on an average of 7.3 vertebral levels. Cobb angle was 50.0°±10.6° pre-op and 30.2°±10.7° at the FE visit. In the sagittal plane, kyphosis was unchanged (28.0°±15.0° pre-op and 27.6°±13.5° at the FE visit (p=0.766). The mean segmental derotated kyphosis (TrueKyphosis) of T5-T12 was 5.5°±11.0° pre-op and 11.2°±11.0° at the FE visit (p<0.001). In the transverse plane, apical vertebral rotation of 13.2°±5.0° was corrected to 9.8°±6.7° postoperatively (p=0,0001). SRS-30 self-reported outcome showed an increased satisfaction with the management, even if pain was increased and function diminished.

**Conclusion**
AVBT offers a significant correction in the coronal and transverse planes immediately post-op. Although the correction was achieved through an anterior compression approach, there was no impact on the kyphosis of the patient. As expected, changes in the segmental TrueKyphosis are probably related to the coupling effect of derotation and coronal correction of the deformity more than actual kyphosis generation. A long-term follow-up of this population will be needed to appreciate this technique's potential.




## 45. Isolated Posterior Ligamentous Reinforcement does not Decrease Proximal Junctional Kyphosis in Adult Spinal Deformity

*Sravisht Iyer, MD; Francis Lovecchio, MD; Jonathan Charles Elysée, BS; Renaud Lafage, MS; Frank J. Schwab, MD; Virginie LaFage, PhD; Han Jo Kim, MD*

**Summary**
In our consecutive series of Adult Spinal Deformity (ASD) patients, we describe a Proximal Junctional Kyphosis (PJK) rate of 27% at 6 weeks. There was no difference in the rate of PJK between those with posterior ligamentous structures (PLS) reinforcement (26%) and those without reinforcement (28%). Because PJK has a multifactorial etiology with a number of possible causes; simple reinforcement of the PLS alone may not be sufficient to prevent PJK.

**Hypothesis**
Reinforcement of the PLS with a surgical nylon tape will reduce the incidence of PJK.

**Design**
Retrospective Cohort Study

**Introduction**
Violation of the posterior soft tissues is believed to contribute to the development of PJK. It is unclear if attempted reinforcement of the PLS will reduce the incidence of PJK.

**Methods**
We consecutively enrolled patients in a single surgeon series. All

patients age > 18 with >5 level fusions extending to the sacrum/pelvis were included. PLS+ patients had reconstruction of the PLS with a surgical nylon tape while PLS- patients did not. Demographic, surgical and radiographic data were reviewed. The two groups were compared using a students t-test and chi-squared analysis as appropriate. A backward, conditional multivariate regression model was constructed to determine if PLS reinforcement would be retained as a predictor of PJK.

**Results**

126 patients were included. Average age was 64 years (range 38-85 years). 35 patients (27.8%) were PLS+ and the remainder were PLS-. There was no differences between groups with age and pre-operative sagittal alignment. PLS+ pts had slightly lower BMI (25 vs. 28, p=0.011). The rates of three-column and Smith-Peterson osteotomies were similar between groups (p>0.05). At 6 week follow up, the PLS- group had a larger T1PA (15 vs 9,p=0.004), otherwise there were no differences in sagittal alignment between groups. The rates of PJK for PLS+ (26%) and PLS- (28%) were similar (p=0.842). In our multivariate analysis, only pre-operative sagittal alignment parameters were retained as predictors of PJK at 6 week; PLS reinforcement did not have any predictive role.

**Conclusion**

Reinforcement of the PLS alone is not sufficient to reduce the incidence of PJK. This finding disproves our hypothesis and highlights the multifactorial etiology of PJK.

## 46. Two Birds, One Stone: A Change in Hand Positioning for Low Dose Stereoradiography AIS Imaging Allows Concurrent, Reliable Sander's Scoring

*Taylor Jackson; Daniel J Miller, MD; Susan Nelson, MD, MPH; Patrick J. Cahill, MD; John M. Flynn, MD*

**Summary**

Positioning patients to visualize the hands during routine low dose stereoradiography imaging for adolescent idiopathic scoliosis (AIS) allows for assessment of skeletal maturity with excellent reliability, without the additional time, cost and radiation of dedicated hand films.

**Hypothesis**

Low dose stereoradiography can replace separate hand bone age films to assess skeletal maturity in AIS patients.

**Design**

Prospective survey

**Introduction**

Sanders skeletal maturity staging system has proven very valuable in AIS management, but obtaining dedicated hand films adds time, radiation exposure and expense to the clinic visit. Our study seeks to evaluate the reliability of using routine low dose stereoradiography images for assessing skeletal maturity.

**Methods**

A survey consisting of 30 standard bone age hand films and 26 PA spine low dose stereoradiography images (magnified view of hands visible next to face) was created in a survey-generating website and distributed to two pediatric orthopaedists and two fellows. Images were graded according to Sander's skeletal maturity in two trials conducted one week apart. In the first trial all standard hand bone age films were presented first, followed by the low dose stereoradiography films. The images were randomized in trial two. Images from Sander's original description were distributed to graders for reference. Interrater and intrarater reliability was assessed using the mean linearly weighted kappa to provide an overall index of agreement.

**Results**

In trial one there was strong interrater reliability for both standard bone age films ($\kappa = 0.84$) and low dose stereoradiography films ($\kappa = 0.81$). In trial two, reliability was slightly improved for both standard bone age films ($\kappa = 0.866$) and low dose stereoradiography films ($\kappa = 0.831$). Intrarater reliability was strong for both standard films ($\kappa = 0.889$) and low dose stereoradiography films ($\kappa = 0.858$).

**Conclusion**

A simple change in patient positioning for low dose stereoradiography allows clinicians to simultaneously assess a patient's spinal deformity and skeletal maturity with excellent reliability, thereby minimizing cost, time, and radiation exposure for the growing child.


Figure 1: A) Full-length PA Spine for routine surveillance of a patient with AIS using low dose stereoradiography. B) Magnified view of hand from the same radiograph.

## 47. 3D Printing Innovation in the Surgical Management of Adolescent Idiopathic Scoliosis Patients

*Alpaslan Senkoylu, MD; Mehmet Cetinkaya; Ali Eren, MD; Ismail Daldal; Erdem Aktas; Dino Samartzis, DSc; Elsan Necefov*

**Summary**

In this prospective study, low cost 3D rapid-prototyping (3DRP) devices were created for personalized guidance of pedicle screws in

patients with adolescent idiopathic scoliosis. Following postoperative CT assessment, the use of these 3D printed devices illustrated that pedicle screw insertion was safe and accurate.

**Hypothesis**
Screw insertion accuracy with 3D rapid-prototyping (3DRP) guides is a safe and effective technique.

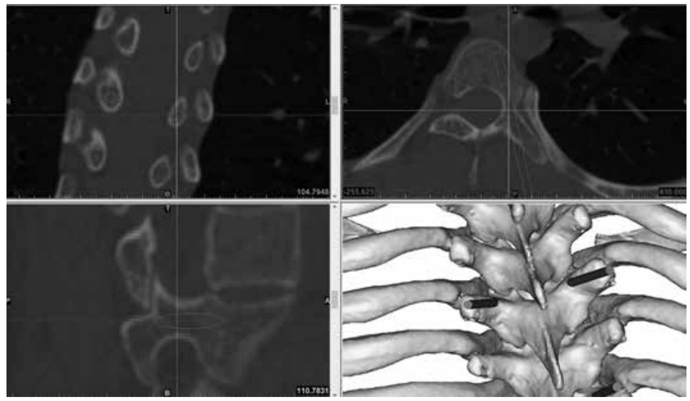
**Design**
Prospective cohort study.

**Introduction**
Free-hand pedicle screw placement to a scoliotic spine is a technically challenging procedure that carries risk of neurologic injury. Computer-assisted pedicle screw insertion has shown to be more accurate. However, it has disadvantages, such as high radiation exposure, long operation time and is costly. However, devices manufactured with 3DRP technology may be used intraoperatively and may promise similar outcomes.

**Methods**
Eleven (8 female, 3 male) adolescent idiopathic scoliosis (AIS) patients with 15-year-mean-age were included in this study from a single institution. After selecting fusion levels and fixation points, 3DRP guides were produced for all individual levels. Preoperatively, 0.63 mm thickness sliced CT scan images were used for creating 3D bone models. Safe pedicular trajectories were determined in all three planes on these models (Fig-1). 3D guides were modelled according to these trajectories and manufactured with a 3D printer from a biocompatible material. 3DP guides were used during surgeries of AIS patients. All screws were evaluated and scored with CT images, obtained postoperatively. Class 1 (Accurate) screw axis deviates by less than 2 mm from the planned trajectory, Class 2 (Inaccurate) 2 mm or more but less than 4 mm, and Class 3 (Deviated) 4 mm or more. The mean angle between the inserted pedicle screw and the intended trajectory (ASIT) and the mean distance between the central longitudinal axis of a screw and pedicle (DBSP) were also measured.

**Results**
The cost of a 3DRP guide per level was  2. On the concave and convex sides, the mean medial malposition was 0.5±0.78-0.4±0.62, the mean lateral malposition was 1.43±2.33-0.83±1.27, ASIT was 4.18±4.63 and 4.28±5.99, and DBSP was 1.45±2.11 and 0.93±1.24, respectively. 29 screws had no penetration, 117 Class-1, 14 Class-2, and 3 Class-3 penetration. There was a 92.5% positional accuracy of the screws (n=134 inserted screws). There was no screw-related complications.

**Conclusion**
This is the first study to report the implementation of 3DRP guides for the application of pedicle screws in AIS. Our study showed that the use of these low-cost guides is safe, can be applied in complex deformities and revision cases.



## 48. Patient Specific Navigation Yields Accurate Pedicle Screw Placement Across Surgeons of Varying Experience

*Kyle Walker, MD; Joel Kolmodin, MD; Michael P. Silverstein, MD; Eric J. Rodriguez, BS; Brandon L. Raudenbush, DO; David P. Gurd, MD*

**Summary**
This study demonstrates a faster average screw placement and fewer high-grade perforations when placing pedicle screws with the aid of a patient specific navigation (PSN) device.

**Hypothesis**
We hypothesize a PSN device made from a 3-dimensional (3D) reconstruction of a computed tomography (CT) scan can improve pedicle screw placement and reduce operative room (OR) time.

**Design**
Preclinical Randomized Controlled Trial

**Introduction**
Accurate placement of pedicle screws is a key component of spine surgery which allows a small margin of error. Misplacement can damage local anatomy. Current methods require surgeons to blindly place screws or use expensive equipment that typically exposes the patient to significant radiation. Some studies have shown the utility of 3D-printed PSN devices but none have directly compared their efficacy over freehand (FH) placement.

**Methods**
This study was funded by a grant from the SRS. Five cadaver torsos were CT scanned at 0.6mm slice thickness. A pedicle in each vertebra, T1-L5, was randomized to receive a PSN screw. The contralateral side received a FH screw. For the PSN group, each trajectory was planned to avoid perforation. Each cadaver was assigned to a different surgeon. Experience ranged from PGY-1 to senior staff surgeon. All screw sizes were chosen by rounding down from 80% of the pedicle's isthmus diameter. All PSN screws were placed first and surgeons were blinded to trajectory/starting point of the PSN screws when placing the FH screws. A postoperative CT scan was reconstructed and the vertebrae were aligned to the preoperative spine for accuracy analysis. Each spine was grossly dissected and given a perforation grade of 0 (no perforation), 1 (<2mm), 2 (2-4mm), or 3(>4mm).

**Results**

Across all surgeons the PSN placed screws were had an average accuracy of 2.63mm (CI95: 2.25-3.01mm) and 5.93o (4.94-6.92o) measured at the mid-pediclar point. When compared to the FH placed screws, the PSI screws showed fewer grade 2 and 3 perforations (13/84 vs 26/85; p=0.019). The time to placement for the PSI screws was an average of 65 seconds less per screw (136 +/- 80s vs 201 +/- 82s; p<0.001).

**Conclusion**

The PSN device offers an inexpensive and accurate method to pedicle screw placement and potential to significantly decrease OR time. In a clinical setting, fewer high grade perforations will likely further reduce OR time and radiation exposure by limiting the need to alter screw placement. Figure 1 depicts the comparison between an L1 PSI and FH placed screw.

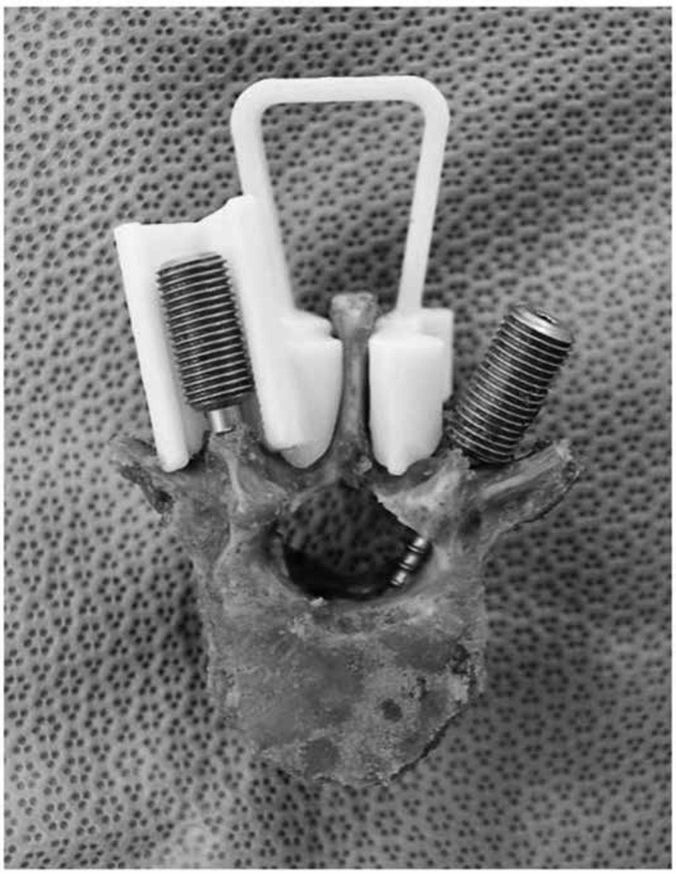


Figure 1: Image of PSN placed screw (left) and FH placed screw (right) at L1 with PSN device (white) in place.

### 49. Development of a Software Estimates Spinal Alignment Utilizing Artificial Intelligence for Scoliosis Screening

*Kota Watanabe, MD, PhD; Ran Choi, MD; Nobuyuki Fujita, MD, PhD; Yoji Ogura; Satoru Demura, MD; Toshiaki Kotani, MD, PhD; Kanichiro Wada, MD; Masashi Miyazaki, MD; Hideki Shigematsu, MD; Yoshimitsu Aoki, MD; Morio Matsumoto, MD*

**Summary**

We have developed a software estimates spinal alignment utilizing artificial intelligence for scoliosis screening based on 10788 sets of training data consisted of Moiré image and standing whole spine radiograph. The software was designed to output the estimated Cobb angle. The mean error between estimated Cobb angles and measured Cobb angles was 2.7°. If threshold of scoliosis was set at 15° and more, the sensitivity was 0.81 and the false positive rate was 0.09.

**Hypothesis**

The developed software estimates spinal alignment utilizing artificial intelligence is beneficial for scoliosis screening

**Design**

Retrospective study of consecutive collected data for creation and validation of a software.

**Introduction**

Since early detection and early treatment was considered to be beneficial for adolescents, school screening system has been adapted in many countries. While, downsides of the previous school screening system were its accuracy and its qualitative decisions. Thus, we purposed to develop a software that can automatically estimate the spinal alignment and Cobb angle from Moiré image utilizing Convolutional Neural Network (CNN) deep learning algorithm.

**Methods**

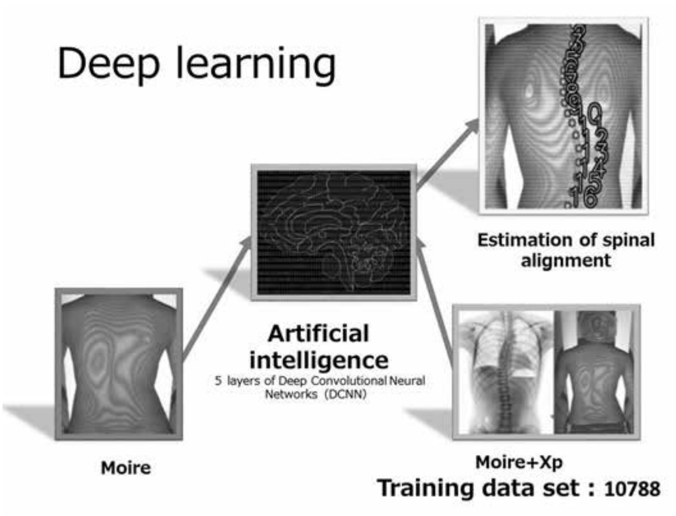
10788 sets of training data consisted of Moiré image and standing whole spine radiograph with Cobb angles between 0° and 55° were used for CNN deep learning to create the software. The software was designed to output the estimated spinal alignment and the Cobb angle as the results. Additional 3372 sets were used for validation of the software. The estimated Cobb angles were compared with the measured Cobb angles by the spine surgeons. Sensitivity and false positive rate supposing clinical school screening setting were also evaluated.

**Results**

The mean error of estimated vertebral position was 3.6±1.5 pixel. The mean error between estimated Cobb angles and measured Cobb angles was 3.14° in patients with Cobb angle of less than 10°, 2.97° in 10°- 20°, and 2.7° in more than 20°. If threshold of scoliosis was set at 10° and more, the sensitivity was 0.98 and the false positive rate was 0.43. While, the threshold was set at 15° and more, the sensitivity was 0.81 and the false positive rate was 0.09.

**Conclusion**

Our developed software estimated spinal alignments and Cobb angles from Moiré images with high accuracy. The inferior error at smaller Cobb angle might be due to the observer variability in measurements. Since the false positive rate was reported as 0.13 for > 10°, and 0.61 for >15° using previous screening system, the developed software will be beneficial for school screening to pick up the students with the Cobb angle of 10-15° and more.




## 50. Temporary Magnetic Controlled Growing Rods (MCGR) for the Treatment of Severe Scoliosis Provides Maximum Curve Correction and Spinal Height Restoration: A 6 Years Experience from First to Latest Case.

Heiko Koller, MD; Axel Hempfing, MD; Aiman Tateen, MD; Michael Mayer, MD, PhD

**Summary**
In 8 pts with severe thoracic curves (TC) Ø 115° a staged protocol was applied including 1.) internal temporary distraction with MCGR after posterior spinal release and 2.) definitive correction with segmental pedicle screw (PS) construct. Given curve rigidity, the strategy resulted in impressive TC-corrections and restoration of trunk height. Results indicated that this innovative technique has the potential to reduce indications and resources with Halo-Gravity-traction (HGT) and the need for high-risk 3-CO for correction of severe TC.

**Hypothesis**
Staged correction of severe TC with MCGR achieves safe and maximum TC-correction

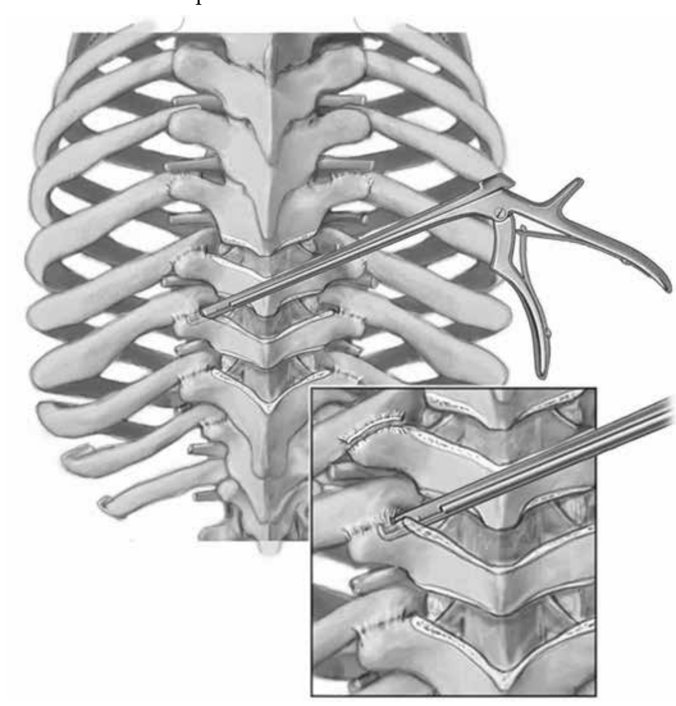
**Design**
Prospective analysis of patient specific characteristics w/ a new innovative technique

**Introduction**
Correction of severe TC (>100°) poses challenges. Since 2011, the authors made experiences w/ the technique of temporary distraction using MCGR for severe TC.

**Methods**
8 pts (Ø15 yrs) with TC were assessed. 5 had AIS and 2 dislocating NF-1. Preop TC was Ø115° (89-138°) and TC-flexibility was 18%. Concept of staged surgery is with PS fixation, segmental apical release using aggressive Ponte's first (Fig.) incl. release of costotransversal joints, segmental insertion of PS and a single MCGR. Postop daily distractions places the corrective forces at the level of greatest TC rigidity. After Ø 14 days, the 2nd surgery was performed with removal of MCGR and corrective fusion using segmental long-head PS. Pts had serial biplanar x-rays until F/U. The spinal height from lowest instrumented vertebra (LIV) to T1 was measured. TC-correction was calculated as scoliosis correction index (SCI: Postop TC-correction (%)/ Preop TC-Flexibility (%)).

**Results**
No pts suffered a major complication or neurologic deficit. Instrumentation was from T2 to L1-L4. Staged surgery achieved excellent correction with postop TC of Ø 61° indicating a TC-correction of 60% and a SCI of Ø 4.8. Preop thoracic kyphosis changed from 82° to 55° postop. At F/U rib hump correction was Ø29mm and shoulder height difference at F/U was Ø 9.8mm. Spinal height LIV-T1 increased from preop Ø281mm to postop Ø 370 mm by Ø 91 mm. SRS-24 sum score was Ø 97 and all pts reported they would undergo the same procedure again. 6 pts reported to be very satisfied and 2 satisfied with outcome at F/U of Ø 14mos.

**Conclusion**
This is the first larger series after temporary internal distraction using a MCGR. The technique carries the potential to replace HGT or 3-CO for the treatment of severe TC. Spinal height restoration could be accomplished w/ improvement by about 9 cm which is a unique characteristic.



## 51. Posterolateral Diskectomies for Pediatric Spinal Deformities: Indications, Outcomes, and Comparison with Anteroposterior Spinal Arthrodesis

Amit Jain, MD; Brian T. Sullivan, BS; Hamid Hassanzadeh, MD; Paul D. Sponseller, MD, MBA

**Summary**
Children with severe, rigid spinal deformities are frequently treated with anteroposterior spinal fusion or with vertebral column osteotomies. The aim of this study was to investigate the use of posterolateral diskectomies at the apex of the curve with an

all-posterior arthrodesis as an alternative to anteroposterior spinal fusion.

**Hypothesis**
A novel technique consisting of posterolateral diskectomies (PLD) at the apex of the curve with an all-posterior arthrodesis can be an effective alternative to anteroposterior spinal arthrodesis (APSA) for treatment of children with severe deformities.

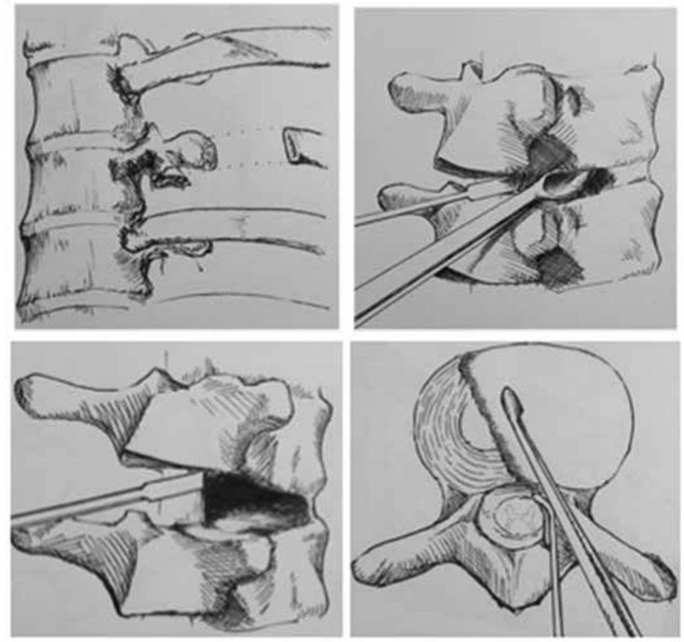
**Design**
Retrospective

**Introduction**
The study aim was to investigate the indications, patient and surgical characteristics, radiographic outcomes, and complications in children with spinal deformities treated with PLD.

**Methods**
We evaluated records of all patients 21 years or younger who underwent treatment for spinal deformity between 2010 and 2015 by a single surgeon using PLD (n = 56) vs. APSA (n = 21).

**Results**
Indications for PLD were: large, rigid curves (37 patients); curves with severe rotation (10 patients); and large curves with open triradiate cartilage (9 patients). PLD patients had a mean of 31 diskectomies and 14±3 posterior spinal levels fused. Compared with the APSA group, the PLD group had greater major curve correction (mean, 81° ± 18° vs. 58° ± 28°, P < 0.001), less blood transfused (mean, 2.5 ± 2.6 vs. 4.0 ± 3.3 units, P = 0.038), and a lower rate of staged surgery (1.8% vs. 86%, P < 0.001). There was no significant difference between the PLD and APSA groups in T1-S1 length gained (mean, 6.2 ± 3.4 vs. 6.6 ± 8.8 cm, respectively; P = 0.77).

**Conclusion**
Posterolateral diskectomies at the convex apex of the curve with an all-posterior arthrodesis is an effective alternative to APSA for treating children with severe spinal deformities. It distributes the correction over many segments in a curve, minimizing translation. It is effective for treating large, rigid curves, curves with severe rotation, and large curves in children with open triradiate cartilage.



## 52. Building the Case for Optimal Prophylaxis for Growth-Friendly Surgery for Non-Idiopathic Scoliosis: Using Vancomycin and Aminoglycosides

*Anas A. Minkara, BHS; Michael Vitale, MD, MPH; Hiroko Matsumoto, MA; Michael P. Glotzbecker, MD; John M. Flynn, MD; John T. Smith, MD; Amer F. Samdani, MD; Lisa Saiman, MD, MPH; Children's Spine Study Group*

**Summary**
The pathogens and susceptibility profiles causing deep SSIs (n=99) following growth-friendly surgery for children with non-idiopathic scoliosis were assessed to optimize perioperative prophylaxis (ppx). Gram positive cocci (GPC) were detected in 90.1% of SSIs and cefazolin and vancomycin susceptibility remained unchanged throughout the study period. Gram negative rods (GNR) were detected in 16.5% of SSIs and cefazolin susceptibility decreased while susceptibility to aminoglycosides (AGA) increased. AGA play a critical role in GNR coverage and should be incorporated into ppx.

**Hypothesis**
Patients with nonidiopathic scoliosis who develop SSI following growth-friendly surgery will exhibit a trend of increasing antibiotic resistance.

**Design**
Multicenter Retrospective Cohort Study

**Introduction**
Analyzing the susceptibility profiles of pathogens causing deep surgical site infections (SSIs) could optimize perioperative ppx. The purpose of this study was to assess the pathogens causing deep SSIs following growth-friendly surgery and ppx regimens used by the study sites.

**Methods**
The Children's Spine Study Group database was queried for

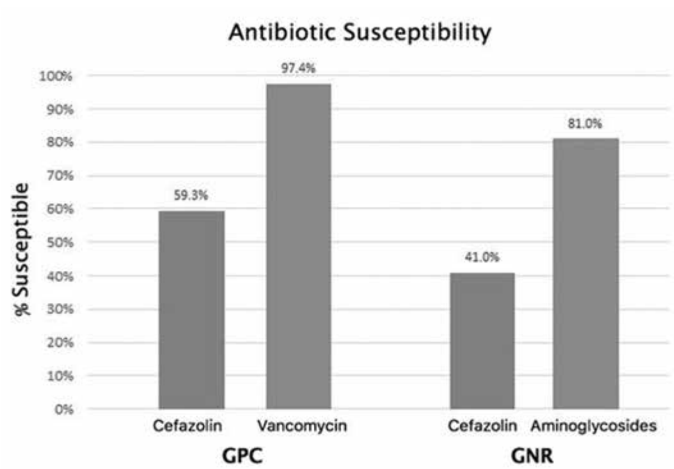
children ≤18 years of age undergoing growth-friendly surgery for non-idiopathic scoliosis at 11 institutions. Deep SSIs (CDC definition: occurring ≤ 90 days) reported from 9/2001-1/2016, associated pathogens, susceptibility profiles, and periop ppx regimens were analyzed.

**Results**

Of 593 patients undergoing 5,072 growth-friendly procedures, 75 (12.6%) patients developed 99 deep SSIs (1.95% of procedures). Cultures were available from 91 SSIs and 89 (97.8%) had >1 pathogen identified. GPC were detected in 82 (90.1%) SSIs; methicillin-susceptible Staph aureus (48.4%), methicillin-resistant S. aureus (MRSA, 23.1%), and coagulase negative staphylococci (8.8%) were most common. GPC susceptibility to cefazolin and vancomycin was unchanged during the study period. GNR were detected in 15 (16.5%) SSIs; E coli (5.5%), Enterobacter cloacae (4.4%), and Pseudomonas aeruginosa (4.4%) were most common. GNR susceptibility to cefazolin decreased while susceptibility to AGA increased during the study period. Currently, all sites use cefazolin and intravenous/topical vancomycin and 78% use agents as periop ppx for GNRs. Antibiotic susceptibility to these agents is shown (Figure).

**Conclusion**

In patients with nonidiopathic scoliosis, GPC susceptibility to cefazolin and vancomycin remains unchanged, while GNR susceptibility to cefazolin has decreased. These findings suggest that institutions should consider use of AGA for GNR ppx and monitor the susceptibility patterns of infecting pathogens to agents used for antimicrobial ppx.




## 53. Deep Surgical Site Infections (SSIs) Following Growth-Friendly Procedures in Children with Non-idiopathic Scoliosis Requiring Repetitive Surgery: Per Patient Risk 6-Fold Higher than Per Procedure Risk

*Anas A. Minkara, BHS; Michael Vitale, MD, MPH; Hiroko Matsumoto, MA; Michael P. Glotzbecker, MD; John M. Flynn, MD; John T. Smith, MD; Amer F. Samdani, MD; Lisa Saiman, MD, MPH; Children's Spine Study Group*

**Summary**

This multi-center (n=11) study assessed surgical site infections (SSIs) in patients ≤18 years of age undergoing growth-friendly procedures requiring repetitive surgery for non-idiopathic scoliosis from 2001-2016. In all, 593 patients underwent 5,072 procedures; deep SSIs occurred in 75 (12.6%) patients following 99 (1.5%) procedures. Overall, 49% of deep SSIs followed expansion procedures. Future studies will assess the cumulative SSI risk per patient associated with different types of procedures.

**Hypothesis**

The risk of deep surgical site infections in patients with non-idiopathic scoliosis following growth-friendly procedures requiring repetitive surgery will be considerably higher per patient compared to risk per procedure.

**Design**

Multicenter Retrospective Study

**Introduction**

The risk of SSIs following growth-friendly procedures for children with non-idiopathic scoliosis should be determined to establish a baseline risk as new instrumentation techniques are introduced. The purpose of this study was to assess rates of deep SSIs following growth-friendly surgery requiring repetitive surgery.

**Methods**

The Children's Spine Study Group database was queried for demographic and clinical characteristics of children ≤18 years of age undergoing growth-friendly instrumentation requiring repetitive surgery for non-idiopathic scoliosis at 11 institutions. Deep SSIs reported from September 2001 to January 2016 were included using the current Centers for Disease Control and Prevention case definition, i.e., deep SSIs occurred within 90 days of surgical procedures.

**Results**

In all, 593 patients with congenital (45%), neuromuscular (39%), and syndromic (16%) scoliosis underwent 5,072 procedures. The incidence of deep SSIs per patient was 12.6% as 75 patients had an SSI, whereas the risk of deep SSIs per procedure was 1.95% as 99 SSIs were reported during the study period. The demographic and clinical factors of patients with deep SSIs are shown (Table). Overall, 49% of deep SSIs followed expansion procedures.

**Conclusion**

The risk of deep SSIs in patients with non-idiopathic scoliosis following growth-friendly procedures requiring repetitive surgery is 6-fold higher per patient (12.6%) than the risk per procedure (1.95%). Future analysis will assess the risk of deep SSIs associated with different expansion procedures such as proximal rib based constructs and magnetically controlled growing rods.

| Characteristics | Deep SSI |
|---|---|
| | N=99 SSIs |
| **Mean age at time of SSI, years** (range) | 8.4 (0.8-17.7) |
| **Timing after procedure, days** (range) | 33 (1-90) |
| **Procedure Type** | |
| Initial Implant | 21 (21%) |
| Expansion | 48 (49%) |
| Revision | 16 (16%) |
| Other* | 14 (14%) |
| | N=75 patients |
| **Scoliosis Etiology** | |
| Congenital | 32 (43%) |
| Neuromuscular | 32 (43%) |
| Syndromic | 11 (15%) |

*Includes: new/additional implant, exchange, or removal (including with implant or fusion)

## 54. Analysis of Explanted Magnetically Controlled Growing Rods from 7 UK Spinal Centers

*Thomas J Joyce; Simon L Smith; Paul RP Rushton; Andrew J Bowey, MB ChB MRCS(Glasg) FRCS(Tr&Orth); Michael J Gibson*

**Summary**

Failures of magnetically controlled growing rods (MCGR) have been reported which in some cases have been associated with metallosis surrounding the rods and drive pin fractures. Thirty-four failed MCGR were cut open to determine why they failed. All showed internal wear debris, identified as titanium. Pin fractures as well as bearing and O-ring failure were also seen. Offset loading of the MCGR causes internal wear debris which may then escape into the body of the child.

**Hypothesis**

Analyze explanted MCGR used in management of early onset scoliosis and identify the mode of failure in such cases.

**Design**

Analysis of explanted MCGR

**Introduction**

MCGR are increasingly used as the treatment of choice for early onset scoliosis. However, being more complex than conventional growing rods they are perhaps more likely to succumb to multifarious failure modes. Failures of MCGR have been reported clinically which in some cases have been associated with metallosis surrounding the rods and drive pin fractures.

**Methods**

Explanted MCGR from 7 UK spinal centers were obtained for independent analysis. Thirty-four rods, from 18 children, explanted for reasons including failure of rod lengthening and maximum rod distraction reached, were cut open to allow internal components to be evaluated and assessed.

**Results**

Externally, all MCGR rods showed localized marks, which were termed 'growth marks' as they indicated growth of the rod in vivo, on the extending bar component. After cutting open, titanium wear debris was found inside all 34 (100%) MCGR. Typical wear debris is shown in the included figure. Ninety-one percent (31/34) of MCGR showed measurable wear of the extending bar, towards the magnet end. Substantial damage to the radial bearing was seen inside 74% (25/34) of MCGR rods while O-ring seal failure was seen in 53% (18/34) of cases. In 44% (15/34) of the MCGR the drive pin was fractured but this was felt to be an effect of rod failure, not a cause.

**Conclusion**

The combination of high volumes of titanium wear debris alongside O-ring seal damage likely accounts for the metallosis reported clinically around some MCGR. Based on this explant data, a failure mechanism in MCGR due to the natural offset loading in the spine was proposed. This is the largest data set reporting a complete analysis of explanted MCGR to date. Given the paucity of long term clinical data for MCGR, reported cases of significant metallosis in children, together with the findings from the current study, we urge caution in the use of MCGR.

## 55. Continued Deterioration in Pulmonary Function at Minimum 18-Year Follow-Up from Early Thoracic Fusion in Non-Neuromuscular Scoliosis

*Daniel Bouton, MD; Lori Ann Karol, MD; Kiley Poppino, BS; Charles E. Johnston, MD*

**Summary**

Patients who underwent thoracic spinal fusion at a young age returned at minimum 18-year follow-up for pulmonary function and functional activity testing. There was a statistically significant decline in their pulmonary function test results when compared to previous values from 11-year follow-up, and their functional activity was limited. One patient had expired from pulmonary complications.

**Hypothesis**
As they enter adulthood, patients who underwent thoracic spinal fusion at a young age will have very poor pulmonary function and functional activity, which will continue to decline as they age.

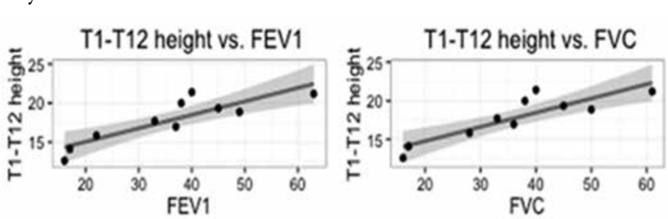
**Design**
Retrospective cohort study

**Introduction**
A decline in pulmonary function has been shown to develop in patients with thoracic fusion at a young age and is associated with decreased thoracic spinal height. The purpose of this study was to determine if there is a continued decline in pulmonary function at long-term follow-up in patients with scoliosis who underwent thoracic fusion prior to the age of nine years while also assessing their functional activity and limitations.

**Methods**
Patients who had thoracic spinal fusions before the age of nine years with a minimum 18-year follow-up underwent pulmonary function and functional activity testing and radiographic evaluation with biplanar imaging. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) were measured and compared with age-matched normal values. Patients with neuromuscular disease, skeletal dysplasias or preexisting pulmonary disease were excluded. The pulmonary function values were then compared to previously obtained values from an average 11-year follow-up.

**Results**
A total of 28 patients were identified who met our inclusion criteria. Nine patients were able to return for testing. One patient had expired due to pulmonary complications. The average age at the time of surgery was 2.7 years with 23.4 year follow-up (18.8-27.9). All nine patients had previous pulmonary function tests on average 11.7 years prior. When compared to their previous pulmonary function test results, there was a decline in FVC (38.7% vs. 48.7% of age-matched normals, $p=0.0154$) and FEV1 (38.2% vs. 47.8% of age-matched normals, $p=.0160$). The average patient's 6-minute walk test results were 62% of age-matched normals.

**Conclusion**
Patients with a thoracic spinal fusion at a young age have a continued decline in pulmonary function relative to their age as they enter adulthood, which can be life-threatening. In addition, their functional capacity is severely limited.. One must consider the potential consequences of an early thoracic fusion when treating early-onset scoliosis.




T1-T12 height (cm), FEV1 (Forced expiratory volume in one second, percentage of normal), FVC (Forced vital capacity, percentage of normal)

## 56. Improvement of Pulmonary Function Measured by Patient-Reported Outcomes in Patients with Spinal Muscular Atrophy after Growth-Friendly Instrumentation

*Hiroko Matsumoto, MA; John David Mueller, BS; Anas A. Minkara, BHS; Patrick J. Cahill, MD; Peter F. Sturm, MD; John T. Smith, MD; George H. Thompson, MD; Paul D. Sponseller, MD, MBA; David L. Skaggs, MD, MMM; Michael Vitale, MD, MPH; David Price Roye, MD; Growing Spine Study Group; Children's Spine Study Group*

**Summary**
This multicenter retrospective study reports improvement in pulmonary function (PF) as perceived by caregivers in patients with Spinal Muscular Atrophy (SMA) undergoing growth-friendly procedures. EOSQ24 PF scores increased from 70.2 pre-operatively to 84.6 at one year post-operatively and to 91.2 at two years ($p < 0.05$). There was no change in FVC values, suggesting that this parameter may not be sensitive enough to capture PF in daily living. Patient-reported outcomes can be utilized in evaluating the effectiveness of surgical procedures.

**Hypothesis**
The pulmonary function of SMA patients undergoing growth-friendly procedures will improve postoperatively as measured by patient-reported outcomes (EOSQ-24 pulmonary function domain scores).

**Design**
Multicenter retrospective cohort study

**Introduction**
Surgical intervention with growth-friendly constructs can halve the rate of PF decline and allow lung growth. While PF has been traditionally assessed via PFTs, disease severity and young age patients with SMA precludes them from taking PFTs. This study aimed to demonstrate that the Early Onset Scoliosis Questionnaire (EOSQ-24) PF domain could be used to evaluate PF changes in patients after growth-friendly instrumentation.

**Methods**
Two national registries were queried for patients with SMA operated on between 2005 and 2015. Patients diagnosed with SMA and treated with growth-friendly instrumentation were eligible for our study. Pre-operative and post-operative EOSQ24 PF domain scores at 1 year and 2 years as well as PFT results measured by forced vital capacity (FVC) were assessed.

**Results**
92 patients meeting criteria were identified (mean preoperative coronal curve=67.9°; 51%F; 6.9 years at implant, range 2-13). Mean initial major coronal correction was 26.4° ($p < 0.05$). EOSQ24-PF scores increased from 70.2 pre-operatively to 84.6 at one year post-operatively, and to 91.2 at two years ($p < 0.05$), exceeding the minimal clinically important difference of 10%. No significant difference was observed between pre-operative and post-operative FVC values. The minimum age at preoperative EOSQ completion was 2 years compared to a minimum age of 5 years with FVC.

**Conclusion**
Caregivers perceived a significant improvement in PF in children following growth-friendly instrumentation. This study reiterates the utility of the EOSQ-24 in evaluating the PF of patients with SMA undergoing growth-friendly procedures. No significant difference between pre and postoperative FVC was observed, suggesting PFT may not be sensitive enough to capture PF in daily living. EOSQ-24 PF also allows for the evaluation of PF at a younger age compared to FVC.

## 57. MRI in Early Onset Scoliosis: Is Universal Screening Necessary?

*Scott Herron, MD; Anthony Kouri, MD; Elizabeth, W Hubbard, MD; Vishwas R. Talwalkar, MD; Ryan D. Muchow, MD; Henry J. Iwinski, MD; Cale Jacobs, PhD*

**Summary**
Among 53 patients with presumed idiopathic early onset scoliosis (EOS), there were no distinguishing demographic or radiographic features that were predictive of identifying a neural axis abnormality (NAA) on magnetic resonance imaging (MRI). 24.5% of patients in this study had an identifiable NAA on MRI, which supports using universal MRI screening in this population.

**Hypothesis**
There is a subset of presumed idiopathic EOS patients that have a low incidence of NAA such that they can be excluded from undergoing screening MRI.

**Design**
Retrospective chart review

**Introduction**
Individuals presenting with EOS of a presumed idiopathic nature have a significantly increased incidence of NAA compared to the general population. At our institution, screening MRIs are obtained for all patients with EOS. The purpose of this study is to determine if there are certain idiopathic patients in which routine screening MRI may be avoided.

**Methods**
This is a retrospective study of 53 presumed idiopathic EOS (onset ≤5 years) patients who had screening MRIs at our institution from 1997-2015. Demographic information including age at presentation, sex, and body mass index (BMI) were recorded. Additionally, radiographic characteristics including curve location, magnitude, secondary curves, rib phase, and rib vertebra angle difference (RVAD) were collected. Continuous variables were compared using two-tailed independent t-tests, and categorical variables were compared using Fisher exact tests. A binary regression using both continuous and categorical variables was used to determine if a model could be created to accurately predict the need for MRI.

**Results**
Of the 53 patients with EOS, 13 had positive MRI findings, resulting in a 24.5% incidence of NAAs. The mean age at presentation (27 v. 24 months), sex, and BMI had no predictive value for an abnormal MRI (P>0.05). The mean curve magnitude at presentation was 34.60 ± 150 with a normal MRIvs. 43.20 ± 13.90 in those with an abnormal MRI (P>0.05). The mean RVAD was 18.50 ± 15.60 with a normal MRI vs. 18.40 ± 15.60 with an abnormal MRI (P>0.05). The 13 positive MRI findings consisted of 7 Arnold-Chiari malformations, 3 syrinx, 1 tethered cord, 1 arachnoid cyst, and 1 ganglioneuroblastoma – 2 patients required surgery and 1 chemotherapy.

**Conclusion**
There are no distinguishing demographic or curve characteristics in those with presumed idiopathic EOS that allow patients to be excluded from a screening MRI. An incidence of 24.5% positive MRI findings in these patients is higher than previously reported.

## 58. All that Glitters is Not Gold – Serial Casting for EOS Negatively Affects Health-Related Quality of Life even after Discontinuation of Serial Casting: A 2 Year Follow-up

*Hiroko Matsumoto, MA; Emily Auran, BA; Chun Wai Hung, MEng; Peter F. Sturm, MD; Sumeet Garg, MD; James O. Sanders, MD; Matthew E. Oetgen, MD; David Price Roye, MD; Michael Vitale, MD, MPH; Children's Spine Study Group; Growing Spine Study Group*

**Summary**
Serial casting is an important treatment for EOS, but its effects on HRQoL is still poorly understood. This study compared the change in EOSQ-24 scores between non-idiopathic and idiopathic patients as a result of casting.

**Hypothesis**
HRQoL declines and burden of care increases during casting treatment and is restored post-casting for both idiopathic and non-idiopathic EOS.

**Design**
Multicenter retrospective cohort

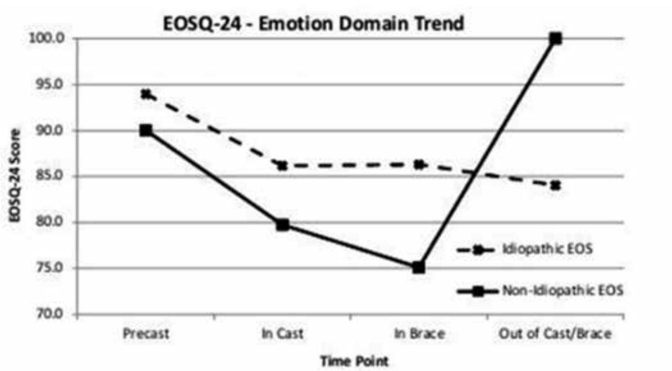
**Introduction**
The treatment of early onset scoliosis (EOS) is controversial and evolving. Serial body casting is a safer alternative to surgical intervention in correcting spinal deformity. It is thus critical to discern the impact of casting on patients and their caregivers. This study aims to compare the health-related quality of life (HRQoL) of patients with EOS before, during, and after casting using EOSQ-24.

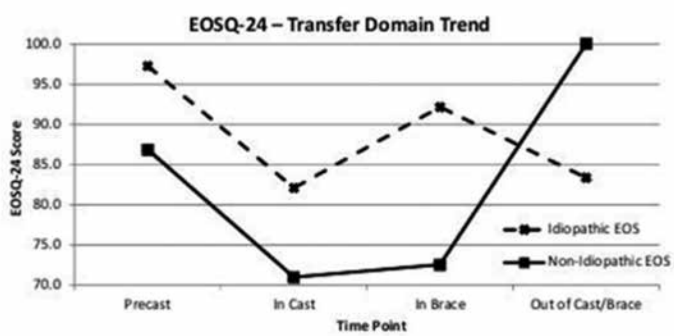
**Methods**
This study identified 91 EOS patients from 2 multi-center databases from 2005-2016. Mean index casting and final cast removal ages were 2.1±1.2yr and 4.1±2.0yr respectively. 32 had non-idiopathic and 59 had idiopathic EOS. EOSQ scores were compared pre-, during, and post-casting. Mean follow-up between index casting and post-brace was 2.8±0.9yr. Pre-cast and in-cast scores were obtained at mean 13 days before and 9 months after index casting respectively. Post-cast EOSQ evaluation was at mean 5 months after cast removal. Scores were compared to age-matched healthy norms.

**Results**
For all time points and EOSQ domains, non-idiopathic patients

had lower scores than idiopathic. Pre-cast, idiopathic scores were similar to age-matched norms except in the burden domains, while non-idiopathic's were consistently lower. In-cast, non-idiopathic patients declined in Transfer and Emotion (p<0.05), while idiopathic patients declined in those 2 as well as Physical Function, Daily Living, Overall HRQoL and Burden (p<0.05). In-cast scores for both groups were significantly lower than norms. In-brace, non-idiopathic scores slightly increased while idiopathic scores did not change. Post-brace, non-idiopathic scores increased from in-cast scores in all but 1 domain, while idiopathic scores remained unchanged.

**Conclusion**
Understanding the impact of serial body casting on HRQoL in different populations with EOS help clinicians make more informed decisions about treatment options. Due to the generally healthier medical status of idiopathic patients, their EOSQ scores drops more starkly than non-idiopathics while subjected to restrictive casting, with residual effects persisting after cast removal. The more complex disease states of non-idiopathics may mask the effect of casting on their HRQoL.




## 59. Results of Casting in Severe Infantile Scoliosis

*Peter J. Stasikelis, MD; Ashley Carpenter, BS*

**Summary**
This study examines the results of casting in 44 children with severe infantile scoliosis (≥50° at the initiation of treatment) who had a minimum three year follow up. Resolution of the curve was observed in 10 of 25 (40%) of idiopathic children, while only two of 19 (11%) children with genetic syndromes or syrinx resolved their curves. At the time of submission, only four children have had to undergo growth friendly instrumentation.

**Hypothesis**
This study sought to examine the hypothesis that significant delays in the need for growth friendly instrumentation would be possible with casting even in the largest curves (minimum 50°). It also sought to examine the hypothesis that comorbidities would affect the rate of resolution of these larger curves.

**Design**
This is an IRB approved retrospective study of all children casted for infantile scoliosis at a single institution.

**Introduction**
Previous work has demonstrated that casting for infantile scoliosis is most likely to result in curve resolution when the curves were small and the child is under two years of age. Therefore, the authors sought to limit this study to large curves (minimum 50°).

**Methods**
After IRB approval, a consecutive series of children undergoing casting for infantile scoliosis at one institution over an eight year period was examined. Inclusion criteria included initial curve at first casting of ≥50°, age ≤3 years at initiation and a minimum follow up of three years. Of the 145 children undergoing serial casting during this time period, 44 met our inclusion criteria. All children underwent MRI imaging. Ten children were found to have a syrinx, none of which had neurosurgical intervention. Nine children with genetic syndromes were grouped with the 10 children with a syrinx (NIS group) and compared with the 25 children without these comorbidities (IS group). Curve magnitude in the IS group ranged from 50-105° while in the NIS group curves ranged from 50-106°.

**Results**
Ten of the 25 (40%) children in the IS group demonstrated resolution of their curves, while only two of the 19 (11%) in the NIS group did. Of the children that did not have resolution of their curves, 14 were maintained over the entire follow up period to within 15° of their initial curve and 13 were improved 15°or more. Only five children had an increase of 15° or more over the follow up period and four of these have undergone growth friendly instrumentation after a mean delay from initial cast of 71 months (range: 18-100 months).

**Conclusion**
This study of children with severe infantile scoliosis showed casting to be effective in delaying instrumentation in all cases, and led to resolution of the curve in 40% of IS curves and 11% of NIS curves.

## 60. Does Decompression of Chiari I Malformations Alter the Progression of Early-onset Scoliosis (EOS) -The Importance of Associated Syringomyelia?

*Eric A. Davis, BS; Amanda T. Whitaker; Michael J. Troy, BS; Michael T. Hresko, MD; John B. Emans, MD; Daniel J. Hedequist, MD; Mark Proctor, MD; Brian D. Snyder, MD, PhD; Michael P. Glotzbecker, MD*

**Summary**
Neurosurgical decompression of Chiari malformations may alter progression of EOS in patients with concomitant syringomyelia

and does not alter curve progression in patients without concomitant syringomyelia.

**Hypothesis**
Neurosurgical decompression of Chiari malformations may alter natural history of EOS.

**Design**
Retrospective review of patients diagnosed before age 10 with scoliosis (Cobb>10°) and Chiari malformations (>5mm) over a 20-year period.

**Introduction**
Chiari malformations have long been associated with scoliosis; however, it is unclear if surgical decompression influences progression of EOS. The purpose of this study is to describe the natural history of EOS in patients with Chiari malformations with or without decompression.

**Methods**
Retrospectively, patients <10 years old with scoliosis (Cobb>10°) and Chiari malformations (>5mm) were included. Patients with concomitant causes of neuromuscular curves were excluded. 67 patients (44M, 23F) with mean age 6.7 years (1-9) and 7 years (5-15) at EOS diagnosis and decompression were included. Indications for decompression included scoliosis, headache, or back pain. Clinical and major curve characteristics were measured at time of diagnosis, before decompression and at mean follow-up of 12.6 ± 4.56 years. Statistical significance was defined as $p \leq 0.05$.

**Results**
45 patients presented with and 22 without associated syringomyelia. In both groups, younger patients were less likely to require spinal fusion (OR 1.85; p<.05). Syringomyelia was associated with Cobb 9° larger (p=.003) at presentation. Of 45 patients with syringomyelia, 21(46%) had atypical (left-sided) curves. Average preoperative syringomyelia width, area and levels spanned were 7.9±3.67mm, 1356.3±972.56mm², and 12±4 levels, respectively. 43/45 underwent decompression with 4/43 experiencing complete syrinx resolution. Chiari decompression was associated with -5.5±3.44mm decrease in syringomelia width (p<0.001), 66% decrease in area (p<0.001), and 4±4 decrease in vertebral levels spanned (p<0.001) at last follow-up. After decompression, 20(47%) had curve improvement(>-5°), 6(14%) no progression(≤5°), and 17(40%) progressed(>5°) with 11(26%) requiring spinal fusion. No association with curve improvement and bracing was found p=.22. Syringomyelia negative patients saw no Cobb improvement following decompression (p=1).

**Conclusion**
Overall, 63% of Chiari malformations associated with syringomyelia had EOS improvement or stabilization following decompression, suggesting a benefit. Syringomyelia negative patients had no Cobb improvement, suggesting decompression does not alter curve progression in these patients.

## 61. Pelvic Obliquity Correction in Distraction-Based Growth Friendly Implants

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**Summary**
There was better correction of pelvic obliquity in the screw group compared to the S hook group in distraction based growing spine constructs. There were more complications in the S hook group (25%) than in the screw group (15%) though this did not achieve significance.

**Hypothesis**
There will be more pelvic obliquity correction when screws are used for pelvic fixation than S hooks.

**Design**
Multicenter retrospective review.

**Introduction**
Multiple options exist for pelvic fixation in distraction based growing rod systems, however, limited comparative data is available. Our purpose was to evaluate the radiographic outcomes and complication rates of patients treated with distraction based implants with either screws (sacral-alar-iliac (SAI) screws or iliac screws) or hooks (s hook iliac fixation).

**Methods**
EOS patients of all diagnoses with distraction based implants with pelvic fixation from 2000 to 2013 were reviewed from two EOS multicenter databases. Patients were divided into two groups by type of pelvic fixation (1) screw group (sacral-alar-iliac (SAI) screws or iliac screws) or (2) S hooks. Exclusion criteria were as follows: index instrumentation ≥ 10 years old and follow up < 2 years. 154 patients met the inclusion criteria. Mean age at index surgery was 6.2 years old (range 1.0-9.9 years) and mean follow up was 4.9 years.

**Results**
Pelvic fixation in the 154 patients was as follows: screw group=41 and S hook group=113. When comparing patients with >20 degrees of initial pelvic obliquity (PO) the screw group had significantly more correction; mean 26.1±11.9 degrees for the screw group vs mean 17.3±9.2 degrees in the S hook group (p=0.039). There was no significant difference in change in T1-S1 length (40.4 vs 39.5 mm, p=0.90) or correction of Cobb angle (31.2 vs 24.1, p=0.13). Rate of complications for the screw group was 14.6% (6/41) vs 25.7% (29/113) in the S hook group, though this did not achieve significance (p=0.21), see Table 1.

**Conclusion**
In distraction based growing spine constructs, pelvic fixation with screws achieved better correction of pelvic obliquity than S hooks.

**Table 1. Complications (S hooks vs. Screws)**

| Complication | S hooks (n=28) | Screws (n=7) |
|---|---|---|
| Implant migration | 12 (43%) | 1 (14%) |
| Implant failure | 8 (28%) | 4 (57%) |
| Implant prominence | 5 (18%) | 2 (29%) |
| Other | 3 (11%) | |

## 62. Hemoglobin Levels Pre- and Post-Treatment as a Surrogate for Disease Severity in Early Onset Scoliosis

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**Summary**
Elevated hemoglobin (HgB) may be a marker for preoperative hypoxia in patients with Early Onset Scoliosis (EOS) and Thoracic Insufficiency Syndrome (TIS). The changes in HgB level after treatment may be a surrogate marker for improved oxygenation.

**Hypothesis**
In patients with elevated pre-operative HgB, surgical treatment for EOS leads to improved oxygenation, as noted by decreased HgB levels.

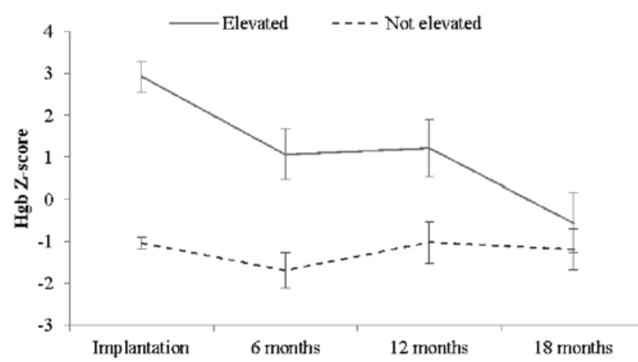
**Design**
From 2012 to 2016, 196 EOS patients were prospectively enrolled from a multicenter database. Inclusion criteria included patients with EOS that had planned treatment with rib based distraction, growing rod (GR), or MCGR for TIS. Exclusion criteria included previous spine surgery or underlying hematologic disorder. Pre-operative HgB levels at initial implant and following surgery at 6, 12, and 18 months were collected.

**Introduction**
Elevated HgB is associated with hypoxia and may be a surrogate for preoperative disease severity in patients with EOS and TIS. Previous retrospective studies have noted EOS patients with elevated HgB decrease 6-24 months following treatment with rib based distraction) and expansion thoracostomy or GR surgery. The purpose of this study was to prospectively 1) quantify the prevalence of elevated HgB in patients with EOS who require surgery and 2) quantify the response of HgB levels to treatment.

**Methods**
HgB laboratory values were prospectively collected in a multicenter database prior to initial implantation and following surgery at 6, 12, and 18 months. Because normal HgB values vary with age, HgB values were converted to Z scores, calculated by dividing age-adjusted mean HgB levels by the age-adjusted standard deviation. Elevated HgB was defined by a Z-score >1. Change in HgB Z-score and curve measured by Cobb angle over time were assessed using piecewise linear mixed modeling.

**Results**
196 EOS patients were enrolled, comprising GR (12%), MCGR (33%), and rib based distraction (53%) treatment. The average age at implantation was 6.7 years. The prevalence of elevated HgB (Z >1) was 15%. HgB Z-scores in elevated HgB patients decreased preoperative to 6 months (p<0.001), showed no change 6 to 12 months (p=0.33), then decreased from 12 to 18 months (p=0.03). Patients with non-elevated HgB preoperative showed no postoperative HgB change over time (p=0.14).

**Conclusion**
There appears to be a significant and ongoing positive impact on oxygenation from distraction instrumentation in patients with EOS and TIS as evidenced by a meaningful proxy measurement: improvement in abnormal pre-op HgB levels after surgery.




## 63. Congenital Spine Deformity with Fused Ribs Treated with Proximal Rib- vs. Spine-Based Growing Constructs

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**Summary**
Rib-based and spine-based devices for treatment of congenital spine deformity with rib fusions achieved on average 3.6 cm increased T1-T12 height and 6.4 cm T1-S1 height with a mean of 11 surgeries over 6.5 years prior to definitive fusion. Patients with rib-based proximal anchors became more kyphotic over time and had less Cobb angle correction at completion of distraction-based treatment.

**Hypothesis**
We hypothesized that there would be improved thoracic height and Cobb angle in patients with congenital fused ribs treated with proximal spine anchors (spine-based growing devices) compared to constructs with proximal rib anchors (rib-based devices).

**Design**
Retrospective review of prospectively collected data from two large multicenter databases.

**Introduction**
Treatment for severe early-onset spinal deformity with rib fusions includes growing spine devices with proximal rib or spine anchors. The results of treatment, however, have not been compared

between spine-based vs. rib-based proximal anchors.

**Methods**

181 patients with congenital rib fusions treated with either rib-based or spine-based constructs and with minimum 2-year follow-up were included. 20 patients were treated with growing rods and 161 with rib-based devices. Four of the growing rod patients also had proximal rib anchors in addition to proximal spine anchors. We evaluated change in T1-T12 and T1-S1 height, coronal Cobb angle, kyphosis and number of lengthening/revision surgeries. Any construct with a proximal spine anchor was considered to have spine-based fixation.

**Results**

Kyphosis increased in the rib-based group over the study period ($p<0.0001$), but did not change in the growing rod group (Table). Major Cobb angle decreased in both the spine-based and rib-based group ($p<0.0004$, $p<0.001$), although spine-based patients had lower Cobb at latest follow-up (0.007). After initial implantation surgery, in the rib-based group, there was a mean 2.3 cm increase in T1-T12 height from a mean of 8 lengthening surgeries (0.29 cm per lengthening) compared to 2.0 cm increase over 6 lengthening surgeries (0.3 cm per lengthening) in the spine-based group. Patients with rib-based constructs had a mean of 11.3 total procedures, whereas spine-based patients had a mean of 7.7 surgeries. A subanalysis was performed excluding the 4 patients with both rib and spine anchors without any change in the presented findings.

**Conclusion**

Patients underwent a mean of 7 lengthenings prior to final fusion or cessation of lengthenings with a 2 cm increase in T1-T12 height. Proximal spine anchors may help to control kyphosis and improve Cobb angle correction for congenital scoliosis with rib fusions.

| | Spine-Based Devices | Rib-Based Devices | P-value |
|---|---|---|---|
| Age at Initial Surgery | 5.2 (3.6-6.9) | 4.6 (4.1-5.0) | 0.41 |
| Gender (M/F) | 7/13 | 77/82 | 0.39 |
| Preoperative Cobb | 66 (56-75) | 66 (64-69) | 0.89 |
| **Preoperative Max Kyphosis** | **54 (40-68)** | **38 (35-41)** | **0.029** |
| Time to Follow-Up/Definitive Fusion | 5.6 (4.2-7.0) | 6.6 (6.1-7.1) | 0.15 |
| **Total # of Surgeries** | **8 (6.2-9.8)** | **11.2 (10.4-12.0)** | **0.0025** |
| **# Lengthening Surgeries** | **6 (4.4-7.7)** | **7.9 (7.3-8.5)** | **0.04** |
| # of Revision Surgeries | 1.7 (0.7-2.7) | 2.3 (1.9-2.6) | 0.3 |
| **Postop Cobb** | **46 (37-55)** | **60 (57-63)** | **0.007** |
| **Postop Max Kyphosis** | **40 (32-49)** | **54 (51-57)** | **0.007** |
| **Change in Cobb** | **20 (9-31)** | **7 (4-10)** | **0.03** |
| **Change in Kyphosis** | **14 (0-28)** | **-15 (-12,-18)** | **0.006** |
| Total T1-T12 Ht Increase | 4.9 (1.2-8.7) | 3.5 (2.9 – 3.9) | 0.4 |
| Total T1-S1 Ht Increase | 7.2 (5.4-8.9) | 6.3 (5.4-7.2) | 0.37 |
| Increase T1-T12 from Initial Implant | 3.1 (1.6 – 6.6) | 1.0 (0.7-1.4) | 0.22 |
| Increase T1-S1 from Initial Implant | 2.7 (1.4-4.0) | 1.8 (1.2-2.3) | 0.20 |
| Increase T1-T12 from Lengthenings | 2.0 (0.6-4.5) | 2.3 (1.8-2.9) | 0.76 |
| Increase T1-S1 from Lengthenings | 4.7 (3.0-6.5) | 4.5 (3.5-5.5) | 0.80 |
| Increase at T1-T12 Final Fusion (38 pts only) | 0.75 (-0.7-2.2) | 1.3 (0.6-2.1) | 0.39 |
| Increase T1-S1 Final Fusion (38 pts only) | 0.6 (-1.5, 2.7) | 2.1 (1-3.1) | 0.16 |

## 64. Self Sliding Growth Guidance Technique with Multisegmenter Pedicle Screw Fixation in the Treatment of EOS

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**Summary**

A new surgical strategy called Self Sliding Growth Guidance (SSGG) technique provides and maintains satisfactory curve corrections on both planes, allows self growing of the spine with a rate of 1.15 mm growth per month, decreases the number of repeated lengthening procedures, and shown to have low complication rates and improved pulmonary functions.

**Hypothesis**

SSGG will maintain correction of EOS deformity on both planes and reduce the number of lengthening procedures and avoid spontaneous fusion.

**Design**

Retrospective

**Introduction**

Traditional growing rods (TGR) used for the treatment of EOS had various drawbacks including repeated lengthening procedures,implant failure,junctional kyphosis and spontaneous fusion.The aim of this study is to assess whether SSGG which provides dynamic fixation in contrast to TGR; works, decrease the complication rates and improve the pulmonary functions.

**Methods**

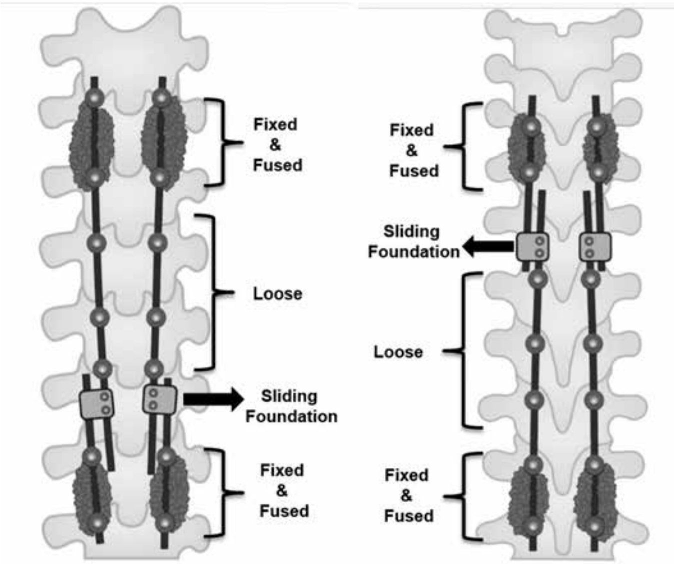
22(15F/7M) pts with mean age 6.3(3-10) yrs were evaluated.Technique included placement of pedicle screws to the proximal,distal,apical, and intermediate vertebrae with muscle-sparing technique. Following rod placement and correction,the most proximal & distal two segments were fixed and fused;the rest of the set screws were kept loose (unlocked) to allow vertical spinal growth.Sliding foundation was placed either below the most proximal or above the most distal fixed and fused segments and self-lengthening was achieved by side to side connectors. Preop, f/up, latest x-rays & pre/latest PFTs were evaluated.

**Results**

Mean f/up was 33.3 months(24-58). MT curve of 55,1° was corrected to 19,6° (67% correction) and TL/L curve of 45,6° was corrected to 13,4° (75% correction). Preop TK of 32,1° and LL of 55,1° was maintained at 31,4° and 53.5° respectively. Mean increase in T1-T12 length was 0.79mm and 1.15mm /month in T1-S1 height. None of the pts had neurological impairment. There were no rod breakage,infection or spontaneous fusion. Only 2 screws were revised for loosening in 1 patient. Set screw dislodgement was found in 5 pts (%22) on the concave side. In 4 pts (%18) distal sliding foundation was converted to proximal foundation due to correction loss during f/up. SSGG prevented 73 planned lengthenings. Mean %pre.FVC of 72,5 improved to 85,4 and FEV1 of 79,2 improved to 87,9 at final f/up.

**Conclusion**

In contrast to TGR, SSGG is a dynamic growth guidance technique which allows self growing of the spine and maintains correction on both planes. SSGG demonstrated low complication rates, decreased the number of planned lengthenings, avoided spontaneous fusion and improved the pulmonary functions. Better curve control can be achieved when sliding foundation is placed proximally.




### 65. Growth Guidance - Evolution of a New Procedure: Rate of Complications in the First Two Years Following Implantation in the First 80 Patients

*Richard E. McCarthy, MD; Frances McCullough, MNSc; David B. Bumpass, MD*

**Summary**
As the growth guidance system (GGS) technique has evolved for use in early-onset scoliosis (EOS), progression along the surgeon learning curve has resulted in fewer implant-related complications and fewer returns to surgery.

**Hypothesis**
Increasing surgeon experience in the development of the GGS technique would result in a decrease in complications requiring surgery during the first 2 years post-implantation.

**Design**
Retrospective cohort study

**Introduction**
The GGS technique allows for continued spinal growth without repeated rod lengthening procedures in children with EOS. We sought to learn whether the evolution of the GGS technique has resulted in an overall decrease in complications over the first 2 years post-GGS implantation, and to identify which refinements in the surgical technique may have resulted in fewer complications.

**Methods**
A retrospective review was performed comparing the first 40 patients (Group A) undergoing GGS at our institution with the next 40 patients (Group B). The groups were reviewed for number and type of complications occurring within the first 2 years after insertion. All surgeries were performed by a single surgeon.

**Results**
Group A had 4 patients that either died from their underlying disease, were lost to follow up, or had definitive procedures prior to 2 years after index procedure, while group B lost 6 patients. Table 1 summarizes gender and diagnoses, with equal distributions between groups. Group A patients had 42 additional surgeries (1-6 per patient) involving 20 patients, a surgical complication rate of 56% in the first 2 years after surgery. The reasons for surgery were infection (n=7) and implant failure (n=35). Group B patients had 19 additional surgeries (1-3 per patient) involving 12 patients for a complication rate of 35%, for infection (n=9) and implant failure (n=10). This represents a significant reduction in implant-related complications (p=0.02).

**Conclusion**
A considerable drop in the number of GGS complications requiring revision surgeries was seen in Group B, with both groups being comprised of the same type and severity of patients. The decrease in implant complications in particular was significant. This drop can only be explained as a learning curve. It leads us to conclude that improved implant placement techniques adopted based on initial failures, such as deeper screw insertion with larger diameter screws, better rod contouring, and larger rods resulted in diminished implant problems.

**Table 1 - Baseline Group Comparisons**

| | Group A (N=36) | Group B (N=34) | p |
|---|---|---|---|
| Gender: | | | |
| Male | 15 | 17 | 0.65 |
| Female | 21 | 17 | |
| | | | |
| Diagnosis: | | | |
| Idiopathic | 8 | 9 | 0.70 |
| Neuromuscular | 12 | 11 | |
| Syndromic | 13 | 13 | |
| Congenital | 1 | 1 | |
| Tumor | 1 | 0 | |
| Kyphosis | 1 | 0 | |

### 66. Construct Levels to Anchored Levels Ratio and Rod Diameter are Associated with Implant-Related Complications in Traditional Growing Rods

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**Summary**
In addition to patient characteristics, consideration of length of construct to number of anchored levels ratio and rod diameter should be a part of preoperative planning to minimize implant-

related complications.

**Hypothesis**
The anchor type and configuration in traditional growing rod constructs are associated with implant-related complications.

**Design**
Multicenter retrospective study.

**Introduction**
Implant-related complications (IRC) are among the most common adverse events in traditional growing rods (TGR). The study aim was to determine whether TGR anchor type and configuration are associated with IRC.

**Methods**
Patients with: 1) age ≤10 years at surgery; 2) spine-based dual TGR; 3) minimum 2-year follow up; and 4) available imaging. Cephalad and caudal foundations were grouped based on number of instrumented levels and anchor type. All radiographs were reviewed and IRC was defined as rod fracture, anchor pull out, prominence, and loosening. Based on results a "Construct Levels / Anchored Levels" (CL/AL) ratio was calculated, which is the number of levels spanned by instrumentation divided by the number of levels with bone-anchor fixation. Receiver operating characteristic curve was used to define CL/AL threshold.

**Results**
274 patients divided to complicated (n=140) and non-complicated (n=134) groups. Mean follow up was 6.3 years (2.1-18.0 years). No significant differences in age, gender, BMI, ambulatory status, etiology, primary curve size, T1-S1 height, coronal and sagittal balance, and rod material were observed between two groups. Comparative analysis showed that connector type, presence and location of crosslinks, number of levels instrumented, number and type of anchors, presence of pelvic fixation, and mirroring of cephalad and caudal foundations were not different (Table 1). However, maximum kyphosis and rod diameter were significantly different. CL/AL ratio threshold was 3.5. Multivariate analysis of kyphosis, rod diameter and CL/AL ratio showed a significant association with IRC (p<0.05).

**Conclusion**
with instrumentation failure, it is a combination of characteristics that include rod diameter and CL/AL ratio that showed significant correlation with IRC. Validation of CL/AL ratio is recommended.

Table 1.

| Pre-operative Demographics and Radiographic Parameters | | | | |
|---|---|---|---|---|
| | Complicated | Non-Complicated | | P value |
| N | 140 | 134 | | |
| Age | 6.5 | 6.9 | | 0.186 |
| BMI | 16.7 | 17.4 | | 0.325 |
| Primary Curve (°) | 76.9 | 73.1 | | 0.109 |
| Coronal Balance (mm) | 30.1 | 25 | | 0.598 |
| Sagittal Balance (mm) | 22 | 20.3 | | 0.941 |
| T1-S1 height (mm) | 261.5 | 266 | | 0.393 |
| Maximum Kyphosis (°) | 55.2 | 46.1 | | 0.014* |
| **Comparisons After Controlling for Maximum Kyphosis** | | | | |
| **Max Kyphosis** | **Odds Ratio** 1.1 | **Lower** 0.97 | **Upper** 1.24 | **P value** 0.123 |
| **CL/AL ratio** | | | | |
| <3.5 | 1 | | | |
| 3.5≤ | 3.43 | 1.89 | 6.24 | < 0.001* |
| **Rod Diameter** | | | | |
| <4mm | 5.52 | 1.66 | 18.37 | 0.019* |
| 4-5mm | 3.65 | 1.29 | 10.31 | 0.005* |
| 5 mm < (reference group) | 1 | | | 0.015* |

* Statistical significance was set at p<0.05

## 67.GWAS-Associated Single Nucleotide Polymorphisms are Associated with Curve Progression in Adolescent Idiopathic Scoliosis?

*Gene Chi Wai Man, PhD; Nelson Leung Sang Tang; Ting Fung Chan, PhD, BSc; Bobby Kinwah Ng, MD; Lei-Lei Xu, MD; Tsz-Ping Lam, MD; ZeZhang Zhu, MD, PhD; Yong Qiu, MD; Jack C.Y. Cheng, MD; Wayne YW Lee, PhD*

**Summary**
Although there have been many genes associated with patients with adolescent idiopathic scoliosis (AIS) from different genome-wide association studies (GWAS), there has been no replication study for validating their association with curve severity and curve progression.

**Hypothesis**
The 8 GWAS-associated single nucleotide polymorphisms (SNPs) are associated with curve severity and curve progression in female Chinese AIS.

**Design**
Genetic association study of 8 GWAS-associated SNPs previously reported to be associated with adolescent idiopathic scoliosis in the Chinese population.

**Introduction**
This study aimed to determine whether there is association of the 8 SNPS generated from our GWAS study in Chinese AIS with curve progression.

**Methods**
We recruited 201 non-AIS female controls and 319 female AIS patients with a Cobb angle of 10o or greater. The AIS patients were further subdivided into progressive and non-progressive groups: 1) scoliotic curves 40o or greater were regarded as progressive group, and 2) scoliotic curves less than 40o and had reached skeletal maturation were classified as non-progressive group. We then evaluated the association of 8 SNPs (rs11190870 in LBX1, rs12946942 in SOX9/KCJN2, rs13398147 in PAX3/EPHA4, rs241215 in AJAP1, rs3904778 in BNC2, rs6137473 in PAX1, rs6570507 in GPR126, and rs678741 in LBX1-AS1) by comparing risk allele frequencies between the 1) AIS and non-AIS

groups and 2) compared between progressive Vs non-progressive groups, and with the mean Cobb angle for each genotype.

**Results**
We evaluated the non-AIS controls and AIS subjects, the risk allele frequencies were significantly different for 4 SNPs namely LBX1 ($p<0.01$), BNC2 ($p<0.05$), GPR126 ($p<0.05$), and LBX1-AS1 ($p<0.01$). When comparing between the progressive AIS (N = 114) with non-progressive AIS (N = 205) subjects, the risk allele frequency for LBX1-AS1 was shown to be marginally associated. The mean Cobb angle for each genotype did not showed statistical difference.

**Conclusion**
This is the first study to validate and report the associations of the 4 GWAS-associated SNPs between AIS and non-AIS controls in the Chinese population. In addition, the SNP encoding for LBX1-AS1 was marginally associated with curve progression in AIS. Further replication study across different ethnic groups would be necessary to clarify whether these SNPs could potentially be genetic markers for predicting the occurrence/progression of AIS and institute appropriate timely treatment.

## 68. A Genetic Predictive Model Estimating the Risk of Developing AIS

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**Summary**
A predictive model for adolescent idiopathic scoliosis was constructed on the basis of 7 susceptible genes. It can explain 6.2% of the overall variance. With a cut-off set at 0.5, the predictive model yielded 87% sensitivity and 28.3% specificity.

**Hypothesis**
A combined effects of genetic factors can be used to predict the risk of AIS.

**Design**
A case-control association study

**Introduction**
Previous GWASs have revealed several susceptible variants associated with AIS. Early detection and risk prediction based on these risk variants could potentially improve disease prognosis and outcomes. This study aims to evaluate the independent and combined effects of genetic factors on the development of AIS, and to develop a genetic predictive model.

**Methods**
A total of 900 patients and 1400 normal controls were included. Genotyping assay were performed for 7 previously reported susceptible variants, including rs678741 in LBX1, rs241215 in AJAP1, rs13398147 in PAX3, rs16934784 in BNC2, rs2050157 in GPR126, rs2180439 in PAX1 and rs4940576 in BCL2. Unconditional logistic regression analyses were performed to generate a risk predictive model.

**Results**
All the 7 variants were successfully replicated in our subjects. The model was established using the following formula: $P = 1/[1 + \exp(-1.638 - 0.245*rs241215 + 0.4*rs13398147 + 0.197*rs2050157 + 0.296*rs2180439 + 0.393*rs16934784 + 0.327*rs678741 + 0.223*rs4940576)]$. The Hosmer Lemeshow test showed no significant deviations between the observed and predicted values ($p = 0.15$). The Cox & Snell R Square was 0.062, indicating the predictive model can explain 6.2% of the overall variance. With a cut-off set at 0.5, our predictive model yielded 87% sensitivity and 28.3% specificity.

**Conclusion**
Risk models with currently reported genetic factors have remarkable but limited discrimination power. A predictive model based on more clinical and genetic factors may add to the probability to identify AIS prior to its onset.

## 69. Correlation of the Sanders Skeletal Maturity Stage with Risser Stage in Adolescents with Idiopathic Scoliosis

*Kushagra Verma, MD, MS; Peter G. Gabos, MD; James O. Sanders, MD; Kenneth J. Rogers, PhD, ATC; Suken A. Shah, MD*

**Summary**
We sought to correlate the SMSS with Risser staging, two systems used as an indicator of skeletal maturity in idiopathic scoliosis and compare the distribution of patients within each stage and relatability. The SMSS was more specific, especially in the more immature groups. Correlations were seen which can allow practioners to compare, correlate and convert the two stages when assessing risk of progression of scoliosis.

**Hypothesis**
Specific stages in the SMSS correlate with Risser staging.

**Design**
Retrospective cohort study

**Introduction**
Skeletal maturity is an important indicator for prediction of progression of idiopathic scoliosis. This is based on the predictable timing of physeal closure with skeletal maturity. Risser staging system is based on the lateral/posterior excursion of the iliac apophysis on the iliac crest. The Sanders Skeletal Maturity Staging System (SSMSS) is based on closure of physes of the small long bones of the hand and wrist. There are no studies to date that compare the stage wise distribution of patients in these two staging systems of skeletal maturity used to predict progression of scoliosis.

**Methods**
All patients with idiopathic scoliosis at a single center between 2005 and 2011 were retrospectively reviewed. Patients with idiopathic scoliosis and between Risser stages 0 to 4 with hand and spine radiographs taken on the same day to assess the skeletal age and major curve for scoliosis were included in the study. Patients with non-idiopathic scoliosis and those without hand radiographs were excluded from the study. Patients in Risser stage 5 were also excluded.

**Results**
209 patients, girls (n=168; 80%) and boys (n=41; 20%), met the inclusion criteria. 5 stages in the Risser Staging System (RS0 to RS4) and their distribution within 7 stages in the SSMS (SS1 to SS7) were taken into consideration. Patients in RS0 were distributed in the first three Sanders Stages: SS1 (26%), SS2 (36%) and SS3 (38%). 74% of the patients in RS1 were SS3 and remaining 26% patients were SS4. The majority of the patients in RS2 (62%) were SS4. Patients in RS3 were distributed between SS4 and SS7 with 50% of patients being SS6 and 22% each in SS4 and SS7. All patients in RS4 were SS7.

**Conclusion**
This study compared the SSMSS and the Risser System, which are two systems used for assessment of skeletal maturity in children with idiopathic scoliosis. Sanders staging system maybe more sensitive to predict skeletal maturity in preadolescents and those prior to peak height velocity which are all included in RS0.

## 70. Supine Radiographs are Superior to Standing Radiographs in Predicting Surgical Correction in Adult Spinal Deformity

*Jeffrey J Varghese, BS; Tejbir Pannu; Jonathan Charles Elysée, BS; Sebastien Pesenti, MD; Renaud Lafage, MS; Virginie LaFage, PhD; Han Jo Kim, MD*

**Summary**
Spinopelvic alignment in pre-op supine radiograph is significantly closer to the post-op alignment than is the alignment in the pre-op standing radiograph, regardless of revision status at baseline. As it is more predictive of the surgical correction achieved, supine radiographs should be routine in the pre-operative planning process. Standing radiographs are for defining the deformity; supine radiographs are for planning its correction.

**Hypothesis**
Supine X-rays have no utility in pre-op planning in Adult Spinal Deformity Surgery (ASD)

**Design**
Retrospective Cohort Study

**Introduction**
Surgical planning for ASD surgery is critical to order to achieve dedicated alignment goals and to optimize outcomes. The utility of supine X-rays in the planning process is not well understood.

**Methods**
Patients from 2013-2016 from a single surgeon / single center were reviewed. ASD patients (>18yo) who were fused to the sacrum/ilium and had available pre-op standing, pre-op supine, and post-op six week standing X-rays were included. Pre-op standing and supine sagittal alignments were compared to the six-week post-op standing sagittal alignment. Primary and Revision patients at baseline were also compared. Paired t-tests, independent samples t-tests, and correlations were used for this analysis.

**Results**
Of 144 patients, 110 met the inclusion criteria, with mean age 65, BMI 27, 78% Female. 35% were revision cases. Pre to Post-op successful realignment was noted (PI-LL: 19° vs. 0°, SVA: 80mm vs. 13mm, p=0.000). Pre-operatively, standing sagittal alignment flattened out when the patient was supine (PI-LL: 19° vs. 11°, p=0.000). The pre-op supine alignment was 9° (p=0.000) closer to the post-op standing alignment than the pre-op standing alignment was (ΔPI-LL:-20° vs. -11°, p=0.000). This difference was correlated with the pre to post-op change in standing alignment (r=0.488, p=0.000). While both the pre-op standing and supine PI-LL were significantly higher in revision patients (n=39) than primary patients (n=71), the supine alignment was still closer to the post-op standing alignment achieved than the pre-op standing alignment (Primary ΔPI-LL: -20 vs. -12, Revision ΔPI-LL:-19 vs -10, both p=0.000).

**Conclusion**
Spinopelvic alignment in the pre-op supine radiograph is significantly closer to the post-op alignment than is the alignment in the pre-op standing radiograph, regardless of revision status at baseline. As it is more predictive of the surgical correction achieved, supine radiographs should be routine in the pre-operative planning process. Standing radiographs are for defining the deformity; supine radiographs are for planning its correction.

## 71. Ultrasound Imaging Can Reduce Traditional Radiology in the Follow-up of Children with AIS

*Edmond H. Lou, PhD, P.Eng; Rui zheng, PhD; Douglas Leon Hill, MBA; V. James Raso, MASc; Douglas M. Hedden, MD; Marc J. Moreau, MD*

**Summary**
An ultrasound technique was developed to measure the Cobb angle. Two hundred children with AIS were scanned and analyzed. Results showed high accuracy (2.0° ± 1.7° difference between ultrasound and radiographic measurements) and excellent intra-rater and inter-rater reliabilities (ICC[2,1] ≥0.87). Using 4° to indicate clinically meaningful difference, 146/171 non-progressive and 27/29 progressive cases were identified correctly. This suggests that 146 of the 200 radiographs could have been avoided if ultrasound imaging is used initially to determine curve progression.

**Hypothesis**
Ultrasound(US) techniques can confirm non-progression with sufficient accuracy to reduce the need for follow up radiographs of children with AIS, reducing their exposure to ionizing radiation.

**Design**
A retrospective analysis of how many radiographs could be avoided if US images were used at the time of follow up to determine if progression had taken place.

**Introduction**
An US imaging method was developed to measure the proxy Cobb angles that demonstrated high accuracy (2.0 ± 1.7°) and excellent intra-rater and inter-rater reliabilities (ICC[2,1] ≥0.87). If non-progressive AIS cases could be confirmed from the ultrasound measurements with sufficient accuracy, the number of follow up radiographs could be reduced considerably.

**Methods**

200 AIS children (170 F, 30 M; Cobb:24±10°; age:14.6±1.9 years) with 326 curves and no surgical interventions were recruited. Consent forms were signed by all subjects. Previous posteroanterior (PA) radiographs were used to assist current US measurements. Analysis based on threshold values of 3°, 4° and 5° between US and previous radiographic measurements was completed to determine highest accuracy in true negatives (non-progressive cases) and lowest error in false negatives.

**Results**

Among the 3 threshold values, the 4° difference provided the best true negatives 146/171 and the fewest false negatives 2/29. The sensitivity and specificity were 0.93 and 0.85, respectively. The true negatives can avoid a radiograph, but false negatives could result in delay of treatment. The two false negative cases, both showed 6° increments (18° to 24° and 36° to 42°) in the radiographic Cobb angle, were children who had Risser signs 5 and 4, respectively. Table 1 summaries the progressive and non-progressive cases. Although the positive predictive value is low (52%), the false positive cases just put the patients follow the standard of care.

**Conclusion**

Ultrasound imaging to determine Cobb angles is sufficiently comparable to radiographs to be used as a complementary monitoring modality for children with AIS avavoiding exposing a significant number of children to ionizing radiation.

Table 1. Indication of progressive and non-progressive cases from radiographic and ultrasound measurements (n = 200)

| | Radiograph Yes | Radiograph No |
|---|---|---|
| Ultrasound Yes | 27 | 25 |
| Ultrasound No | 2 | 146 |

## 72. A Consistent Intraoperative Neuromonitoring Team Decreases the Number of Alerts, Stagnara Wake-up Tests, and Aborted Cases

Amer F. Samdani, MD; David S. Casper, MD; Joshua M. Pahys, MD; Maria Zuccaro, CNIM; James Zuccaro, DABNM; Steven W. Hwang, MD

**Summary**

When considering off-site vendor vs. in-house provision of intra-operative neuromonitoring (IONM) services, this retrospective review revealed that the number of alerts, Stagnara wake-up tests, and aborted surgeries were decreased with use of an in-house team versus outside providers. Preoperative discussion between surgeon and IONM team members, standardization of IONM protocols, and establishment of trust through regular collaboration were thought to positively impact these outcomes.

**Hypothesis**

Compared to an outside vendor that may not provide consistent personnel, an in-house IONM team will improve patient safety as determined by number of alerts, Stagnara wake-up tests, and aborted surgeries.

**Design**

Retrospective

**Introduction**

No previous study has explored the impact of a consistent IONM team. We sought to compare IONM-related outcomes with 1) an outside vendor team with offsite supervision (Ven) to 2) 3 in house IONM personnel with on-site supervision (InH) at a complex pediatric deformity center.

**Methods**

IONM was provided by Ven from January 2007 to March 2010 and by InH after March 2010. IONM alerts, number of Stagnara wake-up tests, number and percentage of cases aborted, and postoperative neurologic status were recorded. Univariate analysis compared the two cohorts.

**Results**

Both groups were similar with respect to major clinical and radiographic factors. The Ven cohort consisted of 519 patients who experienced 47 (9.1%) alerts, 37 (7.1%) Stagnara wake-up tests, and 3 permanent neurologic deficits. The InH cohort consisted of 866 patients, resulting in 35 (4.0%, p<0.01) alerts with only 6 (0.69%, p<0.01) Stagnara wake-up tests and 1 postoperative permanent neurologic deficit. In addition, the Ven cohort had a significantly greater percentage of procedures aborted secondary to IONM related changes (Ven= 26% [12/47], InH=14.3% [5/35], p<0.05). OR time was similar in both groups (Ven=507, InH=510, p=0.80).

**Conclusion**

A single center's experience in changing to a smaller consistent IONM team decreased the number of alerts, Stagnara wake-up tests, and aborted surgeries. This team model provides opportunity for preoperative discussion between surgeon and IONM team members and standardization of IONM protocols and builds trust through regular collaboration. Likely, any IONM setup (vendor or in-house) that incorporates the aforementioned attributes would have a similar positive impact on safety.

**Table 1: IONM Details**

| | Total Cases | Total Alerts | MEP & SSEP Changes | SSEP Only | MEP Only | Wake-up Test | Wake-up test Abnormal | Neuromotor Deficit |
|---|---|---|---|---|---|---|---|---|
| Vendor | 519 | 47 (9.1%) | 20 | 5 | 22 | 37 | 6 | 3 |
| In House | 866 | 35 (4.0%) | 6 | 6 | 23 | 6 $p < 0.01$ | 4 | 1 |

## 73. A preliminary Study of Spinal Cord Blood Flow During Posterior Vertebral Column Resection in Severe Rigid Scoliokyphosis Patients

Tao Li, MD; Jingming Xie, MD; Yingsong Wang, MD; Ni Bi, MD; Zhi Zhao, MD; Ying Zhang, MD; Jie Zhang, MD; Zhiyue Shi, MD

**Summary**

The different tension of the spinal cord can lead to spinal cord blood flow (SCBF) unbalanced, and the SCBF increased 56% when the spinal cord gained a proper shortening during correc-

tion.

**Hypothesis**
The tension of the spinal cord can affect the SCBF, a proper spinal cord shortening can increase the SCBF.

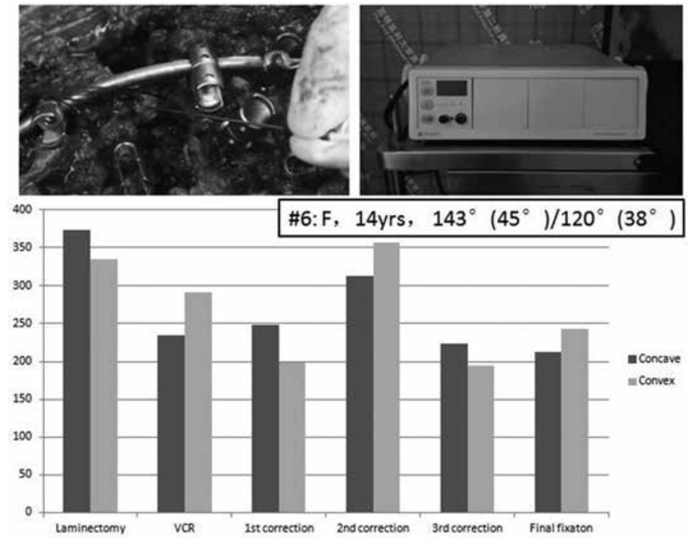
**Design**
Prospective case series.

**Introduction**
PVCR has a higher correction rate, but it has been plagued with high neurologic deficits risk in severe rigid spinal deformity. The fluctuations of spinal cord blood flow (SCBF) during the PVCR is a important influence factors.

**Methods**
Eight severe rigid scoliokyphosis treated with PVCR were included in this study. Neural physical examination were negative and there were no spinal cord malformation in all patients. The correction was base on compression and shortening over the resected gap, exchanged-rods technique, in situ rod bending. Laser Doppler flowmetry was used to monitor the SCBF at the level of the VCR. The SCBF of the convex side and the concave side were monitor at different surgical stages. SEP and MEP were monitored throughout the PVCR.

**Results**
The preoperative scoliosis of 128° was corrected to 40° (68.5%), and the preoperative kyphosis of 112° was corrected to 42° (61.6%). The postoperative neural physical examination, MEP and SEP during surgery were normal. The SCBF on the concave side was higher than convex side in 6 patients (75%) after laminectomy. The SCBF dropped by 34% after VCR. The SCBF increased 56% when spinal cord gained a proper shortening during correction and the convex side could gain a better SCBF than concave side. The SCBF will decrease with further correction and shortening(Fig.). There were 7 (87.5%) patients presented a higher SCBF on the convex side than the concave after final fixation.

**Conclusion**
The severe rigid spinal deformity can lead an SCBF unbalanced on the convex and concave side of the spinal cord that cause by the different tension of the spinal cord. A proper spinal cord shortening is beneficial to SCBF and a proper low tension of the spinal cord can reduce the neurologic deficits risk in PVCR.




## 74. Sagittal Spinal and Pelvic Parameters in Patients with Scheuermann's Disease

*Saif Aldeen Farhan; Martin Christian Eichler, MD; Xiaobang Hu, PhD, CCRP; Isador H. Lieberman, MD, MBA, FRCSC; Theodore A. Belanger, MD; Arif Pendi; S. Samuel Bederman, MD, PhD, FRCSC*

**Summary**
Δ=(TK-45°)+TLK+PLM (Pelvic incidence to Lumbar lordosis Mismatch) maintained within ±10° is a valuable formula to evaluate the global sagittal balance in skeletally mature SD patients. This formula may help us better plan for surgical correction in patients with SD.

**Hypothesis**
There is a mathematical relationship between sagittal spinopelvic parameters in skeletally mature SD patients.

**Design**
Radiographic study

**Introduction**
Sagittal spinopelvic parameters are poorly defined in patients with Scheuermann's Disease (SD). The excessive thoracic kyphosis (TK) and/or thoracolumbar kyphosis (TLK) in SD patients is not reflected in pelvic parameters which could lead to inaccurate preoperative planning and a less than desirable surgical outcome.

**Methods**
In adult deformity surgery, PI-LL (Pelvic incidence to Lumbar lordosis Mismatch, PLM) =±10° has been proven to be the ideal spinopelvic alignment for better clinical outcomes. However, patients with SD have significantly lower PI and there exists no relationship between PI and LL which may be a reflection of the body's compensation for the excessive TK and/or TLK. Thoracic hyperkyphosis is commonly defined as ≥ 45° and it has been reported that PI-LL+TK≤45° is very sensitive for predicting ideal sagittal balance in deformity surgery. Given that normal TLK approximates 0°, we propose the following formula in SD patients: Δ=(TK-45°)+TLK+PLM which should be ±10° if properly balanced. We then retrospectively identified all skeletally mature SD

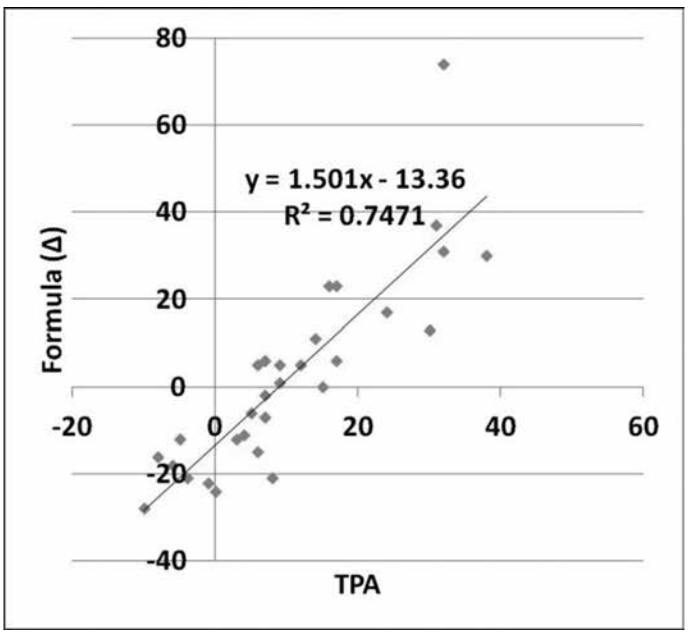
patients without prior spine surgery and validated the proposed formula (Δ) with standard sagittal radiographic parameters. T1 pelvic angle (TPA) was used as a measure of global balance with a normal maximum of 15°.

**Results**

A total of 30 patients were included in this study (15 male, 15 female). The patients' mean age was 39 years (range 18-71). The average value of Δ was 2.4° (range between -28° and 74°) and the mean absolute value of Δ was 16.7°±14.5°. There was a statistically significant and strong correlation between Δ and both TPA (R2=0.75) and PT (R2=0.69). At the maximal normal TPA for a sagittal balanced adult (15°), Δ yielded a maximum of 9.2°. There were 21 patients whose TPA≤15° and their mean Δ was -8.7°±11.6°. There were 9 patients whose TPA>15° and their mean Δ was 28.2°±19.7° (p=0.0003).

**Conclusion**

Δ=(TK-45°)+TLK+PLM maintained within ±10° could be a valuable formula to evaluate the global sagittal balance in skeletally mature SD patients. This formula may help us better plan for surgical correction in patients with SD. Further study is underway to evaluate if maintaining and/or restoring a normal Δ is associated with better clinical outcomes in SD patients.




## 75. Does Preserving or Restoring Lumbar Lordosis Influence the Functional Outcome in Lumbosacral Tuberculous Spondylodiscitis?

*Ajoy Prasad Shetty, MS Orth; S. Rajasekaran, MD, DNB, FRCS, MCh, PhD; Aju Bosco, MS, FNB*

**Summary**

We reviewed 63 patients of lumbosacral tuberculosis treated by operative and conservative methods, to analyse the impact of loss of global lumbar lordosis(GLL) on functional outcomes. In 24/30 patients in operated group and 25/33 patients in conservative group, the post-treatment GLL matched the expected GLL. Pearson's correlation coefficient showed a strong negative correlation between GLL and functional outcomes. In addition to the already established treatment indications, achieving physiological lumbar lordosis must be a prime goal in treatment of lumbosacral tuberculosis.

**Hypothesis**

Preserving or restoring physiological lumbar lordosis has an impact on the functional outcome in lumbosacral tuberculous spondylodiscitis.

**Design**

Retrospective study.

**Introduction**

In lumbosacral tuberculosis, loss of lordosis leads to altered lumbosacral biomechanics. All available studies have assessed treatment outcomes with respect to bone healing, neurological improvement and physical well-being. None have correlated functional outcomes with lumbar lordosis at end of treatment. We reviewed 63 patients with lumbosacral tuberculosis, with an attempt to analyse the impact of loss of global lumbar lordosis on functional outcomes.

**Methods**

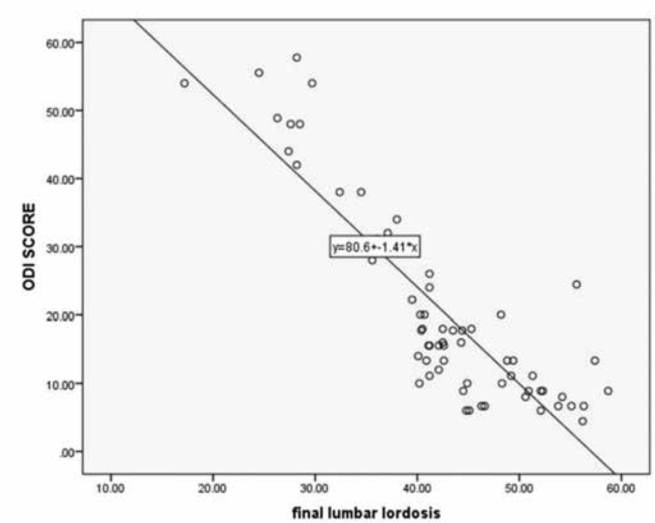
Sixty-three patients with lumbar and lumbosacral tuberculosis were treated conservatively (n=33) or surgically (n=30) from March 2007 to July 2013. Average follow-up period was 35.2+/-8.7 months. The post-treatment global lumbar lordosis (GLL) achieved, was compared with the expected GLL, estimated based on pre-operative pelvic incidence. Correlation between the final post-treatment GLL and functional outcomes (Oswestry Disability Index) were analysed.

**Results**

All patients showed good bone healing (at 8.4+/-1.5 months), significant improvement in neurology,VAS scores,ESR and CRP, p<0.05. Mean loss of lordosis in conservatively treated group was 6.43+/-5.69 degrees,while lordosis was restored by 12.58+/-7.92 degrees after surgery. In 24/30 patients in operated group and 25/33 patients in conservative group, the post-treatment GLL matched the expected GLL. Pearson's correlation test showed a strong negative correlation between lumbar lordosis and the degree of disability(r = -0.867, p<0.001).

**Conclusion**

Early disease with minimal loss of global lumbar lordosis, can be managed conservatively, while in advanced disease with gross hypolordosis/kyphosis, posterior stabilization with or without global spinal reconstruction is essential to regain global lumbar lordosis. The management of lumbosacral tuberculosis should aim at preserving or restoring the physiological lumbar lordosis to achieve optimal functional outcomes.




Pearson correlation coefficient
r= -.0.867, p value - <0.001

### 76. Is There an Anatomic Predisposition to Postoperative Total Hip Arthroplasty Dislocation in Patients with Prior Lumbar Fusion?

*<u>Philip J. York</u>; Christopher Chen, MD; Michael Reiter, PGY3; Craig Hogan, MD; Michael Dayton, MD; Evalina Burger, MD; Christopher J. Kleck, MD*

**Summary**
Prior lumbar fusion has been associated with increased dislocation following total hip arthroplasty (THA). We investigated a nonmodifiable patient variable (Pelvic incidence [PI]) as well as modifiable variables (cup position and head size) in patients with lumbar fusion. Dislocators had significantly smaller mean PI suggesting that certain anatomic variables along with altered lumbopelvic mechanics may play a role in the increased risk for THA dislocation.

**Hypothesis**
We hypothesized that smaller values of PI would be associated with postoperative THA dislocation in patients with preexisting lumbar fusions.

**Design**
Retrospective

**Introduction**
Studies have drawn attention to the relationship between altered spinopelvic mechanics and risk of THA instability. Lumbar fusion alters normal mechanics, leaving patients less capable of modifying their sagittal alignment to maintain coxofemoral balance after THA. Patients with fixed spinal deformity have limited ability to alter their sacral slope and, therefore, functional anteversion during seated position compared to patients with a flexible spinal deformity. The absence of compensatory pelvic tilt leads to loss of functional anteversion and can lead to impingement. PI is a measurement that is closely related to acetabular orientation and has been used to determine the safe range of pelvic motion following THA. We suggest that patients with small PI in the setting of lumbar fusion would have decreased ability to alter their sagittal alignment, increasing their risk for dislocation.

**Methods**
A 5 year retrospective review identified patients with prior lumbar fusion who underwent THA to identify postoperative dislocations. All THAs were performed through a posterior approach. PI, THA anteversion and lateral inclination as well as femoral head size were compared between dislocators and non-dislocators. Dislocators and those without dislocation with minimum 24 month follow up were included.

**Results**
Twenty-five patients were included in the final analysis. Of these, 9 dislocations were identified (36%). All first-time dislocations occurred within 8 months of surgery and each occured due to a low energy mechanism such as bending over or standing from seated position. PI measurement could be performed on all 9 dislocators and 13 of 16 nondislocators. Dislocators had a significantly lower PI (45.2 vs 59.2; p=.005). There were no significant differences in component size or position or in the number of levels fused or lowest instrumented level.

**Conclusion**
Our findings suggest that there may be an anatomic predisposition to postoperative dislocation following THA in the setting of prior lumbar fusion.

### 77. Total Hip Arthroplasty in the Spinal Deformity Population: Does Degree of Deformity Affect Hip Stability?

*<u>Edward M. DelSole, MD</u>; Ran Schwarzkopf, MD; Jonathan Vigdorchik, MD; Thomas J. Errico, MD; Aaron J. Buckland, MBBS, FRACS*

**Summary**
Sagittal spinal deformity is associated with an elevated rate of THA instability despite well-positioned acetabular components.

**Hypothesis**
Patients with sagittal spinal deformity will have elevated rates of THA instability

**Design**
Retrospective cohort study

**Introduction**
Spinal deformity has a known deleterious effect upon the outcomes of total hip arthroplasty and acetabular component positioning. This study sought to evaluate the relationship between severity of spinal deformity parameters and acetabular cup position, rate of dislocation, and rate of revision among patients with total hip arthroplasties and concomitant spinal.

**Methods**
A prospectively collected database of patients with spinal deformity was reviewed and patients with total hip arthroplasty were identified. The full body standing biplanar stereoradiographic images were reviewed for each patient. From these images, spinal deformity parameters and acetabular cup anteversion and inclination were measured. Rates of radiographic safe zone placement

were analyzed. A chart review was performed on all patients to determine dislocation and revision arthroplasty events. Statistical analysis was performed to correlate degree of deformity with acetabular cup position. Subgroup analysis of spinopelvic parameters was performed for patients who sustained dislocations.

**Results**
One-hundred and thirty-nine patients were identified with THA and concomitant spinal deformity, with 152 hips for analysis. The rate of THA dislocation in this cohort was 10.1%, with a revision rate for instability of 7.9%. Among all patients, only 42.1% met the radiographic "safe zone" criteria. Patients with dislocations tended to have cups placed appropriately within the safe zone. Dislocators had significantly higher global spinal deformity, greater pelvic tilt, and pelvic-incidence-lumbar lordosis mismatch.

**Conclusion**
In this cohort, patients with THA and concomitant spinal deformity demonstrated an elevated rate of dislocation compared to normal population. Cup placement within the radiographic "safe zone" was not protective against dislocation. Severity of global spinal deformity and subsequent pelvic compensation may be predictors of hip arthroplasty dislocation.

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## 78. The Ecuador Pediatric Spine Deformity Surgery Program Development and Outcomes, 2008-2014

*Amanda Fletcher; Richard M. Schwend, MD*

**Summary**
The purpose of this study was to describe the development of the pediatric spinal deformity program at the Roberto Gilbert Hospital for Children, Guayaquil, Ecuador and to assess the outcomes after surgery.

**Hypothesis**
The Ecuador Pediatric Spine Deformity Surgery Program is a safe and effective program for LMIC children with surgical outcomes comparable to domestic outcomes.

**Design**
Retrospective case series

**Introduction**
The Scoliosis Research Society, through its members and the Global Outreach Mission Programs (SRS-GOP), is very interested in international program site development to provide safe surgical care for children in low- and middle-income countries (LMIC). While there are currently 20 endorsed sites, there is a scarcity of literature from these sites.

**Methods**
After several years of building local relations and infrastructure, the program started performing spine surgery in 2008. 22 (68%) of the 32 children who received surgery for a spinal deformity between May 2008 and May 2014 were seen at the most recent follow-up and are included in this study. At total of 18 (82%) were female and 4 (18%) were male, with an average age of 14 years (range 4-19) at the time of surgery and 19 years (range 12-25) at follow-up in May 2016. At an average of five years and minimum of two years post-operative, patients received a clinical evaluation, standing PA and lateral radiographs, and the validated Spanish SRS-22r questionnaire.

**Results**
At this most recent follow-up, the mean total SRS-22r score was 4.3. The individual domain scores for pain, self-image, function, mental health, and overall satisfaction were 4.4, 4.2, 4.3, 4.2, and 4.9, respectively. The mean percentage major curve correction (MCC) was 56% (SD=9.0%). Among a multitude of predictors for postoperative SRS-22r explored, curve location was significant with double curves having poorer total SRS-22r scores (p=0.02) than thoracic or lumbar/thoracolumbar curves. Two reported complications were noted: pseudarthrosis with implant failure after a fall and postoperative delayed paraplegia. Both cases resolved after revision surgery. No infections or other long-term complications have occurred in the first seven years.

**Conclusion**
This spinal deformity program in Ecuador was safely developed to meet the surgical needs of children in this LMIC with good midterm HRQOL outcomes, similar to SRS-22r scores demonstrated in the spine literature, and no permanent complications. The development of equitable surgical care for all children is a primary goal of the SRS-GOP. Our program demonstrates that this can be achieved for spinal deformities with strategic planning and sustained investment in local relationships and infrastructure.

**Table 1. Demographic, Clinical, Radiographic Data**
**n=22**

| Variable | Mean (range) | |
|---|---|---|
| Age at surgery, years | 14 (4-19) | |
| Age at latest follow-up, years | 18 (12-25) | |
| Follow-up, years | 5 (2-8) | |
| Levels of fusion, n | 10 (2-15) | |
| | n | % |
| Sex | | |
| Female | 18 | 81.8 |
| Male | 4 | 18.2 |
| Primary Diagnosis | | |
| AIS | 14 | 63.6 |
| Congenital Scoliosis | 2 | 9.1 |
| Neuromuscular Scoliosis* | 2 | 9.1 |
| Syndromic Scoliosis** | 2 | 9.1 |
| Kyphosis | 2 | 9.1 |
| Location of Major Curve | | |
| Thoracic | 10 | 45.4 |
| Lumbar/Thoracolumbar | 8 | 36.4 |
| Double Major | 4 | 18.2 |
| | Mean (Standard Deviation) | |
| Radiographic Data | | |
| Preoperative Major Cobb angle (degrees) | 70 (14.3) | |
| Postoperative Major Cobb angle (degrees) | 31 (9.3) | |
| Mean major Cobb correction (degrees) | 39 (9.4) | |
| Percentage major curve correction (%) | 56 (9.0) | |

* Spinal Muscular Atrophy (n=2)
** Neurofibromatosis type 1 (n=1), Ehlers-Danlos (n=1)

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## 79. Neurological Complications and Recovery Rates in Adult Cervical Deformity Surgery

*Han Jo Kim, MD; Hongda Bao, MD PhD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Munish C. Gupta, MD; Todd J. Albert, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Virginie LaFage, PhD; Christopher P. Ames, MD; International Spine Study Group*

**Summary**

Patients undergoing surgery for adult cervical deformity (ACD) sustained neurologic complications (NC) at a rate of 21%. Motor deficit (11%, n=10) was the most common followed by, radiculopathy (6%, n=6), sensory deficit (5%, n=5) and spinal cord injury (1%, n=1). Major NC was seen in 11% of the cohort. The rate of recovery was 92% partial or complete at 0.5-30 months. No demographic or surgical risk factors for NC could be identified.

**Hypothesis**

CD pts have a high rate of NC but the majority of these NC are minor

**Design**

Prospective cohort study

**Introduction**

The rates of Neurologic Complications and Recovery Rates in ACD patients are poorly defined. To our knowledge, there are no reports on the rate of NC and their resolution following CD surgery.

**Methods**

CD pts undergoing surgery from 2013-2015 were enrolled in a prospective, multicenter database. CD was defined as: cervical kyphosis >10°, cervical scoliosis >10°, C2-7 SVA >4cm and/or chin-brow vertical angle >25°. Pts with NC were identified; demographics, operative details and radiographic parameters were compared. Recovery was noted as none, partial and complete. Statistical analysis was performed with a t-test or $X^2$ test as appropriate.

**Results**

106 pts were included in the study. Average age was 61.6yrs with a mean f/u of 29 months. The overall rate of NC was 21% (23 in 21 patients). One case was excluded for lost to f/u. The incidence of a major NC was 11% while a minor was 11% and the majority of cases (57%, n=14) were identified within 30 days of surgery. Motor deficit (11%, n=10) was the most common followed by, radiculopathy (6%, n=6), sensory deficit (5%, n=5) and spinal cord injury (1%, n=1). Of the motor deficits, 50% of them were C5 Palsies (n=5). There was no correlation between age, gender, body mass index and NC. Pts with NC had a higher pre-op mJOA scores (p=0.01) but similar NDI and EQ5D. Of the deficits, 92% (n=20) had partial or complete recovery in 0.5-30 months after surgery with only 8% with permanent deficits (60% w/ complete recovery, 32% partial). No operative variables (prior cervical surgery, estimated blood loss, total operation time, fusion levels, BMP use, osteotomy and surgical approach) were associated with an increased risk of NC. No differences in HRQOLs were noted between groups at latest f/u.

**Conclusion**

The overall NC rate in ACD surgery was 21% of cases and the incidence of a major NC was 11%. While motor deficit was the most common, found in 11%, spinal cord injury was rare (1%). Permanent deficits were noted in 1.7% of patients. No demographic or operative risk factors for NC could be identified.

## 80. Prospective Multicenter Assessment of All-Cause Mortality Following Surgery for Adult Cervical Deformity (ACD)

*Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Renaud Lafage, MS; Gregory M. Mundis, MD; Eric O. Klineberg, MD; Virginie LaFage, PhD; Frank J. Schwab, MD; Justin K. Scheer; Michael P. Kelly, MD; D. Kojo Hamilton, MD, FAANS; Munish C. Gupta, MD; Vedat Deviren, MD; Richard Hostin, MD; Todd J. Albert, MD; K. Daniel Riew, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group*

**Summary**

All-cause mortality at a mean of 1.1 yrs following ACD surgery was 8.9% in this prospective multicenter series. Causes of death were varied and reflective of a high-level of comorbidities. These findings may prove useful for treatment decision-making and patient counseling in the context of the substantial impact these conditions can have on patient health, quality of life, and neurological function.

**Hypothesis**

All-cause mortality following ACD surgery will be high, reflective of a high-level of comorbidities.

**Design**

Retrospective review of prospectively-collected, multicenter database of consecutive patients

**Introduction**

ACD can profoundly impact patient health and function. Surgical treatments are often complex and have high complication rates. Our objective was to assess all-cause mortality following ACD surgery.

**Methods**

ACD patients (>18 yrs) in a prospective multicenter database were assessed for all-cause mortality following surgical treatment. Baseline demographics, radiographic measures, and operative parameters were compared between deceased and alive patients.

**Results**

The 123 patients that met inclusion criteria had a mean age of 61 yrs (SD=11) and 75% were women. Patients had a mean preop Charlson Comorbidity Index (CCI) of 0.73 (SD=1.09; range=0-6), mean BMI of 30.0 (SD=8.1), and 9 (7.3%) were smokers. Surgical approaches included: ant-only (16.3%), post-only (50.4%), ant-post (30.9%), and post-ant-post (2.4%). The mean number of levels fused was 8.1 (SD=4.5), and procedures included 6 VCRs and 22 PSOs. Of 123 patients, death was reported for 11 (8.9%) at a mean of 1.1 yrs (SD=0.8; range=7 d to 2 yrs; only 2 within 90 d of surgery). Mean follow-up for remaining patients was 1.1 yrs (SD=.6 yrs). Causes of death included: cardiac arrest/MI (n=2), pneumonia/cardiopulmonary failure (n=2), deep wound infection/sepsis (n=1), OSA/respiratory depression (n=1), subsequently diagnosed ALS (n=1), burns due to smoking while using sup oxygen (n=1) and unknown (n=3). Patients that suffered mortality did not differ from those who were alive at follow-up based on any parameters assessed, including age (p=.88), sex (p=.11), CCI (p=.39), BMI (p=.50), approach (p=.84) or levels fused (p=.44).

**Conclusion**

All-cause mortality at a mean of 1.1 yrs after ACD surgery was 8.9% in this prospective multicenter series. Causes of death were varied and reflective of the high-level of comorbidities. These findings may prove useful for treatment decision-making and counseling in the context of the substantial impact these conditions can have on health, quality of life, and neurological function.

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## 81. Establishing the Minimum Clinically Important Difference in NDI and mJOA for Adult Cervical Deformity

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**Summary**

The minimum clinically important difference (MCID) represents the smallest change in patient-reported outcomes corresponding to meaningful improvement. There are no established MCID thresholds in the adult cervical deformity (ACD) population. Using anchor and distribution based methods to generate MCID thresholds, we recommend an MCID threshold of 1.8 for the mJOA and of 7.0 for the NDI in ACD patients.

**Hypothesis**

There are currently no established MCID thresholds in the ACD population for the NDI and mJOA. Establishing MCID thresholds for this specific pathology is an important step in evaluating the success of surgery for patients undergoing adult cervical deformity correction.

**Design**

Prospective multicenter database of surgically treated adult cervical deformity patients.

**Introduction**

Patient-reported outcome (PRO) questionnaires are commonly used to measure the effectiveness of surgical intervention. The MCID represents the smallest change in PRO corresponding to meaningful improvement, and can vary according to specific disease. ACD patients have characteristics that are unique when compared to the degenerative cervical conditions used in the development of the cervical-specific PRO questionnaires. There are currently no established MCID thresholds in the ACD population for the NDI and mJOA.

**Methods**

Surgically treated ACD patients who completed one-year follow up were included. PROs (NDI, mJOA, and EQ-5D) were administered pre- and 1-year post-operatively. The minimally detectable measurement difference (MDMD) was calculated. The EQ-VAS was used as an anchor and anchor-based MCID thresholds were computed. Distribution-based MCID calculations (SEM method) were also performed.

**Results**

Of 122 patients eligible for 1-year follow-up, 73 (60%) patients met inclusion criteria. 42 (57.5%) were female with a mean age of 62.23 years, and average BMI of 29.28. Pre-operative NDI score was 46.49, vs 37.04 post-operatively (p=0.0001). Pre-operative mJOA score was 13.17 vs 13.71 post-operatively (p=0.12). The MDMD was 6.41 for the NDI, and 1.82 for the mJOA. Distribution-based MCID values were 7.48 for the NDI, and 1.85 for the mJOA. Anchor-based MCID values were 7.0 for the NDI (AUC 0.72), and 1.0 for the mJOA (AUC 0.61). We recommend using an MCID threshold of 1.8 for the mJOA and of 7.0 for the NDI in adult cervical deformity patients.

**Conclusion**

This study established adult cervical deformity specific MCID thresholds for the NDI, and mJOA. These newly thresholds will be useful in future studies evaluating the success of surgery for adult cervical deformity patients undergoing deformity correction.

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## 82. Surgical Correction of the Rigid Sharp Angular Kyphotic Deformity with Gradual Sequential Posterior Compression and Simultaneous Anterior Column Lengthening Technique After PVCR

*Selhan Karadereler, MD; Sinan Kahraman, MD; Cem Sever, MD; Emel Kaya, MD; Ayhan Mutlu, MD; Tunay Sanli, MA; Meric Enercan, MD; Azmi Hamzaoglu, MD*

**Summary**

Surgical treatment of rigid sharp angular kyphosis (RSAK) is technically challenging. As an alternative to anterior-posterior combined surgery, correction technique of the rigid sharp angular kyphosis during posterior only surgery must include gradual sequential posterior compression with simultaneous anterior column lengthening and placement of an expandable cage to restore anterior column height and ideal sagittal balance after PVCR. This technique prevents iatrogenic neurological deficit due to dural buckling.

**Hypothesis**

Gradual sequential posterior compression and simultaneous anterior column lengthening technique after PVCR provides safe and ideal correction of RSAK deformity.

**Design**

Retrospective

**Introduction**

The correction technique of RSAK is totally different from the correction of other kyphotic deformities.Pain, progressive deformity causing sagittal imbalance and deterioating neurological deficit are major problems. The purpose of this study is to evaluate the efficacy of gradual sequential posterior compression and simultaneous anterior column lengthening technique after PVCR in correction of RSAK deformity.

**Methods**

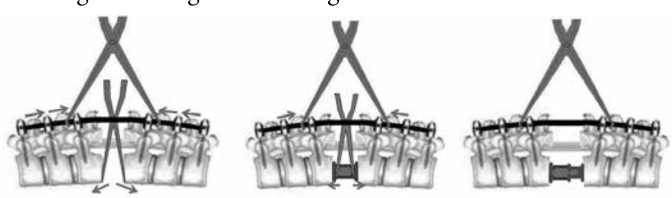
52pts (35M,17F), ave age 42.1yrs (19-74), who underwent PVCR for RSAK were evaluated. Following PVCR, correction technique included anterior column lengthening with gradual posterior compression sequentially and placement of an expandable cage anteriorly to prevent any dural buckling. Preop,postop and f/up x-rays were evaluated for radiological data including local kyphosis angle (LKA) and sagittal parameters. Functional status were assessed by Oswestry score.

**Results**

Ave f/up was 47 months (24-120). Etiologies were posttraumatic kyphosis for 38 pts and neglected congenital kyphosis in 14 pts. PVCR's were single level in 39 pts and multi-level in 13 pts. Preop ave LKA of 49.52° improved to 7.35° (89% correction). Preop SSA of av 118.3° was restored to 132.7°. 28 pts who had preop neurologic deficit (14 ASIA D, 8 ASIA C, 6 ASIA B) had at least one grade improvement at the final f/up. Most common complication was dural tears in 9 (17%) pts. Oswestry scores improved from 56 to 16. Solid fusion was achieved in all patients without significant loss of correction in the sagittal plane at the final f/up.

**Conclusion**

Correction of rigid sharp angular deformity can only be achieved with gradual sequential posterior compression and simultaneous anterior column lengthening after PVCR. This technique provides ideal restoration of kyphosis, decompression of neural structures, improves preop neurological deficit, prevents dural buckling and iatrogenic neurologic deficit.



## 83. SRS-Schwab Grade 4 Osteotomy for Angular Congenital Kyphosis: A Minimum 2-Year Follow-Up Study

*<u>ZeZhang Zhu, MD, PhD</u>; Xu Sun, MD, PhD; Qinghua Zhao, MD; Shifu Sha, MD, PhD; Bangping Qian, MD; Bin Wang, MD; Yang Yu, MD; Yong Qiu, MD*

**Summary**

Surgical management of congenital kyphosis (CK) remains challenging in terms of kyphosis correction and vertebral column reconstruction. Our study demonstrated that SRS-Schwab Grade 4 osteotomy instead of vertebral column resection (VCR) can achieve successful realignment of sagittal balance by optimally correcting kyphosis with less complications.

**Hypothesis**

As an alternative for correction of kyphosis deformity other than VCR, Grade 4 osteotomy may provide effective and safe correction for CK.

**Design**

retrospective study

**Introduction**

Various osteotomy techniques, including Smith-Petersen osteotomy, pedicle subtraction osteotomy and VCR, are currently employed in the correction of CK. Each has its own indications and compilications. According to SRS-Schwab classification, Grade 4 osteotomy is defined as resection of pedicles and posterior elements, partial vertebral body and the superior adjacent disc, which offers direct removal of the anomaly and bone-on-bone reconstruction of vertebral column. As an alternative for correction of kyphosis deformity other than VCR, however, Grade 4 osteotomy has been noted in very few reports in the treatment of CK.

**Methods**

This study retrospectively reviewed a consecutive series of CK patients with Grade 4 osteotomy at a single level from Jan 2010 to Dec 2014 and, were followed no less than 2 years. Totally, 31 CK patients (14 males and 17 females) were included. Their age averaged 15.8 years. The apex of the kyphosis located in the thoracolumbar spine (T10–L3). Kyphosis correction were evaluated through X-rays taken preoperatively, postoperatively and latest follow-up. SRS-22 questionnaire was used to assess the quality of life.

**Results**

The mean operation time was 205 min. Blood loss averaged 550 ml. Fusion span averaged 5.1 levels. The mean follow-up was 35 months. Segmental kyphosis was averagely corrected from 38.6° to 7.2° after surgery, and was maintained at 9.1° at final follow-up. Correction rate of kyphosis averaged 81.3 %. After surgery, thoracic kyphosis was significantly improved from 18.3° to 28.5° ($P<0.01$), and to 29.3° at latest follow-up. Notably, the sagittal vertical axis was improved from was improved from -43.1 mm to -5.2 mm ($P<0.01$). No significant differences were observed in lumbar lordosis, pelvic tilt and sacral slope ($p>0.05$). Twenty patients responded to SRS-22 questionnaire and showed significant improvement. All patients achieved solid bony fusion. Complications occurred in two patients, including one case with incidental dural tear and another with root injury.

**Conclusion**

As an alternative option, SRS-Schwab Grade 4 osteotomy instead of VCR provides effective and safe correction for CK.

## 84. Cluster Analysis Describes Constellations of Cardiac Anomalies Presenting in Spinal Anomaly Patients

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**Summary**

Incidence per 100,000 was as follows: 8.85 Fusion of spine, 3.51 Hemivertebra, 1.19 Missing Vertebra, and 20.7 cardiac anomalies, 10.1 GI anomalies, and 13.3 GU anomalies. Certain Cardiac, GI, and GU anomalies occurred together at elevated rates in vertebral anomaly patients.

**Hypothesis**
Conccurent anomalies second to vertebral anomalies occur in recurring patterns.

**Design**
Retrospective analysis of the prospectively collected KID's inpatient database.

**Introduction**
Vertebral anomalies occur early in development during the formation of the mesoderm, and are associated with 15-60% occurrence of a second or multiple deformities. Literature discussing the incidence of vertebral congenital anomalies of the spine is usually methodologically limited by small sample sizes. However, the KID inpatient database was made to yield national estimates of rare pediatric conditions such as congenital disorders.

**Methods**
KID supplied hospital- and year-adjusted weights allowed for accurate assessment of incidence of vertebral anomalies (consisting of Hemivertebra, block vertebra and missing vertebra), as well as cardiac, GI, and GU anomalies. K-means clustering analysis was run to discover patterns of concurrent cardiac and GI/GU anomalies in vertebral anomaly patients. K was set to n-1 where n=first incidence of significant drop/little gain in Sum of Square error within clusters.

**Results**
Incidence per 100,000 was as follows: 8.85 Fusion of spine, 3.51 Hemivertebra, 1.19 Missing Vertebra, and 20.7 cardiac anomalies, 10.1 GI anomalies, and 13.3 GU anomalies. 20.1% of vertebral anomaly patients presented with any cardiac anomaly, 26.2% a GI, and 20.8% a GU anomaly. The top associations between cardiac anomalies included: 55.3% of Secunduum ASD cases also presented with Patent Ductus Arteriosus, 43.4% of Secunduum ASD cases also presented with Ventricular Septal Defect, 36.1% of Ventricular Septal Defect cases also presented with Patent ductus arteriosus, and Persistent Fetal Circulation cases also presented with Patent Ductus Arteriosus. Top relationships in GI/GU anomalies were: 39.4% of Necrotizing Enterocolitis cases also presented with Large Intestine Atresia, 30.6% of Tracheoesophageal Fistula cases also presented with Large Intestine Atresia, 40.7% of Obstructive Defects of Renal Pelvis and Ureter also presented with Large Intestine Atresia, and 62.5% of Cystourethral Anomalies also presented with Large Intestine Atresia.

**Conclusion**
Patients diagnosed with vertebral anomalies of the spine had concurrent cardiac, GI, and GU anomalies 20.1, 26.2, and 20.8% of the time respectively. Cardiac, GI, and GU anomalies themselves present at elevated rates in association with each other.

## 85. Is It Possible to Correct Congenital Spinal Deformity Associated with Tethered Cord without Detethering?

*Hui-Ren Tao, MD, PhD; Michael S. Chang, MD; Bo-bo Zhang, MD*

**Summary**
40 pts with both congenital scoliosis and tethered cord were treated using an individualized strategy that avoided dethering entirely. Our series shows that significant deformity correction may be achieved without compromising safety

**Hypothesis**
Congenital spinal deformity with tethered cord may be treated without an intradural detethering procedure

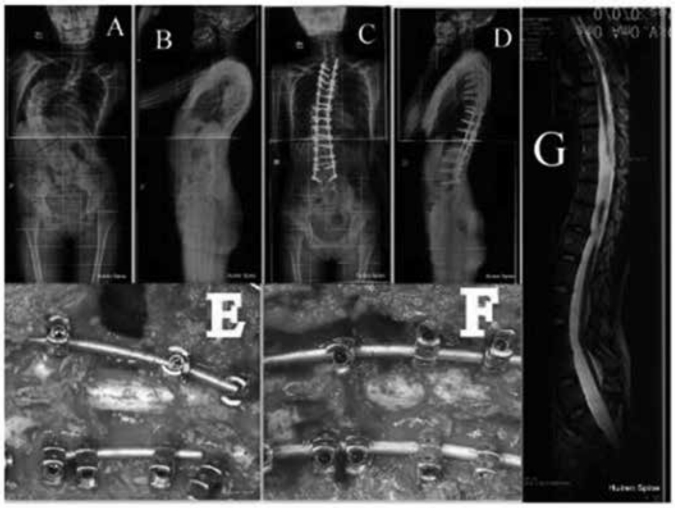
**Design**
Retrospective clinical study.

**Introduction**
Traditionally, congenital spinal deformity with tethered cord is treated with detethering followed by a second surgery to correct the deformity. However, the dethering procedure carries significant risk and morbidity. There is therefore significant benefit to establishing the efficacy of an alternative surgical strategy that avoids these complications.

**Methods**
40 pts with congenital scoliosis and tethered cord from 2006 to 2016 were divided into 3 groups: a vertebral column resection (VCR) group, a pedicle-subtraction osteotomy (PSO) group and a posterior fusion only group (PSF). All pts had >2 yr follow-up. VCRs and PSOs were performed at the apical vertebra without a cage in order to shorten the spine and to indirectly relieve the tension of the spinal cord without an extra intradural detethering procedure.

**Results**
40 pts had a mean age of 14.2 yrs and average follow-up of 49.8 mo (24-77 mo). The conus ended at L3 in 13 pts, L4 in 16 pts, L5 in 6 pts, S1 in 3 pts, and S2 in 2 pts. 17 pts had other intraspinal anomalies. The pre-op Cobb angle was 102.2 ± 24.9° (VCR), 71.2 ± 13.9° (PSO) and 69.7 ± 21.3° (PSF). By 2 yrs, correction stabilized at 44.6° ± 16.5° (60.3%), 20.6° ± 13.3° (65.3%) and 19.8° ± 8.9° (67.8%), respectively. In the VCR group (n=21), the mean spinal column shortening was 28.0mm (18-39 mm). Among 13 pts with pre-op neurological deficits, 11 pts were improved, while 2 pts did not change by final follow-up. In the PSO group (n=9), the mean shortening was 20.0mm (15-23 mm). All 9 pts had pre-op neuro deficits and by final follow-up, 6 pts had improved, while 3 pts did not change. The PSF group (n=10) had no deficits. Five pts had complications. Other than 1 UTI in the PSF group, the other complications were all in the VCR group and included transient weakness (x2), durotomy, and hemothorax.

**Conclusion**
Congenital spinal deformity with tethered cord may be safely and effectively treated without direct untethering, but the surgical strategy should be individualized. For pts with severe, rigid curves or neurological deficits, VCR or PSO is effective to relief cord tension while allowing for substantial curve correction. Pts with more moderate curves and no neurological deficits can be corrected safely without need to consider the tethered cord




17-year-old female, who complained of weakness of right leg, had curve of 114° and mild kyphosis（A，B）. Pre-op MRI showed the conus medullaris at L5 level(G). The deformity was significantly corrected postoperativly(C, D) by spine-shortening VCR of T9 without a cage in osteotomy gap(E, F) to indirect relieve spinal cord tension that avoided detethering entirely. At final follow-up, her pre-op weakness of leg were improved significantly.

## 86. Does Untreated Intraspinal Anomalies in Congenital Scoliosis Impact the Safety and Efficiency of Corrective Surgery for Scoliosis? A Prospective Case-Control Study

*Qinghua Zhao, MD; Xu Sun, MD, PhD; Shifu Sha, MD, PhD; Yong Qiu, MD; ZeZhang Zhu, MD, PhD*

**Summary**

Identification of intraspinal anomalies associated with congenital scoliosis (CS) leads to complexity in decision-making for corrective surgery of scoliosis. This study demonstrated that one-stage scoliosis correction for CS patients with intraspinal anomalies and intact or stable neurological status, could be safe without any prophylactic neurological intervention though neurological surgery for intraspinal anomalies are traditionally considered option.

**Hypothesis**

Prophylactic neurosurgical intervention for intraspinal anomalies before scoliosis correction may be unnecessary.

**Design**

prospectively study

**Introduction**

CS associated with intraspinal anomalies remains a challenge for spine surgeon due to the potential neurological complication. However, to date, there is no case-control study for identifying the risk of neurologic complications and surgical outcomes for scoliosis correction surgery in CS patients with untreated intraspinal anomalies.

**Methods**

The inclusion criteria were as follows: 1) CS with Cobb angle 40° to 90°, 2) age 10 to 20 yrs, 3) single posterior surgery, 4) with an intact or stable neurological status over the preceding 2 years and 5) a minimum two-year follow-up. The patients were divided into two groups: CS patients with intraspinal anomalies (CS+IA) group and CS patients without intraspinal anomalies (CS-IA) group. The surgical results and complications of correction were compared between two groups.

**Results**

There were 57 patients in CS+IA group and 184 patients in CS-IA group, respectively. Mean ages at the time of surgery were 14.1 and 14.3 years, and mean follow-up lasted 30.6 and 29.2 months, respectively. There were no significant differences in age, gender, curve pattern, major curve magnitude and flexibility of the major curve between CS+IA group and CS-IA group (P 0.05). The post-operative correction rates of the major curve were comparable between two groups (53.5% vs 55.7%). Also, corrections of other radiographic parameters including coronal and sagittal plane balance were similar in both groups (P 0.05). None in CS+IA group developed a neurological complication from surgery to the latest follow-up, but one in CS-IA group experienced transient weakness of left lower extremities after surgery.

**Conclusion**

The coexisting intraspinal anomalies in CS patients with normal or stable neurological status do not increase the risk of neurological complications of corrective scoliosis surgery or influence its long-term surgical results. For these patients, prophylactic neurosurgical intervention for intraspinal anomalies before scoliosis correction may be unnecessary.

## 87. Thoracic Cage Deformities Affected Cardiopulmonary Function in Patients with Congenital Scoliosis

*Youxi Lin, MD; Xingye Li, MD; Wangshu Yuan; Hui Cong, MD; Haining Tan; Jianxiong Shen, MD*

**Summary**

This study revealed the impact of chest deformity on patients' cardiopulmonary function.

**Hypothesis**

Thoracic cage deformities influences cardiopulmonary function in patients with congenital scoliosis.

**Design**

A prospective study.

**Introduction**

Deformities of thoracic dimensions, as a result of congenital scoliosis, causes pulmonary dysfunction. However, it is still unknown whether they affect patients' cardiopulmonary exercise capacity. The aim of this study is to investigate the correlation of chest deformity and exercise tolerance in patients with congenital scoliosis.

**Methods**

40 patients with congenital scoliosis were included in this prospective study from January 2014 to December 2016. All patients

had radiological assessment of spine and rib cage, as well as pulmonary function test and cardiopulmonary cycle ergometer test. 2-tailed Pearson correlation test was performed to investigate the correlation of thoracic cage parameters and pulmonary function and physical capacity.

**Results**

26 female aged 17.5±8.2 years and 14 male subjects aged 18.9±6.9 years were included. All radiographic parameters were calibrated by patient's own pelvic inlet width. Most of static pulmonary function parameters were significantly correlated with T1 to T12 height, difference of hemithorax height and thoracic transverse diameter respectively, as demonstrated by forced expired volume in one second, forced vital capacity, peak expiratory flow, vital capacity, total lung capacity and residual volume/total lung capacity ratio($P<0.05$). In cardiopulmonary exercise test, most of the parameters of ventilation, including tidal volume($P<0.001$, $r=0.647$), respiratory rate($P=0.001$, $r=-0.532$) and breathing reserve both at rest($P=0.002$, $r=0.490$) and maximum exercise($P=0.021$, $r=0.378$) were significantly correlated with T1 to T12 height. Blood oxygen saturation at rest($P<0.001$, $r=0.642$) and at maximum exercise ($P=0.002$, $r=0.537$) were also significantly correlated with T1 to T12 height. Most of the parameters of cardiovascular system, including heart rate, pulse pressure at rest and at maximum exercise, and the increase of them, were significantly correlated T1 to T12 height ($P<0.05$, r from 0.361 to 0.472) and thoracic transverse diameter ($P<0.05$, r from 0.454 to 0.620).

**Conclusion**

Overall exercise tolerance did not correlate with the severity of the thoracic cage deformities. However, disorders of the thoracic development, especially retardation of longitudinal growth and loss of spinal height, did influence the function of both respiratory and cardiovascular systems.

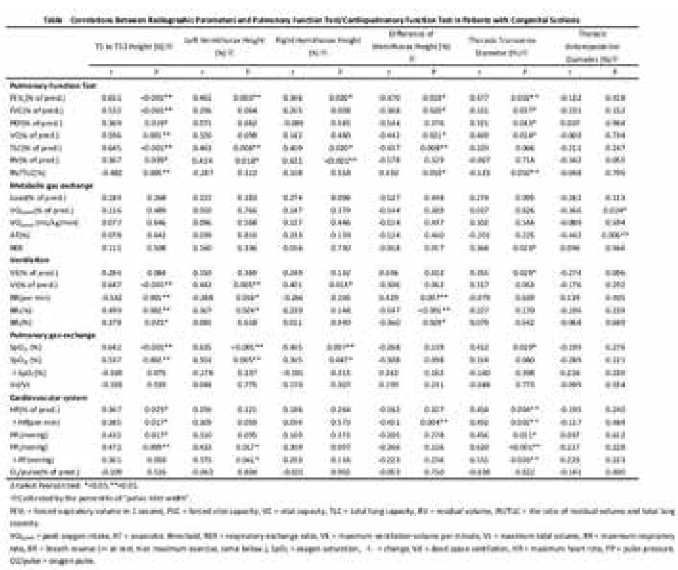


Table Correlations Between Radiographic Parameters and Pulmonary Function Test/Cardiopulmonary Function Test in Patients with Congenital Scoliosis

## 88. Maternal Risk Factors for Congenital Spinal Deformity Diagnosed in Infancy

*Hillard T. Spencer, MD; Ming-Sum Lee, MD PhD*

**Summary**

This study demonstrates maternal congenital cardiac conditions and maternal diabetes are risk factors for congenital spinal deformity diagnosed in infants, and estimates the rate of congenital spinal deformity detected in the first two years of life at 72.5/100,000 births.

**Hypothesis**

There is an association between maternal health and infant congenital spinal deformity.

**Design**

Retrospective, population-based study of births in a large integrated health care system between January 1, 2003 and December 31, 2014.

**Introduction**

Large population based studies are important to estimate the prevalence of a rare condition such as congenital spinal deformity and to identify risk factors.

**Methods**

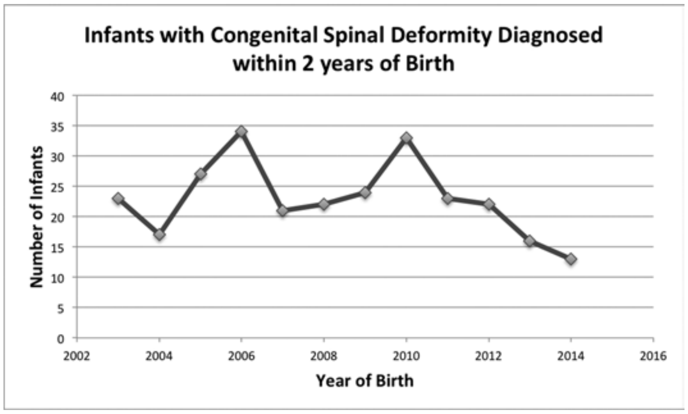
Maternal and infant characteristics for all births in this healthcare system were examined by searching a comprehensive research database (which contains diagnoses from all ambulatory visits, emergency room visits, and inpatient admissions). Infants with congenital spinal deformity were identified using diagnoses in medical records during the first two years of life, ICD9 codes 754.2 (congenital deformity of spine) and 756.10-19 (congenital anomalies of spine). Maternal health conditions were recorded for all births.

**Results**

There were 379,238 births in this study, including 275 infants with a diagnosis relating to congenital spinal deformity, for an average incidence of 72.5/100,000. There was no difference in M:F ratio between infant groups, but 12% of cases were smaller than the 3rd percentile size for gestational age ($p<0.001$). Mean maternal age was slightly higher (31.1 vs. 29.8 years, $p=0.0002$) among affected births; in univariate analysis, there were differences in the rate of maternal congenital cardiac disease (6.9% vs. 0.7%, $p<0.001$), hypertension (14.9% vs. 7.8%, $p<0.001$), diabetes (17.1% vs. 4.1%, $p<0.001$), hyperlipidemia (20.3% vs 10.0%, $p<0.001$), peripheral vascular disease (1.5% vs 0.3%, $p=0.009$), and kidney disease (1.8% vs. 0.6%, $p=0.02$). In multivariate logistic regression, maternal congenital cardiac disease (odds ratio 8.3, $p<0.001$) and diabetes (odds ratio 3.3, $p<0.001$) remained significantly associated with congenital spinal deformity in the infant.

**Conclusion**

Maternal congenital cardiac conditions and diabetes are risk factors for infant congenital spinal deformity.




## 89. Risk of Surgical Treatment for Idiopathic-Like Scoliosis Associated with Chiari 1 Malformation Following Decompression

*Dong-Phuong Tran, MS; Charles E. Johnston, MD; Kaitlyn E. Brown, MS; John A Herring, MD*

**Summary**
We performed a study to determine the clinical characteristics of patients diagnosed with Chiari malformation and the associated risk of spinal deformity correction surgery after Chiari decompression.

**Hypothesis**
CM decompression reduces the risk of corrective scoliosis surgery in patients <10 y.

**Design**
IRB approved retrospective review from a single institution from 2000-2014.

**Introduction**
The effect of CM decompression on scoliosis curve magnitude with no other known comorbidities is largely unknown. This study determined the risk of surgical intervention in post CM decompression and the likelihood of resolving scoliosis.

**Methods**
Inclusion criteria: scoliosis associated with CM and underwent sub occipital decompression. Spina bifida, congenital, NM, and syndromic scoliosis were excluded. Clinical and radiographic measurements were collected at presentation and last follow-up, ≥2 years.

**Results**
57 patients met inclusion criteria. At presentation, mean cohort age was 10 y (range 0.9-15.3) and major curve was 40.2° (15-109). 24 patients (42%) required surgical correction while 33 were treated nonoperatively. Surgical patients were older at presentation [11 y, range 4-15.3 vs 9 y, 0.9-14.4, p<.001), and had greater curve magnitude, 52 v 32° (<0.001). 61% of nonop group were <10y at presentation compared to 29% in the operative group (p=.001). Nonoperative rx (cast/brace/observation) for mean 3.9 y (0.5-10.3) has resulted in 13 discharges at skeletal maturity, while 9 are currently under observation after brace/cast treatment, and 11 are currently braced. Logistic regression showed that each additional year of age increases risk for surgical intervention, odds ratio (OR) = 37.9%. Adjusting for age, major curve >35° has the OR 4.1 (95% CI, 1.033-16.573, p=0.045) risk for surgical intervention.

**Conclusion**
Following decompression for CM, risk for eventual scoliosis surgical treatment is significantly higher for patients age >10 y or with initial curve magnitude >35o. Patients with juvenile presentation can often be effectively managed nonoperatively.

## 90. Progression of Scoliosis in Children Who Sustained Spinal Cord Injuries at 5 Years of Age and Younger

*Jennifer Schottler, MPT; Purnendu Gupta, MD; Kim W. Hammerberg, MD; Erin H. Kelly, PhD; Lawrence C Vogel, MD*

**Summary**
Children sustaining a spinal cord injury (SCI) at a young age have a high incidence of scoliosis. We retrospectively reviewed records of children injured between 0 and 5 treated at our center. Thirty-eight subjects were followed to skeletal maturity. No injury-related factors were predictive of rate of curve progression; however, etiology and completeness of injury were predictive for development of scoliosis. We continue to recommend routine radiographs on all children with SCI until skeletal maturity.

**Hypothesis**
Certain SCI-related characteristics predispose children to the development of severe scoliosis and a faster rate of curve progression.

**Design**
Retrospective review

**Introduction**
A majority of children who sustain a SCI prior to puberty develop scoliosis. Different types and levels of SCI can result in varying degrees of disability and it is unclear if these characteristics can assist in identifying who develops scoliosis or the rate of curve progression.

**Methods**
Children injured between 0 and 5 years (y), seen at Shriners Hospitals for Children-Chicago were identified and medical records reviewed to obtain demographic and SCI information. Cobb angles were measured on radiographs obtained at follow-up visits.

**Results**
Of the 113 eligible children, 57% were male, 51% complete SCI, 66% paraplegia, and the most common cause of SCI was vehicular-related incidents (47%). Mean age of follow up was 12.9 y (range, 1.7 to 21.7 y.) 94% developed scoliosis (defined as >10º); 38% developed a curve of ≥ 40º or had spine fusions for scoliosis. Best fit prediction line for the Cobb angle is: Cobb = 16.744 + Age (0.648). On average, the Cobb angle of subjects increased 3.5º (SD 8.95) per year. Those with paraplegia demonstrated greater curve progression than those with tetraplegia (4.7º/year (SD 10.2) vs. 1.4º/year (SD 5.5); p=0.075). 38 subjects were followed to skeletal maturity (14 y). Mean age of follow up was 17.8 (range, 14.6 to 21.7 y). Of these, 95% (n=36) developed scoliosis

with 32% developing a curve ≥40º or undergoing a spine fusion for scoliosis. Analyses of this group demonstrated that etiology (traumatic) was a predictive factor for a curve ≥ 10º and complete injury (AIS A) was a predictive factor for a curve ≥ 40º.

**Conclusion**

The majority (94%) of children who sustain a SCI at age 5 or younger develop scoliosis. No injury-related factors were found to be predictive of rate of curve progression. However, we found etiology and complete injuries to be predictive factors for development of scoliosis in the group followed to skeletal maturity. We continue to recommend routine radiographs be performed on a regular basis to follow these children to maturity.

## 91. Improving Health Related Quality of Life in Patients with Non-Ambulatory Cerebral Palsy: Who Stands to Gain from Scoliosis Surgery?

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**Summary**

This study compared patients with non-ambulatory cerebral palsy (CP) who reported substantial improvement in health-related quality of life (HRQOL) following posterior spinal fusion (PSF) with those who did not show a considerable increase from baseline. Preoperative and postoperative radiographic parameters did not differ significantly between the two groups. Patients with substantial improvement in HRQOL following surgery tended to have lower baseline function when compared to those who did not improve considerably.

**Hypothesis**

Improvement in HRQOL following PSF for patients with non-ambulatory CP is independent of radiographic parameters

**Design**

Retrospective review of a prospectively collected multicenter database

**Introduction**

It is unclear what factors influence HRQOL in neuromuscular scoliosis. The aim of this study was to evaluate which factors are associated with a substantial improvement in HRQOL following spinal fusion surgery for non-ambulatory patients with cerebral palsy.

**Methods**

157 patients with non-ambulatory CP (GMFCS IV and V) with a minimum of two year follow-up after PSF were identified from a prospective multicenter registry. Radiographs and QOL were evaluated at pre-op and 2 years post-op. QOL was evaluated using the validated CPCHILD questionnaire. Patients who had an increase of 10 points or greater from baseline CPCHILD scores were considered to have substantial improvement at 2 years post op. 10 points was chosen as a threshold for substantial improvement based on differences between GMFCS IV and V patients reported during the development of the CPCHILD. Patients with substantial improvement were compared to those without substantial improvement to identify difference between the two groups.

**Results**

36.3% (57/157) of patients reported substantial improvement in CPCHILD scores at 2 years post op. Preoperative radiographic parameters, postoperative radiographic parameters, and deformity correction did not differ significantly between groups (Figure 1). Patients who experienced substantial improvement from surgery had significantly lower preoperative CHPILD scores (43.8 vs 55.2, p < .001).

**Conclusion**

Analysis of 157 CP patients revealed a substantial improvement in HRQOL in 36.3% of patients. These patients tended to have lower preoperative HRQOL, suggesting more “room for improvement” from surgery. Radiographic parameters of deformity or curve correction was not associated with substantial improvement following surgery.

| Time Point | Parameter | Mean in Group With Improvement >10 pts. | Mean in Group Without Improvement >10 pts. | p value |
|---|---|---|---|---|
| Pre-op | CP CHILD total score | 43.8 +/- 13.6 | 55.3 +/- 13.6 | **< .001** |
| | Major curve Cobb angle (°) | 82.1 +/- 25.3 | 81.6 +/- 27.1 | 0.89 |
| | Pelvic obliquity (°) | 27.9 +/- 15.0 | 26.5 +/- 16.2 | 0.61 |
| | Sagittal Balance (cm) | 2.2 +/- 6.9 | 2.3 +/- 7.3 | 0.96 |
| 2 years Post-op | CP CHILD total score | 63.6 +/- 12.8 | 53.3 +/- 14.1 | **< .001** |
| | Major curve Cobb angle (°) | 29.9 +/- 14.7 | 28.0 +/- 16.0 | 0.44 |
| | Pelvic obliquity (°) | 8.5 +/- 8.2 | 7.9 +/- 7.3 | 0.69 |
| | Sagittal Balance (cm) | 0 +/- 5.9 | -0.9 +/- 6.5 | 0.39 |
| Change from Pre to Post Op | Change in CPCHILD | 19.7 +/- 8.3 | -2.0 +/- 8.7 | **< .001** |
| | Change in Cobb | -52.1 +/- 21.5 | -53.6 +/- 21.7 | 0.7 |
| | Change in pelvic obliquity | -19.0 +/- 16.1 | -19.2 +/- 15.8 | 0.97 |
| | Change in Sagittal Balance | -2.5 +/- 6.3 | -3.1 +/- 8.3 | 0.71 |

## 92. Pelvic Fixation in Cerebral Palsy Scoliosis: Differences Evident at 5-Year Follow-Up

*Oussama Abousamra, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Burt Yaszay, MD; Patrick J. Cahill, MD; Peter O. Newton, MD*

**Summary**

A review of a prospective database showed that correction of pelvic obliquity in cerebral palsy can be achieved using the three different spinopelvic fixation methods (unit rod, sacral alar iliac screws, and iliac screws). Correction was maintained over 5 years in all methods. However, at 5 year follow up, pelvic obliquity was higher in iliac screw group, and implant related complications and reoperations occurred in the unit rod and iliac screw groups but not in sacral alar iliac screw group.

**Hypothesis**

In cerebral palsy scoliosis surgery, different methods of spinopelvic fixation lead to different outcomes and should be assessed over 5 years to best determine the optimal fixation.

**Design**

Retrospective review of a multicenter study group prospective database.

**Introduction**

Multiple options for pelvic fixation in cerebral palsy (CP) exist. This study compares the outcomes, at 5 year follow up, between the unit rod (UR), sacral alar iliac (SAI) screws, and iliac screws (IS).

**Methods**
Children with CP who underwent posterior spinal fusion with a 5 year follow up were included. Major coronal curve and pelvic obliquity (PO) measurements were compared at preop, postop, 1, 2, and 5-year follow-up radiographs. Three types of pelvic fixation were compared: UR, SAI, and IS. Comparison was performed for each group between the different time points. Complications were recorded.

**Results**
70 patients were identified (UR:9 patients; SAI:16 patients; IS:45 patients). For all groups, PO was significantly corrected and maintained. The loss of PO correction (last follow up PO – Postop PO) was higher in IS (3 deg) than UR (0 deg; p=0.04) and SAI (-1 deg; p=0.004). At five year follow up, PO was significantly higher in the IS (12 deg) compared to UR (5 deg; p=0.002) and SAI (6 deg; p=0.005). Pelvic implant-related complications were found in one case of UR (11%), which required reoperation. No implant related complications were found in SAI. Implant related complications in IS totaled 6 cases (13%) including 2 prominent screws (no intervention needed), 3 loss of connection between the rod and iliac screw (1 needed no intervention, 1 needed screw replacement, and 1 needed screw removal), and 1 loose screw (needed removal).

**Conclusion**
In children with CP scoliosis, and over 5 years of follow up, correction of pelvic obliquity was achieved and maintained using the different available fixation methods. Implant related complications were more common in the iliac screw group. At 5 year follow up, there was less final correction of pelvic obliquity than the unit rod and SAI screws. Minimizing the number of implant connections at spinopelvic junction may help eliminate complications in CP scoliosis surgery.

**Table 1:** Demographic data and preoperative functional impairments for 70 children with cerebral palsy who underwent posterior spinal fusion. Pts.: patients. Data were presented as mean (standard deviation) and count (percentages).

| | Unit Rod (9 pts.) | SAI screws (16 pts.) | Iliac screws (45 pts.) |
|---|---|---|---|
| Age at Surgery (years) | 13 (2) | 14 (2) | 14 (3) |
| History of Seizures | 5 (56) | 11 (69) | 34 (76) |
| Non-Verbal | 7 (78) | 11 (69) | 40 (89) |
| Tracheostomy | 0 (0) | 1 (6) | 1 (2) |
| Tube Feeds | 6 (67) | 8 (50) | 25 (56) |

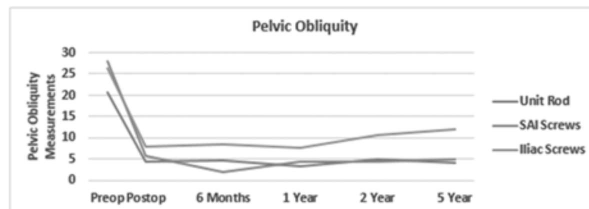
**Table 2:** Radiographic measurements for the three groups preoperatively, postoperatively and at 5 year follow up. FU: follow up; SD: standard deviation; UR: unit rod; SAI: sacral alar iliac screws; IS: iliac screws.

| | | Preop | | Postop | | Last FU | | p value |
|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | Postop – Last FU |
| Major Coronal Curve | UR | 67 | 21 | 18 | 11 | 23 | 10 | 0.33 |
| | SAI | 87 | 26 | 22 | 11 | 27 | 15 | 0.29 |
| | IS | 82 | 27 | 26 | 13 | 33 | 17 | 0.04 |
| Pelvic Obliquity | UR | 21 | 9 | 5 | 3 | 5 | 4 | 0.95 |
| | SAI | 25 | 15 | 7 | 5 | 6 | 6 | 0.69 |
| | IS | 22 | 12 | 9 | 7 | 12 | 12 | 0.07 |

**Table 3:** Pelvic implant revisions by implant type.

| | Unit Rod | SAI Screws | Iliac Screws |
|---|---|---|---|
| Reoperation | 1 case (11%) | 0 | 3 cases (7%) |
| Time of Reoperation | Within 1 year of surgery | - | 1 reoperation was performed within 1 year of surgery and 2 reoperations were performed between the second and third year following surgery |

**Figure 1:** Pelvic obliquity measurements of the coronal major curve for all instrumentation groups showing the similarity of correction between the unit rod and SAI screws and the loss of correction in the iliac screw group.




## 93. Relative Valuation of Interventions for Severe Cerebral Palsy: Spinal Correction Ranked the Most Beneficial, but Below G-tube

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**Summary**
152 CP caregivers answered surveys comparing relative impact of spinal fusion surgery with other procedures on their child's life. At the 2-year follow-up, 73% of caregivers ranked or co-ranked spine surgery as the most important surgical intervention that the child had received. However, the G-tube was ranked as the most beneficial.

**Hypothesis**
Caregivers of children with cerebral palsy (CP) consider spinal fusion surgery as having the greatest impact on their child's life compared to other common surgical interventions.

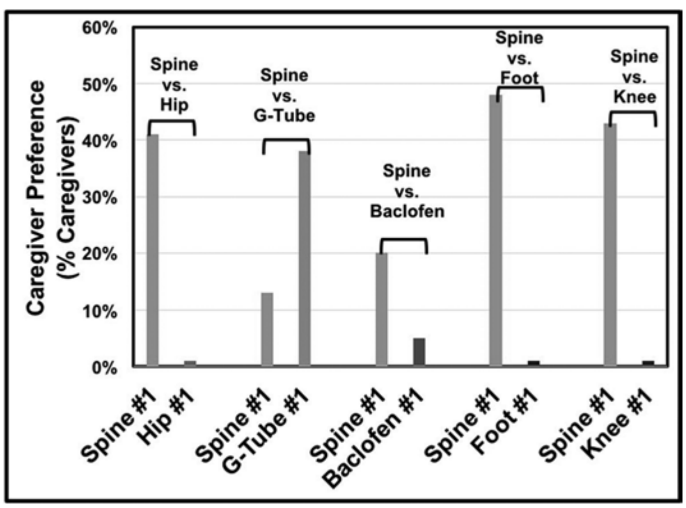
**Design**
Observational Cohort

**Introduction**
Children with CP have several major surgical interventions in their lives. Caregivers may intuitively rank their benefits. We aimed to compare the impact of this surgery on the quality of life and health relative to other common surgical interventions they receive.

**Methods**
A multicenter prospective registry of operatively treated children with cerebral palsy was studied. Included in the study design was a question assessing perceived relative benefit (ranking) of procedures the child has undergone. Of 193 patients with 2-year clinical and radiographic follow-up, 152 (79%) caregivers performed this rating of the impact and relative importance of spinal fusion surgery on their child's life.

**Results**
At the 2-year follow-up, 91% caregivers (CG) reported that the overall quality of life, and 80% reported that the overall health of their child, improved "a little" or "a lot" as a result of spinal fusion surgery. At the 2-year follow-up, 73% caregivers ranked or co-ranked spine surgery as the #1 (most important) surgical intervention that the child had received. Of the 64 patients who underwent both spine surgery and hip surgery, 20 (31%) CG co-ranked both as #1, 26 (41%) ranked spine surgery as #1, and none ranked hip surgery as #1 (Table 1). Of 78 CG who ranked both spine surgery and G-tube placement, 31 (40%) co-ranked both as #1, 38% ranked G-tube as #1, and only 13% ranked spine surgery as #1. Spine surgery was ranked or co-ranked as the most important intervention in 16 of 20 (80%) patients who received a baclofen pump, in 19 of 27 (70%) patients who underwent foot surgery, and in 8 of 14 (57%) patients who underwent knee surgery.

**Conclusion**
Caregivers of children with cerebral palsy who undergo spinal fusion surgery usually rank or co-rank spinal surgery as most important intervention in their child's life, secondary only to G-tube placement.




## 94. Don't You Wish You Had Fused to the Pelvis the First Time: A Comparison of Reoperation Rate and Correction of Pelvic Obliquity

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**Summary**
Fusing to the pelvis (PF) at the index spinal fusion leads to twice the correction of pelvic obliquity and half the reoperation rate compared to PF at a revision surgery.

**Hypothesis**
There will be better outcomes with PF done during the index spinal fusion than PF done at revision surgeries.

**Design**
Retrospective multicenter

**Introduction**
Our objective was to compare pelvic obliquity correction and reoperation rate in neuromuscular patients who had PF at their index procedure vs revision procedures.

**Methods**
Charts and radiographs were reviewed of patients with PF for neuromuscular scoliosis from 01/2003 to 08/2015 at 4 high volume pediatric spine centers with >2 year follow-up.

**Results**
319 patients met inclusion criteria; 298 had PF done at index surgery and 21 had PF done during revision surgery. Preoperatively there were no differences in age at PF (index= 13.6 years, revision= 12.4 years, p= 0.13), Cobb angle (index= 76.7 degrees, revision= 67.8 degrees, p= 0.15), or pelvic obliquity (index= 21.2 degrees, revision= 16.2 degrees, p=0.08) between the 2 groups. Estimated blood loss (index= 1710 ml, revision= 1115 ml, p=0.11) and operative time (index = 370 min, revision= 372 min, p= 0.95) did not differ between index and revision procedures. Percent correction in pelvic obliquity was greater for patients with index PF (52%) than revision PF (29%) (p= 0.02). 82 patients had a total of 103 returns to the OR. There was a lower reoperation rate with index PF (24%, n= 72/298) than revision PF (48%, n= 10/21) (p= 0.02). Implant failures were higher in the revision group (index=8%, 25/298; revision= 33%, 7/21; p<0.001).

**Conclusion**
PF at the index spinal fusion lead to significantly greater correction of pelvic obliquity with approximately half the reoperation rate compared to PF at a revision surgery. While we would intuitively think that extension to the pelvis is a relatively small procedure, operative time and blood loss were similar to the index spinal fusion.

| | Index | Revision | P-value |
|---|---|---|---|
| **Total reoperations** | **24% (*n*= 72/298)** | **48% (*n*= 10/21)** | **0.02** |
| Pain | 1% (*n*= 3/298) | 10% (*n*= 2/21) | 0.04 |
| Pseudarthrosis | 1% (*n*= 3/298) | 10% (*n*= 2/21) | 0.04 |
| Infection | 16% (*n*= 49/298) | 5% (*n*= 1/21) | 0.22 |
| Implant failure | 8% (*n*= 25/298) | 33% (*n*= 7/21) | <0.001 |
| **Correction of pelvic obliquity** | **52%** | **29%** | **0.02** |

## 95. Incidence and Description of Scoliotic Curves in Friedreich Ataxia Patients at Skeletal Maturity

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**Summary**
Friedreich Ataxia (FA) is frequently associated with scoliosis. Studies focusing on scoliotic evolution in FA patients are scarce. Questions remain concerning the incidence of the different curve types and the right time for surgery. To date, a trend toward an as-late-as-possible corrective spinal surgery is observed given the concern of potential postoperative loss of walking ability.

**Hypothesis**
A comprehensive description of FA scoliotic patients at skeletal maturity is needed to characterize their curve shape.

**Design**
After Local Ethics Committee approval, 68 FA patients were included into a prospective monocentric cohort between 2008 and 2016.

**Introduction**
Friedreich ataxia (FA) is a common spinocerebellar degenerative disorder responsible for gait impairment in children and young adults. It is associated with scoliosis. Studies focusing on scoliotic curves in FA patients at skeletal maturity are scarce. The present study aimed to characterize spinal shape, surgery rates and gait quality in a monocentric FA pediatric cohort.

**Methods**
Clinical (gait study) and radiological (full-spine AP and lateral x-rays) records were conducted anually. Coronal curve type, segmental measurements and Risser sign were assessed.

**Results**
Mean follow-up was 5 +/- 2.3 years. Scoliosis was noted for 51 patients (75%) and 27 were followed until skeletal maturity (Risser sign > 4). Sex ratio was 13F/14M. Mean age for scoliosis diagnosis was 12.7 +/- 2.5 y.o. and did not differ from FA molecular diagnosis (12.6 +/- 3.2 y.o.).Thoracic main curve was present in 12 patients (44%) with a Cobb angle of 34° +/- 15.5° (10°-58°), sex ratio was 7F/5M. Eight patients (30%) presented with a double major curve with a Cobb angle of 41° +/- 11.4° (23°-61°), sex ratio was 2F/6M. A lumbar curve was noted in 7 (26%) with a Cobb angle of 27° +/- 17.8° (10°-62°). Hyperkyphosis (T1T12 sagittal Cobb angle > 50°) was present in 9 patients (33%) including 3 with a main thoracic curve (25%), 2 in the double major group (25%) and 4 in the main lumbar scoliosis group (57%). Overall spinal deformity correction surgery rate was 33% (9/27), for main thoracic 3/12 (25%), for double major 4/8 (50%) and 2/7 (29%) for main lumbar curves. Five patients were non walking before spinal surgery and 4 patients out of nine (44%) kept an autonomous walk 7 years after surgical correction and fusion.

**Conclusion**
All scoliotic curve types can be equally present in FA, with a balanced sex ratio. Thoracic hyperkyphosis is a frequently found spinal deformity that is not shown to be associated with any scoliotic curve type. Loss of an autonomous walk in FA scoliotic patients is not associated with spinal surgery. Level of evidence: IIb

## 96. Implementing a Multidisciplinary Clinical Pathway Can Reduce the Deep Surgical Site Infection Rate After Posterior Spinal Fusion In High Risk Patients

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**Summary**
Implementation of a clinical pathway aimed to reduce infection in patients at high risk after spinal fusion led to a significant reduction in deep SSI rate

**Hypothesis**
Adherence to a protocol using multiple strategies to reduce infection can result in a lower SSI rate

**Design**
Retrospective comparative

**Introduction**
An institutional clinical pathway was created in 2012 based on nationally published Best Practice Guidelines as well as hospital practices with a goal of reducing the rate of deep SSI in high risk patients. It was based on multidisciplinary input and focused on care from patient optimization preoperatively through the postoperative care period.

**Methods**
Patients were retrospectively reviewed from 2008-2012, and a comparable number of patients were retrospectively reviewed from a prospectively collected database of patients at high risk for SSI. Patients with neuromuscular or syndromic diagnosis at high risk for infection based on medical co-morbidities were included. Patients with AIS, growth friendly operations, trauma, or current infections were excluded. Number of deep SSIs (defined by CDC) before and after implementation of the guideline were compared, as were compliance with measures within the guideline. Uni- and multivariable logistic regression analysis using penalized maximum likelihood estimation was used to assess the effect of changes in surgical practices on infection rate.

**Results**
18/135 (13% (95% CI: 8.3-20.5%)) patients treated before implementation of the guideline had a deep SSI were compared to 2/116 (2% (95% CI 0.3-6.7%)) patients treated on the clinical pathway (p<.001). The groups were similar with regard to age, sex, and implant metal type (p>0.05). The percentage of neuromuscular diagnosis (75% vs. 82%) was similar between the two groups. There was no difference in surgical time, length of ICU stay, or total LOS between the two groups. There was an increase in the percentage of patients that received topical vancomycin (85% vs 0%) and betadine irrigation (75% vs 7%) after implementation of the pathway. Appropriate dosing of antibiotics within one hour of incision improved from 52% to 91% after implementation.

**Conclusion**
Implementation of a clinical pathway aimed to reduce infection in patients at high risk for SSI after spinal fusion led to a significant reduction in deep SSI rate. While multiple changes were made, it is impossible to attribute the drop in the deep SSI rate to any one factor. However adherence to a protocol using multiple strategies to reduce infection can result in a lower SSI rate.

## 97. Postoperative Surgical Site Infection after Spine Surgery: An Update from the Scoliosis Research Society (SRS) Morbidity and Mortality Database

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**Summary**
This data provides an updated benchmark for postoperative spine infections and may be valuable in the ongoing effort to prevent these complications.

**Hypothesis**
Patients with kyphotic deformities will have a higher rate of postoperative spine infections.

**Design**
Retrospective review of prospectively collected data

**Introduction**
The SRS has prospectively gathered surgeon-reported complications, including instrumentation failure, new neurological deficits, infections, and death.

**Methods**
The SRS M&M database was evaluated to define patient demographics, perioperative risk factors, antibiotics and bacterial host profiles of deformity patients with postoperative spine infections following corrective surgery.

**Results**
Of the 47,755 procedures reported to the SRS in 2012, there were 578 diagnosed infections, accounting for an infection rate of 1.2%. Infection rates for patients with kyphosis, spondylolisthesis, and scoliosis were 2.4%, 1.1%, and 1.1%, respectively. Deep infection, defined as those occurring below the fascia, accounted for 68.0% of infections. The mean age for patients with infection was 40.8±26.2years. The most frequent comorbidities included hypertension, diabetes and pulmonary disorders (31.5%, 20.8%, and 16.6%). Infections were identified at an average of 18.4±16.2days from the index procedure. Spinal fusion was performed in 86.3% of patients, with the majority performed posteriorly(75.1%). Cefazolin was the most common perioperative antibiotic administered(83.0%), and intrawound vancomycin powder was applied at the index procedure in 10.2% of cases. Infection was more frequent in patients with perioperative antibiotics limited to the first 24hrs after surgery (39.6%), compared to those receiving prophylaxis for 48hrs(26.1%) or until drain removal(20.9%). Methicillin-sensitive and methicillin-resistant Staphylococcus aureus were the most commonly isolated pathogens (41.9% and 17.0%, respectively) with gram-negative bacteria isolated in 147 cases(25.4%). Treatment was operative in 81.8% of cases, with primary closure performed 59.7% of the time. Removal of implants and >4 operative debridements were required in 9.9% and 3.8% of patients, respectively. Long-term antibiotic suppression was required for 18.9% of patients, resulting in an antibiotic complication rate of 4.5%.

**Conclusion**
Our analysis suggests that post-operative infection occurs in 1.2% of deformity cases, with a rate twice as high in patients with kyphosis. Additionally, gram-negative bacteria account for over one quarter of these post-operative infections.

| **Infection Complications (%)** | |
|---|---|
| Number of cases | 578 (1.2) |
| Age, (range) | 40.8±26.2 (2-87) |
| Female | 360 (62.3) |
| **Diagnosis with Infection (%)** | |
| Kyphosis | 112 (19.4) |
| Scoliosis | 294 (50.9) |
| Spondylolisthesis | 169 (29.2) |
| **ASA Classification (%)** | |
| 1-Normal healthy individual | 127 (22.0) |
| 2-Mild systemic disease | 184 (31.8) |
| 3-Severe systemic disease | 218 (37.7) |
| 4-Incapacitation systemic disease | 35 (6.1) |
| **Patient Characteristics (%)** | |
| Diabetes | 120 (20.8) |
| Smoker | 60 (10.4) |
| Hypertension | 182 (31.5) |
| Vascular Disease | 54 (9.3) |
| Coronary Artery Disease | 42 (7.3) |
| Thromboembolic history | 24 (4.2) |
| Pulmonary History | 96 (16.6) |
| Cancer History | 17 (2.9) |
| **Surgical Factors (%)** | |
| Fusion Performance | 499 (86.3) |
| Intra-op blood loss cc, std (range) | 918.9±1356.2 |
| *Anterior Fusion* | 4 (0.7) |
| *Posterior Fusion* | 434 (75.1) |
| *Combined Anterior/Posterior Fusion* | 59 (10.2) |
| Staging | 49 (8.5) |
| Osteotomy Performance | 174 (30.1) |
| **Osteotomy Type(%)** | |
| *Smith-Petersen* | 110 (19.0) |
| *3 Column osteotomy* | 61 (10.6) |
| **Operative times (%)** | |
| *<2hr* | 56 (9.7) |
| *2-6hr* | 384 (66.4) |
| *6-9hr* | 96 (16.6) |
| *9-12hr* | 29 (5.0) |
| *>12hr* | 3 (0.5) |

| **Days from Surgery to Infection** | |
|---|---|
| Average | 18.4±16.2 |
| **Infection Location (%)** | |
| Superficial (Above Fascia) | 158 (27.3) |
| Deep (Below Fascia) | 393 (68.0) |
| **Perioperative Antibiotics for Index Surgery (%)** | |
| Ancef 1G | 183 (31.7) |
| Ancef2G | 219 (37.9) |
| Ancef per weight | 78 (13.5) |
| Vancomycin 1G | 59 (10.2) |
| Vancomycin per weight | 32 (5.5) |
| Vancomycin powder at surgical site | 59 (10.2) |
| **Timing of Antibiotics Before Incision (%)** | |
| <30mins | 272 (47.1) |
| 30-60mins | 248 (42.9) |
| >60mins | 22 (3.8) |
| **Intraoperative Antibiotics Redosed (%)** | |
| <q4H | 118 (20.4) |
| q4H | 215 (37.2) |
| >q4H | 71 (12.3) |
| Not redosed | 124 (21.5) |
| **Postoperative Antibiotic Continuance (%)** | |
| 24hrs | 229 (39.6) |
| 48hrs | 151 (26.1) |
| Until drain out | 121 (20.9) |
| None of the above | 45 (7.8) |
| **Bacteria Cultured (%)** | |
| Gram Positive - Staph Aureas MSA | 242 (41.9) |
| Gram Positive - MRSA | 98 (17.0) |
| Gram Positive - Staph Epidermitis | 48 (8.3) |
| Gram Negative - E. Coli | 56 (9.7) |
| Gram Negative - Proteus | 10 (1.7) |
| Gram Negative - Pseudomonas | 26 (4.5) |
| Gram Negative - Not listed | 55 (9.5) |
| **Number of patients requiring Long Term Suppression (%)** | |
| Long Term Antibiotic | 109 (18.9) |
| **Type of Closure (%)** | |
| Primary | 345 (59.7) |
| Secondary | 103 (17.8) |
| **Returned to Surgery (%)** | |
| Return to OR | 473 (81.8) |

| **Number of Return to OR for Irrigation and Debridement (%)** | |
|---|---|
| 1 | 282 (48.8) |
| 2 | 106 (18.3) |
| 3 | 46 (8.0) |
| 4 | 10 (1.7) |
| >4 | 22 (3.8) |
| **Packing Used (%)** | |
| Closed system (i.e. Vacpack) | 192 (33.2) |
| Inflow-Outflow Irrigation System | 23 (4.0) |
| Open Packing | 11 (1.9) |
| Antibiotic beads | 17 (2.9) |
| **Instrumentation Removed (%)** | |
| Yes | 57 (9.9) |
| **Instrumentation Reinserted (%)** | |
| Yes | 23 (4.0) |
| **Complications from Antibiotics (%)** | |
| Complications from Antibiotics | 26 (4.5) |
| Acute Renal Failure | 1 (0.2) |
| Allergic Reaction | 4 (0.7) |
| Arthralgia | 1 (0.2) |
| Clostridium Difficile | 3 (0.5) |
| Colitis/diarrhea | 3 (0.5) |
| DRESS syndrome | 1 (0.2) |
| Mouth Ulcers | 1 (0.2) |
| Acute Kidney Injury | 1 (0.2) |
| Ertapenam Hepatitis | 1 (0.2) |
| Fever/Neutropenia | 2 (0.3) |
| Pancytopenia | 1 (0.2) |
| Redman Syndrome | 1 (0.2) |
| PICC Line Infection | 1 (0.2) |
| Neck Line Deep Venous Thrombosis | 1 (0.2) |
| Rhabdomyolysis from Daptomycin | 1 (0.2) |

## 98. Topical Vancomycin Increased the Rate of Superficial Infection Without Impacting Deep Infection

*Kelly Harms, BA; Benjamin Hooe, MD; Megan Mignemi, MD; Gregory A. Mencio, MD; Jeffrey E. Martus, MD, MS*

**Summary**
The application of topical vancomycin powder was not associated with a reduced rate of deep infection after posterior spinal fusion (PSF) in pediatric patients while an increased rate of superficial infection was observed.

**Hypothesis**
The use of local vancomycin powder reduces the incidence of deep surgical site (SSI) after PSF in pediatric patients.

**Design**
Retrospective cohort study

**Introduction**
The rate of SSI following pediatric spinal deformity correction ranges from 1-5% for adolescent idiopathic scoliosis and as high as 24% for neuromuscular scoliosis. The use of topical vancomycin has been implemented despite a lack of strong evidence. Previous research has suggested efficacy of local vancomycin in spinal surgery, however studies have been limited to adult patients. The purpose of this study was to investigate the effect of topical vancomycin powder on the rate of SSI in pediatric patients following PSF.

**Methods**
Data was retrospectively collected for patients aged less than 18 years who underwent PSF for spinal deformity from 2007 -2014. Demographics, operative details, local and intravenous antibiotic dosing, and postoperative complications were recorded. The routine use of topical vancomycin powder began in 2010. The

association of deep SSI with vancomycin powder usage was determined using a proportional hazard ratio model.

**Results**

338 patients were included. The demographic variables were similar between the untreated (n = 244) and topical vancomycin-treated groups (n = 94). (Table 1) The mean age was 13.5 years, 66% were female, and 26% had a neuromuscular diagnosis. The rate of superficial SSI was greater in the vancomycin group (13% vs. 7%, p=0.03), while there was no difference in the rate of deep SSI between groups (7% vs. 5%, p=0.61). The use of vancomycin did not affect the risk of deep SSI in all patients (HR = 1.78, 95% CI = [0.81, 3.93], p=0.155) or within the neuromuscular subgroup (HR = 2.61, 95% CI = [0.99, 6.88], p=0.052). The risk of deep SSI significantly increased when the arthrodesis included greater than 10 levels (p=0.049).

**Conclusion**

In this study, the application of local vancomycin powder was not associated with a significant reduction in deep SSI after posterior spinal fusion in pediatric patients. This varies from previous research that indicates local vancomycin powder reduces SSI. More invasive procedures increase the risk of deep SSI, suggesting that providers should exhibit greater precaution in this high-risk group.

| | No Vancomycin N=244 | Topical Vancomycin N=94 | P value (*p<0.05) |
|---|---|---|---|
| Age (yrs) | 13.5 | 13.6 | 1.0 |
| Female Sex | 64% | 71% | 0.19 |
| ASA score 1 | 8% | 6% | 0.52 |
| ASA score 2 | 51% | 47% | |
| ASA score 3 | 34% | 43% | |
| ASA score 4 | 7% | 4% | |
| Neuromuscular Diagnosis | 25% | 31% | 0.24 |
| Operative Time (min) | 333 | 330 | 0.39 |
| Number of Levels | 11.3 | 12.3 | 0.09 |
| Number of Screws | 16.1 | 18.6 | 0.03* |
| Superficial infection | 12 (5%) | 12 (13%) | 0.01* |
| Deep infection | 13 (5%) | 6 (7%) | 0.61 |

Table 1. Comparison of untreated vs. topical vancomycin-treated groups

## 99. Vertebral Column Resection for the Treatment of Adult Spinal Deformities: Outcomes and Complications with Minimum 2 Year Follow Up

*Mostafa H. El Dafrawy, MD; Micheal Raad, MD; Moustafa Abou Areda, BA; Khaled M. Kebaish, MD*

**Summary**

All-posterior vertebral column resection (VCR) technique offers a single stage approach for severe deformity correction. The purpose of this study was to to analyze surgical and functional outcomes associated with the all-posterior VCR technique for severe adult spinal deformity and report on health related quality of life (HRQL) using SRS-22 and ODI with minimum 2 year follow up.

**Hypothesis**

All posterior VCR in ASD is a valuable technique in deformity correction with improved functional outcome at 2 year follow up.

**Design**

Retrospective review of prospectively collected data

**Introduction**

Severe rigid spinal deformity was traditionally managed via a combined anterior/posterior approach. Recent studies showed that single incision VCR is associated with high peri-op complications, little is known is about the functional outome and HRQL at 2 years after VCR.

**Methods**

114 consecutive adult patients underwent all posterior VCRs by one surgeon from 2004 through 2014 for severe spinal deformity, 85 pts completed minimum 2 year follow up and were assessed for clinical and functional outcomes. ODI and SRS-22 were analyzed using a t-test for paired samples for comparing preoperative patient reported outcomes (PRO) with PRO at the last clinic visit (significance, p<.05). Three patient cohorts were designated: kyphosis (N = 43), severe scoliosis (N = 7), and kyphoscoliosis (N = 35). Preoperatively, the major Cobb angle (coronal deformities) averaged 42°, thoracic kyphosis (thoracic deformities) averaged 50°, and lumbar lordosis (lumbar deformities) averaged -33°. Preoperative overall sagittal imbalance averaged 111 mm; overall coronal imbalance averaged 28 mm. Most patients (81) underwent one-level VCR; 4 patients had two nonadjacent levels.

**Results**

Corrections achieved were: to 11° for major Cobb angles (scoliosis and kyphoscoliosis), to 45° for thoracic kyphosis, and to -45° for lumbar lordosis. Focal correction averaged 36° in the coronal plane for the scoliotic group and 35° in the sagittal plane for the kyphotic group. In the kyphoscoliosis group, the focal correction at the osteotomy site was 32° in the coronal plane and 30° in the sagittal plane. At final follow-up, the sagittal alignment averaged 35 mm and the coronal alignment averaged 17 mm. There were 26 major and 25 minor perioperative complications (41 pts) table. All functional outcome measures improved significantly at final follow-up.

**Conclusion**

Vertebral column resection in adults has a significant risk for perioperative complications; however, it is an effective method for treating rigid adult spinal deformities with improved HRQL at 2 year follow up.

Major and minor complications and reoperations in 41 patients

| Parameter | No. (type/comments) |
|---|---|
| Major complications (26) | |
| Neurologic deficit | 5 (weakness in a single nerve root, 4 of which completely resolved) |
| Cord deficit | 2 (epidural hematoma and PJF) |
| Deep wound infection | 5 (4 treated with delayed closure) |
| Pulmonary embolism | 4 |
| Myocardial infarction | 1 |
| Pneumonia | 1 (antibiotics) |
| Reintubation | 2 (secondary to respiratory failure) |
| Pseudarthrosis | 6 (6 requiring revision surgery) |
| Minor complications (N = 25) | |
| Dural tears | 12 (1 required operative repair for dural leak) |
| Pulmonary complications | 4 (2 PTX, 2 pleural effusion) |
| Wound dehiscence | 2 treated with wound VAC |
| Superficial wound infection | 5 (4 required irrigation and drainage) |
| Excessive intraoperative bleeding | 2 underwent unplanned staging |
| Reoperations (N= 28) | |
| Revision decompression | 4 |
| Proximal junction kyphosis | 4 |
| Coronal mal-alignment | 3 |
| Pseudarthrosis | 6 |

## 100. Perioperative Complications After Vertebral Column Resection (VCR) for Severe Pediatric Spinal Deformity

*Lawrence G. Lenke, MD; Munish C. Gupta, MD; Brenda Sides, MA; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Suken A. Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Sumeet Garg, MD; Oheneba Boachie-Adjei, MD; Michael P. Kelly, MD*

**Summary**
135 Consecutive VCR for severe pediatric spinal deformity had an intraoperative complication rate of 43% and postoperative rate of 29%. Excessive blood loss (>50% Body Volume) was the most common complication, though it was not associated with subsequent complications. Intraoperative neurological deficits, 17%, were similar to reported adult rates in severe spinal deformity.

**Hypothesis**
Perioperative complications after VCR for severe pediatric spinal deformity will be similar to adult rates.

**Design**
Prospective, observational cohort

**Introduction**
VCR is commonly performed for severe pediatric spinal deformity. Retrospective cohorts have reported intraoperative neuromonitoring changes and new neurological deficit rates of 27%. A prospective cohort of severe adult deformity has reported a new neurological deficit rate of 22%. No prospective cohort of severe pediatric deformity exists.

**Methods**
Consecutive pediatric patients with severe spinal deformity were enrolled in a multi-center observational cohort. Patients undergoing VCR for management of the deformity were selected. Demographic data and perioperative data were collected. The prevalence of intraoperative and immediate postoperative complications was calculated. The relationships between intraoperative and postoperative complications were investigated with logistic regression.

**Results**
136 Patients were identified, Female 73(54%), Male 63(46%), average age 15.3(+2.8). Most common diagnoses were congenital scoliosis (27(20%)) and congenital kyphoscoliosis (23(17%)). Mean maximum coronal Cobb was 66.1(range: 0-161)degrees; mean maximum sagittal Cobb was 105.3 (R: 28-178). 62/135(46%) Sustained some intraoperative complication; excessive blood loss was the most common 39(29%). 39/136(29%) Sustained a postoperative complication; pulmonary system complications being the most common 17(12.5%). 22/136 (16%) Sustained a new neurological deficit intraoperatively (17/136) or postoperatively (5/136). Intraoperative complications were not associated with postoperative complications.

**Conclusion**
VCR for severe pediatric deformity remains a challenging procedure with perioperative complication rates approaching 50%. Methods to minimize intraoperative blood loss and optimize neurologic safety are required for these challenging procedures.

## 101. Single Stage Multi-Level PVCR for Severe & Rigid Adult Spinal Deformity Associated with Neurologic Deficit: Clinical, Radiological Results and Complications

*Cem Sever, MD; Selhan Karadereler, MD; Gokce Feride Inan, MD; Emel Kaya, MD; Sezgi Burcin Barlas, MD; Ayhan Mutlu, MD; Yesim Erol, BSc; Tunay Sanli, MA; Sinan Kahraman, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD*

**Summary**
Single stage multi-level PVCR provides direct decompression of neural structures & improvement of neurological deficit, enables rigid deformity correction and restores both coronal & sagittal alignment.

**Hypothesis**
Severe and rigid adult spinal deformity (ASD) associated with neurologic deficit can be managed successfully with single stage multi-level PVCR.

**Design**
Retrospective

**Introduction**
Correction of severe & rigid deformities may require extended resections for satisfactory results. The aim of this study is to

evaluate the efficacy & clinical, radiological results of single stage multi-level PVCR technique for the treatment of severe and rigid ASD.

**Methods**

19 (12F,7M) pts, ave age 47,2 (18-79) years who had multi-level PVCR were included. In surgical technique; if PVCR level is between T2-T10, we sacrifice bilateral nerve roots to facilitate osteotomy and placement of cage. If resection level is below T10, we preserve all nerve roots.Following multi-level resection, rods with proper sagittal contours were placed & kyphotic deformity is corrected with sequential posterior compression with simultaneous anterior column lengthening technique. According to the level of PVCR ,appropriate end-plate caps were used with expandable cage to correct local angular kyphosis &restore ideal sagittal balance. Preop, postop & latest f/up x-rays were evaluated for coronal & sagittal parameters. Neurological status were assessed according to ASIA Scale & functional results were assessed by Oswestry score.

**Results**

Ave f/up was 50,8(24-132) months. PVCR's included 2 levels in 14, 3 levels in 3 and 4 levels in 1 patient (total 44 levels). PVCR's were thoracic in 7 & thoracolumbar in 12 pts. Surgeries were primary in 8 & revision in 11 pts (ave 2 previous surgery). Ave TK of 67,9° improved to 46,1°. SVA improved from 19,3 mm to 6 mm. LKA improved from 56,9° to 21,7° (66% correction). Ave operation time was 618,4 min. & estimated blood loss was 1819 ml. Preop neurologic deficit (2 ASIA A, 2 ASIA B, 3 ASIA C, 12 ASIA D) showed at least one grade improvement in 15 pts (78%) on final ASIA scale. The most common complication was dural tear in 4 pts (21%). 2 pts underwent revision surgery for pseudoarthrosis (10%) & 1 pts for PJK (5%). Oswestry score improved from 62 to 26 at final f/up.

**Conclusion**

Multi-level PVCR is a technically difficult, but enables satisfactory corrections of rigid deformity in both planes. It also provides direct decompression of neural structures & improvement of the initial neurologic deficit. Although limited case number, the major challenges were dural tears (21%) & pseudoarthrosis (10%) for revision surgery.

| | MEAN (min – max) | |
|---|---|---|
| | PREOP | FOLLOW/UP |
| T2-T12 Kyphosis Angle (°) | +67,9 (38 - 114) | +46,1 (35 - 58) |
| SVA (mm) | +19,3 (-44 - 125) | 6 (-16 -28) |
| Local Kyphosis Angle (°) | 56,9 (17 - 117) | 21,7 (2 -42) |
| Lumbar Lordosis (°) | 58,5 (36 – 94) | 52,3 (40 – 66) |
| Operation time (min) | 618,4 (420 – 900) | |
| Estimated Blood Loss (ml) | 1819 (850 – 3100) | |

## 102. Postoperative Radiological Predictors for Proximal Junctional Kyphosis: Comparison of Four Radiological Predictive Models

*Amer Sebaaly; Guillaume Riouallon; Ibrahim Obeid, MD; Maroun Rizkallah, MD; Féthi Laouissat, MD; Yann-Phillippe Charles, MD, PhD; Pierre Roussouly, MD*

**Summary**

Only two of four predictive methods could accuratly predict the occurrence of PJK: GSA >45° and restoration of sagittal apex of lordosis according to PI. Of these two, the sagittal apex of lordosis had the higher predictive value.

**Hypothesis**

The main objective of this study was to evaluate the most reliable radiological predictor for the occurrence of PJK. between 4 described methods: the assessment of the global sagittal alignment (GSA), the correction to the theoretical values of lumbar lordosis (LL) and thoracic (TK) corresponding to pelvic incidence (PI), the evaluation of TK + LL and finally the restoration of the sagittal apex of LL to its theoretical values according various spine shapes

**Design**

Retrospective multicentric study based on homogenous database of adult scoliosis.

**Introduction**

Radiological incidence of proximal junctionnal kyphosis (PJK) in adult spinal deformity is variable and ranges between 6% and 50% and there is no unanimity on its risk factors Moreover, there is a lack of consensus on the immediate postoperative radiological predictive parameters for PJK

**Methods**

Adult patients (idiopathic or de novo) with full spine X-rays on regular follow-up intervals were included. Patients with whole spine X-rays at the required follow-ups (FU) periods were included. Spinal and pelvic parameters (LL, TK,PI, Sacral slope (SS) and Pelvic tilt (PT)) were measured and calculated to compare four proposed predictive methods: PJK occurrence was assessed at the last follow up (FU).

**Results**

171 patients were kept for final analysis; with a mean age of 51.6 years. PJK occurred in 25% of cases. The comparison of the four predictive methods showed only two significant predictive methods. PJK occurred in 19% in patients with a GSA <45° and in 29% where GSA was > 45° (p=0.04) with an OR = 1.71. Restoring the sagittal apex of LL according to the theoretical value of PI deceased the risk for PJK to 14.8% compared to 35.09% in cases where LL and PI were not concordant (p=0.01,OR = 3,5). The two other methods (restoring theoretical values of LL and TK, and LL+TK > 0) were not significant predictors (Figure 1)

**Conclusion**

The comparison between the four predictive methods showed that GSA>45° and restoration of sagittal apex of lordosis according to PI were the most predictive methods for PJK in ASD. The latter had the higher predictive value. This could have implications in several clinical situations (pedicle substraction osteotomy level, anterior cage lordosis...)

| | Incidence of PJK | | |
|---|---|---|---|
| | Yes | No | p [Odds ratio] |
| Restoring the GSA to less than 45° (Yagi et al) | 19% | 29% | p=0.04 [OR= 1.71 (1.06-2.90] |
| Restoring the sagittal parameters to theoretical values (Vialle et al) | 25% | 26% | p=0.80 [OR=1.006 (0.57-1.8)] |
| Restoring TK+LL to negative value (Mendoza-Lattes et al) | 23% | 27% | p=0.24 [OR=0.64 (0.36-1.2)] |
| Restoring the sagittal apex of the lordosis (Roussouly et al) | 13.5% | 41.4% | p=0.01 [OR=4.6 (2-9.3)] |

## 103. The Role of Posterior Ligamentous Tension Band in Proximal Junctional Kyphosis

*Samuel K. Cho, MD; Jun S. Kim, MD; John M. Caridi, MD*

**Summary**
Anterior column (vertebral body and disc) support is more important than posterior ligamentous tension band in preventing proximal junctional kyphosis (PJK). Augmentation of posterior tension with interspinous polyester fiber failed to decrease flexion loads in our cadaveric long spinal fusion model of PJK.

**Hypothesis**
Preservation or augmentation of supra- and interspinous ligaments between the upper instrumented vertebra (UIV) and UIV+1 would mitigate excessive flexion loads on the proximal junctional segment immediately following surgery.

**Design**
Biomechanical cadaveric study

**Introduction**
PJK is a well-known postoperative complication following long spinal fusion for deformity. Multiple risk factors are associated with PJK. Among these, disruption of soft tissue tension band during surgical dissection is thought to be an important risk factor.

**Methods**
Six adult (average age 69 years) human thoracolumbar spines (T7-L2) were dissected with intact supra- and interspinous process ligaments, and the end vertebrae were embedded in bone cement. Pure moments of 4 Nm were applied to the native spine in flexion-extension (FE), lateral bending (LB), and axial rotation (AR). Bilateral pedicle screw fixation was used to fuse T10-L2. The supra- and intersinous process ligaments were severed between UIV and UIV+1. A polyester fiber suture was used to reconstitute the ligamentous complex. For each instrumentation step, the spine was loaded to 8 Nm in FE, LB, and AR to represent the increased postoperative loads that may result from soft tissue dissection and decreased muscle function.

**Results**
The flexion range of motion (ROM) at T9-T10 increased 50% with the fused spine loaded at 8 Nm, relative to the native spine loaded at 4 Nm. When the ligamentous complex was severed, the excess flexion ROM in the fused spine did not worsen and remained the same (p=0.5). Augmentation of posterior tension with polyester fiber did not improve flexion ROM (p=0.2).

**Conclusion**
Biomechanical models of PJK assume that an increased load exists at the proximal segment following fusion, as was observed in this model. The role of posterior ligamentous tension band in mitigating PJK may only be secondary to anterior column support provided by the vertebral body and the disc, explaining why significantly more wedging or compression fracture of vertebral body is seen in clinical cases of PJK than pure posterior distraction. Augmentation of posterior tension with polyester fiber failed to decrease flexion ROM.

## 104. Recurrent Proximal Junctional Kyphosis: Incidence, Risk Factors, Revision Rates and Outcomes at 2-Year Minimum Follow-Up

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**Summary**
Bilateral pedicle screws at the UIV, SVA correction >5cm, PT correction >5° and pre-op C2-T3 SVA >4cm were independent predictors of recurrent PJK in our multivariate analysis. In pts with all 4 risk factors, 100% developed recurrent PJK and 91% needed another revision surgery. These characteristics are one of the many to consider to minimize R-PJK.

**Hypothesis**
Recurrent PJK cases have similar characteristics as non-recurrent cases of PJK

**Design**
Retrospective multicenter Cohort Comparison

**Introduction**
There are few reports studying PJK recurrence (R-PJK) after revision surgery that was performed for PJK. The purpose of this study is to assess the incidence, risk factors and outcomes of R-PJK in PJK revision pts.

**Methods**
Pts who underwent PJK revision surgery with 2yr f/u were analyzed. R-PJK was defined by the Glattes' criteria. Demographics, operative, radiographic, and clinical outcomes (post-op SRS-22r, SF-36, and ODI) were compared in pts with R-PJK vs those w/o recurrence (N-PJK). Sagittal vertical axis (SVA), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), T1 slope (T1SS), PI-LL mismatch, and T1 pelvic angle (TPA) at pre-op and latest f/u were assessed. Multivariate analyses were used to determine R-PJK risk factors.

**Results**
A total of 71 pts met inclusion (67yo). R-PJK incidence was 45%

(32/71) and rate of revision surgery was 19.7% (14/71). Females had a higher prevalence of R-PJK (p=0.03). Smaller # of fusion levels (p<0.01) and B/L PS use at UIV (p=<0.01) were risk factors for R-PJK. Greater corrections of PT (-0.9° vs. -7.2°), PI-LL (0.1° vs -12.9°), TLK (6.7° vs 19.6°), SVA (-2.1 vs -7.3cm) and TPA (-2.6° vs -12.3°) were a/w R-PJK (p<0.01). PJK angle after revision (PJA2) showed a positive correlation with pre-op C2-T3 SVA (r=0.40, p<0.01) and C7SVA (r=0.34, p=0.01). Multivariate analysis revealed that using B/L PS at the UIV level (OR 8.99, p<0.01), pre-op C2-T3 SVA >4cm (OR 4.96, p=0.01), SVA correction>5cm (OR 6.43, p=0.01), and PT correction > 5° (OR 8.18, p<0.01) were independent risk factors a/w R-PJK. In pts with all 4 risk factors (n=6) 100% had R-PJK and 91% needed revisions, while those w/o any of the above 4 risk factors, 0% developed R-PJK (n=12). The post-op SRS, SF-36, and ODI scores were similar between groups.

**Conclusion**

Pts after PJK revision surgery had a high incidence of recurrence. Gender, use of B/L PS at UIV, a smaller # of fused segments, and greater deformity correction were significant risk factors for R-PJK. Using B/L PS at the UIV and greater SVA and PT correction and pre-op C2-T3 SVA, were independent risk factors for R-PJK.

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## 105. Incidence and Risk Factors of Post-Operative Neurological Decline After Complex Adult Spinal Deformity Surgery: Results of the Scoli-RISK-1 Study

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**Summary**

This prospective, multicenter, international study (Scoli-RISK-1 Study) assessing neurological outcomes following complex adult spine deformity (ASD) surgery reported that 23.0% of patients experienced decline in lower extremity motor scores at discharge. Univariate analysis showed that the factors associated with post-operative neurological deterioration included age, blood loss, and three-column osteotomy. Multivariate analysis revealed that older age, larger blood loss and larger coronal deformity angular ratio (DAR) are the key predictors for post-operative neurological decline.

**Hypothesis**

The objective of the present study was to evaluate the incidence and risk factors for post-operative neurological motor decline in patients undergoing surgery for complex ASD.

**Design**

Prospective, multicenter, international cohort study from 15 sites.

**Introduction**

Significant variability in neurologic outcomes following surgical correction for ASD has been reported. Risk factors for decline in neurologic motor outcomes are poorly understood.

**Methods**

From September 2011 to October 2012, 273 patients undergoing complex ASD surgery were prospectively enrolled. Neurological decline was defined as any post-operative deterioration in American Spinal Injury Association Lower Extremity Motor Scores (LEMS) compared to pre-operative status. To identify risk factors, 10 candidate variables were selected for univariate analysis from the dataset based on the clinical relevance, and a multivariate logistic regression analysis was used with backward stepwise selection.

**Results**

Complete data sets on 265 patients were available for analysis and 61 (23.0%) patients showed decline in LEMS at discharge. Univariate analysis showed that the key factors associated with post-operative neurological deterioration included older age, larger blood loss, and three-column osteotomy. Multivariate analysis revealed that older age (odds ratio [OR] = 1.4 per 10 years, 95% confidence interval [CI]: 1.1 – 1.9, p = 0.02), larger blood loss (OR = 1.1 per 500 cc, 95% CI: 1.0 – 1.2, p = 0.04) and larger coronal DAR (OR = 1.1 per 1 unit, 95% CI: 1.0 – 1.2, p = 0.03) are the three major predictors for neurological decline.

**Conclusion**

Twenty-three percent of patients undergoing complex ASD surgery experienced a post-operative neurological decline. Age, blood loss and DAR were identified as the key contributing factors.

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## 106. Unilateral vs. Bilateral Lower Extremity Motor Deficit Following Complex Adult Spinal Deformity Surgery: Is there a Difference in Recovery Up to 2-Year F/U?

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**Summary**

Among the 265 patients included in the Scoli-RISK-1 study with available American Spinal Injury Association Lower Extremity Motor Scores (LEMS) at discharge, 61 (23%) had a post-operative decline in lower extremity motor function. Patients with either unilateral (n=32, 12%) or bilateral (n=29, 11%) lower extremity motor exam worsening post-operatively had similar neurologic recovery at 2 years with 15 (63%) and 14 (67%) returning to or surpassing their pre-operative motor exam, respectively.

**Hypothesis**

This study aims to evaluate if bilateral postoperative neurologic deficits have a worse recovery than unilateral.

**Design**
Secondary analysis of a prospective, multicenter, international cohort study at 15 sites.

**Introduction**
Scoli-RISK-1 is a multicenter prospective cohort designed to study neurologic outcomes following complex adult spinal deformity (ASD). The effect of unilateral versus bilateral post-operative motor deficits on the likelihood of long term recovery has not been previously studied in this population.

**Methods**
Prospective cohort of 272 consecutive patients were enrolled from September 2011 to October 2012. Neurologic decline was defined as deterioration of the American Spinal Injury Association Lower Extremity Motor Scores (LEMS) compared to preoperative status. Patients with lower extremity neurologic decline were grouped into unilateral and bilateral cohorts. Wilcoxon rank sum test was used to compare the total LEMS and change in total LEMS at 6 week, 6 month, and 24-month time points.

**Results**
265 patients had LEMS completed at discharge, and 61 (23%) displayed decline in LEMS at hospital discharge. Unilateral weakness was seen in 32 patients (12%), while the other 29 (11%) had bilateral symptoms. In both groups the majority of LEMS decline was 5 points or less (unilateral n=25, 78%; bilateral n=19, 66%). At 2 years there was no difference in either mean LEMS (unilateral 48.32.9; bilateral 47 .74.7, p=0.939) or change in LEMS (unilateral -0.93.0; bilateral -1.03.2, p=0.920). In both groups approximately two-thirds of patients with initial worsening in motor exam saw recovery to at least their pre-operative baseline by two years post-operatively (unilateral n=15, 63%; bilateral n=14, 67%).

**Conclusion**
The prognosis for recovery of new motor deficits following complex adult spinal deformity is similar with both unilateral and bilateral weakness.

LEMS change compared to preop at follow-up according to decline at discharge unilateral versus bilateral (only patients with decline in total LEMS)

| | Type of LEMS decline at discharge (compared to preop) | | |
|---|---|---|---|
| Characteristic | unilateral N=32 | bilateral N=29 | Total N= 61 |
| Change in total LEMS at last discharge vs. preop, n (%) | 32 | 29 | 61 |
| Maintenance | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Improvement | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Decline | 32 (100.0) | 29 (100.0) | 61 (100.0) |
| Change in total LEMS at 6 weeks vs. preop, n (%) | 30 | 28 | 58 |
| Maintenance | 10 (33.3) | 8 (28.6) | 18 (31.0) |
| Improvement | 4 (13.3) | 2 (7.1) | 6 (10.3) |
| Decline | 16 (53.3) | 18 (64.3) | 34 (58.6) |
| Change in total LEMS at 6 months vs. preop, n (%) | 31 | 28 | 59 |
| Maintenance | 17 (54.8) | 12 (42.9) | 29 (49.2) |
| Improvement | 5 (16.1) | 6 (21.4) | 11 (18.6) |
| Decline | 9 (29.0) | 10 (35.7) | 19 (32.2) |
| Change in total LEMS at 2 years vs. preop, n (%) | 24 | 21 | 45 |
| Maintenance | 13 (54.2) | 12 (57.1) | 25 (55.6) |
| Improvement | 2 (8.3) | 2 (9.5) | 4 (8.9) |
| Decline | 9 (37.5) | 7 (33.3) | 16 (35.6) |

## 107. Visual Loss Following Spine Surgery: What Have We Seen Within the Scoliosis Research Society (SRS) Morbidity and Mortality Database?

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**Summary**
Limited literature exists on postoperative visual complications, a rare but devastating complication following spine surgery.

**Hypothesis**
The majority of visual acuity complications either completely resolve or improve postoperatively.

**Design**
Retrospective review

**Introduction**
SRS compiles surgeon-reported complications into a morbidity and mortality database, tracking particular postoperative complications including visual loss, instrumentation failure, neurological deficits, infections, and death.

**Methods**
We utilized the SRS database to determine the patient profile, perioperative risk factors, and prognosis for visual related complications in deformity patients undergoing corrective spine surgery from 2009-2012.

**Results**
A total of 167,972 patients were identified with an overall visual acuity complication rate of 0.01%. Visual acuity complication rates for patients with scoliosis, spondylolisthesis, and kyphosis were 0.01%, 0.01%, and 0.04% respectively. The 21 patients with visual complications had a mean age of 34.8+-24.3years. Preoperatively, 9.5% had vision changes, 9.5% were diabetic, 9.5% had vascular disease, 4.8% had thromboembolic disease and 23.8% had hypertension. Seventeen patients(81.0%) were positioned prone during surgery for an average time of 264.2+-143.2mins. Visual loss was bilateral-partial in 19.0%, bilateral-total in 23.8%, unilateral-partial 38.1%, and unilateral-total in 14.3% patients. 19.0% developed anterior ischemic optic neuropathy, 19% posterior ischemic optic neuropathy, 23.8% central retinal artery occlusion, and 23.8% cortical blindness. Greater than 50% of the visual complications occurred within 48hr postoperatively. Complete vision recovery occurred in 47.6% and improvement in 19.0%. All patients supported with a commercial head-holder and 75% with tongs/halo experienced complete improvement. Only 42% of patients positioned flat experienced resolution.

**Conclusion**
Visual complications occur in 12.5 per 100,000 deformity patients, with a rate 4 times higher in patients with kyphosis. More than 50% of these complications occur within 48 hours postoperatively and nearly half resolve completely.

| Visual Acuity Complications (%) | | Type of Visual Acuity Complication | |
|---|---|---|---|
| No. of cases | 21 (0.01) | Bilateral Partial | 4 (19.0) |
| Age yrs, std | 34.8±24.3 | Bilateral Total | 5 (23.8) |
| Female | 12 (57.1) | Unilateral Partial | 8 (38.1) |
| **Diagnosis with Visual Acuity Change (%)** | | Unilateral Total | 3 (14.3) |
| Kyphosis | 8 (38.1) | **Visual Recovery (%)** | |
| Scoliosis | 10 (47.6) | Resolution | 10 (47.6) |
| Spondylolisthesis | 3 (14.3) | Improvement | 4 (19.0) |
| **ASA Classification (%)** | | No Change | 6 (28.6) |
| 1-Normal healthy individual | 11 (52.4) | **Time of Vision Loss (%)** | |
| 2-Mild Systemic Disease | 7 (33.3) | Day of Surgery | 4 (19.0) |
| 3-Severe systemic disease | 2 (9.5) | Immediate Postoperatively | 5 (23.8) |
| **Patient Characteristics (%)** | | Postoperative Day 1 | 3 (14.3) |
| Preoperative Vision Changes | 2 (9.5) | Postoperative Day 2 | 1 (4.8) |
| Preop Occular Disease | 0 (0) | Postoperative Day 3 | 2 (9.5) |
| BMI, std | 26.1±6.8 | Postoperative Day 4 | 1 (4.8) |
| Diabetes | 2 (9.5) | Postoperative Day 5 | 4 (19.0) |
| Smoker | 2 (9.5) | **Vision Loss Type (%)** | |
| Hypertension | 5 (23.8) | Anterior Ischemic Optic Neuropathy (AION) | 4 (19.0) |
| Vascular Disease | 2 (9.5) | Central Retinal Artery Occlusion (CRAO) | 5 (23.8) |
| Coronary Artery Disease | 2 (9.5) | Cortical Blindness (CB) | 5 (23.8) |
| Thromboembolic history | 1 (4.8) | Posterior Ischemic Optic Neuropathy (PION) | 4 (19.0) |
| Cancer History | 2 (9.5) | Other/unspecified | 3 (14.3) |
| **Surgical Factors (%)** | | **Intraoperative Head Support (%)** | |
| Prone Positioning | 17 (81.0) | Head Holder (Commercial) | 6 (28.6) |
| Time in Prone Position, std | 264.2±143.2 | Horseshoe | 3 (14.3) |
| Fusion Performance | 19 (90.5) | Pillow | 7 (33.3) |
| Anterior Fusion | 1 (4.8) | Tongs/Halo | 4 (19) |
| Posterior Fusion | 17 (81.0) | **Head Position (%)** | |
| Combined Anterior/Posterior Fusion | 1 (4.8) | Flat (Neutral) | 12 (57.1) |
| Staged Procedure | 0 (0) | Reverse Trendelenberg | 1 (4.8) |
| Osteotomy Performed | 7 (33.3) | Trendelenberg (Down) | 3 (14.3) |
| Intraoperative blood loss cc, std | 1409.6±988.6 | **Perioperative Eye/Orbit Characteristics (%)** | |
| **Operative times (%)** | | Evidence of Eye Pressure | 1 (4.8) |
| <2hr | 1 (4.8) | Eye/Orbit Swelling | 6 (28.6) |
| 2-6hr | 15 (71.4) | Embolic Event | 1 (4.8) |
| 6-9hr | 4 (19.0) | | |
| >12hr | 1 (4.8) | | |

## 108. Impact of Resolved Early Major Complications on Two-Year Follow-Up Outcome Following Adult Spinal Deformity Surgery

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**Summary**

The effect of early (six months) resolved major complications on health related quality of life (HRQL) two years after adult spinal deformity (ASD) surgery was evaluated on a series of consecutive patients from an international multicenter international database. Patients with resolved major complications had a significantly worse outcome (ODI, SRS-22 function, SF-36 PCS) than those without any complications, even after an 18-month complication free period.

**Hypothesis**

Major complications, even if resolved within the first six months after surgery, do have a relevant impact on HRQL at two-years.

**Design**

Retrospective study using prospectively collected data from a multicenter international database.

**Introduction**

Major complications are an important concern following ASD surgery. Even if complications are properly managed and resolved, they might still have a relevant impact on HRQL. We aimed to investigate the impact of early resolved major complications on the two-year outcome after ASD surgery.

**Methods**

Two groups of consecutive surgical patients were extracted from a prospective multicenter database. Complication Group (G1): patients presenting any major complication resolved within the first six months after surgery. Patients with further major complications during follow-up were excluded. Control Group (G2): patients without any major complications during the whole length of follow-up. An analysis of covariance adjusting for the preoperative baseline values was performed to compare the improvement on each HRQL item between both groups at two-years.

**Results**

From 402 eligible patients, 175 fulfilled the inclusion criteria and had complete HRQL data at 2-years (24 G1, 151 G2). Patients on the G1 were older, had greater deformity and worse HRQL at baseline (Table). There were 27 resolved major complications at six months (8 implant related, 5 deep surgical site infections, 5 medical complications, 2 motor deficits with full recovery, 2 PJK, 5 other). There were 19 additional surgeries (18 revisions, 1 cholecystectomy). At two-years, and after adjusting for preoperative baseline data, patients on the complication group had 5.98 (SE 3.03) points higher ODI ($p=0.05$), 0.36 (SE 0.13) lower SRS-22function ($p=0.01$), 4.07(SE 1.93) lower SF-36 PCS ($p=0.04$) and 0.16 (SE 0.13) lower SRS-22 subtotal ($p=0.22$).

**Conclusion**

The current results underline that patients presenting major complications after ASD surgery do improve significantly less in terms of function (SRS-22function, ODI, SF-36 PCS) even if complications were considered to be resolved and outcome was measured after an 18-month complication free period.

| | | | | | |
|---|---|---|---|---|---|
| Gender | G1 | F: 13 (54.2%) | | | |
| | | M: 11 (45.8%) | | | |
| | G2 | F: 118 (78.2%) | | | |
| | | M: 33 (21.8%) | | | |
| Age | G1 | 62.3 (SD 16.8) | | | |
| | G2 | 48.5 (SD 19.1) | | | |
| ASA | G1 | I: 6 (25.0%) | | | |
| | | II: 14 (58.3%) | | | |
| | | III: 4 (16.7%) | | | |
| | G2 | I: 70 (46.4%) | | | |
| | | II: 68 (45.0% | | | |
| | | III: 13 (8.6%) | | | |
| Estimated Blood Loss | G1 | 1880.4 (SD 1225.7) | | | |
| | G2 | 1395.9 (SD 1155.8) | | | |
| Surgical Time | G1 | 364.0 (SD 148.7) | | | |
| | G2 | 310.1 (SD 174.2) | | | |
| 3CO | G1 | Yes: 5 (20.8%) | | | |
| | | No: 19 (79.2%) | | | |
| | G2 | Yes: 25 (16.6%) | | | |
| | | No: 126 (83.4%) | | | |
| HRQoL (Raw values) | | | PreOp | 6m | 2y |
| | G1 | ODI | 44.8 | 39.0 | 32.9 |
| | | SRS22 function | 3.02 | 3.00 | 3.28 |
| | | SRS subtotal | 2.82 | 3.25 | 3.45 |
| | | SF36 PCS | 33.5 | 35.5 | 38.5 |
| | | SF36 MCS | 42.1 | 43.0 | 45.5 |
| | G2 | ODI | 37.7 | 27.9 | 23.1 |
| | | SRS22 function | 3.15 | 3.32 | 3.70 |
| | | SRS subtotal | 2.91 | 3.49 | 3.67 |
| | | SF36 PCS | 36.4 | 40.5 | 43.8 |
| | | SF36 MCS | 43.9 | 48.1 | 47.3 |
| Radiographic Parameters | | | PreOp | 6m | 2y |
| | G1 | Major Cobb | 38.8 | 20.2 | 20.6 |
| | | SVA | 72.7 | 39.3 | 34.6 |
| | | PT | 23.8 | 20.7 | 21.4 |
| | | SS | 30.4 | 33.4 | 33.6 |
| | G2 | Major Cobb | 41.3 | 28.3 | 20.8 |
| | | SVA | 21.8 | 4.1 | 12.2 |
| | | PT | 18.9 | 17.7 | 17.4 |
| | | SS | 33.3 | 34.2 | 34.1 |

## 109. Impact of Adverse Events on the Readmission Rate, Revision Surgery and Mortality 2 Years After Complex Spine Surgery - a SAVES Follow-Up Study.

*Sven Karstensen, MD; Mathias Dahl Sørensen, BSc; Tanvir Bari, MD; Martin Gehrchen, MD, PhD; John T. Street, MD PhD; Benny T. Dahl, MD, PhD, DMSci*

**Summary**
In a consecutive, single-center, 2-year follow-up study, we found that the occurrence of minor or major adverse events significantly increased the risk of readmission and/or revision surgery up to two years after index surgery.

**Hypothesis**
Adverse events (AEs) during index admission are related to the rate of readmissions, unplanned revision surgery and the mortality beyond 30 days follow-up.

**Design**
Prospective consecutive cohort study.

**Introduction**
Increasing interest has been directed towards determining the impact of adverse AEs on morbidity and mortality in spinal surgery. Also, prospective studies more accurately reflect the true incidence of AEs. However, the frequency of long-term morbidity and mortality in relation to AEs is yet to be evaluated.

**Methods**
The study population consisted of a single-center, consecutive cohort of patients undergoing complex spine surgery from January 1 to December 31, 2013 inclusive. AEs were prospectively identified using the previously validated SAVES system. Patients were followed for a minimum of 2 years and readmission, revision surgery and mortality were determined. Multivariate and hazard ratio analysis were applied to examine the relationship between index admission AEs and readmission, revision surgery or mortality.

**Results**
A total of 679 procedures were included. The overall 30-day, 90-day, and two-year readmission rates were 13.3%, 26.4%, and 49.3% respectively. Having one severe intraoperative AE increased the risk of readmission after 90 days with a hazard ratio (HR)=1.71 (p=0.02) and after 2 years HR=2.3 (p=0.001). There was an increased rate of revision in cases with minor AEs (HR=2.01; p=0.01) and severe AEs (HR=3.08; p =0.001). The mortality rate was 2.7% (30 day), 15.0% (1 year) and 17.5% (2 year). Adverse events, minor or major, during admission had no significant impact on the mortality.

**Conclusion**
Both minor and major adverse events increase the risk of unplanned revision surgery up to two years after the index procedure in complex spine surgery. Only major adverse events are associated with increased readmission rates. The study identifies previously unrecognized high rates of readmission and revision surgery and confirms that long-term follow-up is necessary to accurately assess the impact of AEs in complex spine surgery.

## 110. Utilizing the Fracture Risk Assessment Tool (FRAX) to Assess Risk of Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery

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**Summary**
We aimed to determine if the WHO Fracture Risk Assessment Tool (FRAX) could assess the risk of proximal junctional kyphosis (PJK) in patients who had undergone ASD surgery. The mean FRAX 10-year osteoporotic fracture probability for patients with PJK (11.8 ± 1.06%) was significantly higher compared to non-PJK (7.7 ± 0.36%, p = <0.001). The optimal diagnostic cutoff point for developing PJK was a 10-year osteoporotic probability of 8.6% with an odds ratio of 3.10 (p = <0.001).

**Hypothesis**
FRAX 10-year osteoporotic fracture probability can assess risk of PJK in patients undergoing ASD surgery.

**Design**
Retrospective Chart Review

**Introduction**
Proximal junctional kyphosis (PJK) is a difficult complication in adult spinal deformity. While several risk factors for PJK have been identified, there is concern that osteoporotic bone can contribute to the development of PJK. To date, there is no cumulative risk calculation that correlates with PJK development. The Fracture Risk Assessment Tool (FRAX) is a well-validated risk model that predicts the 10-year probability of significant osteoporotic fracture. Because the FRAX tool is a comprehensive osteoporotic fracture risk assessment, we believe that it will be a useful surrogate in predicting the development of PJK after ASD surgery.

**Methods**
We identified 188 patients who underwent ASD surgery (UIV T9 and below) with at least 2-year follow-up. Patients were assessed for the development of PJK, which was defined as a sagittal Cobb angle >10º two levels above the uppermost instrumented vertebra. 10-year osteoporotic fracture probability was then calculated using the Fracture Risk Assessment Tool (https://www.shef.ac.uk/FRAX/tool.jsp). We then compared patients with PJK to non-PJK patients to determine if an association exists between fracture probability and PJK.

**Results**
A total of 188 patients were identified with 115 non-PJK and 73 PJK patients. The mean age at the time of surgery for non-PJK and PJK patients was 61.7 years and 65.1 years, respectively. The mean FRAX osteoporotic fracture probability was 7.7 ± 0.36% in non-PJK and 11.8 ± 1.06% in PJK patients (p = <0.001). The optimal threshold of osteoporotic fracture risk was determined to be 8.6%. A FRAX 10-year osteoporotic fracture risk greater than 8.6% confers a positive likelihood ratio of 1.89 and an odds ratio of 3.10 (p = <0.001) for developing PJK.

**Conclusion**

The WHO FRAX tool is a useful metric to assess the risk of PJK in patients undergoing ASD surgery. Patients with a FRAX 10-year osteoporotic fracture probability >8.6% were three times more likely to have PJK compared to patients with a probability below that threshold.

**Figure 1**: Patients who develop PJK have an increased fracture probability than non-PJK patients and a patient with a fracture probability > 8.6% has 310% the odds of developing PJK.


## 111. Pulmonary Cement Embolism Following Cement Augmented Fenestrated Pedicle Screw Fixation in Adult Spinal Deformity Patients with Severe Osteoporosis (Analysis of 2978 Fenestrated Screws)

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**Summary**

The incidence of pulmonary cement embolism (PCE) following cement augmented fenestrated pedicle screw fixation (CAFPS) in 281 pts with severe osteoporosis was 16.3% in this study. Among those symptomatic PCE incidence was 1.4%.The risk of symptomatic PCE increased as number of levels,screws and cement volume increased.

**Hypothesis**

The incidence of symptomatic PCE is related with the number of levels performed, number of CAFPS used and the cement volume used.

**Design**

Retrospective

**Introduction**

There is very limited information about PCE following cement augmented fenestrated pedicle screw fixation in the literature.The aim this study to report the incidence of PCE following CAFPS fixation in adult deformity pts with severe osteoporosis and to identify risk factors such as; the number of levels, number of screws and the cement volume used.

**Methods**

281 pts (204F,77M) in whom CAFPS fixation was used during deformity surgery were included. All patients' routine postop 2.day chest x-rays and any available CT scans were reviewed by two radiologist. In patients with PCE; preop,early postop and latest echocardiography studies were compared in terms of changes in pulmonary artery pressure (PAP) and right ventricular dilatation. Estimated cement volume used was calculated as; 2cc (1cc+1cc) per thoracic and 3cc (1.5cc+1.5cc) per lumbar levels, which are our routine protocol.Statistical analysis for risk factors were assessed with point biserial correlation test.

**Results**

Ave age 70,5(51-89) and ave f/up 3,2 years(2-5). A total of 2978 CAFPS were instrumented with a mean of 10.5 levels (2-16) in 281 pts. PCE was diagnosed radiologically in 46 pts (16,3%). Among this 46 pts, PCE was clinically symptomatic in only 4 pts. Overall incidence of symptomatic PCE was 1.4% (4 of 281). Symptomatic PCE was statistically significant when; CAFPS fixation was performed >7 levels; >14 screws were used and >20-25 cc cement was used for augmentation (r=0.378). In PCE group, mean preop PAP values of 27,40 (20-37)mm/Hg increased to 32,34(20-50) mm/Hg in early postop and decreased to 28,29 (18-49)mm/Hg at final f/up. In symptomatic PCE pts, mean preop PAP values of 30,75 (28-36)mm/Hg increased to 45,74(40-50) mm/Hg in early postop and decreased to 38,75 (37-40)mm/Hg at final f/up.

**Conclusion**

This study showed an overall 16,3% radiological PCE and 1.4% symptomatic PCE incidence when CAFPS were used due to severe osteoporosis. The symptomatic PCE risk was significant when CAFPS were >7 levels; >14 fenestrated screws and >20-25 cc cement volume is used and this may cause PAP increase and right ventricule dilatation.

## 112. Topical Vancomycin in Pediatric Spine Surgery Does Not Reduce Surgical Site Infection: A Retrospective Cohort Study

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**Summary**

Topical vancomycin did not reduce incidence of SSI among pediatric patients undergoing PSF

**Hypothesis**

Incidence of surgical site infections (SSI) will be significantly lower among patients who receive topical vancomycin during posterior spinal fusion (PSF) compared to those who do not.

**Design**

Level III Retrospective Cohort Study

**Introduction**

In 2013, our institution implemented the use of topical vancomycin in definitive primary and revision PSF as part of our infection control protocol. The purpose of this study is to evaluate the efficacy of topical vancomycin in reducing SSI in pediatric patients undergoing PSF.

**Methods**

After IRB approval, a consecutive series of 531 patients (536 procedures) undergoing primary or revision PSF from January 2010 to December 2014 were retrospectively reviewed to identify the occurrence of SSI. An a priori power analysis based on published results from a similar study determined a minimum of 190 patients were needed in each group to achieve a power of

0.90. All available charts were used. There were 226 procedures where vancomycin powder was used (VANCO) and 310 procedures where it was not (NO VANCO). Exclusion criteria were less than 90 days follow-up, patient greater than 18 at time of surgery, and combined anterior and posterior fusion. Two-sample t-tests, Wilcoxon rank-sum tests and Fisher's exact tests were used to compare the cohorts.

**Results**

Groups were similar in age, sex, implant density, fusion length, risk categorization (low risk for adolescent idiopathic patients undergoing primary PSF, high risk for all others), and surgical time (p>0.05). Patients in NO VANCO had significantly higher blood loss, incidence of intraoperative allogenic transfusion, amount transfused intraoperatively, and clinical follow-up; p<0.001. Incidence of SSI in VANCO was 3% (7/226) and in NO VANCO was 2% (6/304); p=0.4077. 6/7 of infections occurred in high risk patients in VANCO and 5/6 infections occurred in high risk patients in NO VANCO; p=1. Re-operation within one year occurred in 7% (16/226) in VANCO and 4% (13/310) in NO VANCO; p=0.1762. Occurrence of other complications, detailed in table 1, was similar between VANCO, 2% (9/226), and NO VANCO, 1% (6/310); p=0.1913.

**Conclusion**

There was not a significant association in the use of vancomycin powder and SSI or return to OR within one year. Procedures in the NO VANCO cohort occurred earlier than in VANCO with significantly higher operative blood loss and transfusion. Due to use of a multidisciplinary developed infection control protocol, our institution has a low infection incidence that may require a larger patient cohort to identify significant differences between groups.

**Table 1. Complication types**

| Complication | VANCO (n=9) | NO VANCO (n=6) |
|---|---|---|
| Dehiscence w/out infection | 2 (22%) | 4 (67%) |
| Hematoma/Seroma | 3 (33%) | 0 (0%) |
| Implant failure | 1 (11%) | 1 (17%) |
| Implant malposition | 1 (11%) | 1 (17%) |
| Prolonged drainage (>7 days post-op) | 1 (11%) | 0 (0%) |
| Pseudoarthrosis | 1 (11%) | 0 (0%) |

## 113. The Significance of Clunking in Magnetically Controlled Growing Rod Distractions: A Prospective Analysis of 22 Patients

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**Summary**

A prospective study of 22 patients with magnetically controlled growing rods (MCGRs) was performed to determine the significance of clunking and identify possible risk factors. Clunking contributed to reduced length gain achieved with distractions. Patients who are older experienced earlier clunking.

**Hypothesis**

Increased deviation between expected and achieved distraction lengths occur due to frequent clunking.

**Design**

Prospective analysis.

**Introduction**

Ability to achieve successful MCGR distraction is vital for gradual spine lengthening. The phenomenon of "clunking" has been described as a failure of magnet rotation to lead rod lengthening, and is thought to be due to a slippage of the internal mechanism. However, its onset, risk factors and significance are currently unknown. Hence, the aims of this study are to identify the risk factors of early onset clunking and increased clunking frequency, and to determine its effect on achieved length gain.

**Methods**

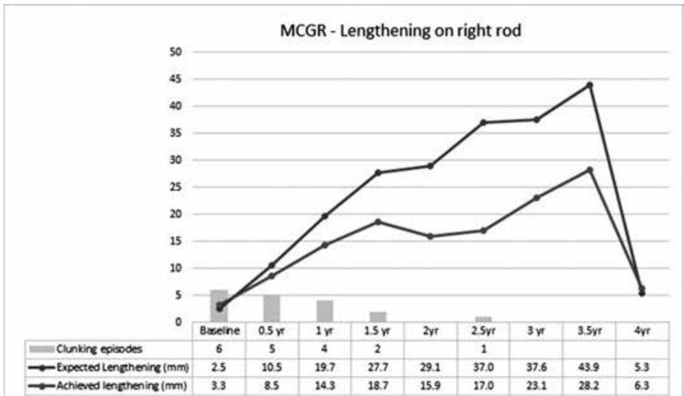
22 patients with MCGR implantation with at least 6 distraction episodes were prospectively studied. Parameters including maturity status, age of implantation, total number of distractions, months of distraction from initial implantation, initial and post-operative Cobb angle, T1-T12, T1-S1, T5-T12 kyphosis, fulcrum flexibility, fusion block length, and distance between magnets in dual rods and between the magnets and apex of the curve were studied as risk factors for onset and number of clunks per distraction by regression analysis. Differences between expected and achieved distraction lengths were assessed with regards to clunking episodes.

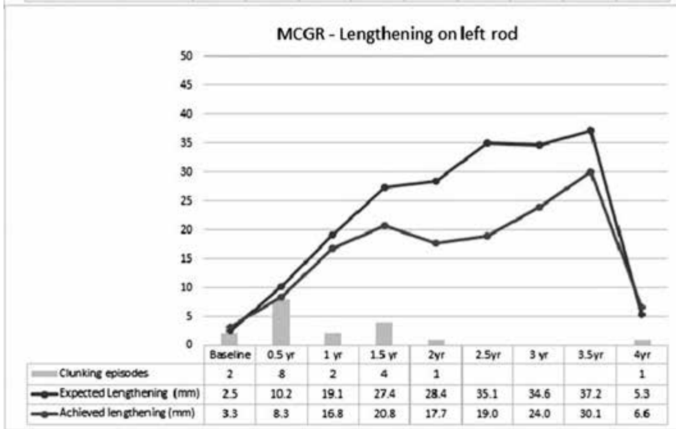
**Results**

Patients had a mean age of 10.2 years at initial rod implantation, mean follow-up of 49.8 months and mean 32.4 distractions. The mean onset of clunking was the 5th distraction for the right rod and 9th distraction for the left rod. The total number of clunking episodes were 456 and 492 for right and left rods, respectively. Although regression analysis did not yield significant risk factors, those who clunked early (<6 distraction episodes) were idiopathic (p=0.03) and older (p=0.02) (mean 12 years old at initial rod implantation). Expected distraction lengths did not translate to achieved distraction lengths (Figure) and this deviation increased when clunking occurred.

**Conclusion**

This is the first prospective study to specifically analyze the impact of clunking on distraction lengths and the risk factors associated with its onset and frequency. Clunking is an important factor determining continuous spine lengthening. Larger sample sizes are necessary to identify significant risk factors.




## 114. National Trends and In-Hospital Outcomes of Patients with Solid Organ Transplant Undergoing Spinal Fusion

*Hiroyuki Yoshihara, MD, PhD; Carl B. Paulino, MD; Daisuke Yoneoka*

**Summary**
During the last decade, the incidence of patients with solid organ transplant (SOT) undergoing spinal fusion has increased in the US. In-hospital outcomes of patients with SOT undergoing spinal fusion were inferior to those of patients without SOT.

**Hypothesis**
The incidence of SOT patients undergoing spinal fusion has increased during the last decade, and in-hospital outcomes of spinal fusion patients with SOT would be inferior in comparison to those without SOT

**Design**
A retrospective analysis of population-based national hospital discharge data collected for the Nationwide Inpatient Sample

**Introduction**
Solid organ transplantation has become more common in recent years and some of these patients undergo spinal fusion surgery. However, there is little information regarding the trends and outcomes in such patients. The purpose of this study was to examine the demographics and in-hospital outcomes of patients with SOT undergoing spinal fusion on a national level

**Methods**
Clinical data were derived from the US Nationwide Inpatient Sample between 2000 and 2009. Patients with or without SOT who underwent spinal fusion were identified. Data regarding, patient- and healthcare system-related characteristics, comorbidities, in-hospital complications, and mortality were retrieved and analyzed. In-hospital outcomes were compared between patients with or without SOT and analyzed with the use of multivariate logistic regression.

**Results**
5,984 patients with SOT underwent spinal fusion in the US during the last decade. From 2000 to 2009, population growth-adjusted incidence of patients with SOT who underwent spinal fusion has increased more than 2-fold (0.102 in 2000 to 0.236 in 2009, per 100,000, $p < 0.001$). Comparison between patients with or without SOT showed that patients with SOT had significantly higher overall in-hospital complication rate (22.4% vs. 9.5%) and in-hospital mortality rate (1.3% vs. 0.3%). Graft versus host disease occurred in 0.7% of patients with SOT undergoing spinal fusion. Patients with SOT had a significant higher risk of urinary and renal complications and overall in-hospital complications (Table).

**Conclusion**
During the last decade, the incidence of patients with SOT undergoing spinal fusion has increased in the US. In-hospital outcomes of patients with SOT undergoing spinal fusion were inferior to those of patients without SOT.

**Table: Regression modeling predicting influence of solid organ transplant on in-hospital outcomes**

| Outcome variables | Solid Organ Transplant AOR (95% CI) | p-value |
|---|---|---|
| Neurologic * | 0.453 (0.114, 1.802) | 0.261 |
| Respiratory * | 0.873 (0.611, 1.247) | 0.455 |
| Cardiac * | 1.487 (0.869, 2.545) | 0.148 |
| Gastrointestinal * | 1.289 (0.793, 2.094) | 0.306 |
| Urinary and renal * | 2.158 (1.521, 3.061) | 0.000 |
| Pulmonary embolism * | 0.743 (0.225, 2.455) | 0.627 |
| Wound-related complications * | 1.008 (0.626, 1.624) | 0.973 |
| Overall complications * | 1.264 (1.024, 1.561) | 0.030 |
| Died in hospital** | 1.444 (0.701, 2.971) | 0.319 |

AOR = Adjusted odds ratio; CI = Confidence interval

* Model adjusted for for age, gender, race, Elixhauser Comorbidity Score, surgical level, hospital size, hospital teaching status, hospital region, payer information

** Model adjusted for age, gender, race, Elixhauser Comorbidity Score, surgical level, hospital size, hospital teaching status, hospital region, payer information, complications

## 115. Sagittal Realignment Goals Should Be Set to Ideal Proportionate Shape and Alignment Independent of Age

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**Summary**
Achieving non-ideal correction in adult spinal deformity (ASD) patients resulted in more mechanical complications for all ages. Sagittal realignment goals should be to restore proportionate

shape and alignment independent of age to prevent mechanical complications.

**Hypothesis**
Age-adjusted realignment goals towards less rigorous correction will increase mechanical complication rates in elderly pts.

**Design**
Retrospective analysis of a prospectively collected data of ASD pts.

**Introduction**
Spinopelvic parameters and HRQoL are known to change with normal aging. Thus, it was suggested that operative realignment targets should account for age, with elderly patients requiring less rigorous alignment goals. However, the effect of age-adjusted realignment goals on mechanical complications has not been studied. GAP Score is PI-based proportional method of analyzing sagittal spinal shape and alignment that more accurately predicts mechanical complications compared to Schwab modifiers. GAP is categorized into 3 subgroups as proportioned (GAP-P), moderately (GAP-MD) and severely disproportioned (GAP-SD). Similar to Schwab modifiers, normative data studies showed that GAP categories change with age. Aim was to analyze the effect of age on mechanical complications in pts reaching different post-operative GAP categories.

**Methods**
Inclusion criteria were ≥4 levels fusion and ≥2y f/up. Pts were categorized into 3 age groups of <40 (n=67), 40-59 (n=49) and ≥60 (n=106). Mechanical complications were PJK/PJF, DJK/DJF, rod breakage and implant-related complications. Chi Squared test was performed to compare mechanical complication rates for different age groups and post-op GAP categories.

**Results**
222 pts (168F, 54M) met inclusion criteria. Mean age: 52.2±19.3(18-84) years. Mean f/up: 28.8±8.2(24-62) months. Analysis of the whole cohort without dividing into GAP categories showed that mechanical complication rates were higher (p<0.001) in older age groups (Table 1). However, distribution of pts that were GAP-P, GAP-MD and GAP-SD was also different in age groups reflecting a tendency towards non-ideal correction with aging. Mechanical complication rates for each GAP category did not change according to age groups (p>0.05). For all age groups, disproportioned categories resulted with more mechanical complications (p<0.001) (Table 1).

**Conclusion**
Achieving proportionate global sagittal realignment (GAP-P) decreased mechanical complication rates for all age groups. Accepting a non-ideal correction resulted in more mechanical complications for all ages. Sagittal realignment goals should be set to ideal proportionate shape and alignment independent of age to prevent mechanical complications.

Table 1: Distribution of mechanical complications for age groups and GAP categories

| | All Group | | GAP Categories | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Proportioned | | Moderately Disproportioned | | Severely Disproportioned | |
| Age | n | % of Mechanical Complications | n | % of Mechanical Complications | n | % of Mechanical Complications | n | % of Mechanical Complications |
| <40 years | 16/67 | 23.9 % | 2/43 | 4.7 % | 8/18 | 44.4 % | 6/6 | 100 % |
| 40-59 years | 17/49 | 34.7 % | 2/26 | 7.7 % | 6/12 | 50.0 % | 9/11 | 81.8 % |
| ≥60 years | 67/106 | 63.2 % | 0/14 | 0 % | 20/40 | 50.0 % | 47/52 | 90.4 % |
| **Total** | **100/222** | **45.0 %** | **4/83** | **4.8 %** | **34/70** | **48.6 %** | **62/69** | **89.9 %** |
| p[¥] | <0.001** | | >0.05* | | >0.05* | | >0.05* | |

[¥]Chi-Square test, * Not Significant, ** Significantly different

## 116. Global Sagittal Angle (GSA) Defines the Fan of Full Body Alignment

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**Summary**
Predicting full body sagittal alignment following adult spinal surgery is a great challenge for surgeons. This study proposes thresholds of surgically modifiable parameters that correlate with full body sagittal postural alignment measured by GSA.

**Hypothesis**
Global Sagittal Angle (GSA) correlations with surgically modifiable parameters can define thresholds for surgical treatment of adult spinal surgery.

**Design**
Single-center retrospective review.

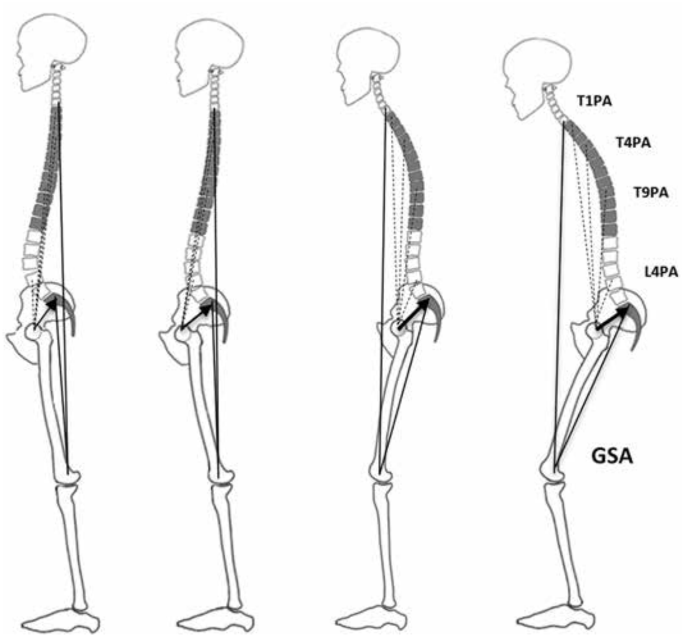
**Introduction**
Predicting full body sagittal alignment following adult spinal surgery is a great challenge for surgeons. Defining the relationship between surgically modifiable parameters and established full standing parameters such as Global Sagittal Angle (GSA) might be of benefit.

**Methods**
Inclusion: pts≥18 yrs with full body stereographic x-rays with various spinal pathologies (Degenerative and deformity). Patients with radicular complaints, fractures, tumor and congenital diseases were excluded. Patients were stratified based on published normative reference of Global Sagittal Angle (GSA: Knee-S1 vs. Knee-C7) into: G1: GSA < -3, G2: GSA (-3 – 3), G3: GSA > +3 and G4: GSA> +6° (Figure). Surgically modifiable angles that do not change based on patients' positioning were compared between GSA groups: T1PA, T4PA, T9PA and L4PA: All angles share one vector the connects the midpoint of femoral heads and midpoint of S1, each one of them has a unique second vector that connects the midpoint of the femoral heads to the aforementioned vertebra. ANOVA and Bonefferoni analysis were used with p<0.05 threshold of significance.

**Results**
3,606 patients were included with a mean age of 56.4 y/o, 65.8% females and BMI of 27. Groups differed in Age (G1: 37.5, G2: 51.2, G3: 62.4, G4: 66.6), BMI (23.5, 25.8, 28.3, 28.9) and gender (86, 65, 61, 69%), all p<0.05. By design, GSA was

significantly different between the groups (-4.2, 0.2, 4.5, 7.3°, p<0.05). T1PA, T4PA, T9PA and L4PA progressively increased between the groups T1PA: (0.3, 11, 20, 25.8), T4PA: (-2.5, 7.5, 16.1, 21.5), T9PA: (-4.3, 4.2, 11.5, 15.8), L4PA: (6.5, 9.7, 12.6, 13.4°), all p< 0.05. Apex of cervical lordosis, thoracic kyphosis and lumbar lordosis was comparable between the groups p>0.05. In the cervical spine, the groups had greater C0-C2 (13.8, 14.9, 15.9, 16.6°), C2-C7 lordosis (-4.2, 3.4, 8.3, 11.5°), and C2-C7 SVA (20.3, 21.3, 24.0, 26.7 mm), all p<0.05. Similarly, below the start point of GSA, the groups had greater ankle dorsiflexion: (3.3, 4.9, 6.9, 8.0°), all p< 0.05.

**Conclusion**
How a patient stands postoperatively is a challenging question for surgeons. This study proposes thresholds of surgically modifiable parameters that correlate with full body sagittal postural alignment measured by GSA.




## 117. Description of the Sagittal Alignment of the Degenerative Human Spine According to Roussouly's Classification

*Amer Sebaaly; Pierre Grobost; Lisa Mallam; Pierre Roussouly, MD*

**Summary**
Degenerative evolution of the normal spine could be described according to evolution of the initial sagittal alignment of the human lumbar spine classification described by Roussouly and classified in 11 types a divided in four subtypes: the classical types, the anteverted types, the false shapes (retroverted) and kyphotic shapes.

**Hypothesis**
The objective of this study is to present the description of sagittal alignment of the degenerative human spine and to propose a possible algorithm for its evolution from normal spinal shapes as described by Roussouly.

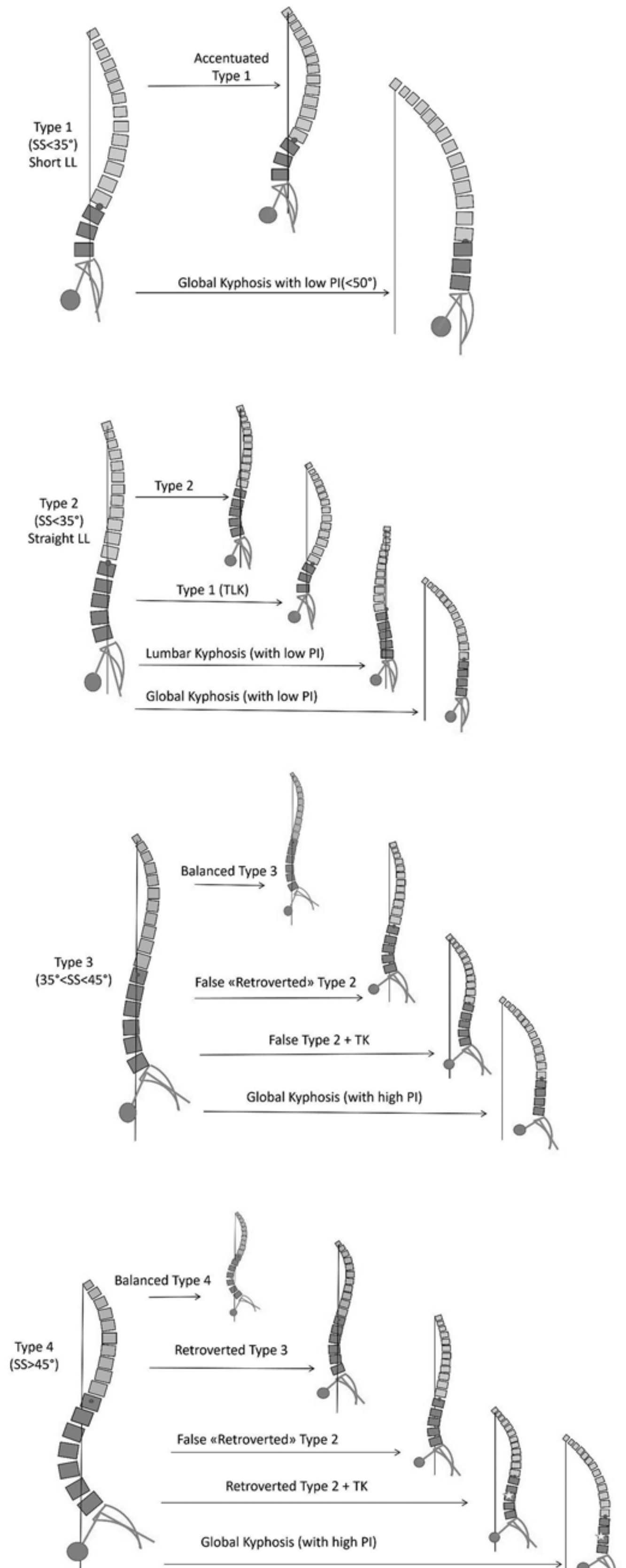
**Design**
Retrospective observational study of degenerative evolution in spinal alignment in low back pain patients.

**Introduction**
Many attempts have been made to classify sagittal imbalance beyond the primitive reasoning of balanced, unbalanced and compensated unbalanced spine but none analyzed the spinal shape. Therefore, there is a need to analyze the shape of the spine with its pathological evolution (evolution from normal spine to degenerative spine).

**Methods**
Full spine sagittal X-rays were analyzed and pelvic and spinal parameters were measured. Spinal shapes were classified on the hypothesis that the possible sagittal shapes of degenerative spine would be divided in 4 categories: "classical" Roussouly's types 1 to 4, anteverted types (PT ≤ 5), retroverted types (PT ≥ 25) and kyphotic types.

**Results**
A total of 331 patients (280 women and 51 men) were included. "Classic" type 1 to 4 represented the majority in this cohort (71.9%). Retroverted types made the second most common category with 20.8% of the cohort. Kyphosis group (lumbar and global) make only 5.8% of this cohort while anteverted group make the lowest incidence (1.5%). Retroverted type 2 with thoracic kyphosis should be considered a separate type and made 1.5% of this cohort. Two theoretical subtypes, retroverted type 1 and type 4 were not found.

**Conclusion**
This is the first description of degenerative spine disease based on its shape and based on the classification of the normal variation in the sagittal alignment of the human lumbar spine described by Roussouly. 11 types, divided in classical types, anteverted types, false shapes (retroverted) and kyphotic shapes, are described and an evolution pathway is proposed. An evaluation of surgical results in order to propose a treatment algorithm based on this classification should follow.




## 118. Minimum Detectable Change (MDC) and Minimum Clinically Important Difference (MCID) of Health Related Quality of Life Parameters in Adult Spinal Deformity

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**Summary**

Measurement and comparison of health related quality of life (HRQOL) have become an essential component of clinical results evaluation in any field. This study has calculated the MDC and MCID values for several assessment tools for HRQoL in ASD as 1.32 and 1.99 for COMI, 11.11 and 10.14 for ODI, 5.33 and 4.93 for SF36PCS, 0.46 and 0.53 for SRS22 respectively. We propose to use these values as standards in ASD population(s).

**Hypothesis**

The MCID and the MDC can be separately and reliability identified in an ASD population.

**Design**

Retrospective review of a prospectively collected multi-centre database.

**Introduction**

By definition, only treatments associated with a substantial HRQOL improvement should be promoted. Minimum clinically important difference (MCID) is a measure of this substantiality, whereas minimum detectable change (MDC) is the minimal amount of change score outside of measurement error that may reflect true change.

**Methods**

Of a total of 893 ASD patients from a multicentric international database, 248 had completed a global outcome score (GOS) question at 1 year follow-up. MDC and MCID values were calculated for COMI, ODI, SF-36 MCS, SF-36 PCS and SRS-22 scores for surgical (296) and non-surgical (597) patients separately. MDC was calculated by multiplying the standard error of measurement (SEM) by the z score associated with the desired confidence level and the square root of 2, adjusting for sampling from 2 different measures whereas MCID was calculated as mean change score on scales based on this anchor question, corresponding to patients with anchor question responses larger than 0; using latent class analysis.

**Results**

Of the 893 patients evaluated in this study, 622(69.7%) were diagnosed as idiopathic and 271(30.3%) were diagnosed as degenerative scoliosis. The calculated overall MDC and MCID scores of HRQOL parameters that were obtained from both surgical and non-surgical patients as 1.32 and 1.99 for COMI, 11.11 and 10.14 for ODI, 5.33 and 4.93 for SF36PCS, 0.46 and 0.53 for SRS22 respectively ( Fig 1).

**Conclusion**

The calculated MDC and MCID values are within the range of what has been described in different populations before. MCIDs of ODI and SRS22 which were calculated to be smaller than MDCs demonstrate that for these tests, the MDC and MCID should be taken as equals, at the calculated values of MDC. We propose to use these values as standards in ASD population(s).

**Fig 1.** Overall MDC and MCID scores of HRQOL parameters in patients with ASD.

| Scale | SEM | MDC | MCID |
|---|---|---|---|
| COMI | 0.48 | 1.32 | 1.99 |
| ODI | 4.01 | 11.11 | 10.14 |
| SF36 MCS | 2.11 | 5.84 | 3.65 |
| SF36 PCS | 1.91 | 5.33 | 4.93 |
| SRS22 | 0.17 | 0.46 | 0.53 |

## 119. How Much Will I Improve After My Surgery and Will I Be Normal? The Critical Importance of Collecting and Discussing Patient Reported Outcomes Measures (PROMS) With Adult Spinal Deformity (ASD) Patients

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**Summary**

Quantification of postoperative PROM improvement and comparison to normative values for different ASD types demonstrated quantifiable gains in pain, function, social and psychological measures at ≥2 year follow up, however, not all will return to normative values. Different deformity types had different improvements. We anticipate these data will assist in the ASD patient treatment counseling process.

**Hypothesis**

Different ASD types will demonstrate different PROM improvements following surgery but will not return to normative values

**Design**

Prospective, observational study

**Introduction**

Surgeons are often asked to quantify the amount of anticipated improvement and potential for return to "normal" during the surgical consent process. Purpose: quantify the amount of PROM improvement for ASD types and capacity to return to PROM normative values following surgery, ≥2 year follow up.

**Methods**

Surgically treated ASD patients (≥4 levels fused) were identified from a multi-center ASD database. Patients organized into ASD type (SRS-Schwab scheme). Demographic, radiographic, and operative data evaluated, and change in PROM (SF-36, SRS-22r, ODI, NRS-back pain, NRS-leg pain) scores from baseline to last follow up within each deformity type quantified and final SF-36 and SRS-22r scores compared to normative values.

**Results**

377/582 patients eligible for study (mean age 57.8 years, mean scoliosis 42.1°, mean SVA 65.4 mm, mean 11.8 levels fused) had ≥2yr follow up (mean 3.2 yrs). Improvement for all patients was 44.4% for back pain, 34.8% for leg pain, 20.7% for function, 50.0% for appearance, 3.8% for general health, and 20.1% for social functioning ($p<0.05$; Table 1). Improvements differed for deformity type; back pain improvement was consistent across groups whereas activity was most improved in SAGITTAL and MIXED (Table 1). Most ASD types demonstrated >50% return to population normative values. Largest return to normative values included appearance scores in THORACIC (11.1 to 73.7%) and activity scores in DOUBLE (24.2% to 63.5%). SAGITTAL had worst return to normative values for all measured domains.

**Conclusion**

Different ASD types demonstrated substantial and quantifiable gains in pain, function, social and psychological measures, however, most did not return normative values. Different deformity types demonstrated improvements in different domains. We anticipate these data will assist in the patient counseling process and encourage surgeons to collect PROMS and accurately measure spinal alignment to aid treatment discussions.

| | THORACIC (N=19) | LUMBAR (N=59) | DOUBLE (N=64) | SAGITTAL (N=97) | MIXED (N=138) | TOTAL (N=377) |
|---|---|---|---|---|---|---|
| NRS-Back pain (baseline/last follow up/% improvement) | 6.1/3.0/51% | 6.8/3.4/50% | 6.4/4.0/38% | 7.9/4.2/47% | 7.3/4.1/47% | 7.2/4.0/44.4% |
| NRS-Leg pain (baseline/last follow up/% improvement) | 2.4/1.1/54% | 4.5/2.7/40% | 3.1/2.4/22% | 5.6/4.0/28.6% | 5.0/3.1/38% | 4.6/3.0/34.8% |
| SRS-22r Activity (baseline/last follow up/% improvement) | 3.5/3.9/11.4% | 3.1/3.6/16.1% | 3.3/3.8/15.2% | 2.5/3.1/24.0% | 2.8/3.5/25.0% | 2.9/3.5/20.7% |
| Generational norm (baseline/last FU) | 33.3%/57.9% | 19%/57.6% | 24.2%/63.5% | 4.3%/31.5% | 16.7%/44.6% | 16%/48% |
| SRS-22r Appearance (baseline/last follow up/% improvement) | 3.1/4.0/29.0% | 2.6/3.7/42.3% | 2.6/3.9/50.0% | 2.2/3.3/50.0% | 2.3/3.5/52.2% | 2.4/3.6/50.0% |
| Generational norm (baseline/last FU) | 11.1%/73.7% | 8.6%/52.5% | 9.3%/66.7% | 3.3%/42.7% | 4.5%/47.7% | 6%/52% |
| SF-36 General health (baseline/last follow up/% improvement) | 47.5/50.8/6.9% | 46.7/48.4/3.6% | 49.4/52.3/5.9% | 41.9/42.7/1.9% | 45.0/46.5/3.3% | 45.3/47.0/3.8% |
| Generational norm (baseline/last FU) | 89.5%/73.7% | 67.8%/74.6% | 82.8%/85.9% | 56.7%/69.1% | 68.8%/71.7% | 69%/74% |
| SF-36 Vitality (baseline/last follow up/% improvement) | 45.8/50.8/10.9% | 43.2/47.3/7.3% | 45.3/50.0/10.4% | 36.4/44.4/22.0% | 38.3/46.7/21.9% | 40.1/47.0/17.2% |
| Generational norm (baseline/last FU) | 73.7%/84.2% | 54.2%/74.6% | 71.9%/ 79.7% | 28.9%/64.9% | 38.4%/67.4% | 46%/71% |
| SF-36 Social function (baseline/last follow up/% improvement) | 41.9/45.9/9.5% | 39.7/46.1/ 16.1% | 42.1/48.2/14.5% | 31.4/40.3/28.3% | 34.7/42.5/22.5% | 36.3/43.6/20.1% |
| Generational norm (baseline/last FU) | 73.2%/73.7% | 49.1%/72.7% | 46.2%/73.4% | 28.9%/53.6% | 26.8%/ 52.9% | 38%/61% |

## 120. Cost-Effectiveness of Operative vs Nonoperative Treatment of Adult Symptomatic Lumbar Scoliosis

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**Summary**

In this study of Adult Symptomatic Lumbar Scoliosis, cost-effectiveness of operative and non-operative treatment is similar at 2-years. However, neither treatment reached the commonly cited threshold of $100,000/QALY. Longer follow-up is needed to determine if the ICER will improve based on durability of clinical benefit or deteriorate due to additional costs associated with revision surgery.

**Hypothesis**
Surgery for Adult Symptomatic Lumbar Scoliosis (ASLS) is more cost-effective than non-operative care.

**Design**
Longitudinal comparative cohort.

**Introduction**
Uncertainty exists regarding the cost-effectiveness of treatments for ASLS. Nonoperative care provides little HRQOL benefit; although these patients may have worsened without treatment. Surgery improves HRQOL, but is costly with high revision rates. This study explores this issue via a cost-effectiveness analysis using data from an NIH sponsored trial.

**Methods**
Patients undergoing Operative (Op) or nonsurgical (NOp) treatment, with at least two year follow-up were included. Costs for the index and revision surgeries within two years were determined using Medicare Allowable rates. Data collected every three months included nonoperative resource use, medication use and employment status. Direct Costs were determined using Medicare Allowable rates, medication costs were determined using the Red-Book and Indirect Costs were calculated based on employment status and income. Quality Adjusted Life Years (QALYs) were calculated by two methodologies, deriving SF6D values from both the ODI and SF12.

**Results**
There were 165 Op cases and 125 NOp cases. In the Op group, mean total cost was $110,023 ($84,101 direct cost, $25,922 indirect cost (lost wages)). In the NOp group, mean total cost was $17,565 ($9,289 direct, $8,276 indirect). Using the ODI, 2-year QALY gain in the Op group was 0.084, with a cost/QALY of $1,304,517. NOp QALY gain was 0.011 with a cost/QALY of $1,559,947. Using the SF12, QALY gain was 0.10 in the Op group, with a cost/QALY of $1,093,668, and 0.02 in the NOp group, with a cost/QALY of $832,464. Incremental Cost Effectiveness Ratio (ICER) was $255,430 in favor of Op treatment using the ODI versus $261,203 in favor of NOp treatment using the SF12.

**Conclusion**
Cost-effectiveness of Op and NOp treatment of lumbar scoliosis is similar at 2-years. Depending on the QALY valuation used, the ICER may favor either surgical or nonsurgical treatment. Neither treatment reaches the commonly cited threshold of $100,000/QALY. Longer follow-up is needed to determine if the ICER for surgical treatment will improve based on durability of clinical benefit or deteriorate due to additional costs associated with revision surgery.

## 121. Preoperative Osteoporosis Treatment in Patients with Lumbar Scoliosis

*Natalia Morozova, MD; Sergey Kolesov, MD, PhD*

**Summary**
The results of surgical correction of scoliosis after six months of preoperative medical treatment of osteoporosis were evaluated and compared to surgical treatment without preoperative preparation.

**Hypothesis**
Preoperative treatment of osteoporosis decreases the number of complications and improve surgical outcome in patients with scoliosis.

**Design**
Prospective single-center study.

**Introduction**
The use of titanium instrumentation for posterior fixation in patients with osteoporosis can lead to unsatisfactory results. At the present time there is a clear increase in complication rate that has to do with implant instability.

**Methods**
A total of 160 patients aged 40 to 82 with low bone mineral density took part in the investigation (90 female and 70 male patients). The level of bone mineral density (BMD) was on average 0.854-0.884 g/cm2 with T-scores ranging from -2.7 to -3.8. All patients received similar surgical treatment: traditional titanium instrumentation and interbody fusion. The patients were divided into two groups: the study group underwent preoperative osteoporosis treatment (6 months) and the control group only underwent osteoporosis treatment in the postoperative period. The treatment of osteoporosis included calcium, vitamin D and antiresorptive medication. The study results were evaluated based on radiographs, CT scans and VAS, SRS22, SF36 and Oswestry questionnaires.

**Results**
The degree of lumbar curve correction in both groups amounted to an average of 22° (10° to 35°). Analysis of radiographs and CT scans at a 2.5-year follow-up in the study group showed no implant instability or major bone resorption. Rod fracture was only present in one patient. Adjacent level instability was not observed, while PJK was observed in 1.5% of the patients. Infectious complications were also observed in 1.5% of the cases. Revision surgery was needed in 2% of the cases. The questionnaire data demonstrated better results in the study group. The complication rates in the control group were as follows: PJK–8%, implant instability–10%, pseudoarthrosis–6%, infections–3%. Revision surgery was needed in 25% of the cases.

**Conclusion**
Preoperative preparation in adult patients with osteoporosis that undergo surgical treatment of scoliosis improves surgical outcomes and decreases the complication rate.

## 122. Cost Effectiveness of rhBMP-2 Use in Adult Spinal Surgery

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**Summary**
Surgical treatment for adult spinal deformity (ASD) is associated with major expense and complications. rhBMP-2 is frequently

used to promote fusion with the goal of reducing pseudarthrosis. We found that in ASD patients, while use of rhBMP-2 during the index surgery increased the direct costs, it was cost-neutral in terms of cumulative costs per QALY gained. Further, use of rhBMP-2 was associated with significant reduction in revision surgery for pseudarthrosis.

**Hypothesis**

Use of rhBMP-2 ("BMP") in adult spinal deformity (ASD) surgery is cost-effective.

**Design**

Analysis of multicenter prospective registry data

**Introduction**

Surgical treatment for ASD is associated with major expense and complications. The aim of this study was to compare the direct costs and costs/QALY gained for patients with vs. without BMP use.

**Methods**

A multicenter prospective registry was used to identity 522 ASD patients with ≥5 level fusion who were eligible for a 2-year follow-up (2Y f/u). A total of 367 pts had a min 2Y f/u (70% rate). The total direct costs (TDC) were calculated by adding the direct costs of the index surgery and of any subsequent revisions. Cumulative QALYs gained were calculated from the change in the baseline to follow-up SF-6D. A discount rate of 3% was assumed, and cumulative cost per QALY gained ($/Q) were calculated for each patient in 2014 dollars.

**Results**

BMP was used in the index surgery in 267 of 367 (73%) patients. The mean direct costs of BMP at the index surgery was $14,178 ± $6,423. Forty patients (11%) ultimately required revision surgery for pseudarthrosis. Patients without BMP use were 2-fold more likely to develop pseudarthrosis (17% vs. 8.6% with BMP, P=0.02, number needed to treat: 12). The mean TDC were significantly higher in patients requiring revision surgery for pseudarthrosis ($138K vs. $61K, P<0.001). There was no significant difference in the cost of the BMP used during the index surgery among patients who did vs. did not develop pseudarthrosis ($14.9K vs. $14.1K, P=0.584). While the mean TDC of patients with BMP use was significantly greater ($73K vs. $61K, P=0.003), patients with BMP were not significantly more expensive in terms of $/Q ($111K/QALY gained in BMP group vs. $127K/QALY gained in the no BMP group, P=0.277).

**Conclusion**

In ASD patients, while use of BMP during the index surgery increased the direct costs, BMP use was cost-neutral in terms of cumulative costs per QALY gained. Use of BMP was associated with 2-fold reduction in revision surgery for pseudarthrosis. Longer follow-up is required to realize the potential cost-savings from reduction in pseudarthrosis revision rates with BMP.

## 123. Association of Degenerative Lumbar Scoliosis with the Genetic Factors in Adolescent Idiopathic Scoliosis and Disc Degeneration

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**Summary**

The etiology of Degenerative lumbar scoliosis (DLS) is largely unclear. However, DLS consists of degenerative changes superimposed on adolescent idiopathic scoliosis (AIS) and de novo type caused by disc degeneration (DD). We investigated the association of DLS with AIS and DD susceptibility genes. AIS susceptibility gene was replicated in DLS population. DLS and AIS might be caused by a similar genetic background.

**Hypothesis**

Degenerative lumbar scoliosis (DLS) has the similar genetic backgroud to adolescent idiopathic scoliosis (AIS) and disc degeneration (DD).

**Design**

Observation case-control study

**Introduction**

DLS is a common spinal deformity that develops and progresses with age. DLS consists of two pathological conditions; degenerative changes superimposed on idiopathic scoliosis, and de novo type caused by degeneration of facet joints and intervertebral discs. The distinguishment of these pathologies is usually difficult by clinical and radiographic features. Although the etiology of DLS is still largely unclear, the genetic factors have been identified in adolescent idiopathic scoliosis (AIS) and disc degeneration (DD). We previously reported that Genome-wide association study (GWAS) identified 4 AIS susceptibility genes: LBX1, GPR126, BNC2, PAX1. And several candidate gene approaches also identified DD susceptibility genes. We investigated the association of DLS with AIS and DD susceptibility genes.

**Methods**

We recruited 356 Japanese DLS patients and 3,341 controls. In this study, DLS was defined as Cobb's angle greater than 15° on standing spinal anteroposterior radiographs. Moreover, the patients were diagnosed with DLS between the age of 40 and 75 and not diagnosed with AIS before the age of 20 by the expert spinal surgeons. SNPs associated with AIS (LBX1: rs11190870, GPR126: rs6570507, BNC2: rs10738445, PAX1: rs6137473) and with DD (CILP: rs2073711, COL11A1: rs1676486, CHST3: rs1245582) were genotyped using the Invader assay. We evaluated the association of 7 SNPs with DLS.

**Results**

Only rs11190870 was significantly different (P = 3.20 x 10-3) and rs6137473 tended to be different (P = 1.99 x 10-2), while rs6570507 and rs10738445 were not significantly different (P = 7.30 x 10-1, P = 3.66 x 10-1). All SNPs associated with DD were not significantly different (P < 0.05/7), but rs1676486 tended to be different (P = 2.30 x 10-2).

**Conclusion**

Since rs11190870 which had the strongest association with AIS was replicated in DLS population, LBX1 can be a common susceptibility gene for DLS and AIS. DLS and AIS might be caused by a similar genetic background. Further studies are necessary to clarify the association between DLS, AIS and DD.

## 124. Fractional Curves in Adult Spinal Deformity: Is it a Driver of or a Compensation for Coronal Malalignment?

*Nicolas Plais; Hongda Bao, MD PhD; Han Jo Kim, MD; Munish C. Gupta, MD; Christopher I. Shaffrey, MD; Jonathan Charles Elysée, BS; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Shay Bess, MD; Frank J. Schwab, MD; Virginie LaFage, PhD; International Spine Study Group*

**Summary**

404 patients with adult spinal deformity (ASD) were classified into three groups based on the C7 Plumb line (C7PL) and its relationship to fractional curve (FC). Our findings suggest that the fractional curve acts as a deformity driver in patients with a C7PL malaligned in the same direction of the FC, and as an insufficient compensation mechanism in patients with C7PL malaligned in the opposite direction of C7PL and FC.

**Hypothesis**

Fractional curves play an important role in ASD coronal malalignment

**Design**

Retrospective analysis of an ASD database

**Introduction**

The coronal fractional curve (FC) resides at the lumbosacral junction; it spans from S1 to L4 or L3 and occurs below the major curve in the mid-lumbar spine. Despite being very common in patients with adult degenerative scoliosis, the impact of the lumbosacral curve on global coronal alignment is not well documented

**Methods**

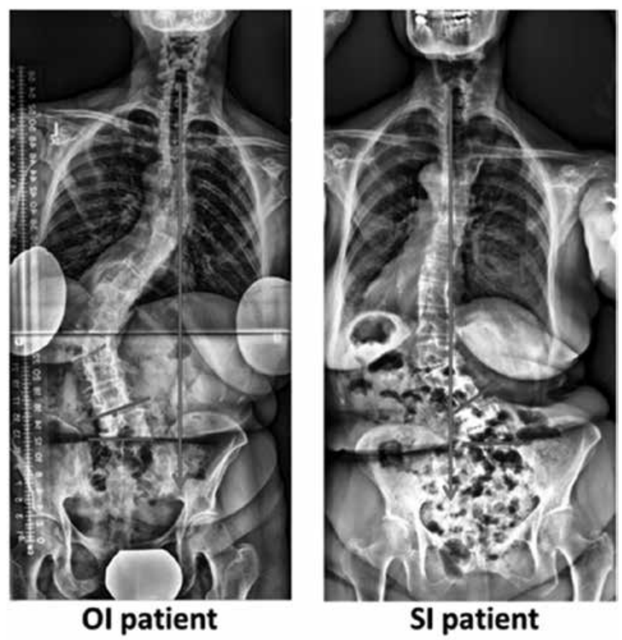
This study focused on ASD pts presenting with a lumbar/thoracolumbar (TL) major coronal curve, with an apex at T11-L3, a Cobb angle >15°, a lower end vertebra at L3 or L4 and >45 yo. Only patients with a fractional curve greater than 5° were included for the study. Fractional ratio (Fractional Cobb/Main Cobb) was reported for the entire cohort. Patients with a C7PL offset>3cm were stratified as the same direction of FC (SI group, C7PL towards the concavity of the FC) or the opposite direction of FC (OI group, C7PL towards the convexity of the FC).

**Results**

404 patients (63.0 yo, 83.3% female) were included: 43 pts were classified as OI, 120 pts as SI, and 241 were coronally balanced. Compared to the balanced pts, SI pts had similar major TL Cobb angles but significantly larger fractional Cobb angles (17.5° vs 22.3°, p<0.001) and larger fractional ratios (p<0.001). On the contrary, OI pts had significantly larger major TL Cobb angles (49° vs 41°, p=0.001) but smaller fractional Cobb angles and fractional ratios (both p<0.001) when compared to balanced patients. Pelvic obliquities >5° in the same direction as the fractional curve was more common in OI pts (20%) than in SI pts (7.5%), which suggests the preferential role of pelvic compensation. C7PL offset correlated with fractional ratios (r=0.46, p<0.01) and fractional Cobb angles (r=0.35, p<0.01) in SI patients, while it only correlated with major TL Cobb in OI patients (r=0.36, p=0.02).

**Conclusion**

Larger lumbosacral fractional curve is the primary driver of coronal imbalance if the C7PL is towards the concavity of the fractional curve. However, fractional curve is an insufficient compensation, even with compensatory pelvic obliquity, when the major TL curve drives C7PL towards the convexity of the FC.




## 125. Can We Stop the Long Fusion at L5 for Selected Adult Spinal Deformity Patients with Less Severe Disability, Superior Bone Quality, and Less Complex Deformity?

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**Summary**

Minimum 5-year outcomes were compared between ASD patients with long fusion to L5 versus S1. There were 33 (83%) out of consecutive 40 patients who underwent corrective surgery by single surgeon. Although fusion to L5 was selected for the patients with less severe disability, superior bone quality, and less complex

deformity, 50% of them required additional fusion to the pelvis mainly due to insufficient deformity correction. Indication to stop the fusion at L5 for the patients (≥50 years) is limited.

**Hypothesis**
For selected adult spinal deformity (ASD) patients with less severe disability, superior bone quality, and less complex deformity, we can stop fusion at L5.

**Design**
Retrospective study on prospectively collected case series.

**Introduction**
It is controversial whether to stop the fusion at L5 or S1 in ASD surgery. Aim of this study was to compare minimum 5-year surgical outcomes between ASD patients with fusion to L5 versus S1.

**Methods**
Consecutive 40 patients (≥50 years of age) with ASD underwent spinal fusion from lower T-spine to L5 or S1 by single surgeon between 2008 and 2011. 33 patients (83%) had a minimum 5-year follow-up (60-104 months). Lowest instrumented vertebra (LIV) was L5 in 12 patients (L5 group) and S1 in 21 (S1 group). Clinical (age, gender, curve type by SRS-Schwab classification, blood loss, OR time, ODI, revision surgery rate) and radiographical parameters (SVA, TK, LL, PT, PI-LL) were compared between L5 and S1 group. Mann–Whitney U test and Fisher's exact test was used for statistical analysis.

**Results**
There were statistically significant differences (p<0.05) between two groups (L5 vs S1) in %Male (50% vs 14%), %N type of SRS-Schwab classification (83% vs 38%), preop ODI (40.5 vs 56), correction loss of LL (11° vs 3°), final TK (32° vs 50°), final improvement of PT (3° vs 10°), final improvement of PI-LL (26° vs 39°), and revision surgery rate (50% vs 14%). Causes of revision surgery in L5 group were distal junctional failure (DJF) in 3 patients, postop foraminal stenosis (FS) in 1, and both of DJF and FS in 2. All of them underwent additional spinal fusion to the pelvis. Whereas, causes of revision surgery in S1 group were rod fracture in 2 patients and proximal junctional failure (PJF) in 1

**Conclusion**
Although fusion to L5 was selected for the ASD patients with less severe disability (lower ODI), superior bone quality (male), and less complex deformity (type N), 50% of the patients required additional fusion to the pelvis mainly due to insufficient deformity correction. Indication to stop the long fusion at L5 for ASD patients with the age of 50 years or more should be limited.

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### 126. Is the "2/3 Lumbar Lordosis Comes from L4-S1" Rule Predictive of Outcome Among Patients with Sagittal Plane Spinal Deformities

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**Summary**
There has been a growing trend to use interbody fusion from L4-S1 to achieve segmental, regional and lumbar lordosis (LL) in adult sagittal plane spine deformities (SPD). This trend is largely due to the rule that L4-S1 should account for 2/3 of total LL. Improving the segmental LL does correlate with PT, SVA, TPA and PI-LL. There is, however, no correlation between restoration of segmental alignment and HRQOL at final follow up.

**Hypothesis**
Patients with a more harmonious segmental realignment will have improved radiographic and clinical outcomes

**Design**
Retrospective review of prospective multicenter adult spinal deformity database

**Introduction**
Normative data has suggested that 2/3 of LL should come from L4-S1. There has been increased interest in using various interbody techniques to restore this anatomic relationship. We aim to investigate this relationship among patients with SPD

**Methods**
Retrospective review of a prospective multicenter database with inclusion criteria including one of the following: PT >20, SVA>5 cm, PI-LL >10, and Cobb >20. 436 patients were available with 2 year data.

**Results**
135 with only SPD were included for analysis. Avg age 63.3 years, 68% female, and avg BMI 29.2. Mean preop PT was 26.5, L1-S1 32.8, PI-LL 22.5, T10-L2 -12.1, SVA 96.6 mm, and TPA 27.6. At baseline, L4-S1 LL was 51.9% of PI, L5-S1 32.4%, and L3-S1 63%. Post op L4-S1 was 56.2% of PI for a 4.3% gain. PI was stratified into small (SM<46), medium (M 46-56), and high (L>56). Preop L4-S1 represents 75%, 52.2%, and 38.5% of SM, M, and L respectively, and improved to 74.4%, 62.3% and 41.5% at 2yrs (p<0.001). The presence of an IBF at 1 level did not result in improvement of L4-S1 LL, however when IBF was at both levels, L4-S1 proportion increased from 2.2% to 14.1% (p=0.022), and L4-S1 angle improved by 1.6 v. 7.2 (p=0.038). The use of osteotomy also improved the L3-S1 proportion form 10.7% to 20.8% (p=0.040) for a 5.3 v 11.3 change (p=0.018). All patients saw improvement in SPD and HRQL at 2 years post op. A change in L4-S1 ratio correlated with final PI-LL (r=-0.489), TPA (r=-0.583), SVA (r=-0.461) and PT (r=-0.500; all p<0.001), however did not correlate with development of PJK. Segmental change did not correlate with any HRQL measures at 2FU.

**Conclusion**
Achieving a more harmonious segmental LL correlated well with sagittal parameters post-operatively. The use of interbody at both levels L4-S1 resulted in significant improvement in segmental lordosis. Despite this radiographic relationship, there was no correlation with restoration of segmental alignment and PJK, or HRQOL at final follow up.

## 127. Intraoperative Neuromonitoring During Adult Spinal Deformity Surgery: Alert Positive Cases in Different Surgical Procedures

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**Summary**
The incidence and cause of intraoperative neuromonitoring (IONM) alarm for consecutive adult spinal deformity (ASD) surgeries were analyzed. Among 275 ASD patients, postoperative follow up revealed 24 cases (8.7%) of IONM alerts and 16 cases (5.8%) of new neurological deficits. Most of IONM alarm appeared at the time of rod rotation maneuver or spinal shorting. Spinal surgeon should perform different managements at the time of IONM alert, because the mechanism of neural damage differed depending on the surgical procedures.

**Hypothesis**
Intraoperative neuromonitoring (IONM) may have a role in identifying and preventing neurological complication.

**Design**
A retrospective study

**Introduction**
The neurological complication is quite variable due to several factors including surgical approach, use of osteotomies, patient's pathology and revision status. This study aimed to assess the mechanisms of neurological complication which was detected by IONM in different surgical procedures.

**Methods**
This study included 275 consecutive ASD patients treated by posterior corrective fusion who had been followed up for more than 2 years. We divided the patients into 1) PCO group: multiple posterior column osteotomies and 2) ACO group: anterior column osteotomy including pedicle subtraction osteotomy (PSO) and vertebral column resection (VCR). We set a 70% reduction of amplitude as an alarm point of transcranial electrical stimulation motor evoked potentials (Tc-MEPs) using 32-channel IONM.

**Results**
Of 275 patients (mean age 63.4yo, 52 male and 223 female), PCO and ACO group were 162 and 113 cases, respectively. IONM revealed 24 cases (8.7%) of Tc-MEPs alerts including 8.0% of PCO group and 9.7% of ACO group. Postoperative follow up revealed 16 cases (5.8%) of new neurological deficits including 5.5% of PCO group and 6.2% of ACO group, clinically. Most of IONM alarm in PCO appeared at the time of rod rotation maneuver. On the other hand, IONM alarm in ACO appeared at the time of spinal shorting. Immediately after the alarm points, neurological deficits might be rescued by foraminal decompression after rod rotation in PCO group and adjusting the length of spinal shorting in ACO group. Totally, 33% (8 of 24) of IONM alerted cases were rescued by intraoperative additional managements. The sensitivity and specificity of IONM were 100% and 96.9%.

**Conclusion**
IONM may reduce the incidence of neurological complication in ASD surgery.

## 128. Does the Use of an Interbody Fusion at the Osteotomy Site Limit the Loss of Correction After 3 Column Osteotomy in Adult Spinal Deformity?

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**Summary**
Correction loss after adult spinal deformity (ASD) surgery is suboptimal. This study investigated if the use of an interbody fusion (IBF) will help prevent postop correction loss. This study revealed that an IBF at the osteotomy site is associated with decrease loss of lumbar lordosis and SVA at 2yr followup.

**Hypothesis**
IBF at osteotomy site may aid in maintaining its correction

**Design**
Retrospective radiographic study

**Introduction**
Correction loss after ASD surgery has been associated with reciprocal changes in the unfused levels, deterioration in quality of life, and revision surgery, especially in patients undergoing 3-column osteotomy (3CO) with a large correction. This study aimed to investigate if the use of an IBF helped limit a post-operative loss of correction.

**Methods**
This is a retrospective review of a prospectively collected multicenter database. Patients (pts) were included if > 18 y/o, underwent 3CO correction for ASD, and with 2yr followup. Pts were stratified into 3 groups: 3CO without IBF (Non-IBF group), 3CO with IBF at osteotomy site (IBF-S group), and 3CO with IBF not at the osteotomy site (IBF-D group). Demographic, surgical, radiographic, outcome, and complication data were collected and analyzed using ANOVA. The loss of correction was calculated from the change in sagittal parameters from early post-op to 2yr followup.

**Results**
A total of 135 pts were included (mean age 63 yo). Demographic and clinical comparisons between the 3 groups revealed no significant differences in age (p=0.52), gender (p=0.23), rate of prior spine surgery, prior spinal fusion, and prior decompression. IBF-S pts had longer lengths of stay and greater EBL but similar ASA grades and OR times. Sagittal alignment, both at baseline and early post-op and surgical correction were not different (Table). Regarding the maintenance of sagittal alignment from early post-op to 2yr followup, significantly less correction loss of PI-LL was

observed in the IBF-S group (-0.6° vs. 3.7° in IBF-D group and 6.0° in Non-IBF group, p=0.032). The maintenance of C7-S1 SVA was also significantly better in the IBF-S group; the C7-S1 SVA in the IBF-S group improved by 4.4mm while it worsened by 14.0 mm and 25.1 mm in the IBF-D and Non-IBF groups, respectively (p=0.031). ODI, SF-36 and SRS-22 scores showed no difference at both baseline and 2 yr follow-up. Revision rates and implant failure rates were also similar (p=0.986 and 0.68).

**Conclusion**

Despite the strong correction power achieved by 3COs for ASD pts, considerable correction loss was observed in 3CO pts without IBF. Adding an IBF at the osteotomy site may aid in maintaining postop correction.

| | N | Age | EBL | Baseline parameters | | | Change from post-op to 2yr *(Positive means decrease)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | PT | PI-LL | SVA | PT | PI-LL | SVA |
| Non-IBF group | 59 | 64.03 | 2352.12 | 30.01 | 35.86 | 136.18 | 1.36 | -6.00 | 25.15 |
| IBF-D group | 41 | 62.65 | 2622.13 | 31.81 | 35.33 | 128.22 | 1.26 | -3.74 | 13.95 |
| IBF-S group | 35 | 61.55 | 3628.68 | 32.12 | 38.73 | 144.22 | 1.76 | -0.45 | -4.35 |
| Total | 135 | 62.97 | 2759.66 | 31.11 | 36.45 | 135.64 | 1.45 | -3.57 | 12.50 |
| p | - | 0.516 | 0.003 | 0.529 | 0.645 | 0.612 | 0.94 | 0.032 | 0.031 |

PT: Pelvic tilt; PI-LL: PI and LL mismatch; SVA: sagittal vertical axis

## 129. Adult Symptomatic Lumbar Scoliosis: Randomized Results from a Dual-Arm Study

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**Summary**

A dual-arm, randomized and observational, study of adult symptomatic lumbar scoliosis (ASLS) found benefits for operative (OP) over nonoperative (NON) care at 2 and 4yr FU. Intention-to-treat (ITT) analysis did not show a benefit, though high rates of crossover compromised these conclusions. Per-protocol (PP) and as-treated (AT) analyses found benefits to surgery. Adverse events, including reoperation, were common in OP.

**Hypothesis**

Operative (OP) and nonoperative (NON) treatment of ASLS will offer similar SRS-22r and Oswestry Disability Index (ODI) outcomes at 2yr FU.

**Design**

Dual arm, randomized (RCT) and observational (OBS) cohort study

**Introduction**

ASLS is a common and costly condition, affecting 10-15% of the population and associated with upwards of $15 billion in charges. There is a paucity of data supporting the superiority of OP over NON. Furthermore, OP is associated with rates of adverse events, including reoperation, approaching 50%.

**Methods**

ASLS Patients were enrolled in a dual-arm RCT and OBS study comparing OP and NON. Patients declining randomization were enrolled in OBS. OP and NON treatments were at the discretion of the surgeon. Standard demographic and radiographic data were collected. Primary outcomes were change in SRS-22r and ODI scores at 2 and 4yr FU. An intention to treat (ITT) analysis was performed for all enrolled in RCT. To account for crossover, per protocol (PP) analysis and an as treated (AT) analyses were performed, with RCT and OBS combined in AT. Student's t-test was used to compare RCT data. A mixed-effects model was used to estimate effect size for AT.

**Results**

63 Patients were enrolled in RCT (OP=30, NON=33). 3 Withdrew prior to 12mnth FU. 6 Crossed over from OP to NON and 14 crossed from NON to OP. Basline data were similar. ITT (N=63) revealed no significant differences in SRS-22r or ODI changes at 2yr FU. PP analysis (40: OP=22, Non=18) found a benefit for surgery (SRS-22r TE: 0.7, p=0.001; ODI TE: 15.2, p=0.001). 223 Patients were enrolled in OBS (OP=112, NON=111). AT (RCT:60, OBS:223, N=283) analyses, adjusting for confounders, found benefits for OP at 2 and 4yrs FU (Table). Adverse events (AE) related to treatment were more common in OP (N=104) than NON (N=5). 26% (46/176) OP patients have undergone a minimum of one revision surgery

**Conclusion**

High rates of crossover limit conclusions from the RCT cohort of this dual arm study. ITT analysis found no significant differences between OP and NON. PP and AT analyses found strong benefits for OP at 2 and 4yrs FU. AE were more common in OP and unplanned reoperation was 26% at 4yr FU. Longer FU is required to examine the effect of AE and reoperation on HRQOL in the OP management of ASLS.

| PROs | Average change from baseline (95%CI) | | Adjusted difference in average change* (95%CI) | p-value |
|---|---|---|---|---|
| | Operative | Nonoperative | | |
| SRS Subscore 2-year | 0.75 (0.68, 0.82) | 0.14 (0.06, 0.22) | 0.69 (0.58, 0.79) | <0.001 |
| SRS Subscore 4-year | 0.73 (0.65, 0.80) | 0.08 (-0.01, 0.17) | 0.72 (0.61, 0.84) | <0.001 |
| ODI Score 2-year | -15.37 (-17.25, -13.50) | -2.44 (-4.71, -0.17) | -15.34 (-18.25, -12.42) | <0.001 |
| ODI Score 4-year | -14.04 (-16.05, -12.04) | -2.02 (-4.50, 0.46) | -14.45 (-17.62, -11.28) | <0.001 |

# Notes

# E-PRESENTATION ABSTRACTS

SCOLIOSIS RESEARCH SOCIETY
52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges Stryker for their overall support of the Annual Meeting & Course.

*The E-Presentations will be recorded onsite at the Annual Meeting and will be available for attendees to view online approximately two weeks after the meeting.*

## 150. The Thoracic Curve Correction Ratio as a Predictor of T1 Tilt Following Correction of Double Thoracic (Lenke 2) Idiopathic Curves

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**Summary**

In patients with double thoracic (Lenke 2) curves, the correction of the upper thoracic curve relative to the main thoracic curve should be modified based upon to the ratio of the preoperative curve magnitudes in order to reduce the likelihood of residual postoperative T1 tilt.

**Hypothesis**

We hypothesized that a mismatch between preoperative T1 tilt and the ratio of proximal thoracic to main thoracic curve correction may be associated with residual T1 tilt following spinal deformity correction.

**Design**

Retrospective review of data from a prospective, multi-center AIS database

**Introduction**

Persistent shoulder imbalance following posterior spinal fusion (PSF) for deformity correction may have a significant negative impact on clinical outcomes. Double thoracic (Lenke 2) curves represent one of the most challenging curve types in which to obtain satisfactory correction of shoulder balance. Residual T1 tilt may increase the risk of postoperative shoulder imbalance.

**Methods**

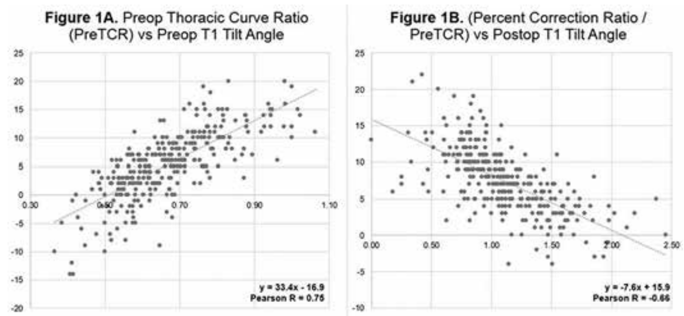
All PSF performed from July 1996 to May 2013 for left upper-thoracic, right main-thoracic, left lumbar Lenke 2 idiopathic curves with a minimum of two-year follow-up were analyzed. Primary measures included proximal thoracic and main thoracic Cobb angles, as well as T1 tilt (left shoulder up = +), at the preoperative and two-year postoperative time points. From these data, the following additional parameters were calculated: 1) Preoperative Thoracic Curve Ratio (PreTCR), 2) Postoperative Percent Correction Ratio (PostPCR).

**Results**

A total of 306 patients with complete two-year follow-up data were included in the analysis. The ratio of the upper thoracic Cobb angle to the main thoracic Cobb angle (PreTCR) displayed a positive correlation (Pearson R=0.75) with T1 tilt (Figure 1A). The ratio of postoperative percent correction of these curves (PostPCR) divided by the PreTCR displayed a negative correlation (Pearson R=-0.66) with T1 tilt at two years postoperatively (Figure 1B).

**Conclusion**

The correlation between the PreTCR and preoperative T1 tilt suggests that T1 tilt can be a good proxy for determining whether a proximal thoracic curve is structural. More importantly, the results give guidance for the management of Lenke 2 cases. We suggest that for those patients with a significant proximal thoracic curve, the surgeon should aim for an asymmetric relative over-correction of the upper thoracic relative to the main thoracic curve that is greater than the ratio of the preoperative curve magnitudes in order to reduce the likelihood of residual postoperative T1 tilt. This may help reduce the likelihood of clinically significant postoperative shoulder imbalance.




## 151. Does Surgical Approach Affect Outcomes in AIS Patients with 70 Degrees or Larger Curves and Less than 30% Curve Flexibility?

*Gabriel KP Liu, FRCS(Orth), MSC; Husam W Najjar, MBBS; Jun Hao Tan, MBBS; Leok-Lim Lau; Hwee Weng Dennis Hey; Joseph Thambiah; Hee-Kit Wong, MD*

**Summary**

Curve correction was not based on preop Cobb magnitude, but curve flexibility (CF). Curves with <30% flexibility have a 64% correction, while curves ≥30% flexibility have a 75% correction. There was no difference in Ant+Post compared to standalone Post surgery.

**Hypothesis**

Ant+Post surgery is not superior to standalone Post. surgery in curve correction.

**Design**

A prospective study of all postop AIS curves ≥ 70deg in a university hospital were reviewed.

**Introduction**

The surgical approach to managing AIS curves ≥70 is often based on one's clinical experience. Few studies have compared the outcomes of surgical approach in large AIS curves based on the CF

**Methods**

Pt's clinical and radiological outcome data were recorded and analyzed using SPSS. CF was defined as: (Pre-op erect Cobb angle of major structural curve–corresponding bending angle)/pre-op Cobb

**Results**

51pts(7♂, 44♀) with mean age of 14(10-18)yrs and median Risser 4 (0-5) were reviewed. Pts were divided into <30% CF(Grp

A), and ≥30% CF(Grp B). Grp A consisted of 20 pts, with mean age of 14±2yrs and Cobb 84(70-117). Grp B consisted of 31 pts, with mean age of 14±2yrs and Cobb 81(70-140). In Grp A, 12 pts had Post surgery only (4 of 12 pts had ave. of 3.8 Ponte osteotomies each), and 8 pts had Ant+Post surgery(4 of 8 pts had ave. of 3.5 Ponte osteotomies each). The mean number of levels fused was 12(8-14), with mean implant density of 1.6 screws/level. The mean curve correction was 54(26-82). In Grp B, 25 pts had Post surgery only, and 6 pts had Ant+Post surgery. The mean number of levels fused was 12(11-15), with mean implant density of 1.5 screws/level. The mean curve correction was 60(43-102). Multivariate analysis showed that in Grp A pts, there is a statistically significant longer operation time (OR=7.6,95%CI:1.6-36,p-value=0.011), hospital stay (OR=3.2,95%CI:1.8-6.1,p-value=0.005), and less Cobb angle correction(OR=0.92,95%CI:0.85-0.94,p-value=0.05), and a trend towards more blood loss. There was no statistical difference in demographics between both groups. Interestingly, subgroup analysis comparing Post vs Ant+Post surgery in Grp A pts does not show a significant difference in Cobb correction and postop outcomes scores. Analysis of Grp B was similar

**Conclusion**

This study suggests that Cobb angle correction were based on curve flexibility. Curves with <30% flexibility have a 64% correction, while curves ≥30% flexibility have a 75% correction. Interestingly, there was no evidence to demonstrate that Ant+Post surgery is superior to standalone Post surgery, suggesting a need for larger cohort studies to validate the routine need for anterior release for large rigid scoliosis curves

## 152. Implant Density Unrelated to Patient Reported Outcome in a Nationwide Survey of 328 Patients with Idiopathic Scoliosis

*Anastasios Charalampidis; Anders Möller; Paul Gerdhem, MD, PhD*

**Summary**

In a nationwide survey of 328 patients treated surgically for idiopathic scoliosis, patient reported outcome at a mean of 3 years was not associated with implant density

**Hypothesis**

The number of implants used per operated vertebra in patients with idiopathic scoliosis is not associated with patient reported outcome.

**Design**

Retrospective analysis of prospectively collected data from the Swedish spine register

**Introduction**

Studies have not been able to define the optimum number of implants to be used in surgical treatment for idiopathic scoliosis. The aim was to describe the number of implants per operated vertebra (implant density) in patients treated for idiopathic scoliosis in Sweden and the association to patient reported outcome.

**Methods**

Data on 328 patients with idiopathic scoliosis treated with surgery between ages 10 and 20 years were collected from the Swedish Spine register. Radiographic images were analyzed by two of the authors. Outcome were the SRS22r and the EQ-5D with a minimum follow-up of 2 years (mean 3 years). The patients were divided into tertiles based on implant density. Data were analyzed with analysis of variance, or logistic regression, and some analyses were adjusted for sex, age at surgery and major curve flexibility. Data are presented as mean (range) or (SD).

**Results**

Implant density in the lowest tertile was 1.36 (1.00-1.54), in the middle tertile 1.65 (1.55-1.75) and in the highest tertile 1.91 (1.77-2.0). Preoperative major curve flexibility was 38%, 35% and 30% in the low, middle and high tertile groups respectively (p=0.027). The SRS22r subscore, the SRS22r domains, EQ-5D, curve size, curve types, apical vertebral rotation, perioperative blood loss, curve correction, or length of stay did not differ significantly between the groups at baseline (all p>0.10). At the mean 3 year follow-up, there were no statistically significant differences in the SRS22r total score, EQ-5D, or number of reoperations between the groups (all p>0.34, after adjustment). The SRS22r satisfaction domain was 4.0 (1.0), 4.0 (0.9) and 4.3 (0.8) in the low, middle and high implant density groups, respectively (p=0.027, after adjustment). Subgroup analyses in patients with Lenke 1 and Lenke 1A curves did not reveal any statistically significant differences in patient reported outcomes between groups with low or high implant density.

**Conclusion**

There was a tendency to use more implants in more rigid curves. There did not seem to be any clear association between patient reported outcomes and implant density.

## 153. Quality of Life and Back Pain in Middle Aged Idiopathic Scoliosis Patients >20 Years After Brace or Surgical Treatment

*Johan L. Heemskerk, MD; Mark Altena, MD; B.E.E.M.J. Veraart, MD, PhD; René M. Castelein, MD, PhD; Diederik HR Kempen, MD, PhD*

**Summary**

Teenagers with idiopathic scoliosis(IS) are treated to alter the natural history of the disease and prevent future problems in adulthood. This study compares quality of life(QoL) in adult IS patients >20 years after brace or surgical treatment with an age matched cohort and shows that IS is a chronic disease with a serious impact on QoL in adulthood, even after treatment.

**Hypothesis**

QoL in middle aged IS patients is the same as an age matched reference cohort without scoliosis

**Design**

Retrospective cross-sectional cohort study

**Introduction**

Treatment of IS attempts to alter the natural history of this disease and prevent future problems in adulthood. However, there is limited information on the effects of treatments on QoL & back problems in middle aged IS patients.

**Methods**
IS patients, treated during childhood between 1978-1996 at the Amsterdam OLVG hospital, were selected from a historic database and contacted to participate in this study. Patients were treated with Boston brace or operated by Harrington spondylodesis at least 20 years ago. They were send a digital questionnaire focusing on back pain(Oswestry Disability Index) & QoL(SF-36). SF-36 was compared with a local age matched reference cohort(N=4172) in Amsterdam(mean age 43 yrs)

**Results**
Currently 183 patients completed the questionnaire of the 402 eligible patients. Patients(81% women) had an age of 43±3.6yrs with a follow up of 28±4yrs. 136 patients were brace treated(BT) and 47 were surgically treated(ST). BT patients had a Cobb of 32°±12 at end of treatment. Age at surgery was 16±3.1yrs with a Cobb of 57°±10 before surgery. At early adulthood, Cobb of the BT and ST group were 34°±14 and 35°±12, respectively. 70% of BT and 83% of the ST patients had back pain with a ODI of 9±10 and 19±19, respectively. Scores on the SF-36 domains were all lower in ST cohort compared to the BT cohort and were significant in 6 of the 8 subscales(P<0.03). Significant differences were larger than minimal clinically important differences. Compared to the reference cohort, BT patients had lower scores in 5 domains. Only the vitality subscale was significant(62±17 vs 69±19;P=0.005). The ST patients had significant lower scores(P<0.01) on all subscales compared to the reference cohort with exception of mental health. The differences in social functioning score(65±23 vs 85±22;P=0.002) and emotional role limitation score(58±32 vs 83±32.3;P=0.001) were the largest

**Conclusion**
The study confirms that IS is a chronic disease with a serious impact on QoL in adulthood. Despite frequent back pain, pain intensity was not severe. Overall, Boston BT patients had better QoL scores compared to Harrington ST patients.

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## 154. Global Alignment and Proportion (GAP) Score: Development and Validation of a New Method of Analyzing Spinopelvic Alignment to Predict Mechanical Complications after Adult Spinal Deformity Surgery

*Caglar Yilgor, MD; Nuray Sogunmez, MSc; Yasemin Yavuz, PhD; Louis Boissiere, MD; Sleiman Haddad; Ibrahim Obeid, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R. Acaroglu, MD; Anne F. Mannion, PhD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; European Spine Study Group*

**Summary**
The GAP score is a PI-based proportional method of analyzing the sagittal plane that accurately predicts mechanical complications after adult spinal deformity (ASD) surgery.

**Hypothesis**
PI-based proportional understanding will help better quantify spinopelvic parameters.

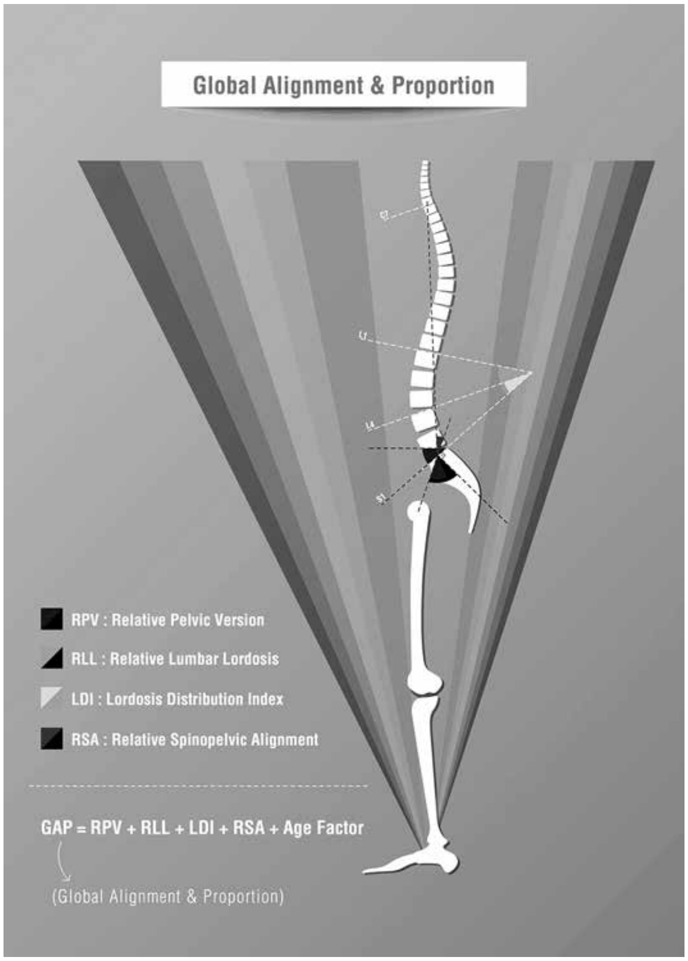
**Design**
Retrospective analysis of a prospectively collected data of ASD pts.

**Introduction**
The restoration of normal sagittal alignment is a critical goal in ASD surgery to achieve favorable outcomes and prevent mechanical complications. Schwab's sagittal modifiers have been accepted as targets for appropriate alignment but addressing these does not always prevent high mechanical complication/revision rates. This may be because the linear absolute numerical parameters do not cover the whole PI spectrum, and the distribution of lordosis, pelvic anteversion and negative malalignment are not considered as potential causes of failure.

**Methods**
222 pts (168 F, 54 M) who had ≥4 levels fusion with ≥2y follow-up were included. Mean age was 52.2±19.3(18-84) years. Mean follow-up was 28.8±8.2(24-62) months. GAP score was developed and validated in groups of patients randomly assigned to derivation (n=148, 66.6%) and validation (n=74, 33.3%) cohorts. GAP score parameters comprised Relative Pelvic Version (Measured minus Ideal Sacral Slope), Relative Lumbar Lordosis (Measured minus Ideal Lumbar Lordosis), Lordosis Distribution Index (L4-S1 lordosis/L1-S1 lordosis x100), Relative Spinopelvic Alignment (Measured minus Ideal Global Tilt) and age factor. Mechanical complications were PJK/PJF, DJK/DJF, rod breakage and implant-related complications. The predictive accuracy of the GAP score was analyzed using ROC analyses. Associations between GAP categories and mechanical complications were analyzed using Cochran-Armitage tests.

**Results**
In the validation cohort, 32 pts (43.2%) experienced mechanical complications and 17(23.0%) underwent mechanical revision. The area under curve for the GAP score in predicting mechanical complications was 0.92(SE:0.034, p<0.001, 95%CI:0.85-0.98). Postoperatively GAP proportioned patients had a mechanical complication rate of 6.1%, while GAP moderately disproportioned and severely disproportioned patients had rates of 47.4% and 95.5%, respectively.

**Conclusion**
The GAP Score denotes "normal" and "pathologic" spinal shape and alignment as a single score for every PI size. This PI-based proportional method of analyzing the sagittal plane predicts mechanical complications in ASD surgery. Setting surgical goals according to the GAP Score may decrease the incidence of mechanical complications.




## 155. Complications and Additional Procedures Following Anterior Vertebral Tethering for AIS: A Six Year Experience

John T. Braun, MD

**Summary**
Complications and additional procedures were analyzed in 22 patients undergoing anterior vertebral tethering (AVT) for AIS. The overall complication rate was low with no medical or surgical complications. A single early post-op instrumentation failure involving tether rupture required revision without sequelae. Three additional late procedures were required (2 tether removals for overcorrection and 1 PSF for lumbar decompensation below a tether).

**Hypothesis**
The overall complication rate for AVT in AIS patients will be low but some additional procedures will be required.

**Design**
Retrospective review of consecutive patients (2010-2015).

**Introduction**
Although AVT has been proposed as an alternative to fusion surgery for AIS, the rates of complications and additional procedures are unknown. This study analyzed patients undergoing AVT for AIS over a six year period.

**Methods**
Twenty-two consecutive AIS patients were treated with AVT for T, TL and L curves in the 33-60° range. Endoscopic approaches were used for T curves and mini-open for TL/L curves. Charts and radiographs were reviewed for complications and additional procedures. Cobb angles were used to compare curve magnitude pre-op, post-op and final.

**Results**
Twenty-two AIS patients (20F/2M) with 33 curves (16T, 13TL,4L) were treated with AVT for 42.1° curves on average (33-60°) at 14+0 years (9+2-17+10) and skeletal maturity of R=2.2 (0-5). The overall initial scoliosis correction from 42.1° to 18.2° (p<0.001) was achieved without any medical or surgical complications. A single instrumentation failure involving ligament rupture at an L1 screw occurred POD #2 and was revised without sequelae (Pt 22: 14+10F, R=4.5, 44°T/49°TL pre-op, 24°T/8°TL post-op and 20°T/2°TL final). Fourteen of 22 patients achieved 3.3 year (2-6) F/U with 3 requiring additional procedures: 2 tether removals for overcorrection (Pt 4: 11+10F, R=0, 38°T/34°TL pre-op, 8°T/0°TL post-op then tether removal at 2 years)(Pt 7: 13+11F, R=1, 22°T/33°L pre-op, 0°T/0°L post-op then tether removal at 2 years) and 1 PSF for decompensation (Pt 3: 9+6F, R=0, 36°T/28°L pre-op, 26°T/-3°L post-op then PSF for lumbar decompensation below a tether at 2.5 years). Eleven of these 14 demonstrated significant curve correction from 43.7° pre-op to 20.5° post-op and 18.4° final (p<0.001) at 3.6 years (2-6) without complication or additional procedures.

**Conclusion**
The overall complication rate for AVT in AIS is low with no medical or surgical complications and only 1 early ligament rupture (1/33 or 3.0%) revised without sequelae. Additional late procedures were required in 2 patients for overcorrection (2/14 or 14.2%) and 1 for decompensation (1/14 or 7.1%).

## 156. Progression of Spinopelvic Parameters in Patients with Thoracolumbar Adult Spinal Deformity: A Two Year Longitudinal Follow Up

*Gabriel KP Liu, FRCS(Orth), MSC; Jun Hao Tan, MBBS; Gerald Fung, Orthopaedics; Kevin Chan; Hee-Kit Wong, MD*

**Summary**
Reversal of lumbar lordosis(LL) and early menopause are predictors for scoliosis progression, and kyphotic thoracolumbar angle(TL), poor global alignment and increased T1-sagittal angle predicts sagittal deterioration. Despite radiological deterioration, >80% of pts improve with conservative treatment with good clinical outcome scores.

**Hypothesis**
Sagittal vertical axis (SVA) and LL predicts for sagittal deterioration. Radiological deterioration does not correlate with clinical outcome scores.

**Design**
A prospective study of patients with minimum of 2 years follow-up was conducted in a university hospital.

**Introduction**

Recent advancements in the understanding of sagittal alignment have improved surgical outcomes in patients with ASD. However, sagittal parameters reported in the literature are limited to measurements performed at a specific time point.

**Methods**

Clinical and radiological parameters according to SRS-Schwab classification were recorded. SRS24, Oswestry Disability Index(ODI) and visual analog scale(VAS) scores were recorded.

**Results**

168 pts(142 , 26 ) were reviewed. Mean age, menarche, and menopause was 66.4, 13.5 and 51.1 years respectively. The average scoliosis Cobb angle was 26.1(17-70). 70% of pts had Nash and Moe grade 2 rotation. Mean SVA was 35(-42-201) mm, mean pelvic incidence was 56(30-90), and mean pelvic tilt(PT) was 24(3–49). 77(46%)pts had radiological scoliosis progression of ≥5deg at 2 years follow-up. Mean Cobb progression was 8(5-27). Multivariate analysis showed that reversal of LL of ≥0 (OR=7.0,95%CI:1.8-27,p-value=0.005), and menopause≤50years old (OR=46,95%CI:7.9-250,p-value=0.0) are predictors of scoliosis progression. 16(10%)pts had ≥5cm SVA progression, with mean progression of 67mm±19mm. Multivariate analysis showed that a larger kyphotic TL predicts for SVA worsening (OR=0.96,95%CI:0.93-9.9,p-value=0.005). 56(33%) patients had PT progression≥5deg, with an average of 9±8. Univariate analysis showed increasing TL, T1-pelvic angle and abnormal global alignment predicted for PT progression. 91% of pts improved more than the established minimum clinically important difference (MCID)in VAS, and 83% of patients improved more than the MCID in ODI. The spearman correlation with radiological progression was poor (r=0.23). 6(4%) pts in the study had intractable radicular leg pain and underwent decompression and deformity correction surgery.

**Conclusion**

Few have reported the natural history and predictors for sagittal alignment progression. Reversal of LL and early menopause are predictors for scoliosis progression, and kyphotic TL, poor global alignment and increased T1-sagittal angle predicts sagittal deterioration.

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## 157. Utility of Supine Lateral Radiographs in the Assessment of Segmental Instability in Degenerative Lumbar Spondylolisthesis

*Foster Chen, MD; Woojin Cho, MD, PhD; Sandip P. Tarpada, BA; Louis Amorosa, MD*

**Summary**

Standing flexion-extension lateral radiographs are routinely obtained in the management of lumbar spondylolistheis, as they are believed to demonstrate the forward-backward motion of the segment in question. Recent studies with MRI and CT, however, have shown that the relaxed supine position may better facilitate the reduction of the anterolisthesed segment than flexion-extension lateral radiographs. Here, we show that supine lateral radiographs increase the amount of segmental instability visualized in single-level lumbar spondylolisthesis when compared to traditional lateral radiographs.

**Hypothesis**

We hypothesize that inclusion of supine lateral radiographs increases the amount of segmental instability seen in single-level lumbar spondylolisthesis when compared to traditional lateral radiographs.

**Design**

Retrospective Cohort study

**Introduction**

Accurate evaluation of segmental instability is critical to the management of lumbar spondylolisthesis. Standing flexion-extension lateral radiographs are routinely obtained, as it is believed to precipitate the forward-backward motion of the segment; however recent studies with MRI and CT have shown that the relaxed supine position can facilitate the reduction of the anterolisthesed segment. Here, we show that inclusion of supine lateral radiographs increases the amount of segmental instability seen in single-level lumbar spondylolisthesis when compared to traditional lateral radiographs.

**Methods**

Supine lateral radiographs were added to the routine evaluation (standing neutral/flexion/extension lateral radiographs) of symptomatic spondylolisthesis at our institution. In this retrospective study, 66 patients were included. The amount of listhesis was measured and compared on each radiograph: Standing neutral lateral ("neutral"), Standing flexion lateral ("flexion"), Standing extension lateral ( "extension"), and Supine lateral ("supine").

**Results**

66 patients, with a mean age of 60.9 years (+/- 11.8 years) were included in this study. The mean mobility seen with flexion-extension was 5.57%. The mean mobility seen with flexion-supine was 8.13%. This difference was significant in paired t-test (p<0.001), and independent of age and BMI. Maximal mobility was seen between flexion and supine radiographs in 40 patients, between neutral and supine radiographs in 14 cases, and between traditional flexion-extension studies in only 11 cases.

**Conclusion**

Supine radiograph demonstrates more reduction in anterolisthesis than the extension radiograph. Incorporation of a supine lateral radiograph in place of extension radiograph can improve our understanding of segmental mobility when evaluating spondy.

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## 158. Does Prior Spine Surgery or Instrumentation Affect Surgical Outcomes Following Three-Column Osteotomy for Correction of Thoracolumbar Deformities?

*Darryl Lau, MD; Andrew K. Chan, MD; Vedat Deviren, MD; Christopher P. Ames, MD*

**Summary**

This study evaluates whether prior instrumentation and the number of prior spine surgeries effect surgical outcomes, com-

plications, and future need for revision surgeries in patients that undergo long construct fusion and three column osteotomy.

**Hypothesis**
We hypothesize that there is an increase in complication, readmission, and reoperation rate with greater number of prior surgeries.

**Design**
This is a retrospective study and review of medical records from a single institution and surgeon.

**Introduction**
Adult spinal deformity is most commonly due to asymmetric arthritic degeneration and/or iatrogenic causes such as prior spinal instrumentation. Many patients who present with spinal deformity have undergone prior spine surgery. There is lack of contemporary studies that evaluate whether prior surgery and/or instrumentation affects perioperative outcomes, readmission, and need for reoperation.

**Methods**
All adult patients who underwent three-column osteotomy for correction of thoracolumbar spinal deformity from 2006-2016 were identified. We compared outcomes between primary (first-time) vs. revision cases, concentrating on number of prior surgeries (0, 1, 2, 3, 4, and 5 or more) and prior instrumentation. Multivariate analysis was used to adjust for relevant and significant confounders.

**Results**
A total of 300 cases were included, and 38.3% were male. Overall complication rate was 24.7% and mean hospital stay was 8.1 days. Ninety-day readmission rate was 9.0% and reoperation rate was 26.7%. There was no significant difference in complication rate (26.6% vs. 24.0%, p=0.645), hospital stay (8.7 vs. 7.9 days, p=0.229), readmission rate (11.4% vs. 8.1%, p=0.387), and reoperation rate (26.6% vs. 26.7%, p=0.984) between primary vs. revision cases. There was no significant difference in wound infections and dehiscence requiring reoperation (5.1% vs. 6.3%, p=0.683). When analyzed based on the number of prior spine surgeries or history of spinal instrumentation, no significant differences were observed for all outcomes of interest. Additionally, after adjusting for covariates on multivariate analysis, there were no significant associations between prior surgical histories (primary vs. revision, number of prior surgeries, and prior instrumentation), and all of the outcomes of interest.

**Conclusion**
The findings from this study suggest that patients who have undergone prior spine surgery with or without instrumentation are not at increased risk for perioperative complications, readmission, or reoperations following three-column osteotomy. These findings were also seen for patients that had undergone 5 or more prior surgeries.

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### 159. Effectiveness and Safety of Botropase , Tranexamic Acid and a Combination in Reduction of Blood Loss in Lumbar Spinal Fusion Surgery

*Ajoy Prasad Shetty, MS Orth; S. Rajasekaran, MD DNB FRCS MCh PhD; Srikanth Dumpa*

**Summary**
Prospective randomized placebo controlled study comparing the effectiveness of Botropase , Tranexamic acid and their combination in single level lumbar fusion surgery. 100 patients were randomized into 4 groups and outcome analysis done based on perioperative blood loss,haemoglobin, allogenic blood transfusion requirement. Intraoperative blood loss (p<0.001)and postoperative drain collection (p<0.001) was significantly higher in placebo group when compared to Botropase and combination group . No significant differences are noted in allogenic blood transfusion(p=1.000) ,preoperative and postoperative haemoglobin(p=0.195) .

**Hypothesis**
Combination of tranexamic acid and botropase causes significant reduction of blood loss in single level lumbar fusion surgery.

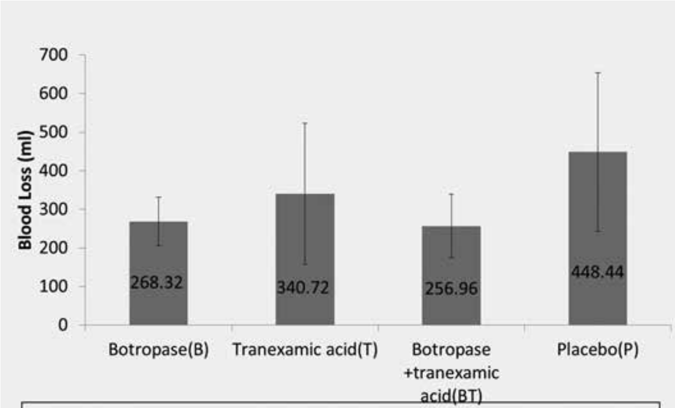
**Design**
Prospective, randomized, placebo controlled, double blinded study.

**Introduction**
We aimed to study effect and safety of tranexamic acid , botropase and their combination in controlling blood loss in spinal surgery.

**Methods**
100 patients with age ranging from 18-65 years with ASA I-II undergoing single level lumbar spinal fusion surgery were randomised into 4 groups. Group B- receive batroxobin ,group T - receive tranexamic acid ,group BT - receive batroxobin and tranexamic acid and group P - receive placebo. Exclusion criteria are duration of surgery >3 hours, dural tear, haemoglobin <10g/dl , hepatic and renal disorders, allergic to medications, patients on anticoagulants and coagulation disorders, DVT. Outcomes assessed are intraoperative and postoperative blood loss, haemotocrit , blood transfusion requirement and postoperative venous doppler.

**Results**
Demographic parameters and surgical duration were comparable. Mean intraoperative blood loss in Group B, T, BT, and P were 268.32±62.92ml, 340.72±182.75ml, 256.96±82.64ml and 448.44±205.86ml respectively (Graph I). Post operative surgical site drain collection in Group B, T, BT, and P were 218.00± 100.54ml, 260.40±100.85ml, 191.00±87.84ml and 320.00±125.83ml respectively . Intraoperative blood loss of Group P was statistically higher than Groups B and BT (p<0.001). Mean post operative surgical site drain collection was statistically significant (p<0.001). No statistically significant differences in fluid administration (p=0.751), blood transfusion (p=1.000) and parameters like preoperative and postoperative haemoglobin . Group BT had one case of deep vein thrombosis as compared to other groups which is statistically not significant (p=1.000).

**Conclusion**
Botropase and combination of botropase with tranexamic acid significantly reduced perioperative blood loss when compared to placebo.



Graph I : showing mean Intraoperative blood loss among different groups.

## 160. Predictive Factors of Intraoperative MEP Monitoring "True Positive" Alert During Spinal Deformity Correction Surgery: A Matched Cohort Study based on the Database of 2,336 Patients

*Qianyu Zhuang; Jianguo Zhang; Jianxiong Shen, MD; Shujie Wang, PhD; Guixing Qiu, MD*

**Summary**
Our study aims to evaluate the risk factors of intraoperative MEP monitoring "true positive" alert during spinal deformity correction surgery. Multivariate analysis revealed 3 independent predictive factors and therefore provided important information for preoperative surgical planning.

**Hypothesis**
Preoperative data can be used to predict intraoperative MEP monitoring "true positive" alert in patients with spinal deformity who underwent surgical treatment.

**Design**
Retrospective matched cohort study of prospectively collected database.

**Introduction**
"True positive" MEP alert is defined as the alert followed by observation of a new neurological motor deficit during a wake-up test or at the end of the procedure. The predictive factors of "True positive" MEP alert remain unknown, though being essential for preoperative surgical planning and intraoperative decision making.

**Methods**
A retrospective study was conducted based on a consecutive series of 2336 patients with spinal deformity who received surgical treatment between January 2010 and December 2016. A total of 48 patients with "true positive" MEP alert were identified. The control group was composed of 192 patients (1:4 ratio) with spinal deformity without "true positive" alert, matched for surgeon team and approximate date of surgery. Demographic distribution, radiographic and clinical data of these 2 groups were compared. These 2 groups were compared for demographic distribution, radiographic and clinical data to investigate the predictive factors of intraoperative MEP monitoring "true positive" alert.

**Results**
The overall incidence rate of "true positive" alert was 0.49%. The variables of age, body mass index, and number of levels fused were similar between the 2 groups. Compared with the control group, the group with "true positive" alert has more pre-op neurological deficit, more congenital kyphoscoliosis, more spinal cord anomalis, more VCR osteotomy, higher coronal and sagittal deformity angular ratio (DAR), larger pre-op sagittal curve and smaller post-op sagittal curve. Logistic regression analysis showed that sagittal DAR (OR: 2.752; p = 0.001), pre-op Neurological deficit (OR: 0.339; p = 0.035) and VCR osteotomy (OR: 0.319; p = 0.025) were independent predictive factors of intraoperative "true positive" MEP alert.

**Conclusion**
The occurrence of an intraoperative MEP monitoring "true positive" alert in patients with scoliosis who undergo surgical treatment is most likely multifactorial and is related to sagittal DAR, pre-op neurological deficit and VCR osteotomy.

| Predictors | Odds ratio | 95% confidence interval | | P-value |
|---|---|---|---|---|
| | | Lower limit | Upper limit | |
| Sagittal DAR | 2.752 | 1.876 | 4.235 | 0.001 |
| Pre-op Neurological deficit | 0.339 | 0.124 | 0.926 | 0.035 |
| VCR osteotomy | 0.319 | 0.118 | 0.864 | 0.025 |

## 161. Comprehensive Complication Classification for Adult Spinal Deformity: Impact on Patient Outcomes

*Eric O. Klineberg, MD; Alex Soroceanu, MD, MPH; Gregory M. Mundis, MD; Han Jo Kim, MD; Michael P. Kelly, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Virginie LaFage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Sigurd H. Berven, MD; Lawrence G. Lenke, MD; Shay Bess, MD; International Spine Study Group*

**Summary**
A complications classification system that encompasses the global burden of complications with consistency and without bias is needed. This study found that complication characteristics and number were correlated to patient health-related quality of life (HRQL) outcomes at 2 yrs. This work will form the basis for a new complication classification for adult spinal deformity (ASD) surgery.

**Hypothesis**
Complication characteristics and number in ASD surgery will correlate with patient HRQL outcomes at 2 yrs.

**Design**
Retrospective review, prospective multicenter observational ASD database.

**Introduction**
Complications are currently classified as either major or minor, but this has very little external consistency, or granularity, and limits its usefulness in predicting outcome metrics and impact of

complications. Grading complications by treatment severity may provide more granular and impactful information.

**Methods**
Retrospective review of a prospective observational cohort study in a multicenter ASD database. Inclusion criteria: ASD (>18yrs), surgical treatment and 2-yr follow-up. Complications were categorized by severity (adverse event/major/minor), intervention (noninvasive, invasive, surgical, death), resolution of complication at time of last follow-up, and timing (table). T-tests and univariate regression analysis was performed. The significance level was p<.05.

**Results**
456/625 patients met criteria, with 324 sustaining at least one complication. Patients with at least one complication had lower 2-yr improvements in HRQL measures (SF-36 PCS 6.91 vs 9.48, p=.012, and SRS-22r 0.79 vs 0.95, p=.03). Univariate analysis revealed that 2-yr HRQL improvement was significantly correlated with maximum (PCS -0.1157, p=0.016) and cumulative (PCS -0.1223, p=.011, SRS -0.1487, p=.03) severity score, maximum (PCS -0.16, p=.001, SRS -0.125, p=.008) and cumulative (PCS 0.1245, p=.0096) intervention score, and number of complications (PCS -0.1159, p=.016, SRS -0.0929, p=.048). Complication resolution also affected HRQL improvement (PCS: resolved complication -2.22, p=.048, unresolved complication -3.12 p=.012, compared to patients without complications).

**Conclusion**
This study found characteristics of complications other than severity that are associated with HRQL improvements. These characteristics include the total number of complications, intervention required, and resolution of complication, and are potentially more objective than classifying complications based simply on severity. This provides the first groundwork to develop a comprehensive complication classification system for ASD, that is less prone to bias and more consistent than current methods of classifying complications.

| Complication Score | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Severity | Adverse Event | Minor | Major | Death |
| Intervention | None | Non-Invasive | Invasive | Surgical |
| Neurologic | Sensory | Motor | Bowel/Bladder | Spinal Cord Injury |
| Impact on Length of Stay | None | <2 days | 3-7 days | >7 days |
| Readmission | No | Yes | | |
| Revision Surgery | No | Yes | | |
| Resolution | Resolved | Unresolved | | |
| Timing | Intra-op | In Hospital | Early Post-Op (<90 days) | Late Post Op (>3 mo - 1 yr) |

## 162. Impact of Congenital Thoracic Spinal Deformities on Cardiopulmonary Function in Patients with Congenital Scoliosis

*Youxi Lin, MD; Jinmei Luo, MD; Wangshu Yuan; Hui Cong, MD; Zheng Li; Jianxiong Shen, MD*

**Summary**
This study revealed the impact of congenital thoracic spine curvature on patients' cardiopulmonary function.

**Hypothesis**
The severity of thoracic curve correlates with cardiopulmonary function in patients with congenital scoliosis.

**Design**
A prospective study.

**Introduction**
Congenital scoliosis led to dysfunction of respiratory system. However, little is known about its impact on exercise capacity of patients. This study aims to investigate the correlation of spinal deformity and exercise tolerance in patients with congenital scoliosis.

**Methods**
A total of 40 patients were included from January 2014 to December 2016. All patients had radiological assessment of the spine, as well as pulmonary function test and cardiopulmonary cycle ergometer test. The radiographic parameters of the spine were measured, and indices of pulmonary function and exercise test was collected. 2-tailed Pearson and Spearman correlation test were performed.

**Results**
26 females aged 17.5±8.2 and 14 males aged 18.9±6.9 years, with thoracic curve of 77.5°±37.1° and 68.5°±40.2° respectively, were included. Major thoracic curvature, thoracic apical vertebral rotation, thoracic apical vertebral translation, number of thoracic vertebra involved and of thoracic vertebra with congenital deformities were significantly correlated with most of static pulmonary function parameters respectively, as shown in forced expired volume in one second(P<0.01, r from -0.629 to -0.521), forced vital capacity(P<0.01, r from -0.688 to -0.546), peak expiratory flow(P<0.05, r from -0.482 to -0.366), vital capacity(P<0.001, r from -0.707 to -0.621), total lung capacity(P<0.001, r from -0.705 to -0.611), residual volume(P<0.05, r from -0.425 to -0.351) and residual volume/total lung capacity ratio(P<0.05, r from 0.421 to 0.514). In cardiopulmonary exercise test, radiographic parameters were significantly correlated with most of the parameters of ventilation, including tidal volume(P<0.05, r from -0.604 to -0.379), respiratory rate(P<0.01, r from 0.441 to 0.621) and breathing reserve both at rest(P<0.01, r from -0.681 to -0.438) and maximum exercise(P<0.05, r from -0.584 to -0.371), but not with minute ventilation. Blood oxygen saturation at maximum exercise(P<0.05, r from -0.524 to -0.374) and its decrease(P<0.05, r from 0.363 to 0.511) were also significantly correlated with radiographic parameters.

**Conclusion**
Although exercise capacity did not correlate to the severity of the thoracic deformity, static pulmonary function test demonstrated respiratory dysfunction, and cardiopulmonary exercise tests revealed decompensation and changes of breathing pattern as thoracic deformities worsened.

Table Correlations Between RadiograpNic Parameters and Pulmonary Function Test/Cardiopulmonary Function Test in Patients with Congenital Scoliosis

| | Major thoracic curvature (deg) (P) | | Major thoracic apical vertebral rotation (Nash-Moe grade) (S) | | Major thoracic apical vertebral translation (cm) (P) | | Number of thoracic vertebra involved (S) | | Number of thoracic vertebra with congenital deformities (S) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | r | P | r | P | r | P | r | P | r | P |
| **Pulmonary Function Test** | | | | | | | | | | |
| $FEV_1$(% of pred.) | -0.629 | <0.001** | -0.521 | 0.001** | -0.548 | <0.001** | -0.694 | <0.001** | -0.583 | <0.001** |
| FVC(% of pred.) | -0.585 | <0.001** | -0.548 | <0.001** | -0.428 | 0.006** | -0.688 | <0.001** | -0.546 | <0.001** |
| PEF(% of pred.) | -0.398 | 0.011* | -0.366 | 0.020* | -0.378 | 0.016* | -0.482 | 0.002** | -0.414 | 0.008** |
| VC(% of pred.) | -0.664 | <0.001** | -0.617 | <0.001** | -0.621 | 0.001** | -0.681 | <0.001** | -0.707 | <0.001** |
| TLC(% of pred.) | -0.699 | <0.001** | -0.684 | <0.001** | -0.611 | <0.001** | -0.675 | <0.001** | -0.705 | <0.001** |
| RV(% of pred.) | -0.425 | <0.001** | -0.339 | 0.058 | -0.351 | 0.049* | -0.240 | 0.185 | -0.348 | 0.051 |
| RV/TLC(%) | 0.463 | 0.008** | 0.432 | 0.014* | 0.388 | 0.028* | 0.514 | 0.003** | 0.421 | 0.016* |
| **Metabolic gas exchange** | | | | | | | | | | |
| Load(% of pred.) | -0.170 | 0.308 | -0.015 | 0.930 | -0.109 | 0.513 | 0.113 | 0.498 | -0.027 | 0.871 |
| $VO_{2peak}$(% of pred.) | -0.067 | 0.690 | 0.135 | 0.419 | -0.067 | 0.691 | 0.130 | 0.437 | 0.000 | 0.999 |
| $VO_{2peak}$ (mL/kg/min) | 0.044 | 0.794 | 0.165 | 0.321 | 0.158 | 0.344 | 0.383 | -0.145 | 0.085 | 0.613 |
| AT(%) | -0.105 | 0.531 | -0.027 | 0.872 | -0.126 | 0.450 | 0.029 | 0.861 | -0.080 | 0.634 |
| RER | -0.040 | 0.810 | -0.109 | 0.515 | 0.050 | 0.766 | -0.146 | 0.382 | -0.065 | 0.696 |
| **Ventilation** | | | | | | | | | | |
| VE(% of pred.) | -0.158 | 0.342 | -0.256 | 0.121 | -0.021 | 0.902 | -0.213 | 0.198 | -0.240 | 0.146 |
| Vt(% of pred.) | -0.466 | 0.003** | -0.461 | 0.004** | -0.379 | 0.019* | -0.537 | 0.001** | -0.604 | <0.001** |
| RR(per min) | 0.534 | 0.001** | 0.494 | 0.002** | 0.529 | 0.001** | 0.441 | 0.006** | 0.621 | <0.001** |
| $BR_r$(%) | -0.557 | <0.001** | -0.438 | 0.006** | -0.439 | 0.006** | -0.681 | <0.001** | -0.537 | 0.001** |
| $BR_t$(%) | -0.433 | 0.007** | -0.408 | 0.012* | -0.371 | 0.024 | -0.584 | <0.001** | -0.526 | 0.001** |
| **Pulmonary gas exchange** | | | | | | | | | | |
| $SpO_{2r}$ (%) | -0.455 | 0.009** | -0.285 | 0.114 | -0.501 | 0.003** | -0.333 | 0.063 | -0.266 | 0.141 |
| $SpO_{2t}$ (%) | -0.524 | 0.003** | -0.464 | 0.010* | -0.575 | 0.001** | -0.374 | 0.042* | -0.471 | 0.009** |
| Δ $SpO_2$(%) | 0.438 | 0.015* | 0.511 | 0.004** | 0.483 | 0.007** | 0.363 | 0.049* | 0.497 | 0.005** |
| Vd/Vt | 0.187 | 0.260 | 0.221 | 0.182 | 0.217 | 0.191 | 0.065 | 0.699 | 0.209 | 0.208 |
| **Cardiovascular system** | | | | | | | | | | |
| HR(% of pred.) | -0.244 | 0.139 | -0.114 | 0.494 | -0.172 | 0.301 | -0.196 | 0.239 | 0.001 | 0.998 |
| $O_2$/pulse(% of pred.) | 0.043 | 0.796 | 0.155 | 0.354 | 0.052 | 0.756 | 0.023 | 0.892 | -0.088 | 0.600 |

(P), 2-tailed Pearson test, (S), 2-tailed Spearman test. *<0.05,**<0.01.

$FEV_1$ = forced expiratory volume in 1 second, FVC = forced vital capacity, VC = vital capacity, TLC = total lung capacity, RV = residual volume, RV/TLC = the ratio of residual volume and total lung capacity.

$VO_{2peak}$ = peak oxygen intake, AT = anaerobic threshold, RER = respiratory exchange ratio, VE = maximum ventilation volume per minute, Vt = maximum tidal volume, RR = maximum respiratory rate, BR = breath reserve (r= at rest, t=at maximum exercise, same below.), $SpO_2$ = oxygen saturation, Δ = change, Vd = dead space ventilation, HR = maximum heart rate , O2/pulse = oxygen pulse.

## 163. Comparison of Iliac and Sacral-Alar-Iliac Fixation in Early Onset Scoliosis at 5.8 years Mean Follow-up

*<u>Ethan Cottrill</u>; Adam Margalit, BS; Cameron Brucker; Paul D. Sponseller, MD, MBA*

**Summary**

This retrospective review of early onset scoliosis (EOS) patients compares the use of sacral-alar-iliac (SAI) screws to iliac-only methods of pelvic fixation at a 2-year minimum (5.8 years mean) follow-up. While both SAI and iliac-only methods corrected major curve, only SAI screws were shown to correct pelvic obliquity with statistical significance. SAI screws also had significantly fewer complications.

**Hypothesis**

SAI screws offer better clinical outcomes compared to iliac-only methods of pelvic fixation in EOS patients at a 2-year minimum follow-up.

**Design**

Retrospective.

**Introduction**

Pelvic fixation in growing constructs is challenged by poor bone, anchor migration, and displacement. The objective of this study was to compare clinical outcomes in EOS patients treated with SAI screws vs. iliac-only methods of pelvic fixation at a 2-year minimum follow-up.

**Methods**

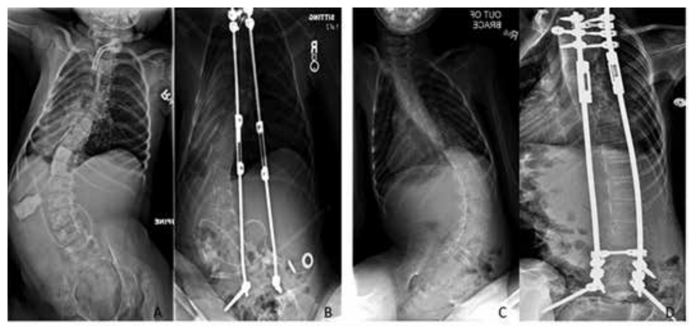
We retrospectively reviewed EOS patients in a single center from 2000-2016. Inclusion criteria were posterior spinal instrumentation with pelvic fixation before 10 years of age and an associated 2-year minimum follow-up. Clinical and radiographic data were analyzed using T- and chi-squared tests, with significance defined as $p<0.05$.

**Results**

7 subjects were included in the iliac-only fixation group (Galveston technique=2, iliac screws=5) and 17 in the SAI group. For the iliac-only group (mean follow-up=6.8 years), pelvic obliquity improved from a mean of 18° at initial presentation to 11° at first instrumentation (p=0.096) to 9° at end follow-up (p=0.060), while major curve improved correspondingly from a mean of 84° to 50° (p=0.002) to 39° (p=0.006). For the SAI group (mean follow-up=5.4 years) at the same time points, pelvic obliquity improved from a mean of 25° to 6° (p<0.001) to 5° (p<0.001), while major curve improved from a mean of 83° to 38° (p<0.001) to 29° (p<0.001). Complications for the iliac-only group were rod breakage (1), pelvic fixation breakage (2) and loosening (3), and superficial (1) and deep infection (3), with corresponding values for the SAI group of 7, 1, 1, 0, 2 (all complications, p=0.04). Neither method was associated with pelvic growth disturbances or neurological deficits.

**Conclusion**

In EOS patients at a 2-year minimum (5.8 years mean) follow-up, both SAI and iliac-only methods corrected major curve. SAI fixation was also shown to correct pelvic obliquity and have fewer complications. This may be due to length and direction of the anchors and abutment on the sciatic cortex of the ilium.




Iliac (A and B) vs. SAI (C and D) pelvic fixation pre- and post-operatively.

## 164. The Incidence and Associated Risk Factors of Thoraco-lumbar Epidural Hematoma Following Adult Trauma

*<u>Ravi Verma, MD</u>; Pedro A Ricart; Steven Fineberg; Kyle Fink; Neel Patel; Jordan Gross, MD; Paul Lucas; David Asprinio; Louis Amorosa, MD*

**Summary**

Our study found the incidence of posttraumatic thoracolumbar epidural hematomas to be 11.4% with elevated INR identified as a risk factor. Additionally, patients with higher INR and Injury Severity Scores had increased risk of cord or dural sac compression due to epidural hematomas.

**Hypothesis**

The objective of our study is to determine the incidence and associated risk factors for epidural hematoma in the setting of thoracic and lumbar spine trauma.

**Design**

Retrospective review of Level I academic medical center's state-mandated, prospectively collected trauma database.

**Introduction**

Very little literature exists examining thoracic and lumbar epidural hematomas caused by trauma. Scoring systems have been introduced to guide treatment recommendations in the setting of thoracic and lumbar spine trauma. The presence of an epidural hematoma was not included in these systems, however they can be associated with spinal cord or dural sac compression and may necessitate surgical decompression.

**Methods**

Institutional Review Board approval was obtained. We performed a retrospective review of all traumas at our institution between 2010 and 2014. Patients with ICD-9 codes for T1 to L5 fractures were further investigated. Patients <18 or >90 years old, or who were without MRI imaging were excluded. Patients who had thoracic and/or lumbar epidural hematoma (TLEH) were compared to those who had no epidural hematoma (NEH). A subgroup analysis of the TLEH arm was performed, based on the presence (CC) or absence (NCC) of cord or dural sac compression. Age, gender, race, admitting INR/PT, PTT, and injury severity score (ISS) were compared between groups.

**Results**

1185 patients were identified with thoracic or lumbar fractures, of which 578 subjects had MRI. 66 patients (11.4%) were found to have a posttraumatic TLEH. Age, gender, and race were found to be similar in both analyses. Higher INR levels were found to be significant in the TLEH group (1.17 vs 1.09; p<0.05). In the subgroup analysis of the TLEH group, the CC group had higher ISS (18.9 vs. 17.6; p<0.05) and INR (1.3 vs. 1.07; p<0.05) when compared to the NCC group.

**Conclusion**

The incidence of thoracic and lumbar spinal epidural hematoma following trauma was found to be 11.4% in our study, of which 42.4% presented with spinal cord or dural sac compression. We found that the greater the INR was in the setting of spine trauma, the higher the risk of spinal epidural hematoma. Additionally, patients with TLEH who had higher ISS and INR levels, had increased chances of having dural sac compression. Age, gender, race, admitting ISS or PTT had no effect on the incidence of epidural hematoma.

# Notes

# Notes

# E-POSTER ABSTRACTS

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges OrthoPediatrics for their support of the Annual Meeting & Course Announcement Board and Beverage Breaks.

The Goldstein Award is presented to the best clinical research poster at the 52nd Annual Meeting. The Moe Award is presented to the best basic research poster at the 52nd Annual Meeting. The Program Committe selects the nominees based on abstracts and selects the winners based on final posters.

## *200. T-spine Correction Has a Significant Effect on Bracing Success and is Ameliorated by Combined Night and Daytime Bracing Through Different Brace Models


*Peter Bernstein; Andreas Selle; Falk Thielemann; Jens Seifert*



**Summary**

This cohort study displays the beneficial effect of combined nighttime and daytime bracing with separate types of braces - thus enhancing the effectivity of the non-operative management of idiopathic scoliosis.


**Hypothesis**

Additional nighttime bracing ameliorates bracing results in idiopathic scoliosis.

**Design**

Prospective cohort study

**Introduction**

We present results of a double-brace strategy, in which the nighttime bending brace (NTB) allows for the application of higher thoracic correction forces whereas a modified Cheneau type daytime brace (DTB) secures retention of the curves.

**Methods**

All data has been gathered prospectively. From January 1997 through May 2004, a total of 111 patients were included (idiopathic scoliosis, compliant, curves between 25° and 40°). The follow-up (FU) of patients was scheduled to be 2 years after brace treatment termination at maturity (Risser stage 4). Angles are expressed in means with the standard deviation, significance was tested via t-test. Percentage of correction was calculated, angles were grouped: 1 (<=25°), 2 (26°-35°), 3 (36°-45°) and 4 (>45° or surgery).

**Results**

Patients averaged 12.8 years (±1.8 years) at brace initiation with COBB angles of 27.4° (±6.3°, T-spine) and 25.2° (±6.7°, L-spine). Best achieved in-brace correction was 16.6° (±6.3°, T-spine), 13.4° (±6.4°, L-spine) in DTB and 10° (±6.5°, T-spine), 10.5° (±5.6°, L-spine) in NTB. Follow-up (FU) COBB-angles of 24.6° (±9.6°, T-spine) and 19.5° (±9.3°, L-spine) were measured. Average bracing duration was 3.6 years (±1.2). Of the 111 compliant patients, all have completed therapy. 22 patients did not show at the scheduled FU, 19 patients will have their FU in the upcoming 2 years. 60 patients (85%) had improved or maintained their angles, 10 worsened, 3 had to be operated. T-spine initial COBB-angles correlated with T-spine FU COBB angles ($r^2$=0.4), whereas this correlation could not be seen in the L-spine ($r^2$=0.2). DTB correction did not differ between FU-groups 1–4. NTB mediated T- and L-spine correction was significantly higher (p=0.003-0.045) in FU groups 1&2 (63-66%, 53-66%) than in FU groups 3&4 (45-58%, 44-61%).

**Conclusion**

Compliant brace treatment can achieve successful results in the majority of patients, when pronounced T-spine correction - as with NTB - is secured. Low COBB angles at follow-up were correlated with high NTB-mediated corrections, but not with DTB-mediated corrections. We therefore recommend a double-brace strategy in order to ameliorate brace therapy results.

| | | COBB angle at FU (grouped) | | | |
|---|---|---|---|---|---|
| | | < 25° | 26°-35° | 36°-45° | >45° or surgery |
| | | n | n | n | n |
| Initial COBB angle at start of therapy (grouped) | <= 25° | 13 | 3 | 0 | 1 |
| | 26°-35° | 26 | 14 | 4 | 2 |
| | 36°-45° | 2 | 2 | 3 | 0 |

## *201. Comparison of SRS 22r Scores in Non-Operated AIS Patients with Curves ≥ 40° Grouped by Age > or < 18 Years


*W. Timothy Ward, MD; James W. Roach, MD; Tanya S Kenkre, PhD; Maria Mori Brooks, PhD*



**Summary**

SRS 22r scores are similar in surgical range AIS patients younger or older than 18 years who elect to forgo surgery, providing evidence that functional outcomes of non-operatively treated patients do not deteriorate as adolescents enter adulthood.


**Hypothesis**

SRS 22r scores in patients with curves ≥ 40° treated non-operatively do not substantially diminish as patients reach age 18 and older.

**Design**

Observational cohort study.

**Introduction**

The SRS 22r scores of patients less than age 18 years with curves ≥ 40° electing to forgo surgery has not been published, and a comparison of SRS 22r scores between non-operated surgical range patients older or younger than age 18 is not available. This study reports the scores for non-operated surgical range patients younger than age 18 and contrasts these scores to older patients who have also forgone surgery.

**Methods**

Consecutive AIS patients, under the care of a single surgeon, with curves ≥ 40°, electing not to undergo surgical treatment were considered for the study. Those who consented to participate and who had completed at least one SRS 22r form and an x-ray were included in the study. X-rays and SRS 22r scores of 192 patients less than age 18 were compared to those of 149 patients older than age 18. The age groups were compared using t-tests. Linear associations within each age group were tested with Pearson correlation coefficients.

**Results**

Comparisons of the younger versus older group included average age at last SRS (years): 15.1±1.6 vs. 23.4±5.2, average time since curve was ≥ 40° (years): 2.7±2.0 vs. 9.8±5.2, and average Cobb angle of largest curve (degrees): 49.0±7.6 (range 40–77) vs. 50.0±7.6 (range 40-72). Statistically significant differences ($p<0.05$) were found in favor of the younger group for Pain: 4.3±0.7 vs. 3.9±0.7, Function 4.7±0.4 vs. 4.5 ±0.6, Self-Image 4.0±0.7 vs. 3.8±0.7, Mental Health 4.2±0.7 vs. 4.0±0.6, and for Total Average SRS Score 4.2±0.5 vs. 4.0±0.5 but not for Satisfaction domain. However when published minimally clinically important difference (MCID) values for selected SRS 22r domains are considered, Pain and Function alone showed a conclusive clinical difference by Carreon anchor MCID but not by Bago MCID values. Pearson correlation coefficients between age group and SRS 22r domain and Total scores and between curve magnitude and SRS 22r domain and Total scores showed weak linear associations ($r < 0.19$).

**Conclusion**

SRS 22r scores of non-operated patients with surgical range curves are not generally clinically worse among young adults than among younger adolescents, providing further evidence that non-surgical approaches for AIS should be considered.

## *202. Residual Lumbar Curve Accelerates Lumbar Intervertebral Disc Degeneration in Patients with Adult Idiopathic Scoliosis

*<u>Satoshi Suzuki, MD, PhD</u>; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Ayato Nohara, MD; Noriaki Kawakami, MD, DMSc; Takehiro Michikawa, MD; Ken Ishii, MD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD; Kota Watanabe, MD, PhD*

**Summary**

This study indicated that the severity of IVDD was significantly higher in patients with lumbar curve than that without. These results suggest that the residual lumbar curve in AIS could have accelerated IVDD in adulthood.

**Hypothesis**

Residual lumbar curve in adult patients with idiopathic scoliosis (AdIS) cause intervertebral disc degeneration (IVDD).

**Design**

Retrospective radiographic analysis with evidence level IV

**Introduction**

Asymmetrical loading on intervertebral disc is one of factors that cause IVDD. However, the influence of residual spinal deformity on lumbar disc is not well understood in AdIS patients.

**Methods**

One hundred-four AdIS patients (7 male, 97 female, mean age 31.8 years) who underwent preoperative whole spine MRI and standing X-ray were included. All patients were diagnosed to have scoliosis in adolescent. We divided the patients into two groups depends on the lumbar curvature, that is group A consisted of patients with lumbar modifier A and group C consisted of modifier C. Lumbar disc was assessed by one radiologist and one spine surgeon using following criteria, Grade 0: normal, Grade1a: partial lower intensity, 1b: mild-moderate lower intensity, 1c: moderate-severe lower intensity containing no signal area, Grade 2: no signal. Logistic regression model was used for statistical analysis.

**Results**

Inter-rater agreement for the evaluation of each disc between the 2 readers were ranged from 0.77 to 0.91. The mean Cobb angle of the main curvature was 66±16° in group A, 56±15° in group C. The numbers of IVDD including Grade 1 and 2 at each disc were as follows (group A, group C). L4/5: (23 cases (56.1%), 40 cases (63.5%)), L5/S1: (19 cases (46.3%), 32 cases (50.8%)), indicating no significant difference between the two groups. The details of IVDD at L4/5 were as follows, 1a: 8 cases (19.5%),, 1b: 10 cases (24.4%), 1c: 5 cases (12.2%) in the group A, and 1a: 6 case (9.5%), 1b: 12 cases (19.0%), 1c: 21 cases (33.3%) , 2: 1 cases (1.6%) in group C, showing that the severity of IVDD was significantly higher in the group C than that it the group A ($p=0.01$). We confirmed the same result at L1/2,2/3,3/4, but not at L5/S1 ($p=0.22$).

**Conclusion**

The results of the study indicated that residual lumbar curve in AdIS have accelerated IVDD. For residual lumbar curves, correction and fusion need to be consider before reach to maturity.

## 203. Does Improved Sagittal Alignment with Advancement of Posterior Corrective Fusion Affect Quality of Life in AIS Patients?

*<u>Daisuke Sakai</u>; Akihiko Hiyama, MD; Masahiko Watanabe, MD PhD*

**Summary**

AIS patients treated with simultaneous translation on two rods technique compared to conventional rod rotation on single rod at 2-year follow-up showed improved sagittal profile which may account for better QOL outcome measures.

**Hypothesis**

Can improved sagittal profile by posterior corrective spinal fusion in treatment of AIS provide better clinical outcome?

**Design**

Single center, retrospective case series.

**Introduction**

Recent advances in posterior spinal implants, instruments and techniques have enabled surgeons to treat AIS patients with improved sagittal profile. Since 2012, we have adopted simultaneous translation on two rods (ST2R) technique, where load on each instrumented vertebrae is reduced, using all uniplanar reduction screws and 6.0 CoCr rods. The 2-year surgical outcome of patients treated with ST2R was retrospectively compared with patients treated with conventional single rod rotation technique (RR) using 5.5mm Ti alloy rods.

**Methods**

Fifty-four AIS Lenke type I patients (ave. main Cobb 51.5 degrees) were reviewed. Thirty-two patients (ave. age 14.8, Cobb 53.5) received ST2R and 22 patients (ave. age 15.1, Cobb 49.6) were treated with RR by a single surgeon at a single institute. Change in main coronal Cobb angle and sagittal profiles (cervical lordosis angle (C2-C7 angle; CL), T1 slope, thoracic kyphosis angle (Th5-12; TK), lumbar lordosis angle (L1-S1; LL), sacral slope (SS), C7 plumb line (C7PL)) were compared by radiograph along with outcome measurement by SRS-22 and SJ27 questionnaire (AIS-specific outcome measurement made by the Japanese Scoliosis Society).

**Results**

Postoperative coronal main Cobb angles in both ST2R and RR treated patients achieved significant correction (ave. reduction rate ST2R: 72.2%, RR:63.1%). Postoperative average sagittal profiles in ST2R treated patients showed improved TK compared to patients treated with RR (ST2: CL-4.2, T1 slope 14.3, TK21.8, LL47.4, SS36.3, C7PL 9.3mm, RR: CL-3.6, T1 slope 12.4, TK15.3, LL44.2, SS34.6, C7PL 10.2mm)($p<0.05$). While result of average SRS-22 questionnaire scores demonstrated minimal difference between ST2R treated patients versus RR treated patients (ST2R: function 4.7, self-image 4.5, satisfaction 4.6, RR: function 4.3, self-image 4.2, satisfaction 4.4), SJ27 demonstrated significantly improved QOL scores in pain and shoulder stiffness domains.

**Conclusion**

Advancement in implant development and techniques for posterior corrective fusion surgery has broadly offered improved correction of sagittal alignment, which may account for providing a better QOL for AIS patients.

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## 204. Surgical Outcomes Based on Cobb Angle Stratification in AIS patients with Minimum Curve of 70° and Above

*<u>Gabriel KP Liu, FRCS(Orth), MSC</u>; Husam W Najjar, MBBS; Jun Hao Tan, MBBS; Leok-Lim Lau; Hwee Weng Dennis Hey, MD; Joseph Thambiah; Hee-Kit Wong, MD*

**Summary**

The study reports a trend of ↑ing op time, bld loss & hosp stay in AIS pts with ↑ing curve size. Yet, similar surgical outcomes are noted suggesting curves of 70-90° behave alike.

**Hypothesis**

To analyse potential differences in outcomes based on curve magnitude with minimum of 70° curve.

**Design**

A retrospective review of all AIS cases ≥70° Cobb angle operated in a university hospital at their 2nd postop. year.

**Introduction**

Surgical management outcomes of AIS ≥70° have been described. Few reports had analysed outcome based on curve size.

**Methods**

Pt`s were divided into 3 groups: A:70-79°, B:80-89° & C:≥90°. Clinical, radiographic, surgical complications & outcome data using SRS24 & pain VAS scores were analysed with SPSS software.

**Results**

20 pt`s (1♂,19♀) with an average age of 13.8(11-18)yrs & Risser stage of 3.1(0-5) were reviewed. Grp A (n=8) had an av. Cobb angle of 73(71-76)°. All Grp A had posterior surgery; 3 of 8 had Ponte osteotomies. None had anterior surgery. The average curve flexibility was 42(18-57)% with mean correction of 53(45-62)° and mean correction rate of 72(61-86)%. Grp B (n=9) had a mean Cobb angle of 83(80-89)°. 6 cases had post. fusion (of whom 1 had Ponte) & 3 had ant. and post. surgeries (none had Ponte). Av. flexibility was 31(14-51)%. Av. correction was 60(42-72)°. Correction rate was 70(51-86)%. Grp C (n=3) had a mean Cobb angle of 102(90-117)°. 2 cases had post. fusion (none had Ponte) and 1 had ant. and post. spinal surgery with Ponte. Av. flexibility was 29(27-32)%. Av. correction was 74(68-82)°. Correction rate was 72(68-79)%. Univariate analysis showed that op. time (grp A: 349min, grp B: 457min, grp C: 435min, $p=0.009$) & hospital stay (grp A: 5.8(5-9)d, grp B: 7.1(4-15)d, grp C: 7.7(7-9)d, $p=0.035$)↑ as the curve size ↑. A trend towards more blood loss (683 vs 781 vs 1267 mL) & blood transfusions as the curve size ↑ was found in the study. No pt had intraop. neuromonitoring signal change. There was no significant difference among the 3 groups in terms of correction loss, SRS score & VAS score at 2 years postop. No implant failure occurred. In grp A 1 pt. had superficial wound infection (WI) & was treated conservatively, & 1 developed distal adding on. In grp B 1 pt. had deep WI & required surgery.

**Conclusion**

There`s a trend towards longer operative time, blood loss & hospital stay as curve size ↑ & an observation of more anterior release was noted in curves≥80°. Interestingly, similar trends of correction rate, postop. complications & outcome scores were found in these large curves suggesting that curves 70° to 90° may behave similarly & have similar expected outcomes. Larger cohort study is needed to validate these findings.

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## 205. Surgical Complications and Radiation Burden with Adolescent and Juvenile Idiopathic Scoliosis: A Population-Based Cohort Study

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**Summary**

Pediatric scoliosis surgery has a high complication rate and radiation burden for patients. Juvenile idiopathic scoliosis (JIS) is associated with higher surgical revision rates and radiation burden than adolescent idiopathic scoliosis. Earlier diagnosis and follow-up of adolescent idiopathic scoliosis (AIS) is associated with reduced surgical revision rates but higher radiation burden.

**Hypothesis**

Pediatric scoliosis surgery has high revision rates, with this rate higher for JIS patients given greater amount of remaining growth when compared to AIS patients. Patients who undergo bracing followed by surgery are exposed to higher radiation burden during their treatment course.

**Design**

Population-based retrospective cohort study

**Introduction**
Complications after pediatric scoliosis surgery can be disabling and associated with high burden for patients. Previous research has shown a wide range of complication rates. Treatment involves imaging modalities that have potentially high radiation burden. It is important to understand the radiation burden and the likelihood of revision surgery for these patients in order to allocated resources and advise patients accurately.

**Methods**
A province-wide healthcare database was used to identify patients diagnosed with scoliosis before age 9 (JIS) and between ages 9 and 16 (AIS). Scoliosis patients were compared to reference groups of patients in the same age group with complaints of back pain with no underlying scoliosis. Scoliosis patients were subgrouped based on treatment received. Healthcare utilization data from a single-tiered public healthcare system was obtained for all patients involved.

**Results**
A total of 22,676 AIS and 3,520 JIS patients were identified. Back pain reference group included 3,338,005 patients for AIS and 3,695,387 patients for the JIS reference group. Average follow-up time was 12.4 years for JIS and 13.2 years for AIS patients. Patients treated with surgery alone had a revision surgical rate of 15.7% and 38.1% for AIS and JIS patients respectively. Concern for infections requiring irrigation and debridement occurred in 2.7% and 4.2% of patients. Revision rates for patients undergoing bracing first before surgery was lower for AIS patients (8.5%) and higher for JIS patients (43%). CT imaging occurred more than twice as often in this patient sub-group.

**Conclusion**
Pediatric scoliosis surgery is associated with a high revision rate, with this rate being significantly higher in juvenile patients that have greater growth potential. Earlier diagnosis and follow-up of AIS patients allows for reduced surgical complication rates but is associated with much higher radiation burden.

## 206. A Comparison of Maximal Voluntary Ventilation (MVV) and Forced Vital Capacity (FVC) in AIS

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**Summary**
While both MVV and FVC are significantly correlated with thoracic Cobb angle, 96% of patients could reliably perform MVV in orthopaedic clinic, but less than half (47%) could perform FVC.

**Hypothesis**
MVV is more practical to use than FVC for assessing pulmonary function of AIS patients in the outpatient setting.

**Design**
Prospective, single center

**Introduction**
Evidence of compromised pulmonary function in patients with severe AIS is well established. The American Thoracic Society (ATS) has established criteria for the reliability and accuracy of pulmonary function tests (PFTs), including for both MVV and FVC. We sought to test 2 parameters, MVV and FVC, using incentive spirometry to determine if pulmonary function can be assessed in an outpatient scoliosis clinic.

**Methods**
92 AIS patients with thoracic curves of 20 degrees or greater were enrolled. Patients performed PFTs using the Carefusion MicroLoop Spirometer. MVV (liters/min) and FVC (liters) values were collected. Results were considered reliable or "passing" when ATS incentive spirometer guidelines were met.

**Results**
88/92 patients (96%) met ATS criteria for the MVV test and 43/92 patients (47%) met criteria for the FVC test. Both MVV ($r=-0.38$, $p<0.01$) and FVC ($r=-0.38$, $p=0.01$) were significantly correlated with Cobb angle.

**Conclusion**
Twice as many AIS patients could perform a MVV test in the orthopaedic clinic compared to an FVC test. MVV and FVC correlated closely with Cobb angle.

## 207. Lenke 5C AIS Curves: Surgical Decision Making and Factors Determining Fusion of the Thoracic Curve for Experienced Spine Surgeons

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**Summary**
In this multi-instutional cohort of experienced spinal deformity surgeons (>10 years), Lenke 5C curves with a main thoracic cobb angle of greater than 35° were associated with a highly significant rate ($p<0.001$) of fusion of both thoracic and lumbar spine.

**Hypothesis**
Aside from preference, experienced surgeons consider specific criteria to perform thoracic fusion for Lenke 5C curve

**Design**
Retrospective review

**Introduction**
In a multi-institutional database, in ~40% of Lenke 5C curves, both thoracic and lumbar curves are fused. However, no uniform selection criteria exist to determine when to perform a non-selective (NS) (thoracic and lumbar curves), versus a selective (S) (lumbar curve only) fusion. The objective is to identify the variables associated with NS fusion for Lenke 5C curves among experienced spinal deformity surgeons.

**Methods**
Patients with Lenke 5C curves undergoing instrumented posterior fusion with a 2 year minimum follow-up period were identified from a large multicenter database. Factors favoring NS fusion were identified by univariate analysis. In subsequent sub analysis, the cohort was divided into 2 surgeon groups: NS dominant – surgeons more likely to perform a NS fusion (UIV T6 or higher)

& S dominant- surgeons more likely to perform a S (TL/ L) fusion. Surgeons performing <10 cases and those exclusively performing S or NS fusions were excluded to avoid preferential bias. Binary logistical regression analysis for individual variables for both NSD group and NS was performed.

**Results**
220 Lenke type 5 patients were identified, of which 82 (37.3%) underwent NS fusion & 138 (62.7%) underwent S fusion. Spinal deformity surgeon experience ranged from 10 to 40 years. Overall, surgeon preference was the only significant predictor for NS fusion. There were 77 (45.5%) & 90 (26.7%) patients in group 1 and 2 respectively, who underwent NS fusion. For NSD group, significant variables for NS fusion included: upper T Cobb & bend radiographs, T Cobb, L Cobb and bend radiographs, T apical translation, & T rib hump. For SD group, significant factors were: T Cobb & bend, T apical translation, & T rib hump. Binary logistic regression resulted in T Cobb ≥35° & T rib hump for Group 1, & TC ≥35°, T apical translation & T rib hump for Group 2. (Fig 1)

**Conclusion**
In the overall analysis, surgeon preference was the significant predictor for determining S or NS fusion for Lenke 5C curves, thus, exhibiting continued equipoise on the treatment of this curve pattern. However, further sub analysis of both SD and NSD spine deformity surgeons, thoracic cobb angle greater than 35° was associated with fusion of both thoracic and lumbar spine.

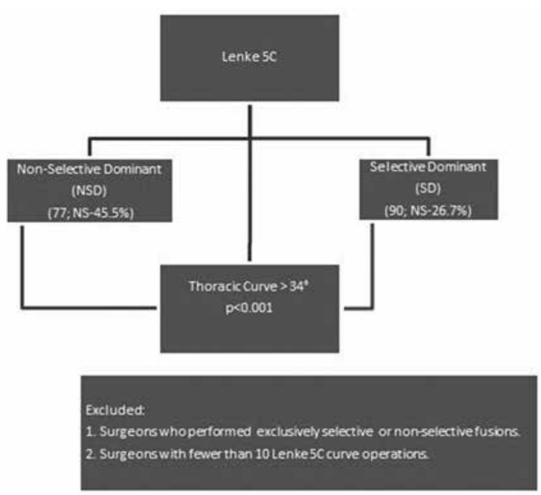


**Figure 1: Associations among Selective Dominant Surgeons versus Non-Selective Dominant surgeons for 5C curves**

## 208. Effect of Direct Vertebral Rotation in Single Thoracic Adolescent Idiopathic Scoliosis: Better Deformity Correction, More Rotational Correction with Limited Fusion Segments

*Dong-Gune Chang, MD, PhD; Jae Hyuk Yang, MD; Ravish S Patel, MS; Seoung Woo Suh, MD, PhD*

**Summary**
Optimum direct vertebral rotation (DVR) is very important factor for deformity correction, vertebral body rotation and preservation of motion segments in the treatment of adolescent idiopathic scoliosis (AIS). Inappropriate maneuver during the DVR may result in under or over-correction of the major and compensatory curves. It may aggravate the unfused curve and cause trunk imbalance and decompensation. However, there have been no reports on the effect of DVR regarding the surgical outcomes in the treatment of thoracic AIS.

**Hypothesis**
Selective thoracic fusion (STF) with pedicle screw instrumentation (PSI) could have better curve correction and more vertebral rotation with DVR in patients with thoracic AIS.

**Design**
A retrospective comparative study.

**Introduction**
There is a paucity of literature demonstrating the long term surgical outcomes of DVR in patients with thoracic AIS.

**Methods**
AIS patients with single thoracic curves (n = 110) treated by STF from neutral vertebra (NV) to NV or NV-1 with a minimum 2-year follow-up were retrospectively analyzed. The patients were divided into two groups; non-DVR (n = 63) and DVR groups (n = 47). Patients in non-DVR group underwent STF with bilateral rod derotation maneuver (RD) while patients in DVR group underwent STF with bilateral RD and DVR maneuver.

**Results**
There was significant difference in the number of fused segments between the non-DVR and DVR groups (P < 0.000). There was significant difference in the curve magnitude of main thoracic curve postoperatively (P = 0.001) and at the last follow-up (P = 0.006) between the non-DVR and DVR groups. However, there was no significant difference in proximal thoracic (PT) and lumbar curve postoperatively (PT curve: P = 0.186, lumbar curve: P = 0.155) and at the last follow-up (PT curve: P = 0.250, lumbar curve: P = 0.060) between the two groups. There was significant improvement of LIV tilt and disc angle and relatively well maintained during the follow-up period in both groups. There was no significant difference of rotation of apical vertebra and end vertebra preoperatively (P > 0.05). However, there was significant difference postoperatively (P < 0.05), and at the last follow-up (P < 0.05).

**Conclusion**
DVR could effectively achieve better deformity correction, and more rotational correction with reduced number of fusion segments. However, it is important that DVR should be applied in proper direction with adequate force.

## 209. When Do We Have to Fuse L4 in Major Thoracolumbar and Lumbar Adolescent Idiopathic Scoliosis?

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**Summary**
Fusion level may influence postoperative surgical outcomes, and improper fusion level may result in under or over-correction of major and compensatory curves which could cause trunk imbalance and decompensation. We compared the surgical outcomes regarding the distal fusion level (L3 versus L4) in rigid curve with major thoracolumbar and lumbar (TL/L) adolescent idiopathic scoliosis (AIS) using rod derotation (RD) with direct vertebral rotation (DVR) following pedicle screw instrumentation (PSI).

**Hypothesis**
Rigid curve with major TL/L AIS may need to extend at L4 in order to avoid the adding-on phenomenon and gain better radiographic results.

**Design**
A retrospective comparative study.

**Introduction**
There is little information on the surgical outcomes with regard to the distal fusion level (L3 versus L4) in rigid curve with major TL/L AIS.

**Methods**
AIS Patients in rigid curve (L3 does not cross CSVL or L3 rotation is more than grade II by preoperative lumbar bending X-rays) with major TL/L curves (n=28) treated by PSI with RD and DVR methods with a minimum 2-year follow-up were divided into L3 and L4 groups by lowest instrumented vertebra (LIV). Adding-on or a lowest instrumented vertebral tilt of more than 10° or coronal balance (CB) of more than 15 mm were considered unsatisfactory results.

**Results**
The groups were not found to be statistically different in operative time, blood loss and follow-up period. There was no significant difference in TL/L (major) curve between the L3 and L4 groups postoperatively (P = 0.162) and at the last follow-up (P = 0.952). Additionally, there was no significant difference in thoracic (minor) and compensatory (caudal) curve postoperatively (thoracic curve: P = 0.426, compensatory curve: P = 0.762) and at the last follow-up (thoracic curve: P = 0.620, compensatory curve: P = 0.762). The overall prevalence of unsatisfactory results was 42.9% (12/28 patients), and the prevalence was 61.1% (11/18) in the L3 group and 10% (1/10) in the L4 group, which was significantly different (P < 0.05).

**Conclusion**
An unsatisfactory result occurred more often in the L3 group than in the L4 group, and an unsatisfactory result had a significant influence on progression of TL/L (major) and distal compensatory curves, which closely correlated with deterioration LIV disc angle in the L3 group. Therefore, if the curve is rigid, LIV should be extended to L4 so as to avoid the adding-on phenomenon in the treatment of major TL/L AIS using RD with DVR following PSI.

## 210. Pain in Adolescent Idiopathic Scoliosis (AIS): Comparing the SRS-22r with the Patient Reported Outcomes Instrument System (PROMIS) – Pain Interference (PI) Score

*Brian A. Kelly, MD; Scott John Luhmann, MD; Davin Cordell, MD; Munish C. Gupta, MD; Michael P. Kelly, MD*

**Summary**
73 Consecutive, non-operated, AIS patients were administered the SRS-22r Pain and PROMIS-PI computer adaptive testing (CAT) test. PROMIS-PI was more sensitive to changes in pain scores relative to age-matched norms. PROMIS-PI reported more moderate/severe pain than SRS-22r. As baseline pain may affect outcomes, further research into the effect of PROMIS-PI on outcomes scores is needed.

**Hypothesis**
PROMIS-Pain Interference will allow for more detailed information regarding pain domain HRQOL in AIS than the SRS-22r instrument.

**Design**
Retrospective cohort

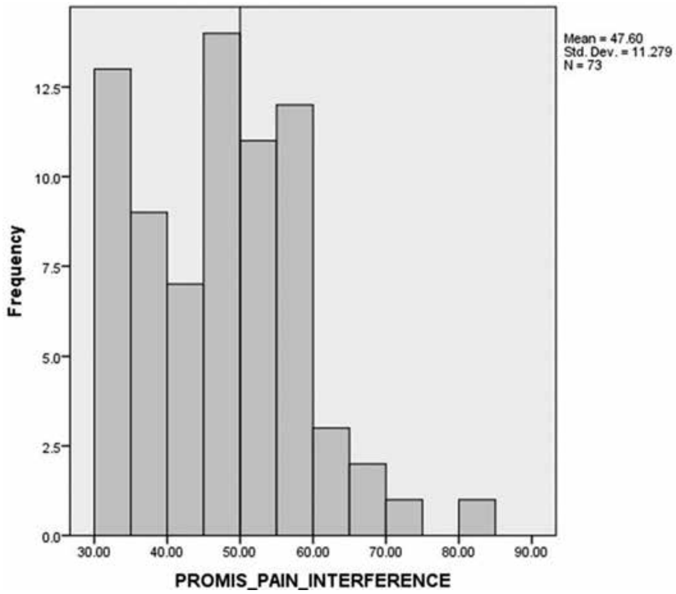
**Introduction**
PROMIS has been developed to offer HRQOL that may be used across diseases to allow for general reporting of outcomes. AIS is generally believed to be a painless condition, though a small proportion of patients do present with pain. HRQOL after surgery may be lower in these patients and accurate identification of AIS patients with antecedent back pain is necessary.

**Methods**
Outpatient visit records were used to identify consecutive patients seen for ICD-9-CM 737.30 and records were reviewed to confirm the diagnosis of AIS. Patients completed the PROMIS-PI CAT and SRS-22r instrument. Standard demographic and radiographic measures were collected. PROMIS-PI scores were normal (¬¬< 50), mild (>50, <60), moderate (>60, <70), or severe (>70). SRS-22r were categorized as non-painful (>3) or painful (<3) as previously described. Spearman correlations were calculated.

**Results**
73 Patients were identified (Male: 17, Female: 56, Mean age 14.2). Lenke Type 1 curves were the most common (31/73, 42.5%) followed by Type 5 (16/73, 21.9%) and Type 3 (14/73, 19.2%). Mean coronal Cobb measurement was 46.3 (R: 12-104). Median SRS-22r Pain domain score was 4.2 (R: 2.0-5); median PROMIS-PI was 48.2 (R:32.2-83.1). 4/73 (5.5%) were characterized as Painful AIS by SRS-22r. With PROMIS-PI, 23/73(31.5%) were characterized as mild, 5/73 (6.8%) were moderate, and 2/73 (2.7%) were severe pain(FIGURE). PROMIS-PI and SRS-22r pain were strongly correlated (r=-0.77) and no correlation existed between pain scores and Cobb measurements.

**Conclusion**
Using the PROMIS-PI CAT, only 43/73 (58.9%) of AIS patients reported normal pain scores. Almost 10% reported moderate/severe pain (7/73). Using the SRS-22r instrument, only 4/73(5.5%) reported pain with their AIS. As preoperative pain may influence

both the decision to have surgery and the outcomes of surgery, further investigations into the severity of pain using a generalized measure, such as the PROMIS-PI, are needed.




## 211. Reducing Blood Transfusion in Paediatric Scoliosis Surgery: Reporting Fifteen Years of a Multidisciplinary, Evidenced Based, Quality Improvement Project

*Alastair Dick; Jonathan Lucas, MD; Thomas Ember; Shirley Lyle, Spr; Richard J. Pinder; Claire Mallinson*

**Summary**
Fifteen year review of over 1000 paediatric scoliosis cases demonstrating sustained reduction in transfusion rates following introduction of a care pathway focussed on reducing blood transfusion.

**Hypothesis**
The introduction of a multidisciplinary blood-transfusion care pathway can reduce the need for blood transfusions in paediatric scoliosis surgery.

**Design**
Retrospective review of our institution's prospectively recorded spinal surgery database and transfusion database including all cases of scoliosis surgery in patients under 18 between 2000 and 2015.

**Introduction**
Paediatric scoliosis corrective surgery can involve substantial bleeding and has historically been associated with high rates of transfusion of blood products. Our aim was to evaluate the efficacy of a blood transfusion reduction care pathway introduced in 2006 including: nurse-led clinics facilitating preoperative haemoglobin optimisation, intraoperative cell-salvage, the use of tranexamic acid, and a transfusion criteria awareness programme.

**Methods**
Retrospective review of our institution's prospectively recorded spinal surgery database and transfusion database including all cases of scoliosis surgery in patients under 18 between 2000 and 2015.

**Results**
1086 procedures were included in the analysis. Overall 26.0% of patients received a transfusion. 45.5% of patients with neuromuscular scoliosis (n=354) received a transfusion compared with 11.4% in idiopathic scoliosis (n=563) ($p<0.001$). For years 2000-2005 (n=168) the transfusion rate was 71.4%, 2005-2010 (n=385) 17.1% and 2010-2015 (n=533) 18.6% ($p <0.001$). For those patients transfused the mean total volume of blood products transfused was 8.2 units, 4.0 and 2.2 respectively ($p<0.001$). The mean volume of packed red cells transfused was 4.6 units, 2.4 units and 1.8 units respectively ($p<0.001$). Transfusion volumes in neuromuscular scoliosis compared to idiopathic were mean 11.9 units vs 4.0 in 2000 to 2005 ($p<0.001$), 4.5 units vs 4.1 in 2005-2010 and 2.4 units vs 1.9 in 2010-2015. Total perioperative haemoglobin drop was unchanged over time at 36.3g/L, 35.0g/L and 38.0g/L respectively.

**Conclusion**
We have demonstrated over a fifteen-year period that the introduction of a multifaceted, multidisciplinary pathway can dramatically and sustainably reduce the need for blood transfusions and their attendant risks in paediatric scoliosis surgery. These data lend weight to the adoption of such a care pathway in paediatric scoliosis surgery.

## 212. Thoracic Cobb, But Not Kyphosis Correction, has a Strong Correlation with Lumbar Cobb Correction in Selective and Non-Selective Thoracic Lenke 3, 4, and 6 patients

*Vishal Sarwahi, MD; Stephen F. Wendolowski, BS; Jesse Galina, BS; Jon-paul Dimauro, MD; Beverly Thornhill, MD; Yungtai Lo, PhD; Terry D. Amaral, MD*

**Summary**
This study evaluates the correlation between lumbar and thoracic Cobb correction in selective thoracic fusion (STF) and no-STF (NSTF) in Lenke 3, 4, and 6 patients. Lumbar correction had a "strong" correlation with thoracic correction and a "weak" correlation with thoracic kyphosis.

**Hypothesis**
Correction of lumbar Cobb correlates to thoracic Cobb correction in Lenke 3, 4, and 6 patients

**Design**
Ambispective review

**Introduction**
STF is often considered in patients with double major curves where the curves are comparable in size. While spontaneous lumbar curve correction occurs, it's correlation with the degree of thoracic Cobb correction, kyphosis and it's comparison to longer fusions is not well studied.

**Methods**
Ambispective chart and XR review of patients who underwent PSF from 2005-2016. Lenke 3, 4, and 6 were included. Preop,

postop, and follow up data was collected. STF and NSTF were included in this study. Wilcoxon rank sum test, Fisher's exact test, and Spearman's correlation analyses were used.

**Results**

89 patients were reviewed, 73 NSTF and 16 STF. Groups were similar in age (14.5 vs 14.6yo, p=0.78), height (63.2 vs 62.4in, p=0.48), weight (133.1 vs 120.3lbs, p=0.23), preop thoracic Cobb (60 vs 51.7, p=0.08) and kyphosis (29 vs 32.5, p=0.97). Postop thoracic (20.1 vs 22.2, p=0.93) and lumbar Cobb (14.3 vs 14.9, p=0.82) were similar, as were kyphosis (30.7 vs 26.9, p=0.25), lordosis (47.4 vs 45.5, p=0.55), and coronal balance (-2.8 vs -0.3, p=0.54). Percent correction of the lumbar curve in NSTF was borderline significant (71.7 vs 57.8, p=0.055). This was despite significantly larger preop lumbar Cobb (49 vs 35.9, p= 0.001). In both groups, lumbar correction showed a 'strong' correlation with thoracic correction (NSTF: r=0.68, p<0.001; STF: r=0.77, p<0.001). However, the percent Cobb correction was similar between the two groups (66.8 vs 66, p=0.28). Increase in kyphosis occurred more often in STF (63 vs 54%, p=0.55), which, correlated 'weakly' with lumbar Cobb correction (STF: r=0.31, p=0.31; NSTF: r=-0.01, p=0.91). Of the 16 STF patients, only 7 had an increase in kyphosis. No significant difference in spontaneous lumbar curve correction occurred with changes in postop kyphosis (14.9 vs 17.2, p = 0.94).

**Conclusion**

Thoracic Cobb correction 'strongly' correlates with lumbar Cobb correction in Lenke 3, 4, and 6 patients undergoing STF or NSTF. Despite similar percent thoracic Cobb correction, significantly better lumbar Cobb correction occurs in NSTF. STF is advantageous for maintaining lumbar flexibility, but is limited by the amount of spontaneous lumbar curve correction.

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## 213. Prevalence, Location, Type, and Predictors of Neck and Back Pain in an Underserved Population of Adolescent Idiopathic Scoliosis.

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**Summary**

Back pain can be associated with adolescent idiopathic scoliosis (AIS). Certain populations may have a higher prevalence of pain due to psychosocial influences. This study shows that AIS patients in underserved communities have a high prevalence of pain with mental status being an independent predictor.

**Hypothesis**

AIS patients in underserved communities have a high prevalence of pain.

**Design**

Retrospective review of prospective observational cohort

**Introduction**

The prevalence of back pain associated with AIS is reported to be between 12-33%. However, our observations of care in an underserved community have led us to believe that this population has a higher prevalence of pain complaints. This study evaluates the prevalence, location, type, and predictors of pain in AIS patients in this population.

**Methods**

This is a prospective study of patients (10-25 y/o) who visited a single surgeon clinic for the evaluation of primary AIS. Patients had a full series of radiographs and completed surveys consisting of patient reported outcomes [Scoliosis Research Society (SRS)-30, Spinal Appearance Questionnaire (SAQ) and Body Image Disturbance Questionnaire (BIDQ)]. Patients defined the location and type of pain on the SRS-30 drawing schematic. Location and type of pain were detailed using descriptive analyses. Curve magnitude and type were compared vs pain location and type. Binary logistic regression analysis was used to determine predictors of pain.

**Results**

52 patients (15±3 y/o, 82.7% F, BMI: 20.3±3.3, 67.3% Black, 17.3% Hispanic) were included. The average main curve was 31.3º±17.3. 39 out of 52 patients (75%) reported pain [neck (11.5%), back (69.2%), or gluteal (3.8%)]. Patients who reported pain were similar in age, gender, BMI, coronal and sagittal profiles compared to those without pain (Main Cobb: 32.7 vs 27.6º, C7PL: 14.9 vs 12 mm; p>.05). The most frequent complaint was lower back pain only (19.2%), upper back only (9.6%) or mid back pain only (9.6%). The most prevalent type of pain was deep ache (46.2%) followed by stabbing (21.2%), pins and needles (17.3%), and burning (11.5%). 87.5% of patients live with >3 house members reported back pain vs 55% of patients living with ≤3 (p<.01). Regression model revealed that lower SRS-30 Mental score was the only predictor of pain [OR: 3.45 (1.07-11.15), p<.05].

**Conclusion**

Three out of four patients with AIS in an underserved population reported neck, back, and/or gluteal pain. These patients had similar demographics and radiographic profiles to those without pain. Mental status and psychosocial influences seem to play an important role in the clinical presentation of AIS patients.

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## 214. Cervical and Global Sagittal Alignment in Patients with Lenke Type 1 or 2 Adolescent Idiopathic Scoliosis: A Long-Term Post-Operative Follow-Up Study

*Ryoji Tauchi; Noriaki Kawakami, MD, DMSc; Tesuya Ohara, MD; Toshiki Saito, MD; Ayato Nohara, MD*

**Summary**

We analyzed 78 patients of Lenke type 1 or 2 adolescent idiopathic scoliosis about the relationship between post-operative cervical sagittal alignment and global spinal alignment after a follow-up period of more than 10 years. An improvement in pre-operative cervical alignment from kyphosis to lordosis or straight at the final follow-up was significantly correlated with thoracic kyphosis, T1 slope angle, LLL, and the apex position of thoracic kyphosis (below T8).

**Hypothesis**
Preoperatively, most of the patients with AIS Lenke type 1 or 2 have kyphotic cervical alignment. However, cervical alignment could be changed on the long-term follow up period. If these patients get appropriate global sagittal alignment after surgery, their cervical alignment would recover to be lordotic finally.

**Design**
Retrospective case series study

**Introduction**
The relationship between cervical kyphosis and adolescent idiopathic scoliosis (AIS) has been evaluated in several studies. The purpose of this study was to analyze the relationship between post-operative cervical sagittal alignment and global spinal alignment after a follow-up period of more than 10 years.

**Methods**
This retrospective study included 78 patients (mean age 14.6 years) with Lenke type 1 or 2 AIS who underwent posterior spinal fusion. Cervical alignment was classified into four types: lordosis, straight, sigmoid, and kyphosis. Pre and post- operative and final follow-up radiographs were used to measure the following clinical parameters: main curve angle, cervical sagittal angle (C2–7 Cobb angle), T1 slope angle, thoracic kyphosis, lumbar lordosis, C2–7 sagittal vertical axis (SVA), C7 SVA, the apex position of kyphosis, and the length of lumbar lordosis (LLL).

**Results**
Preoperatively, cervical alignment was classified as lordosis in 5 patients, straight in 6, sigmoid in 12, and kyphosis in 55. At the final follow-up, cervical alignment was classified as lordosis in 16, straight in 6, sigmoid in 20, and kyphosis in 36. At the final follow-up, the patients in the pre-operative kyphosis group who improved to lordosis or straight (n=9) were compared with those who remained kyphosis (n=36). Thoracic kyphosis (44.9° vs. 26.7°), LLL (5.6 vertebrae vs. 6.9 vertebrae), the apex position of kyphosis (thoracic apex is below T8 or above), and T1 slope angle (25.2° vs. 10.4°) were significantly associated with cervical alignment type.

**Conclusion**
An improvement in pre-operative cervical alignment from kyphosis to lordosis or straight at the final follow-up was significantly correlated with thoracic kyphosis, T1 slope angle, LLL, and the apex position of thoracic kyphosis.

## 215. Pain is the Greatest Preoperative Concern for Patients and Parents Prior to Spinal Fusion for Adolescent Idiopathic Scoliosis

*Priscella S. Chan, MS; David L. Skaggs, MD, MMM; Austin E. Sanders, BA; Paul D. Choi, MD; Vernon T. Tolo, MD; Lindsay M. Andras, MD*

**Summary**
Pain was the most frequent concern reported by patients and parents, but not surgeons, prior to spinal fusion. Aside from neurologic injury, which was a top concern for all groups, there was little overlap in parent, patient and physician concerns.

**Hypothesis**
Patients, parents and surgeons prioritize concerns before spine surgery differently.

**Design**
Prospective single center

**Introduction**
Despite much research on outcomes for posterior spinal fusion (PSF) in adolescent idiopathic scoliosis (AIS), little is reported about preoperative fears or concerns. Our purpose was to evaluate patients' and parents' concerns so they can be addressed with appropriate preoperative counseling.

**Methods**
AIS patients undergoing PSF, their parents, and surgeons, were prospectively enrolled and asked to complete a survey on their concerns about surgery at their preoperative appointment.

**Results**
Forty-eight patients and parents completed surveys. Four attending pediatric spine surgeons participated and submitted 48 responses. Mean age of patients was 14.2 years. On a scale of 0-10, mean level of concern reported by parents (6.9) was higher than that reported by patients (4.6). Surgeons rated the procedure's complexity on a scale of 0-10 and reported a mean of 5.2. Neither patients' nor parents' level of concern correlated with the surgeons' assessment of the procedure's complexity level (R=0.19 and 0.12, p=0.20 and p=0.42 respectively). The top 3 concerns for patients were pain (25%), ability to return to activities (21%), and neurologic injury (17%). The top 3 concerns for parents were pain (35%), neurologic injury (21%), and amount of correction (17%). The top 3 concerns for surgeons were postoperative shoulder balance (44%), neurologic injury (27%), and LIV selection (27%). Patients reported the same concerns 23% of the time as parents, and 17% of the time as surgeons. Parents and surgeons reported the same concerns 21% of the time.

**Conclusion**
Pain was the greatest concern for both patients and parents but was rarely listed as a concern by surgeons. Parent and patient level of concern did not correlate to the surgeon's assessment of the procedure's complexity. Neurologic injury was a top concern for all groups, but otherwise there was little overlap between physician, patient and parent concerns.

## 216. Effect of Lowest Instrumented Vertebrae for Spinal Fusion of Scoliosis on Gait Kinematics

*Karen M Kruger, PhD; Sahar Hassani; Joseph Krzak, PT; Adam Graf, MS; Peter F. Sturm, MD; Kim W. Hammerberg, MD; Purnendu Gupta, MD; Gerald F Harris, PhD*

**Summary**
Appropriate selection of the lowest instrumented vertebrae is crucial to ensure positive outcomes after surgical management of patients with scoliosis. This study shows that lowest instrumented vertebra (LIV) does not have a significant impact on trunk and lower extremity gait kinematics.

**Hypothesis**
We hypothesized that the spinal fusion would result in stiffer gait (as measured by joint range of motion) and that individuals with fusion to more distal LIV (L3 and below) would experience more joint stiffening during gait.

**Design**
Prospective study

**Introduction**
The purpose of the study was to determine the effect of spinal fusion on gait in individuals with adolescent idiopathic scoliosis (AIS) and compare the results of fusion to the lower lumbar spine versus mid lumbar spine.

**Methods**
This was a prospective study of two subgroups with AIS, L2+ (fusions to L2 and above, n=14) and L3- (fusions to L3 and below, n=24). Whole body gait analysis was performed preoperatively and at one year and two years following surgery. Comparisons were made between the L2+, L3-, and an age-matched control group at each time point (linear mixed model, SAS, p=0.05).

**Results**
Slight kinematic differences were observed compared to the control group (Figure 1). Coronal trunk range of motion was lower than the control group in both groups at all test points. Range of motion was lower in the L3- group than in the L2+ group at the 1 year follow-up visit. There were few changes in gait pre and post op despite fusion levels. There was decreased sagittal range of motion in the pelvis at all test points with no differences between the two surgical groups.

**Conclusion**
Although, appropriate selection of the LIV is crucial to ensure positive surgical outcomes of patients with AIS., few clinical studies have addressed how choice of LIV influences possible reductions in motion. These results showed the most significant difference between the LIV groups was the L3- group showed less hip rotation range of motion.

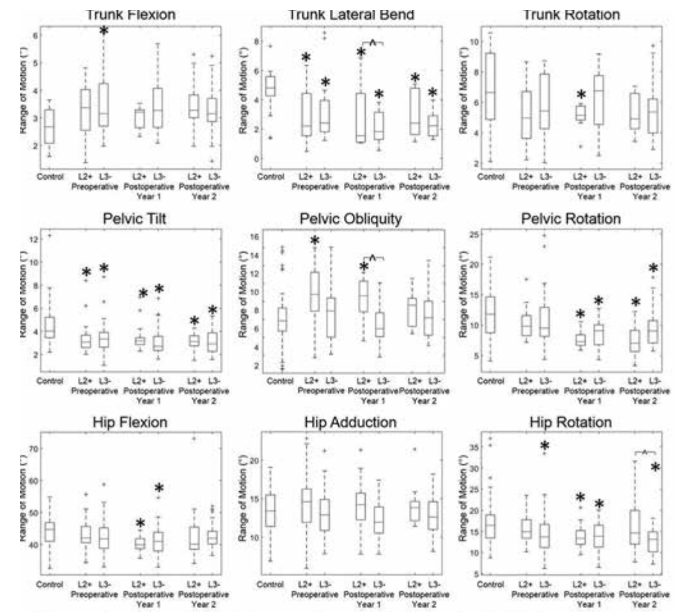



**Figure 1:** Comparison of range of motion during gait for LIV groups at each visit. *=statistical difference from control group, ^=statistical difference between LIV groups

## 217. Predictors for Postoperative Shoulder Balance in Lenke 1 Adolescent Idiopathic Scoliosis: A Prospective Cohort Study

*Alberto O. Gotfryd, MD, PhD; Maria Fernanda Silber Caffaro, MD, PhD; Robert Meves; Osmar Avanzi, MD*

**Summary**
The present study aimed to analyze the predictors of the shoulder balance after surgery in Lenke 1 patients.

**Hypothesis**
Mild deformities of the shoulder before surgery predicts contralateral elevation; Rotation of the proximal thoracic curve predicts shoulder balance; The clavicle angle correlates with clinical deformity.

**Design**
Prospective cohort study

**Introduction**
Shoulder balance is one of the major indicators of success after surgical treatment in patients with AIS [1-5]. In Lenke 1 [6] curves, spontaneous correction of the proximal curve is expected to occur after main thoracic (MT) fusion, leading to balanced shoulders. However, this is not always observed [7].

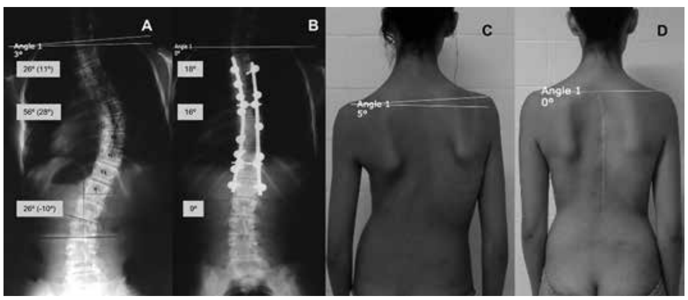
**Methods**
In this prospective cohort study, all consecutive patients with Lenke 1 AIS, operated between July 2009 and July 2011, were included. The shoulder balance was determined using the bi-acromial angle. The following radiographic measurements were determined: Cobb angles and preoperative flexibility of the proximal (PT) and main thoracic (MT) curves, clavicle angle (CA), T1 tilt, PT curve rotation, PT apical vertebra translation (AVT), and postoperative correction of the PT and MT curves. Possible correlations between the radiographic and clinical data, such as level of arthrodesis and amount of coronal correction, were investigated.

**Results**

A total of 51% of patients had unbalanced shoulders before surgery (right side higher). Two years after surgery, 30.77% showed unbalanced shoulders (p < .001). However, 17.1% of patients presented with a higher left shoulder, a reversion of the initial deformity.

**Conclusion**

In Lenke 1 patients, the correction of the main thoracic curve promoted spontaneous correction of the proximal thoracic curve. The presence of mild or no asymmetry of the shoulders prior to surgery was predictive of a reversal of the deformity after the fusion of the main thoracic curve. In cases with a higher right shoulder and absence of abnormalities in the sagittal plane view, the correction of the main right thoracic curve could be enough to balance the shoulders. No correlation was found between shoulder balance and the amount of correction of the PT and MT curves.




## 218. T5-T12 Kyphosis Is a Predictor of Main Curve Coronal Flexibility in Mature Patients with Adolescent Idiopathic Scoliosis

*Vicente García; Jesus Burgos Flores, MD, PhD; Carlos Barrios, MD; Ignacio Sanpera, MD, PhD; Gabriel Piza Vallespir, MD, PhD; Eduardo Hevia; Luis Miguel Anton Rodrigalvarez, PhD; Miguel Castro Torre, MD*

**Summary**

This study evaluates coronal curve flexibility in relation to thoracic sagittal profile and maturity stage in Lenke type 1A AIS. Coronal upper and lower hemicurves showed different stiffness in mature patients, being the upper significantly more rigid. T5-T12 thoracic kyphosis is a good predictor of coronal MT flexibility.

**Hypothesis**

Upper and lower hemicurves in Lenke type 1A curves exhibit different stiffness, which is dependent of maturity and thoracic sagittal profile.

**Design**

Retrospective preoperative radiological review of Lenke 1A curves.

**Introduction**

It is generally accepted that curve stiffness increases with age and curve magnitude. The lost of flexibility of upper and lower hemicurves in relation to sagittal thoracic profile have scarcely addressed. This study evaluates the influence of maturity and thoracic kyphosis on stiffness at the upper and lower coronal hemicurves, and at the Apex ± 2 segment.

**Methods**

The preoperative films of 59 Lenke 1A AIS patients were retrospectively reviewed. Cobb angles of the main thoracic curve (MT), upper and lower hemicurve (UHC and LHC), Apex -2 to Apex +2 segment, and T5-T12 sagittal profile were measured on standing and bending XR. Patients were stratified as immature (n=14, Risser 0-1) and mature (n=45, Risser 2-5).

**Results**

Cobb MT, 57.5º (UHC, 29.9º; LHC, 28.5º). Bending films showed a mean MT correction of 36.7%. T5-T12 sagittal profile was a predictor of MT flexibility in all cases, particularly in mature patients (r=-0,504; p<0.001; Figure 1). LHC Cobb was superior to UHC in immature cases (p<0.01). Both curves showed similar flexibility (mean dif.=3.7%) in these cases. However, UHC was stiffer than LHC in mature patients (29.4% flexibility vs 44.3%) /mean dif.=18.4%; p<0.001; Figure 2). Apex ±2 was the most rigid segment contributing in similar low proportion to the whole bending in mature and immature patients (10.3% versus 11,7%).

**Conclusion**

T5-T12 thoracic kyphosis is a good predictor of coronal MT flexibility. This relationship is specially evident in mature patients in which upper coronal hemicurve is more rigid than lower counterpart. Coronal curve flexibility was not related to curve severity, and apex level.

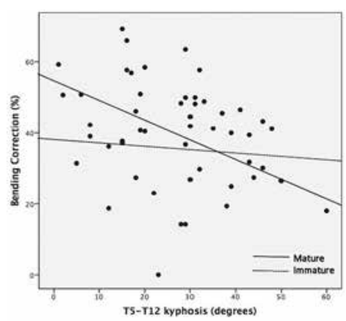



Figure 1

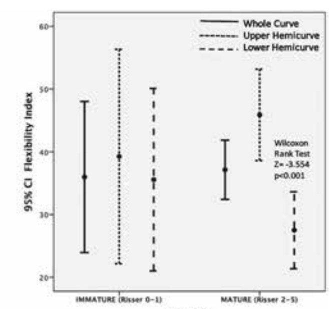



Figure 2

## *219. Impact of Iliac Instrumentation on the Quality of Life of Patients with Adult Spine Deformity

*Mar Perez Martin-Buitrago, MSc; Javier Pizones, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Montse Domingo-Sàbat, PhD; Alba Vila-Casademunt, MSc; Emre R. Acaroglu, MD; Ibrahim Obeid, MD; Frank S. Kleinstueck, MD; Ahmet Alanay, MD; Ferran Pellisé, MD, PhD; Mariana Díaz-Almirón; European Spine Study Group*

**Summary**

Some patients with adult spinal deformity require pelvic fixation with iliac screws; however, it's not clear if the effect on the sacroiliac joint has any impact on patient's quality of life. 129 patients were divided into 2 groups based on the presence or absence of iliac screws. Their quality of life was similar between groups after surgery, at 6 months, and at 2-years'follow up. Accordingly, we couldn't find a negative effect of iliac instrumentation on patient's quality of

**Hypothesis**
Iliac instrumentation can affect the quality of life of the patients with adult spine deformity.

**Design**
Retrospective cohort analysis of data collected prospectively in an adult deformity multicenter database.

**Introduction**
Surgical treatment of adult spine deformity has been shown to improve function and relieve pain. Some patients require pelvic fixation with iliac screws, and this may affect some of their daily activities and functions.

**Methods**
A retrospective cohort analysis of data collected prospectively in an adult deformity multicenter database. Inclusion criteria were patients with a long arthrodesis of at least 8 levels and whose lowest instrumented vertebrae (LIV) were L5 or below. We analyzed age; Cobb angle; coronal and sagittal balance, number of levels instrumented; health-related quality of life questionnaires (HRQLq) ODI and COMI; and physical domains of SRS22 and SF-36 before surgery, at 6 months, and at 2 years' follow-up. Statistical analysis was performed with Student's t-test and Mann-Whitney U test.

**Results**
A total of 129 patients met the inclusion criteria. They were separated into 2 groups: "Iliac yes", with the LIV at the Ilium (N=104), and "iliac no," with the LIV at L5/S1/S2 (N=24). Prior to surgery, both groups were homogeneous for all variables except age and Cobb angle. The group "iliac yes" were older: Me=66 years (IQR= 59,25 to 71,00), while group "iliac no": Me=56 years (IQR= 46,00 to 69,50) (p=0,008) and Cobb angle was larger in "iliac no": Me=45º (IQR=35,00 to 56,00), than in "iliac yes": Me=31,00º (IQR=18,00 to 48,00) (p=0,019). The number of fused levels was larger in "iliac yes", x=12,6 (sd=3,4), than in "iliac no," x=10,9 (sd=3,0) (t=2,28, p=0,020). No statistically significant differences were found in the other analyzed parameters either at 6 months or at 2-years' follow up.

**Conclusion**
Both groups were fairly homogenous and comparable. Iliac instrumentation was more frequent in longer arthrodesis and older patients. The HRQLq scores were similar in both groups preoperatively and at follow up. Therefore, with the currently available tools, we cannot state that iliac instrumentation has a negative influence on patient's quality of life.

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## *220. Alignment Change in Fixed Segment After ASD Surgery

*Tomohiro Banno, MD; Tomohiko Hasegawa, MD, PhD; Yu Yamato, MD, PhD; Sho Kobayashi, MD, PhD; Daisuke Togawa, MD; Go Yoshida; Tatsuya Yasuda, MD; Shin Oe, MD; Yuki Mihara, MD; Hiroki Ushirozako; Yukihiro Matsuyama, MD, PhD*

**Summary**
Loss of alignment can occur in fixed segment, resulting in global spinal malalignment. The use of commercially pure titanium rods and residual sagittal malalignment postoperatively are risk factors for loss of spinal correction.

**Hypothesis**
Alignment change in fixed segment after adult spinal deformity surgery affected clinical outcome.

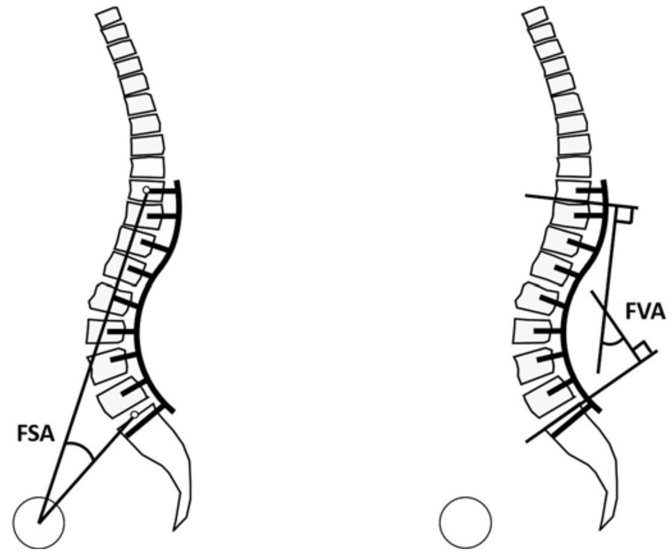
**Design**
Retrospective study

**Introduction**
Change in fixed segment alignment influences global spinal alignment; yet, risk factors of this loss have not been determined. The aim of this study was to determine the prevalence of loss in fixed segment alignment after corrective surgery for adult spinal deformity (ASD) and to identify associated risk factors.

**Methods**
Sixty-three patients with ASD (8 men and 55 women; mean age, 68.0 years), who underwent corrective fusion from the lower thoracic spine to the pelvis and completed the 2-year follow-up, were retrospectively analyzed. Change in alignment early postoperatively and at 2-years postoperatively was evaluated using two novel measurements, the fixed segmental angle (FSA) and fixed vertebral angle (FVA). The predictive value of the following parameters was evaluated: age, sex, body mass index (BMI), high grade osteotomies, rod material, screw loosening, spinopelvic parameters (T1 pelvic angle [TPA], sagittal vertical axis [SVA], pelvic tilt [PT], lumbar lordosis [LL], thoracic kyphosis [TK], and proximal junctional kyphosis [PJA]), and Oswestry Disability Index (ODI) scores.

**Results**
A 2.4º change in FSA and -3.1º in FVA was identified at 2-years postoperatively, with higher intra- and inter-rater reliability for FSA. Using the minimal detectable change in FSA, patients were classified into 2 groups: (+) loss (FSA >3°) and (–) loss (FSA ≤3°). Correction loss occurred in 17 patients, these patients having a greater BMI, higher rate of high grade osteotomies, higher rate of commercially pure titanium (CP) rods implanted, higher rate of screw loosening, higher pre- and postoperative TPA, and higher TPA, SVA and PT at 2-years, compared to patients without correction loss. CP rods and postoperative TPA were independent predictive factors of postoperative correction loss.

**Conclusion**
The loss of sagittal fixed segment alignment was relatively high at 27%, and could be lowered by avoiding use of CP rods and restoring optimal sagittal alignment intraoperatively.




## *221. Disability 2 years After Surgery for Adult Spinal Deformity (ASD) Can Be Reliably Predicted at 6 months' Follow-up

*Miquel Serra-Burriel; Ferran Pellisé, MD, PhD; Susana Núñez Pereira, MD, PhD; Montse Domingo-Sàbat, PhD; Alba Vila-Casademunt, MSc; Ibrahim Obeid, MD; Ahmet Alanay, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Anne F. Mannion, PhD; European Spine Study Group*

**Summary**
Outcomes of surgical treatment are generally assessed after a minimum 2 years of follow-up (2YFU). Clinical experience suggests that the early outcomes are a good indicator of the longer-term results. This study showed that disability 2 years after adult spinal deformity (ASD) surgery can be reliably predicted during the earlier follow-up. On average, major changes in Disability prediction should not be expected after 6MFU. HRQL score models at 6MFU reliably predict outcomes before 2YFU.

**Hypothesis**
Health-related quality of life (HRQL) scores 2y after ASD surgery can be reliably predicted during earlier follow-up

**Design**
Retrospective review of data in a multicenter (6 sites, 4 countries) prospective ASD database.

**Introduction**
Outcomes of surgical treatment are generally assessed after a minimum 2 years of follow-up (2YFU). Clinical experience suggests that early outcomes are a good indicator of the longer-term results. This study sought to analyze the predictability of 2YFU HRQL scores and to identify the HRQL domains that can be reliably predicted during earlier FU.

**Methods**
HRQL scores (ODI, SF36, SRS22) of surgically treated ASD patients were obtained at baseline, 6, 12 and 24 months after surgery. Linear regression models predicting the 24 month results were fitted for each HRQL instrument and its corresponding domains at baseline, 6MFU and 1YFU including all HRQL data. Models with random effects or site fixed effects specifications were employed, with the latter controlling for site-specific factors that are not explicitly modeled and are stable over time. Precision in predictions was compared across models using $R^2$ values.

**Results**
273 patients (220 female, mean age 53.5 y) with minimum 2YFU were included: mean preoperative Cobb 37.9º (SD23.3), SVA 44.7mm (SD64.8), PT 22.7º (SD11.1), PI 55.5º (SD13.3), GT 27.9º (SD17.5), number of fused segments 9.8 (SD4.2), 42% pelvic fixation, 21% 3-CO, 36% sustained major complications and 29% required revision surgery. 102 linear regression models were fitted (17 HRQL scores; see Table). ODI, SF36 physical functioning, SRS22 function and subtotal score models had the highest $R^2$ values at 6MFU (0.63, 0.61, 0.63, 0.65, respectively) and 1YFU (0.69, 0.72, 0.67, 0.72). Overall, the mean increase in $R^2$ between baseline models and 6MFU was 0.20, while increase in $R^2$ between 6MFU and 1YFU was 0.09, $p<0.001$.

**Conclusion**
Disability at 2YFU after ASD surgery can be reliably predicted much earlier during follow-up. Overall, major changes in Disability prediction after 6MFU cannot be expected. ODI, SF36PF, SRS22F and SRS-subtotal score at 6MFU models can be considered reliable when assessing patient outcomes before 2YFU.

*Table 1 Variance explained at Baseline, 6MFU and 1YFU*

*(Terms expressed in $R^2$ values, Site Fixed-Effects specification.)*

| Score | Baseline | Improve Baseline-6MFU* | 6MFU | Improve 6MFU-1YFU* | 1YFU |
|---|---|---|---|---|---|
| **ODI** | **0.44** | **0.18** | **0.63** | **0.06** | **0.69** |
| SF36BP | 0.27 | 0.15 | 0.42 | 0.08 | 0.50 |
| SF36GH | 0.30 | 0.21 | 0.50 | 0.11 | 0.61 |
| SF36MCS | 0.26 | 0.16 | 0.41 | 0.05 | 0.46 |
| SF36MH | 0.27 | 0.19 | 0.46 | 0.07 | 0.53 |
| SF36PCS | 0.27 | 0.25 | 0.52 | 0.12 | 0.64 |
| **SF36PF** | **0.39** | **0.22** | **0.61** | **0.12** | **0.72** |
| SF36RE | 0.23 | 0.08 | 0.31 | 0.06 | 0.37 |
| SF36RP | 0.23 | 0.15 | 0.38 | 0.15 | 0.53 |
| SF36SF | 0.23 | 0.28 | 0.51 | 0.05 | 0.56 |
| SF36VT | 0.25 | 0.20 | 0.45 | 0.11 | 0.56 |
| **SRS22fun** | **0.50** | **0.14** | **0.63** | **0.04** | **0.67** |
| SRS22mh | 0.33 | 0.17 | 0.50 | 0.07 | 0.57 |
| SRS22pain | 0.34 | 0.19 | 0.53 | 0.09 | 0.63 |
| SRS22satis | 0.09 | 0.27 | 0.36 | 0.19 | 0.55 |
| SRS22SI | 0.16 | 0.31 | 0.47 | 0.10 | 0.57 |
| **SRS22subtot** | **0.42** | **0.22** | **0.65** | **0.08** | **0.72** |

## 222. The Ankle-Pelvic Angle (APA): A Summary Measurement of Pelvic and Lower Extremity Compensation

*Max Vaynrub; Jared C. Tishelman, BA; Samantha R. Horn, BA; Peter G. Passias, MD; Aaron J. Buckland, MBBS, FRACS; Thomas J. Errico, MD; Themistocles S. Protopsaltis, MD*

**Summary**
Adult sagittal spinal deformity (SSD) induces compensatory

changes in the adjacent spine, followed by the pelvis and lower extremities. The T1-Pelvic Angle (TPA) quantifies spinal deformity; erect posture necessitates a geometrically complementary angle in the lower body that varies proportionately to balance the body. The Ankle-Pelvic Angle (APA) increases in SSD patients with lower extremity compensation and decreases with spinal realignment surgery.

**Hypothesis**
Pelvic and lower extremity compensation can be summarized with a single angular measurement that correlates with SSD.

**Design**
Retrospective review of single-center full-body imaging database.

**Introduction**
Adult sagittal spinal deformity (SSD) leads to recruitment of compensatory mechanisms to maintain Dubousset's Conus of Economy. After regional spinal compensation and pelvic tilt are exhausted, lower extremity compensation is recruited. Knee flexion (KA) and ankle flexion (AA) increase to drive pelvic shift (PSh) posterior. We aim to describe a summary angle that incorporates all aspects of lower extremity compensation in a single measurement, to demonstrate its correlation with SSD, and to identify a cutoff value that indicates the presence of compensation.

**Methods**
Patients with spine complaints underwent full-body stereoradiographic imaging from a single center. Spinal and lower extremity alignment was analyzed with existing measures and the ankle-pelvic angle (APA), Figure. Regression analysis was used to represent the predictive relationship between TPA and APA.

**Results**
861 patients (mean age 55.1y, 60.4%F) were analyzed. 37.3% had SSD (TPA>20≥°). Patients with lower extremity compensation had higher APA than those without compensation (21.6 vs 17.7o, p<.001). APA demonstrated strong correlation with TPA (r=.81, p<.001), as well as PT, PSh, knee flexion and AA (r=.98 to .24, all p<.001). Corrected postop TPA correlated with postop APA (R=.87 p<.001). Using linear regression analysis, a TPA of 18.3° and an APA of 19.7° corresponded to the threshold value of lower extremity compensation.

**Conclusion**
APA is a single measure of pelvic and lower extremity compensation for SSD. TPA is a measure of global spinal alignment and APA is a geometrically complementary angle that varies proportionately to SSD and balances the body in erect posture. APA increases in SSD patients with lower extremity compensation and decreases with spinal corrective surgery.

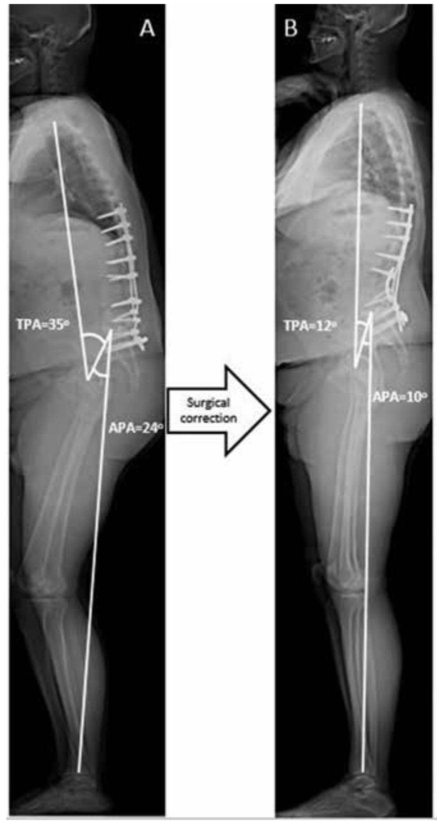



Figure: (A) Preoperative and (B) Postoperative standing full-length radiographs of patient with sagittal spinal deformity. Ankle-Pelvic Angle (APA) is measured as the angle between a line from the bicoxofemoral axis to the midpoint of the sacral endplate, and from there to the ankle malleoli. Surgical correction of sagittal deformity results in decreased TPA, abatement of lower extremity compensation, and complementary decrease in APA.

## 223. Marked Increase in Long Fusion Constructs throughout the United States over a Recent Decade: An Analysis of the Nationwide Inpatient Sample

*Joseph L. Laratta, MD; Comron Saifi, MD; Jamal Shillingford, MD; Joseph M. Lombardi, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD; Steven D. Glassman, MD; Howard S. An, MD*

**Summary**
Advancements in spinal instrumentation and imaging modalities have given surgeons powerful new tools to perform long fusion constructs in spinal deformity surgery which increased 141% between 2004 and 2014. Evolving surgical trends and resource allocation associated with spinal deformity surgery are critical to understanding and improving health care utilization.

**Hypothesis**
Long spinal fusions have increased over the recent decade.

**Design**
Retrospective cohort.

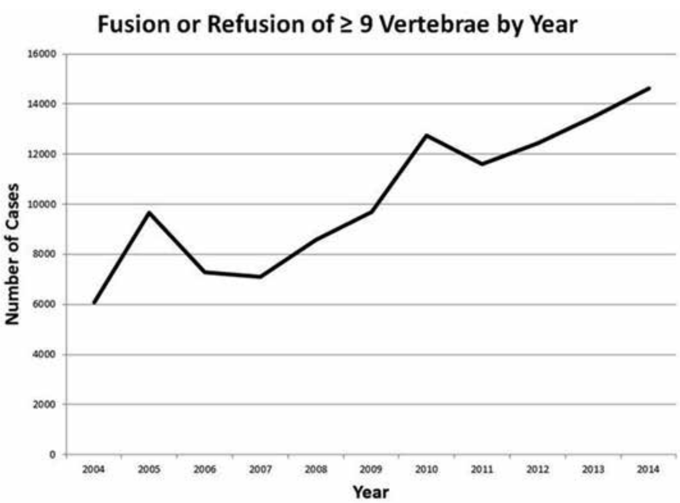
**Introduction**
With increasing biomechanical knowledge of long constructs and a focus on health care utilization and value-based care, it is essential to understand the surgical trends, demographic and economic data involving fusions of 9 or more levels in the United States.

**Methods**
The National Inpatient Sample (NIS) database was queried for patients who underwent fusion or refusion of ≥ 9 vertebrae (ICD-9-CM 81.64) between 2004 and 2014 across 44 states. Demographic and economic data were obtained which included

the annual number of surgeries, age, sex, insurance type, location, and frequency of routine discharge. The NIS database represents a 20% sample of discharges from U.S. hospitals, excluding rehabilitation and long-term acute care hospitals, which is weighted to provide national estimates.

**Results**
In 2014, the estimated total number of patients having fusions involving ≥ 9 vertebrae was 14,615 across the United States. The number of fusion operations involving 9 or more levels has increased 141% from 6,072 in 2004. The mean cost associated with these procedures was $77,265 per case. The mean length of stay (LOS) was 7.4 days in the adult population and 5.3 days in the pediatric population. Based on payer, patients with private insurance comprised 44.1% of patients undergoing fusion of ≥ 9 levels and Medicare comprised another 28.0% of patients.

**Conclusion**
Throughout the United States, there was a 141% increase in the number of long fusion constructs involving ≥ 9 vertebrae between 2004 and 2014. This trend is likely due to the improved safety of the procedure and evolution of spinal instrumentation systems. Further cost analyses are warranted to evaluate the overall societal impact of this marked increase.




## 225. Abnormal Standing Balance in Patients with Symptomatic Spinal Deformities.

Sergio A. Mendoza-Lattes, MD; Monica Paliwal; Christopher M. Graves, MD

**Summary**
Sway path velocity and length during a 30s standing test was used to assess standing balance in patients with symptomatic spinal deformity. A steady increase in path length and sway velocity was observed as the severity of deformity increases, even after controlling for advancing age. Compensation through increasing PT does not significantly affect dynamic standing balance.

**Hypothesis**
Sway path velocity and length increase proportionally to the degree of deformity.

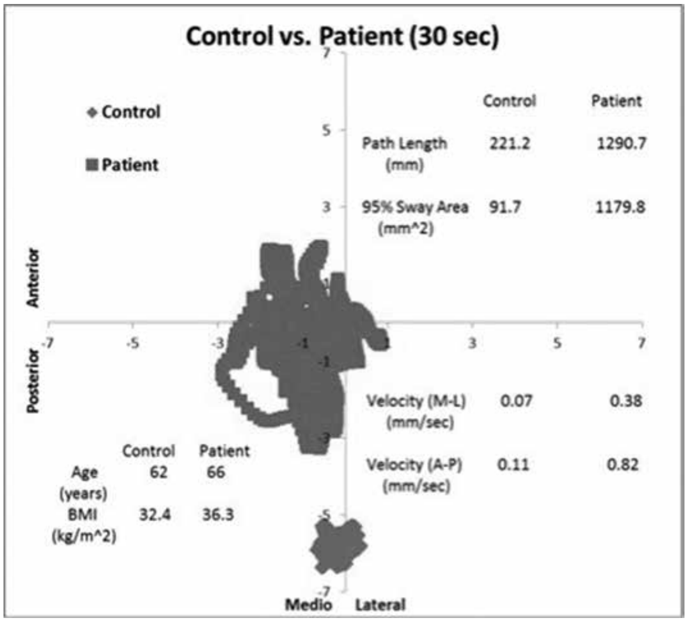
**Design**
Prospective, case-control study investigating the effects of radiographic sagittal imbalance on dynamic standing balance.

**Introduction**
Spinal imbalance and associated compensatory mechanisms are quantified radiographically using sagittal vertical alignment (SVA) and pelvic tilt (PT). Gravity line (GL) measurements using force plates have been previously used to study static standing balance, but no relationship between GL-heel offset and SVA have been found. Compensation through PT, as well as knee and hip flexion and thoracic extension (hypo-kyphosis) contribute to the preservation of this fixed GL-heel distance. However, it is not the exact position of GL, but the ability to maintain GL within the base of support dynamically that is pivotal in stable upright standing, and reflects alterations in the "cone of equilibrium". This has not been investigated in this population. Therefore, dynamic evaluation of GL sway using center of pressure (COP) relative to SVA and PT was investigated.

**Methods**
97 patients with spinal deformities and 58 age-matched controls were included. Radiographic parameters including SVA and PT, were recorded from standing radiographs. A Nintendo Wii Balance Board was used to record COP measurements for 30 seconds and quantified using MatLab software. Sway path length and velocity were calculated and compared between healthy controls and patients with mild, moderate, and severe SVA, with and without PT compensation. Effects of age and sway patterns were also assessed.

**Results**
A steady increase in path length and sway velocity was observed as the severity of deformity increased, even after controlling for advancing age. Path lengths for patients with severe and moderate SVA were approximately 64% and 33% greater than healthy adults.

**Conclusion**
Dynamic standing balance worsens with increasingly positive SVA. Compensatory mechanisms, such as pelvic retroversion, help neutralize SVA but do not improve dynamic standing balance. Increase sway implies higher energy expenditure and thus, reflects on a patient's effort to stand upright, which lead to muscle fatigue and pain. Dynamic COP assessments better characterizes the multifactorial effects of spinal deformities on standing balance.




## 226. A Single Sagittal Parameter for Decision Making in ASD?

Louis Boissiere, MD; Caglar Yilgor, MD; Daniel Larrieu, PhD; Anouar Bourghli, MD; Derek T Cawley, MMedSc, MCh, MRCSI; Takashi Fujishiro, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Ferran Pellisé, MD, PhD; Jean-Marc Vital, MD, PhD; Olivier Gille, MD, PhD; Ahmet Alanay, MD; Ibrahim Obeid, MD; European Spine Study Group

**Summary**

SRS-Schwab classification is a validated complex classification with 27 possibilities regarding sagittal modifiers. In the current study two sagittal modifiers were evaluated for surgical indications: the SRS-Schwab simplified modifier (SSM) and Relative Spinopelvic Alignment (RSA). Both parameters were significant for decision-making but RSA appears to be a more accurate to identify patients.

**Hypothesis**

RSA is a relevant parameter for decision making in ASD.

**Design**

Multicenter, prospective study of consecutive ASD patients.

**Introduction**

The SSM sums up the number of "+", from SRS-Schwab classification, considering PT, SVA and PI-LL. Three sagittal subgroups are identified: aligned: 0+; moderate deformity: 1 to 3 +; severe deformity: 4 to 6+. Despite a good correlation with surgical indication, three radiologic parameters are needed. The RSA is a PI based global parameter (RSA= GT- Ideal GT with Ideal GT = 0.48xPI–15), evaluating the amount of malalignment based on patients ideal GT. Four subgroups are described: negative<-7, aligned -7- 10°, moderate deformity 18-10.1°, severe deformity > 18°. The aim of this study was to evaluate RSA versus SSM accuracy for surgical indication.

**Methods**

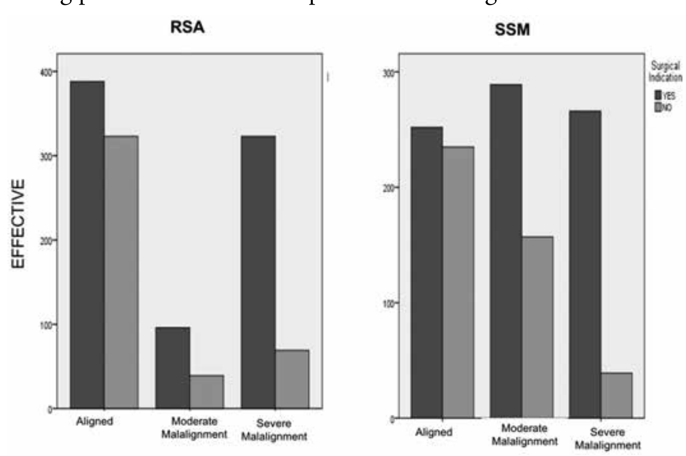
Inclusion criteria were ASD patients, presenting at least one criteria: Cobb ≥ 20°; SVA ≥ 5 cm; TK ≥ 60° or PT ≥ 25°. A total of 1238 patients (431 non-operative and 807 operative) were classified regarding SSM, and RSA. A Chi2 test was performed for surgical indication (operated or not). p<0.05 value was considered significant.

**Results**

For non-operative patients: 235 (55%) were classified as aligned with SSM and 323 (75%) with RSA; 157 (36%) vs 39 (9%) as moderate and 39 (9%) vs 69 (16%) as severe malalignment with each respective modifier. For operative patients: 252 (31%) vs 388 (48%) were classified as aligned, 289 (36%) vs 96 (12%) as moderate and 266 (33%) vs 323 (40%) as severe malalignment with each respective modifier. Both modifiers were significant (p<0.01) for decision making.

**Conclusion**

If both parameters are significant, RSA is more accurate for decision-making. Two categories of patients emerge from this parameter: patients operated for malalignment issues and aligned patients operated for other issues. If RSA is a powerful parameter to delineate operated patients, SSM is less discriminant (45% of non-operative patients are not aligned). RSA is a simple and strong parameter that can help decision making.




## 227. Back and Leg (B&L) Score: An Appropriate Outcome Measure for Adult Spinal Deformity Surgery

Derek T Cawley, Spinal Surgery Fellow; Daniel Larrieu, PhD; Louis Boissiere, MD; Takashi Fujishiro, MD; Anouar Bourghli, MD; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Jean-Marc Vital, MD, PhD; Olivier Gille, MD, PhD; Ferran Pellisé, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; European Spine Study Group

**Summary**

Evaluation of summative back and leg pain (B&L Score) in adult spinal deformity (ASD) has not been performed previously. It provides additional correlation with health-related quality of life (HRQoL) scores and radiographic parameters beyond that of individual scores. Back pain is more correlated with HRQoL scores than leg pain, while leg pain is more correlated with radiological

parameters than back pain. This instrument may provide a simple predictor for pain, disability and HRQoL in ASD.

**Hypothesis**

A summative B&L score provides additional information for patients with spinal deformity thus potentially a useful adjunctive assessment tool.

**Design**

Multicenter, prospective study of consecutive ASD patients.

**Introduction**

Most patients experience clinically important reductions in pain intensity by 3 months post-spinal deformity correction and in physical function (SF36-PCS) and reduction in disability (ODI) by 1 year. Most publications have evaluated back pain and leg pain separately to estimate the pain, HRQoL and sagittal balance improvement after Adult Spine Deformity surgery, but not as a combined entity (B&L score). Aim To evaluate B&L score in the context of pain, HRQoL and sagittal parameters after adult spinal deformity

**Methods**

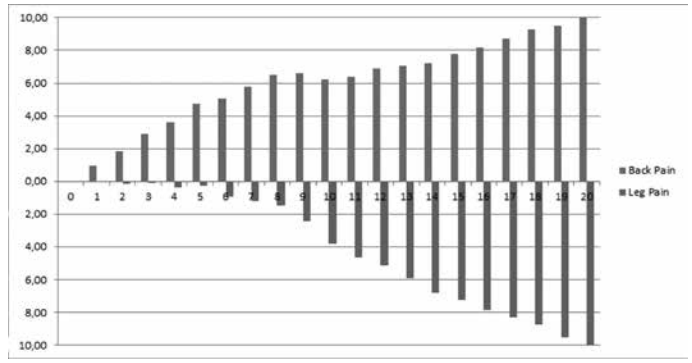
Preoperative pain intensity has been assessed by an 11-points numerical rating scale (NRS) for each of B&L pain and were stratified by classes according their pain level: 3 classes for each of LP and BP (mild pain: 0-4, moderate: 5-7, severe: 8-10) and 4 classes for B&L (very slight: 0-5, mild: 6-10, moderate: 11-15, severe: 16-20). Linear regression analysis was performed to calculate the correlation between pain and radiological parameters (Global tilt: GT, Pelvic Tilt: PT and sagittal vertical axis: SVA) and HRQoL scores (SRS22, SF-36 PCS, SF36 MCS, COMI and ODI). The patients (N=1526) have been stratified into 2 groups: non-operative (N=846) and operative (N=680) patients.

**Results**

There is a significant linear correlation between B&L score and HRQoL and radiological parameters, higher than back or leg (Pearson 0.6 v 0.56 or 0.46, 0.3 v 0.23 or 0.27 respectively)-more correlated with HRQoL than sagittal parameters. . Same results for both Non-Operative and Operative patients. Back pain is more correlated with HRQoL scores than leg pain, whilst leg pain is more correlated with radiological parameters than back pain. The contribution of leg pain to B&L Score is negligible below 8/20, with a much greater increase thereafter.

**Conclusion**

A B&L score may be used to evaluate the level of pain as an adjunct to separate analysis of back and leg pain. It is valid as a predictor for post-operative HRQoL and sagittal parameters.




## 228. Cost-Effectiveness and Clinical Effectiveness in Adult Spinal Deformity Patients: Results from a Prospective, Multicenter Study

*Samrat Yeramaneni, MBBS, MS, PhD; Amit Jain, MD; Jeffrey L. Gum, MD; Michael P. Kelly, MD; Steven D. Glassman, MD; David W. Polly, MD; Khaled M. Kebaish, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Rajiv K. Sethi, MD; Shay Bess, MD; Richard Hostin, MD; International Spine Study Group*

**Summary**

We examined whether patients demonstrating threshold improvement in MCID values will be equally cost effective (CE) after 5- and 8-years of ASD surgery, at willingness to pay (WTP) threshold of 100K. The mean cost/QALY was $234,164 at 5 years and $114,311 at 8 years. At 5-years, patients who were clinically effective were not CE. At 8-years, patients who were clinically effective were also CE at WTP 100k for all health-related quality of life (HRQoL) measures.

**Hypothesis**

Adult Spinal Deformity surgery will be Clinically Effective and CE at 5- and 8-year time horizon

**Design**

Prospective, multicenter study

**Introduction**

Surgical management of ASD patients is complex and costly, with varying HRQoL scores and clinical benefits. The purpose of this study was to determine if ASD surgery is both clinically beneficial and CE at different time horizons.

**Methods**

ASD patients from a multicenter, prospective surgical database, with ≥5 level fusion and 2-year follow-up were included. Total episode of care cost (EOC) in 2014 dollars was calculated using direct hospital cost data obtained from administrative records. QALYs gained were calculated using baseline, 1-year, and 2-year SF-6D scores. CE was determined by calculating cost per QALY using 5 year data and projected 8 year data, at WTP threshold of 100K. Clinical-effectiveness was determined by threshold improvement in MCID values: ODI (-15), SF-36 physical component (5.2), SRS-activity (0.375), SRS-pain (0.587), SRS-appearance (0.8), SRS-mental (0.42), and SRS-total (0.4).

**Results**

Of 522 ASD patients eligible for 2-year follow up, 367 (70%) had complete baseline and 2-year HRQoL data. Patients were enrolled consecutively in the study having varying length of follow-up ranging from 2-8 yrs. The mean cost/QALY was $234,164 at 5 years and $114,311 at 8 years. The mean+SD QALY gain was 0.3±0.4 at 5 years and 0.6±0.8 at years. Percentage of patients who reached MCID at 2-years are; 51% for ODI, 58% for SF-36 PCS, 66% for SRS-Pain, 61% for SRS-Activity, 72% for SRS-Appearance, 44% for SRS-Mental, and 74% for SRS-Total. At 5 years, patients who reached MCID threshold were not CE in any of the patient reported measures. At 8 years patients who reached MCID threshold were also CE at WTP threshold of 100K for all HRQoL measures. ASD surgery was most CE at 8 years in patients whose ODI score reached MCID (Table).

**Conclusion**

The average cost/QALY in our study was $234,164 at 5 years and $114,311 at 8 years. In over 50% of patients, ASD surgery was both CE and clinically beneficial at 8 years. Our results reinforce the fact that 'true' benefits of ASD surgery are observed in the longer time horizon.

**Table 1: Cost Effectiveness and Clinical Effectiveness in ASD Patients**

| Explanatory Variables | Percentage reaching MCID n (%) | Cost/QALY – 5 years | | Cost/QALY – 8 years | |
|---|---|---|---|---|---|
| | | MCID+ | MCID- | MCID+ | MCID- |
| HRQoL Measures | | | | | |
| ODI | 186 (50.7) | $142,937 | $706,516 | $69,144 | $362,269 |
| SF-36 PCS | 213 (58.0) | $151,110 | $780,200 | $72,513 | $429,706 |
| SRS-Pain | 241 (65.7) | $157,512 | $1,491,595 | $76,868 | $737,576 |
| SRS-Activity | 224 (61.0) | $155,815 | $974,211 | $75,652 | $491,789 |
| SRS-Appearance | 265 (72.2) | $194,670 | $524,685 | $93,938 | $280,118 |
| SRS-Mental | 162 (44.1) | $151,512 | $402,174 | $73,459 | $199,098 |
| SRS-Total | 273 (74.4) | $169,941 | $12,481,868 | $82,719 | $17,786,663 |

## †229. The Relationship of Biomechanical Parameters Measured by Gait Analysis with the Functional Parameters Measured by Self-Reported Questionnaires in Patients with Adult Degenerative Scoliosis

*Ram Haddas, PhD; Isador H. Lieberman, MD, MBA, FRCSC*

**Summary**

This study demonstrated a strong correlation between biomechanical parameters as measured with objective gait analysis and functional disability as measured with patient reported outcome measures including the ODI, VAS and SRS22. Quantified gait analysis can be a useful tool to evaluate patients with spinal deformity and to assess the outcomes of treatment in this group of patients.

**Hypothesis**

The purpose of this study was to determine the correlation between self-reported assessments of function with objective biomechanical measures of function.

**Design**

A non-randomized, prospective, concurrent control, cohort study of patients with ADS.

**Introduction**

Patients with adult degenerative scoliosis (ADS) demonstrate an altered gait pattern. Self-reported measures are routinely used in the clinical setting to capture data related to back and leg pain symptoms, to function and to perceived disability, in the setting of adult degenerative scoliosis. However, few studies have examined the correlation between patients' self-reported clinical outcome and objective biomechanical gait analysis.

**Methods**

Twenty-five patients performed clinical gait analysis one week prior to surgery. Spine and lower extremity angles and range of motion (ROM), ground reaction forces (GRF), along with spatio-temporal variables were all measured and recorded. Furthermore, back pain and leg pain VAS, ODI scores, SRS22 scores were obtained on the same day of testing. Pearson's Product Correlation was used.

**Results**

The ODI was strongly correlated with gait speed (r=-0.59), stride (r=-0.67) and step length (r=-0.68) and moderately correlated with step time and sagittal head ROM. The SRS22r was strongly correlated with gait speed (r=0.67), stride time (r=-0.53) and length (r=0.56), and moderately correlated with cadence. The VAS was strongly correlated with gait speed, sagittal knee angle, coronal hip, knee angles, and moderately correlated with cadence, stride length and time and neck coronal plane angle.

**Conclusion**

This study demonstrated a strong correlation between biomechanical parameters as measured with objective gait analysis and functional disability as measured with patient reported outcome measures including the ODI, VAS and SRS22. Quantified gait analysis can be a useful tool to evaluate patients with spinal deformity and to assess the outcomes of treatment in this group of patients. Gait and disability are strongly correlated in surgical patients with adult degenerative scoliosis. Quantified gait analysis can be a useful tool to evaluate patient outcomes.

## 230. SRS Scores Can Predict PROMIS Scores in ASD Patients

*Alvaro Ibaseta, MS; Richard Skolasky, ScD; Rafa Rahman, MD; Khaled M. Kebaish, MD; David B. Cohen, MD, MPH; Daniel M. Sciubba, MD; Brian J. Neuman, MD*

**Summary**

To compare treatments across populations and disease, the NIH developed PROMIS to assess physical, mental and social health. Healthcare providers need methods to translate disease specific patient reported outcome measures to PROMIS. This study established and validated a method to translate SRS scores to PROMIS domains in ASD. Estimated PROMIS scores moderately to strongly correlate with actual scores (r>0.55).

**Hypothesis**

Estimated PROMIS scores derived from SRS scores correlates well with actual PROMIS scores

**Design**

Retrospective Review

**Introduction**

To facilitate comparing the effectiveness of treatment across populations and diseases, the NIH developed PROMIS. In ASD, a disease specific tool, SRS questionnaire, assesses outcomes. To encourage comparisons, existing data needs to be translated to PROMIS. This study establishes and validates a method to accurately translate existing SRS scores to PROMIS.

**Methods**

174 surgical ASD pts completed PROMIS and SRS data. These were divided into a preop cohort (N=81derivation sample) and postop cohort (N=93 validation sample). To establish a method of translation using the derivation sample, each PROMIS domain was modeled as a function on existing SRS domains using linear regression model that included an intercept,  , and coefficients for SRS domains,  i. Based on model fit statistics, the most parsimonious model was selected(Table 1). Using the validation cohort, the regression equation was used to estimate PROMIS domain scores from existing SRS domain scores. PROMIS estimates were correlated to actual PROMIS scores in the validation cohort, to examine adequate translation.

**Results**

PROMIS Pain was significantly dependent on SRS pain and physical function, with a nonzero intercept. PROMIS Physical Function was significantly dependent on SRS pain, physical function and self-image. PROMIS Anxiety and Depression were both significantly dependent on SRS mental health, with nonzero intercepts. PROMIS Satisfaction w/ Participation in Social Roles is significantly dependent on SRS pain, with a nonzero intercept (Table 1). Pearson correlation coefficients showed moderate to strong correlation between estimated and actual PROMIS domain scores in the validation cohort: Pain r=0.79 CI=[0.70 0.86] p<0.001; Physical Function r=0.66 CI=[0.53 0.76] p<001; Anxiety r=0.64 CI=[0.49 0.76] p<0.001; Depression r=0.57 CI=[0.41 0.69] p<0.001; Satisfaction w/ Participation in Social Roles r=0.59 CI=[0.43 0.71] p<0.001.

**Conclusion**

PROMIS domain scores estimated from existing SRS scores through our proposed linear regression model correlate moderately to actual PROMIS domain scores. SRS scores can be directly translated to PROMIS scores in all the evaluated health domains for ASD pts

**Table 1.** Linear Regression Model to determine variables to be used in the model to calculate PROMIS domain scores from SRS domain scores
For example: $PROMIS_{Pain} = \alpha_{Pain} + \beta_{Pain} \cdot SRS_{Pain} + \beta_{Function} \cdot SRS_{Function}$

| | | SRS domains | | | | | |
|---|---|---|---|---|---|---|---|
| PROMIS domains | | Intercept ($\alpha$) | Pain ($\beta_{pain}$) | Physical function ($\beta_{function}$) | Mental health ($\beta_{mental}$) | Self-image ($\beta_{image}$) | Patient satisfaction ($\beta_{satisfaction}$) |
| *Pain* | Coefficient | 93.92 | -4.21 | -6.50 | — | — | — |
| | (SE) | (3.22) | (0.80) | (1.21) | — | — | — |
| | p-value | <0.001 | <0.001 | <0.001 | — | — | — |
| *Physical Function* | Coefficient | — | 3.28 | 4.50 | — | 3.08 | — |
| | (SE) | — | (1.14) | (1.90) | — | (1.27) | — |
| | p-value | — | <0.001 | 0.019 | — | 0.018 | — |
| *Anxiety* | Coefficient | 83.48 | — | — | -7.96 | — | — |
| | (SE) | (3.31) | — | — | (0.93) | — | — |
| | p-value | <0.001 | — | — | <0.001 | — | — |
| *Depression* | Coefficient | 86.36 | — | — | -9.75 | — | — |
| | (SE) | (2.90) | — | — | (0.82) | — | — |
| | p-value | <0.001 | — | — | <0.001 | — | — |
| *Satisfaction with Participation in Social Roles* | Coefficient | 23.83 | 6.34 | — | — | — | — |
| | (SE) | (2.27) | (0.91) | — | — | — | — |
| | p-value | <0.001 | <0.001 | — | — | — | — |

## 231. Pelvic Incidence is All You Need to Know.


*Donald A. Deinlein, MD; Steven M. Theiss, MD; Amit W. Bhandarkar*



**Summary**

Legaye, Duval-Beaupere et al introduced pelvic incidence as a regulator of spinal sagittal curves in 1998. If pelvic incidence is measured ideal pelvic tilt, sacral slope, thoracic kyphosis, lumbar lordosis, and T1 slope are known for that individual and in conjunction with the spinal equation neutral sagittal alignment for that person is measurable.


**Hypothesis**

When measuring angles between 2 horizontal parallel lines, the sum of the angles in opposite directions is equal. T1S + LL = SS + TK

**Design**

Mathematical analysis of pelvic incidence as it relates to spinal sagittal alignment

**Introduction**

If one measures T1 slope and sacral slope parallel lines are created between which are thoracic kyphosis and lumbar lordosis which are angles in opposite directions. T1 slope is in the same direction as lumbar lordosis and sacral slope is in the same direction as thoracic kyphosis. Applying the principle that when measuring angles between 2 horizontal parallel lines, the sum of the angles in opposite directions is equal, we then have T1 slope plus lumbar lordosis equals sacral slope plus thoracic kyphosis (T1S + LL = SS + TK) Similarities of mean values of TK/LL ratio of 0.76 in two independent studies would indicate that this ratio could be used to calculate the ideal value of thoracic kyphosis when pelvic incidence is known and when pelvic incidence is assumed to equal lumbar lordosis.

**Methods**

70 patients in neutral sagittal balance were studied and in all 70 patients T1S + LL = SS + TK was noted within 3 degrees, the difference being measurement error. The spinal equation was applied retrospectively to 30 patients who underwent operative spinal re-alignment. Ideal values were derived after measurement of PI which was assumed to equal LL. TK was calculated as LL X 0.76. PT was assumed to be 20 degrees as found in the Schwab/SRS classification. SS was calculated from the corollary SS = PI - PT. T1 slope was calculated from the corollary T1S = SS + TK – LL. When using this corollary the ideal value for T1 slope in each of those patients was found to be thoracic kyphosis minus 20 degrees in every case, therefore T1S = TK - PT.

**Results**

LL = PI. TK = LL X 0.76. PI = PT + SS ∴ SS = PI –PT or SS = PI – 20. T1S + LL = SS + TK ∴T1S = SS + TK – LL. T1S always TK -20 or T1S = TK -PT

**Conclusion**

Pelvic incidence determines lumbar lordosis and thoracic kyphosis. Pelvic tilt determines sacral slope and T1 slope. For a known pelvic incidence an ideal sagittal alignment exists and can be constructed with the spinal equation

## *232. Impact of Preopeative Spinopelvic Alignment on Outcomes of Total Hip Arthroplasty (THA)

*Bassel G. Diebo, MD; Patrick J. Mixa, MD; Matthew Harb, MD; Qais Naziri, MD, MBA; Frank A. Segreto, BS; William P. Urban, MD; Carl B. Paulino, MD*

**Summary**
The purpose of this study is to examine the influence of pre-operative spinal alignment and degeneration on the outcomes of THA. Patients with spinopelvic mal-alignment had increased acetabular anteversion and abduction after THA.

**Hypothesis**
Pre-operative spino-pelvic alignment affects the post-operative outcomes of THA.

**Design**
Retrospective review of prospectively collected database

**Introduction**
In patients who undergo THA, postoperative component alignment may be affected by un-assessed spino-pelvic mal-alignment.

**Methods**
This is a single center retrospective review of patients that underwent THA between 2013 and 2016 for degenerative joint disease. Pre-operative and all post-operative office notes were used to collect patient demographics, pre-op examination, and any post-op complications or symptoms. Pre-op lateral lumbar xrays were measured using dedicated software to assess apino-pelvic alignment (PT, PI, SS, Pelvic incidence minus lumbar lordosis (PI-LL)). Degree of spondylolisthesis and degree of degenerative changes were assessed at each lumbar level. Post-op AP view of the pelvis was used to measure acetabular anteversion, area of the acetabulum, femoral offset, Theta angle, and Neck Shaft Angle (NSA). Patients were groups based on spino-pelvic alignment thresholds were defined by SRS-Schwab classification.

**Results**
48 patients were included with a mean age of 62.8 ± 8.8. Average post-op AP pelvis x-ray was 4 months. Mean spino-pelvic parameters were: PI-LL 8.3 ± 17, SS 41 ± 9.9, PT 18.2 ± 12.9, PI 59.2 ±15.9). Patients with PI-LL > 10 had significantly higher acetabular anteversion after THA (25.2 vs. 20.6°, P=0.044), and a greater acetabular abduction (Theta: 43.7 vs. 38.4°, P=0.049). Patient with PT more than 20 had also increase Theta angle post operatively (43.8 vs. 38.4). Patients with SS < 40 had increased area of the cup on AP pelvis. PI-LL was significantly correlated with anteversion R=0.300, P=0.043. Patients stratified into those with severe degenerative lumbar degeneration or spondylolithesis revealed no difference in their acetabular anteversion or abduction.

**Conclusion**
Patients with PI-LL > 10 or PT > 20 had greater acetabular anteversion and abduction after THA. Spinopelvic alignment should be assessed preoperatively in each patient undergoing THA and could be taken into account for surgical planning, such as component placement.

## *233. Evolution Of Sagittal Plane Correction Durability and Associations With Patient Reported Outcome Measures (PROMS) For Long Fusions Terminating At The Upper Thoracic (UT) vs. Thoracolumbar (TL) Spine With Minimum 3 Yr Follow-Up

*Munish C. Gupta, MD; Renaud Lafage, MS; Michael P. Kelly, MD; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Shay Bess, MD; Justin S. Smith, MD, PhD; Virginie LaFage, PhD; International Spine Study Group*

**Summary**
Improvement in sagittal alignment was seen at 6W, 1Y and final FU. Slight degradation in sagittal correction was seen in both the instrumented and un-instrumented spine segments in the UT and TL groups, however PROM improvement remained stable until last FU.

**Hypothesis**
Initial sagittal plane correction may degrade following initial surgical correction of sagittal malalignment and this degradation will impact PROMS

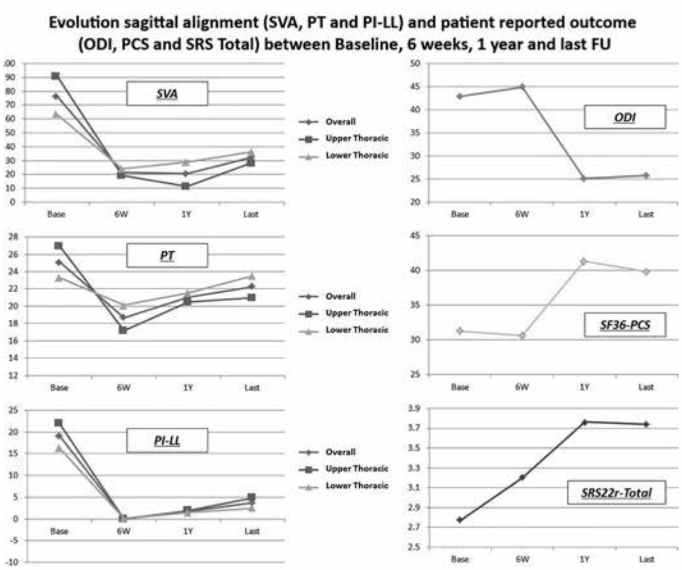
**Design**
Observational cohort study of multicenter adult spinal deformity database

**Introduction**
Sagittal plane correction of adult spinal deformity (ASD) patients is challenging to achieve and maintain. The natural history for the general population is to demonstrate increasing sagittal malalignment with age . Purpose: evaluate the durability of surgical sagittal plane correction at minimum 3 year f/u

**Methods**
Observational cohort study in a multicenter ASD database. Inclusion criteria: age≥18, PI-LL mismatch >10, PT>20, SVA >5 cm and Cobb >20. Patients requiring revision surgery were excluded. Patients divided according to UIV (UT vs. TL) and all patients had fusion to pelvis. Radiographic parameters between UT and TL groups and PROMS evaluated at ≥3 year f/u.

**Results**
115 pts out of 248 pts (mean: age 62 years, BMI 27) met inclusion criteria, mean f/u 46 months. SRS-Schwab deformity; Neutral=26, Thoracic=2, Lumbar=58, Double=29. Mean preop SVA = 7.5 cm, PI-LL = 19, PT = 25. In the UT (n=37) group the SVA, PT, TPA, PI-LL, and UIV-PA improved between baseline and each FU. Thoracic kyphosis (TK) increased from baseline to each FU. Between 6Y and last FU roughly half the patients had TK increase or LL decrease >5°. In the TL group (n=44) the SVA, PI-LL, and UIV-PA improved from baseline to each FU. PT improved from baseline to 6wks. TPA improved between baseline, 6wks and 1yr. TK increases between baseline and each FU. 25% of pts lost >5° of LL. ODI and SF-36 PCS did not change between baseline and 6W but improved at 1Y and last FU. The SRS-22 improved at 6wks, had greater improvement at 1Y and remained stable at last FU.

**Conclusion**
Sagittal alignment was improved in all parameters from baseline to 6W, 1Y and final f/u. There was a gradual increase in thoracic kyphosis in all pts with associated degradation of initial correction in a subset of pts in the instrumented and non-instrumented thoracic spine and instrumented portion of the lumbar spine. All patients demonstrated improvements in PROMS that remained stable over time.




## 234. Bone Mineral Density and Physical Performance of Female Patients 27 Years or Longer after Spinal Fusion for Adolescent Idiopathic Scoliosis

*Tsutomu Akazawa, MD, PhD; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Shohei Minami, MD, PhD; Hisateru Niki, MD, PhD*

**Summary**
In female AIS patients who had undergone spinal fusion in adolescence, we found that 4.3% had osteoporosis and 39.1% had osteopenia after 27 years or longer had elapsed. The exercise performance of these patients was poor when compared with the national standard, and an increase in physical activity should be encouraged to prevent decreasing BMD in middle age.

**Hypothesis**
No reports looked at postsurgical BMD in middle-aged AIS patients.

**Design**
A retrospective cohort study.

**Introduction**
The aims of this study were to assess bone mineral density (BMD) and bone metabolism 27 years or longer after surgery in female patients who had undergone spinal fusion for adolescent idiopathic scoliosis (AIS) during adolescence and to analyze these findings relative to physical performance.

**Methods**
Study subjects were 229 female patients with AIS who underwent spinal fusion from 1968 through 1988. The patients who provided their consent underwent examinations. We examined 23 subjects who gave informed consent from among 229 female patients. The average age at the time of observation was 48.8 years. BMD was measured at the left femoral neck and bone metabolism markers (procollagen type 1-N-propeptide [P1NP] and tartrate-resistant acid phosphatase-5b [TRACP-5b]) were measured from blood samples. Physical performance was measured using grip strength, sit-ups, sit and reach, side step, and standing long jump.

**Results**
The mean BMD was 0.784 g/cm2. According to the WHO diagnostic criteria, 1 subject (4.3%) had osteoporosis, 9 subjects (39.1%) had osteopenia. Among the patients with osteoporosis or osteopenia, the values for P1NP and TRACP-5b were high, and the high metabolic turnover type of loss in BMD was present. The calculated standard scores for physical performance were all lower than in healthy individuals. There was a positive correlation with the standard score for grip strength, and weak positive correlations with the standard scores for side step and standing long jump.

**Conclusion**
In female AIS patients who had undergone spinal fusion in adolescence, we found that 4.3% had osteoporosis and 39.1% had osteopenia after 27 years or longer had elapsed. BMD exhibited a positive correlation with the standard scores for grip strength, side step, and standing long jump. The exercise performance of these patients was poor when compared with the national standard, and an increase in physical activity should be encouraged to prevent decreasing BMD in middle age.

## 235. Predictors of High Cost in Adult Spine Deformity Surgery

*Micheal Raad, MD; Raj Amin, MD; Amit Jain, MD; Khaled M. Kebaish, MD*

**Summary**
Adult Spine Deformity (ASD) is associated with substantial healthcare costs. Cost stratification based on preoperative patient factors helps to enhance resource allocation. Our results show that age>75, Carlson comorbidity index (CCI)>2, morbid obesity (BMI>35) and a combined coronal/sagittal deformity are all significant predictors of high cost surgery (top quartile) after adjusting for the number of levels fused and the type of osteotomy performed.

**Hypothesis**
Certain preoperative patient characteristics such as age and health status can be predictive of high cost surgery and aid in cost stratification.

**Design**
Retrospective Review.

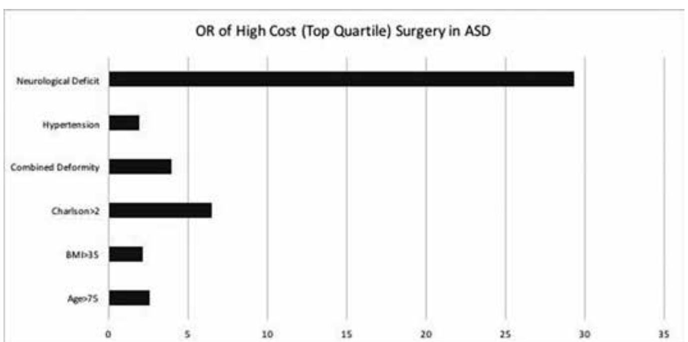
**Introduction**
ASD surgery is associated with substantial healthcare costs. Characterizing the preoperative patient factors predictive of high cost surgery greatly enhances the allocation of healthcare resources. This study aims at defining the major predictors of high cost

surgery in ASD patients undergoing 5 or more level fusions at a single center.

**Methods**
326 consecutive ASD patients undergoing ≥5 level fusions were included in this study. High cost surgery was defined as the top quartile of total surgery costs. Logistic regression controlling for the number of levels fused and the type of osteotomy performed was used to assess the effects of preoperative variables on the likelihood of high cost surgery.

**Results**
After adjusting for the number of levels fused and the type of osteotomy performed, the significant predictors of high cost surgery (top quartile) were age>75(OR=2.56, p=0.042), Charlson comorbidity index (CCI) >2 (OR=6.4, p<0.001), morbid obesity (BMI>35) (OR=2.1,p=0.013) and a combined coronal/sagittal deformity (OR=3.9,p=0.016). Individual components of the CCI that were found to be predictive of high cost surgery were hypertension (OR=1.93, p=0.025) and neurological deficit (OR=29.3, p=0.003) (Figure 1). Revision vs primary was not a significant predictor of high cost surgery (OR=1.1,p=0.724).

**Conclusion**
Our results show that older age and a poor preoperative health status are likely to result in high cost surgery. However, revision surgery is not a significant predictor. Thus further cost-quality analysis in this patient population is important.




## †236. Spinal Biomechanical Properties Are Significantly Altered With a Novel Embalming Method

*Roderick M. Holewijn, BS; Sayf S.A. Faraj, BSc; Idsart Kingma, PhD; Barend J. Van Royen, MD PhD; Marinus De Kleuver, MD, PhD; Albert J. van der Veen, MSc*

**Summary**
To analyze new spinal implants, biomechanical tests using cadaveric spinal specimens are often performed. Fresh frozen specimens carry the risk of infection and specimens embalmed with formaldehyde are too stiff. This study demonstrated that Fix for Life embalming neither maintains physiological spinal biomechanics, but this effect is less detrimental than formaldehyde embalming.

**Hypothesis**
We hypothesized that Fix for Life embalming will maintain physiological spinal biomechanics.

**Design**
Biomechanical study.

**Introduction**
To test surgical techniques or new spinal implants, in vitro cadaver tests using fresh frozen human cadaveric spinal specimens are often performed. However, this carries the risk of pathogen transfer from specimen to the worker and the specimens can only be used for a limited amount of time. Human spinal specimens embalmed with formaldehyde carry an almost absent risk of transfer of pathogens and can be stored and used for a long time, but the tissue properties are strongly affected making this method inapplicable for biomechanical testing. In this study, a new embalming technique, Fix for Life (F4L), claims to preserve the tissue properties, was tested.

**Methods**
Six human thoracic spinal segments (T6-T11) were harvested from fresh frozen human cadavers. The testing setup was described and validated previously (Busscher et al., 2009) . In short, the pots were placed in a custom build spinal motion simulator and pure moments of 4 Nm were applied using a hydraulic materials testing machine. The range of motion (ROM) and stiffness of the fresh human spinal specimens was measured before and after F4L embalming.

**Results**
After F4L embalming, spinal stiffness increased in flexion-extension by 230%, in lateral bending by 284% and in axial rotation by 271%. ROM decreased by 46% in flexion-extension, 56% in lateral bending and 54% in axial rotation.

**Conclusion**
In conclusion, based on this study, F4L does not maintain physiological spinal biomechanical properties, and we propose that this method should not be used for studies that demand physiological spinal biomechanics. Nevertheless, the method may be an alternative to formaldehyde fixation in situations such as training and education because the effect on spinal biomechanics is less detrimental than formaldehyde and tissue color is maintained.

## †237. Morphometric Evaluation of Occipital Condyle: Defining Optimal Trajectories and Safe Screw Lengths for Occipital Condyle-Based Occipitocervical Fixation in Indian Population.

*Ajoy Prasad Shetty, MS Orth; S. Rajasekaran, MD DNB FRCS MCh PhD; Aju Bosco, MS, FNB*

**Summary**
Computed tomographic morphometric analysis was done on occipital condyles(OC) of 70 Indian adults, to analyze the feasibility and safety of occipital condyle-based occipitocervical fixations. The trajectories and safe screw lengths for OC screw and CO-C1 transarticular screw techniques have been defined. There exist significant differences in morphometry, screw trajectories and lengths as compared to Western population. The data presented in this study would serve as a valuable reference guide in placing these screws safely and effectively.

**Hypothesis**
Occipital condyle based craniovertebral junctional fixations are feasible and safe in Indians.

**Design**
Computed tomographic (CT) morphometric analysis

**Introduction**
Limitations of occipital squama-based occipitocervical fixation (OCF) has led to the development of two novel techniques of OCF using the occipital condyle(OC) as cephalad anchors. The purpose of this study is to analyze the feasibility and safety of using the OC in OCF in Indians and to define anatomic zones and screw lengths for safe screw placement.

**Methods**
Morphometry of 140 Indian adult occipital condyles was performed. Feasibility of placing a 3.5mm diameter screw into the OC was investigated. The safe permissible trajectory without hypoglossal canal or atlantooccipital joint compromise was examined. Safe screw lengths and trajectories were measured for placement of OC screws and C0-C1 transarticular screws.

**Results**
The average screw length, safe sagittal and medial angulations for OC screws were 19.9+/-2.3mm, 6.4+/-2.4 degrees cranially, 31.1+/-3.0 degrees medially, respectively. In 27.2% of population the height available for OC screw was less than 4.5mm, thus making screw placement precarious. The safe sagittal angles and screw lengths for C0-C1 transarticular screw insertion were 48.9+/-5.7 degrees cranial, 26.68+/-2.91mm for junctional entry and 36.7+/-4.6 degrees cranial, 31.6+/-2.7mm for C1 arch entry techniques. These measurements showed significant differences in comparison with Western population.

**Conclusion**
Ours is the first study to examine the feasibility of OC based craniovertebral fixations in Indians and to define safe trajectories and screw lengths for the same. There exist significant differences in morphometry, screw trajectories and lengths as compared to Western population. We recommend a thorough preoperative CT evaluation before surgical planning. OC screws and C0-C1 transarticular screws are safe and viable options in Indians. The data presented in this study would serve as a valuable reference guide in placing these screws safely and effectively.

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## †238. Creating Lordosis In Transforaminal And Posterior Lumbar Interbody Fusion (TLIF/PLIF) – The Impact Of Surgical Technique – A Controlled Cadaveric Study.

*<u>Peter A Robertson</u>; Will D Armstrong, BS; Daniel Woods, BS BME; Jeremy J Rawlinson, PhD*

**Summary**
This cadaveric study demonstrated that operation type (TLIF v PLIF), posterior bone resection, and implant selection influence lordosis in lumbar fusion. Unilateral TLIF with an 18° lordotic cage causes minimal lordosis gain, however TLIF with resection of the posterior column increases lordosis by 9°, with further increases utilizing PLIF with 18° and 24° cages.

**Hypothesis**
Surgical resection influences lordosis creation in TLIF/PLIF.

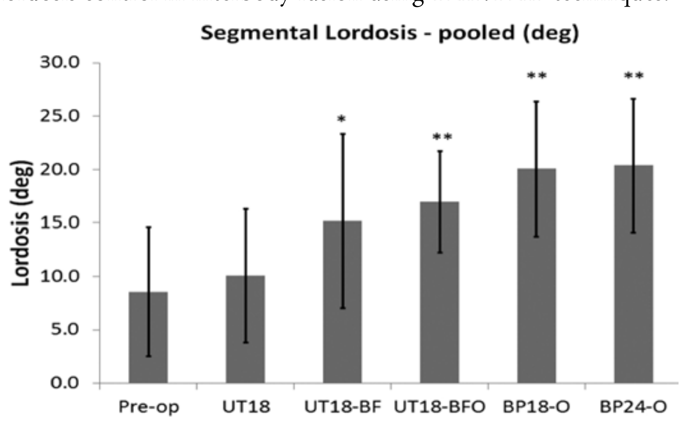
**Design**
Cadaveric Study with surgical simulation and lordosis assessment.

**Introduction**
Recreation of lordosis is important for outcomes in spinal fusion. It is unclear whether TLIF or PLIF is more advantageous and what is the influence of posterior surgical resection and implant selection

**Methods**
Eight cadaveric motion segments (four at L3/4 and four at L5/S1) underwent stepwise-simulated surgery. The steps progressed from a unilateral TLIF (18° lordosis, 27mm length) at three stages of resection (unilateral facetectomy, bilateral facetectomy, then a wide posterior decompression/posterior column osteotomy) to a bilateral PLIF (22mm length) with 18° then 24° lordotic cages. Dorsal compression across pedicle screws (bicortical and cement reinforced to resist loosening on multiple retesting) and rods provided stability before segmental lordosis was captured with lateral radiography. Repeated-measures ANOVA was used to compare across specimens and procedures.

**Results**
Pre-operative lordosis (pooled) was 8.6±6.1° (mean±SD), and maximum post-surgical lordosis was 20.4±6.3° with the 24° cage. No statistical increase in lordosis was achieved with unilateral TLIF and minimal bone resection (10.1±6.3°, 18% increase, p=0.9). Stepwise increase in lordosis occurred with progressive bone resection from unilateral TLIF with bilateral facetectomy (50%) and posterior wide decompression/posterior column osteotomy (12%) to bilateral PLIF (18%) with the 18° cage (15.2±8.2°, 17.0±4.7°, to 20.1±6.3°, respectively). The techniques with wide posterior decompression had significantly greater lordosis than the pre-operative and unilateral TLIF conditions (p<0.01).

**Conclusion**
This cadaveric study demonstrated that operation type (TLIF v PLIF), posterior bone resection, and implant selection influence lordosis control in the lumbar spine. PLIF created more lordosis than TLIF, although TLIF lordosis can be increased with progressive bone resection of contralateral facet and midline structures. This cadaveric study strongly suggested, that along with lordotic cages, operation type and extent of bone resection contribute to lordosis control in interbody fusion using TLIF/PLIF techniques.



## †239. Computational Thoracic Volume Modeling Using Semi-Automated 3D Reconstruction Software from Biplanar Radiographic Images

*Po-chih Lee, PhD; Charles Gerald T. Ledonio, MD; Arthur Guy Erdman, PhD; David W. Polly, MD*

**Summary**
A semi-automated registration software for 3D reconstructions of the thoracic spine interfacing with an open-source 3D graphical software (Blender©) was utilized for computational thoracic volume (TV) modeling of 15 patients with and without scoliosis. The accuracy was within 4% compared to gold standard CT-scan reconstructions

**Hypothesis**
TV is accurately measured by our semi-automated 3D registration software from biplanar radiographs within 4% error compared to gold standard CT-scan

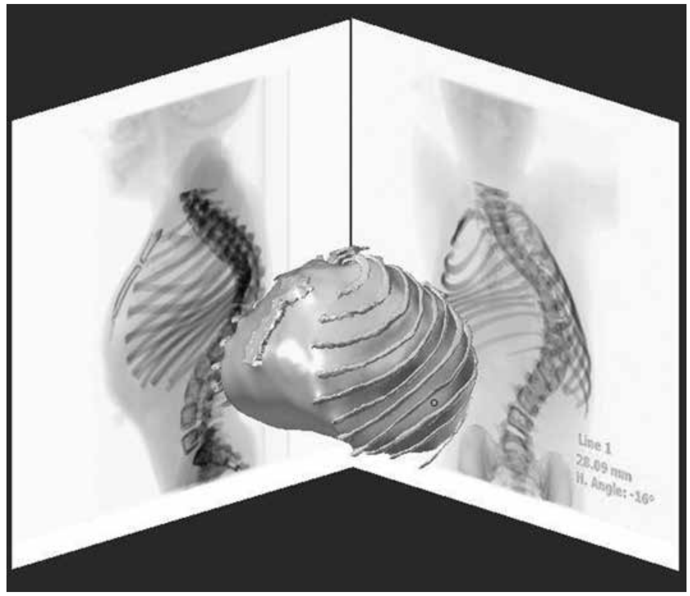
**Design**
Computational thoracic volume modeling using semi-automated 3D registration software

**Introduction**
We first developed a computational thoracic volume model that correlates with total lung capacity in spine patients; our method is accurate (4% error vs. CT). We then developed a novel semi-automated 3D software that reconstructs the thoracic spine and rib cage from biplanar radiographs to calculate thoracic volume. This study validates the accuracy of the new TV reconstructions compared with CT-based 3D reconstructions. The software markedly reduces time for reconstruction from 8 to 4 hours.

**Methods**
We estimated TV from CT-scans of 15 patients via imaging software (Mimics©) as reference standard. For consistency, the CT scout images were used to do the 3D software modeling and were then compared to the standard CT reconstructions. Two individuals reconstructed the rib cage and calculated TV using the semi-automated program (Figure 1). The accuracy of TVs was assessed by computing % volume variation compared to CT.

**Results**
8 adults and 7 children were included. Mean age was 60y (23-84) for adults, 6y (2-10)for children. Cobb angles (1-96°) and differed by age (mean11° adult, 83° pediatric). TV CT estimates varied by age (9665cc adults; 2087cc pediatric). Accuracy of TV reconstruction using the software vs. CT was 2.3%±1.5% (1.8%±1.4% adult; 2.7%±1.5% pediatric). This was more accurate than prior manual methods mean 4% (2-8%)

**Conclusion**
Semi-automated software is capable of measuring TV within 3% error compared to gold standard CT-scan. The efficiency and accuracy of the software makes the measurements more feasible in spine deformity patients




## †240. Planned Staging of Complex ASD Surgery Does Not Result in Increased Length of Stay or Increased Cost

*Jeffrey L. Gum, MD; Amit Jain, MD; Leah Yacat Carreon, MD, MSc; Richard Hostin, MD; Samrat Yeramaneni, MBBS, MS, PhD; Steven D. Glassman, MD; Michael P. Kelly, MD; Douglas C. Burton, MD; David W. Polly, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Rajiv K. Sethi, MD; Brian J. Neuman, MD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group*

**Summary**
We performed a cost comparison analysis on 367 surgical ASD patients from a prospective, multicenter database with minimum 2yr follow up. Across all levels of surgical complexity, as measured by an ASD surgical invasiveness index (ASD-SR), staging resulted in increased length of stay (LOS) and cost. When the most complex surgeries (ASD-SR≥120) were compared, LOS, index and 2yr episode of care (EOC) cost were similar between the groups.

**Hypothesis**
Planned staging of ASD surgeries will lead to increased LOS and cost

**Design**
Cost comparison analysis

**Introduction**
Staging for complex adult deformity can divide the procedure into more manageable, and potentially physiologically favorable intervals. The 2nd operation in theory, can lead to longer LOS and a higher cost. The purpose of this study is to determine if there is a difference in LOS, index and 2yr EOC (iEOC, 2-yrEOC) costs between staged vs non-staged ASD surgeries.

**Methods**
From a prospective, multicenter ASD surgical database, patients undergoing long instrumented fusions (> 4 level) with minimum 2yr follow up were identified. QALYs gained were determined

using baseline, 1yr, and 2yr post-op SF-6D scores. iEOC and 2yrEOC cost was calculated using actual direct hospital cost applied to the database and included any subsequent reoperation. We divided patients into staged vs not for the overall cohort and then for the most complex patients. We determined complexity via a validated ASD surgical invasiveness index (ASD-SR) and compared LOS stay, QALYs gained, iEOC and 2yrEOC cost.

**Results**

Of 522 surgical ASD patients eligible for 2-yr follow up, 367 (70%) had complete baseline and 2-yr SF-6D data and met database inclusion criteria. 69 (19%) patients underwent a staged surgery with no difference in age, gender, CCMI, or baseline HRQOL scores. Although mean number of levels fused was similar, the ASD-SR was greater in the staged cohort (117 vs 92, p<0.001 as well as more ant/post fusions (96% vs 13%,p<0.001). Overall, both LOS and iEOC cost were increased for staged procedures (10.5 vs 7.8 days,p<0.001; $61,391 vs $53,506,p<0.001). Whereas, staging of the most complex ASD surgeries (ASD-SR≥120=104 patients (28%): staged 33 vs non-staged 71) had no difference in LOS (11.9 vs 9.6 days,p=0.100), iEOC ($67,317 vs $63,286,p=0.376) and 2yrEOC ($77,960 vs $75,589,p=0.727). QALYs gained and 2yr Cost/QALY ($133,188 vs $109,397,p=0.424) were similar as well.

**Conclusion**

Staging of the more complex ASD surgeries does not lead to increased LOS, initial or 2yrEOC costs and leads to similar QALYs gained and 2yr cost/QALY. Appropriate selection of which patients to stage may lead to optimization ASD surgery cost-effectiveness.

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## *241. Clinical Impact of T1 Slope Minus Cervical Lordosis Following Multilevel Posterior Cervical Fusion Surgery: Long-Term Follow-Up Data

*Sang Hyun Han, MD; Seung-Jae Hyun, MD, PhD; Jong-Hwa Park, MD*

**Summary**

This long-term follow-up study showed that disability increased with cervical sagittal malalignment following surgical reconstruction and a greater T1 slope cervical lordosis mismatch was associated with a greater degree of cervical malalignment. A mismatch greater than 22.2° corresponded to positive cervical sagittal malalignment, defined as C2-C7 SVA greater than 43.5 mm.

**Hypothesis**

Disability of the neck increased with cervical sagittal malalignment following surgical reconstruction and a greater T1S-CL mismatch was associated with a greater degree of cervical malalignment and worse clinical outcomes.

**Design**

Retrospective study

**Introduction**

To assess the long-term relationship between sagittal alignment of the cervical spine and patient-reported health-related quality-of-life (HRQOL) scores following multilevel posterior cervical fusion, and to explore whether an analogous relationship exists in the cervical spine using T1 slope minus C2-C7 lordosis ('T1S-CL').

**Methods**

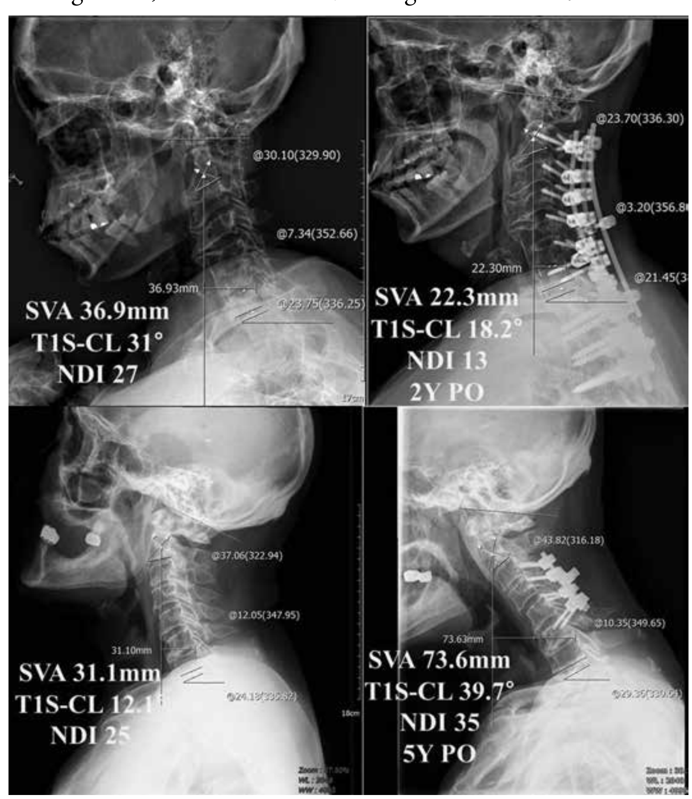
From 2007-2014, 31 consecutive patients having multilevel posterior cervical fusion for cervical stenosis, myelopathy, and deformities met inclusion criteria. To determine the true impact of the alignment on HRQOL, patients who have pseudarthrosis, a misplaced screw, junctional pathologies, or adjacent level disc herniation were excluded. Radiographic measurements included: C0-C2 lordosis, C2-C7 lordosis, C2-C7 sagittal vertical axis (SVA), T1 slope, and T1S CL. Pearson correlation coefficients were calculated between pairs of radiographic measures and HRQOL.

**Results**

Average follow-up period was 61.7 months (ranged from 24 to 117 months). C2-C7 SVA positively correlated with neck disability index (NDI) scores (r = 0.550). For significant correlations between C2-C7 SVA and NDI scores, regression models predicted a threshold C2-C7 SVA value of 43.5 mm, beyond which correlations were most significant. There were significant correlations between the C2-C7 SVA measurements and between each C0-C2 lordosis, C2-C7 lordosis, T1 slope, and T1S-CL. The T1S-CL also correlated positively with C2-C7 SVA and NDI scores (r = 0.827 and r = 0.618, respectively). Results of the regression analysis indicated that a C2-C7 SVA value of 43.5 mm corresponded to a T1S-CL value of 22.2°.

**Conclusion**

The long-term follow-up study showed that disability of the neck increased with cervical sagittal malalignment following surgical reconstruction and a greater T1S-CL mismatch was associated with a greater degree of cervical malalignment. Specifically, a mismatch greater than 22.2° corresponded to positive cervical sagittal malalignment, defined as C2-C7 SVA greater than 43.5 mm.



## *242. Posterior-Only Hemivertebra Resection and Instrumentation for Congenital Cervicothoracic Scoliosis

*Yong Qiu, MD; Zhonghui Chen, MD, PhD; Xu Sun, MD, PhD; ZeZhang Zhu, MD, PhD; Xi Chen, MD, PhD; Changzhi Du, MD, PhD; Song Li, MD*

**Summary**
Cervicothoracic hemivertebra (HV) is a rare congenital deformity. The purpose of this study was to evaluate radiographic and cosmetic outcomes following posterior-only hemivertebra resection and instrumentation at the cervicothoracic junction.

**Hypothesis**
Posterior-only HV resection with instrumentation can achieve excellent radiographic and cosmetic outcomes in the patients with congenital cervicothoracic scoliosis

**Design**
Retrospective

**Introduction**
Cervicothoracic HV is a rare congenital deformity. It locates between the mobile cervical spine and the fixed thoracic spine, leading to rapid curve progression, shoulder imbalance, fixed torticollis and facial asymmetry.

**Methods**
18 patients (8 boys) with cervicothoracic HV treated by posterior-only HV resection and instrumentation were reviewed, with at least a 2-year follow-up period (24-62 months). The mean age was 10.4 years at surgery (range 4-15). There were 12 cases of single hemivertebra, and 6 cases of double hemivertebra, with or without contralateral bar. There were totally 24 hemivertebrae, and 16 of them were fully segmented (66.7%) and 8 semisegmented (33.3%), respectively. Radiographic measurements included the segmental Cobb angle, distal compensatory Cobb angle, segmental kyphosis and global thoracic kyphosis. The shoulder balance was evaluated by T1 tilt and clavicle angle (CA). The neck tilt and head shift were measured.

**Results**
The mean fusion level was 5.2 segments. Mean operation time was 204.6 min with the average blood loss of 384.7 ml. The mean segmental Cobb angle was 45.2° preoperatively, 19.6° postoperatively (56.6% correction rate), and 20.1° at the latest follow-up. The distal compensatory curve of 18.2° was spontaneously corrected to 9.6°, but increased to 16.1° at the last follow-up. The T1 tilt was corrected from 19.6° preoperatively to 9.2° postoperatively ($p<0.001$), and 6.4° at the last follow-up ($p<0.001$). The mean CA was 19.6° preoperatively, 9.7° postoperatively ($p<0.001$), and 5.6 at the latest follow-up ($p<0.001$). The neck tilt was 20.1° preoperatively, 11.2° postoperatively ($p<0.001$), and 8.8° at the latest follow-up ($p<0.001$). The head shift was corrected from 2.2 cm preoperatively to 1.3 cm postoperatively ($p<0.001$), and 0.6 cm at the last follow-up ($p<0.001$). 1 case of Horner syndrome was noted after surgery. Pedicle screw malposition occurred in 5 (27.8%) patients.

**Conclusion**
In the patients with congenital cervicothoracic scoliosis due to hemivertebrae, hemivertebra resection with instrumentation allows for excellent correction in both the coronal and sagittal planes, especially the cosmetic improvement. Great care should be taken to reduce the rate of pedicle screw malposition.

## 243. Predictive Factors of Intraoperative MEP Monitoring "True Positive" Alert During Spinal Deformity Correction Surgery: A Matched Cohort Study Based on the Database of 2336 Patients

*Qianyu Zhuan; Jianguo Zhang; Jianxiong Shen, MD; Shujie Wang, PhD; Guixing Qiu, MD*

**Summary**
Our study aims to evaluate the risk factors of intraoperative MEP monitoring "true positive" alert during spinal deformity correction surgery. Multivariate analysis revealed 3 independent predictive factors and therefore provided important information for preoperative surgical planning.

**Hypothesis**
Preoperative data can be used to predict intraoperative MEP monitoring "true positive" alert in patients with spinal deformity who underwent surgical treatment.

**Design**
Retrospective matched cohort study of prospectively collected database.

**Introduction**
"True positive" MEP alert is defined as the alert followed by observation of a new neurological motor deficit during a wake-up test or at the end of the procedure. The predictive factors of "True positive" MEP alert remain unknown, though being essential for preoperative surgical planning and intraoperative decision making.

**Methods**
A retrospective study was conducted based on a consecutive series of 2336 patients with spinal deformity who received surgical treatment between January 2010 and December 2016. A total of 48 patients with "true positive" MEP alert were identified. The control group was composed of 192 patients (1:4 ratio) with spinal deformity without "true positive" alert, matched for surgeon team and approximate date of surgery. Demographic distribution, radiographic and clinical data of these 2 groups were compared. These 2 groups were compared for demographic distribution, radiographic and clinical data to investigate the predictive factors of intraoperative MEP monitoring "true positive" alert.

**Results**
The overall incidence rate of "true positive" alert was 0.49%. The variables of age, body mass index, and number of levels fused were similar between the 2 groups. Compared with the control group, the group with "true positive" alert has more pre-op neurological deficit, more congenital kyphoscoliosis, more spinal cord anomalis, more VCR osteotomy, higher coronal and sagittal deformity angular ratio (DAR), larger pre-op sagittal curve and smaller post-op sagittal curve. Logistic regression analysis showed

that sagittal DAR (OR: 2.752; p = 0.001), pre-op Neurological deficit (OR: 0.339; p = 0.035) and VCR osteotomy (OR: 0.319; p = 0.025) were independent predictive factors of intraoperative "true positive" MEP alert.

**Conclusion**

The occurrence of an intraoperative MEP monitoring "true positive" alert in patients with scoliosis who undergo surgical treatment is most likely multifactorial and is related to sagittal DAR, pre-op neurological deficit and VCR osteotomy.

| Predictors | Odds ratio | 95% confidence interval | | P-value |
|---|---|---|---|---|
| | | Lower limit | Upper limit | |
| Sagittal DAR | 2.752 | 1.876 | 4.235 | 0.001 |
| Pre-op Neurological deficit | 0.339 | 0.124 | 0.926 | 0.035 |
| VCR osteotomy | 0.319 | 0.118 | 0.864 | 0.025 |

## 244. Surgical Management of Cervical Spine Pathology in Adults with Down's Syndrome

Jad Bou Monsef, MD; Steven M. Mardjetko, MD, FAAP

**Summary**

Cognitive and functional deficits may mask progression of spinal pathology in adult Down's syndrome patients. Current techniques may improve fusion rates with lower risk of complications than reported historically.

**Hypothesis**

Complication rates of cervical spine surgery in adult Down's syndrome patients are higher than controls, but surgery is mostly successful in stabilizing and improving neurologic status.

**Design**

Retrospective review

**Introduction**

Degenerative cervical myelopathy is the most common cause of spinal cord dysfunction in adults, especially prevalent in Down's syndrome patients. Left untreated, cervical pathology may cause cord compression and neurologic deterioration. In addition, complication rates of 73-100% have been reported in Down's syndrome patients after cervical spine surgery in historical studies. This study reports updated perioperative complications rates and long-term outcome in adult Down's syndrome patients undergoing cervical spine surgery.

**Methods**

Retrospective review of adult patients with Down's syndrome who have undergone cervical spine surgery from 1998 to 2016 (mean follow-up 7 years) was undertaken. Series of 27 adults with preoperative diagnoses that included atlantoaxial instability, stenosis, spondylosis, or cervical spondylolisthesis were evaluated. Seventeen patients received recombinant human bone morphogenetic protein-2. Neurologic and ambulatory status were evaluated at regular intervals including pre- and postoperative imaging, range of motion evaluation, strength/neurologic testing, ambulation observation, and patient and caretaker pain reporting.

**Results**

A total of 30 surgical procedures were performed in 27 patients. Average follow-up was 93 months (range: 3-206 months). Overall, 37 complications were observed including pneumonia, respiratory distress, dysphagia, deep venous thrombosis, wound infection, dehiscence, neurologic complications, loss of reduction, pseudarthrosis, and hardware failure. Postoperative pneumonia was most common (15%). Three patients (11%) developed pseudarthrosis (all in the rhBMP-2 group), and three loss of reductions were found (11%). Neurologic complications (11%) included spasticity, loss of ambulation, and postoperative weakness with myelomalacia, two of which fully resolved. No mortalities were reported.

**Conclusion**

Current techniques may improve pseudarthrosis (p = 0.009) and fusion rates (p = 0.012) in adult Down's syndrome patients compared to historical studies. Although associated with a significant complication rate (52%), 96% of patients demonstrated stabilization or improvement in neurologic status. The effective long-term results appear to warrant the risk of perioperative complications.

## 245. Complication Rates of Pediatric Spinal Deformity Surgery: Report of 4481 Cases Prospectively Collected Across Children's Hospitals

Brian K. Brighton, MD; Kelly Vanderhave, MD; Brian Scannell, MD; Michael P. Glotzbecker, MD; Jay Shapiro, MD; Suken A. Shah, MD

**Summary**

Analysis of complication rates for spinal fusion procedures for specific patient populations from the ACS NSQIP-Pediatric demonstrated that SSI, readmission and reoperation rates were highest in the neuromuscular scoliosis group with neurologic deficits after surgery highest in the congenital scoliosis group.

**Hypothesis**

Use of procedure-targeted variables within ACS NSQIP-Pediatric allows for improved understanding of complications and outcomes in patients undergoing surgery for spinal deformity

**Design**

Retrospective review of prospectively collected cohort

**Introduction**

Variation in complication rates exists among patient populations undergoing spinal deformity procedures. The purpose of the study was to examine the complication rates associated with treatment of spinal deformity at hospitals participating in the American College of Surgeons National Surgical Quality Improvement Program-Pediatric (NSQIP-Pediatric).

**Methods**

Procedure-targeted variables were developed within NSQIP-P. In addition to the traditional program variables, data was collected specifically related to spinal fusion procedures including etiology of spinal deformity, neurologic injuries, reoperation at 30 days and 30 and 90-day surgical site infection (SSI). The classification of the spinal deformity and related complications were assessed from prospectively collected data entered in 2014 and 2015.

**Results**

43 participating hospitals contributed 4481 cases to the NSQIP-P spinal fusion procedure targeted pilot. The majority of cases were posterior spinal fusions (98.2% posterior versus 1.8% anterior). Overall surgical site infection rates at 30 days were 1.65% (range 0.68% in idiopathic scoliosis to 5.06% neuromuscular scoliosis) and at 90 days were 2.43% (range 1.20% in idiopathic scoliosis and 7.11% neuromuscular scoliosis). The incidence of new neurological deficits was 1.72% with a 0.47% incidence of spinal cord injury. 6 deaths were reported with 3 occurring in the neuromuscular cohort and 1 each in the syndromic, congenital and kyphosis groups. Bleeding events defined as transfusions >25mL/kg, 30 day readmission rates and unplanned returns to the operating room were also reported for each etiology of spinal deformity (see Table).

**Conclusion**

Inherent complications exist in the treatment of pediatric spinal deformity, but variability was identified in this large, prospectively collected sample. Complications such as SSI, readmission and reoperation rates were highest in the neuromuscular scoliosis group, and neurologic deficit after surgery was highest in the congenital scoliosis group.

2014-2015 NSQIP-Pediatric Spinal Fusion Procedure-Targeted Variable Complication Rates

| | Idiopathic (2927) | Neuromuscular (731) | Congenital/ Structural (339) | Kyphosis (224) | Syndromic (178) | Unclassified (82) | TOTAL (4481) |
|---|---|---|---|---|---|---|---|
| SSI 30 Days | 0.68% (20) | 5.06% (37) | 0.59% (2) | 2.23% (5) | 4.49% (8) | 3.45% (2) | 1.65% (74) |
| Superficial SSI 30 Days | 0.38% (11) | 2.87% (21) | 0.29% (1) | 0.45% (1) | 1.69% (3) | 0.00% (0) | 0.83% (37) |
| Deep SSI 30 Days | 0.31% (9) | 2.19% (16) | 0.29% (1) | 1.79% (4) | 2.81% (5) | 3.45% (2) | 0.83% (37) |
| SSI 90 Days* | 1.20% | 7.11% | 1.18% | 3.13% | 5.06% | 3.45% | 2.43% |
| New Neurological Deficit | 1.47% (43) | 1.09% (8) | 4.42% (15) | 3.13% (7) | 2.24% (4) | 0.00% (0) | 1.72% (77) |
| Spinal Cord Injury | 0.34% (10) | 0.55% (4) | 0.59% (2) | 1.34% (3) | 1.12% (2) | 0.00% (0) | 0.47% (21) |
| Bleeding Event | 3.04% (89) | 24.49% (179) | 10.03% (34) | 5.80% (13) | 12.92% (23) | 4.88% (4) | 7.63% (342) |
| Readmission 30 days | 2.63% (77) | 9.99% (73) | 1.47% (5) | 3.57% (8) | 4.49% (8) | 2.44% (2) | 3.88% (174) |
| Unplanned reoperation 30 Days | 1.71% (50) | 6.70% (49) | 1.77% (6) | 5.80% (13) | 8.99% (16) | 0.00% (0) | 3.04% (136) |

## 246. Meta-Analysis of Risk Factors Associated with 30-Day Unplanned Readmission after Spinal Arthrodesis

Sebastien Pesenti, MD; Tejbir Pannu; Jessica Andres-Bergos, PhD; Daniel M. Sciubba, MD; Marinus De Kleuver, MD, PhD; Ferran Pellisé, MD, PhD; Steven D. Glassman, MD; Justin S. Smith, MD, PhD; Virginie LaFage, PhD; Frank J. Schwab, MD

**Summary**

Thirty-day unplanned readmissions after spinal arthrodesis are a surrogate for early major complications carrying major additional health-care costs. A meta-analysis of 8 studies with 163,844 patients showed that age, comorbidity burden, history of chronic obstructive pulmonary disease (COPD), OR time, length of stay and number of levels fused were significant risk factors for 30-day readmissions (30-D RA).

**Hypothesis**

Patient and Procedure-specific risk factors for 30-D RA can be identified via a meta-analysis.

**Design**

Meta-analysis

**Introduction**

Readmissions following spinal arthrodesis represents a significant driver of health-care costs. We sought to review the existing data regarding the risk factors for 30-D RA in patients undergoing spinal arthrodesis.

**Methods**

Several databases (Medline, Embase and Cochrane) were used to perform our search. Only studies specific to ASD surgeries or thoraco-lumbar fusion were retained. Additional inclusion criteria were documented odds ratio (OR) with 95%CI (or availability of data to calculate OR/CI), and documented rate and reasons for 30-D RA. The meta-analysis was carried out using RevMan 5.1 software. Depending on heterogeneity ($I^2$), OR with 95% CIs were calculated using either the fixed-effects model (when $I^2$ >60%) or the random-effects model (when $I^2$ <60%). Identified risk factors were considered significant when $p < 0.05$.

**Results**

Out of the 6,480 initially identified studies, 8 studies with 163,844 patients were retained for analysis. The pooled readmission rate was 8%. Overall, 34% of 30-D RA were directly related to index surgery. Infection was the most frequent surgical complication resulting in 30-D RA (60%) and accounted for 20% of overall readmissions (Fig1). Patient-related risk factors for 30-D RA included age (OR=1.67 [1.61-1.74]), comorbidities (OR=1.81 [1.74-1.88]), and history of COPD (OR=1.47 [1.28-1.68]). Surgical risk factors included OR time (OR=1.30 [1.18-1.42]), number of levels fused (OR=1.75 [1.66-1.86]) and length of stay (OR=1.17 [1.12-1.22]) .

**Conclusion**

Age, comorbidity burden, history of chronic obstructive pulmonary disease (COPD), OR time, length of stay and number of levels fused are all risk factors for 30-D RA. These factors should be considered in patient counseling as well as treatment approach and surgical strategy.

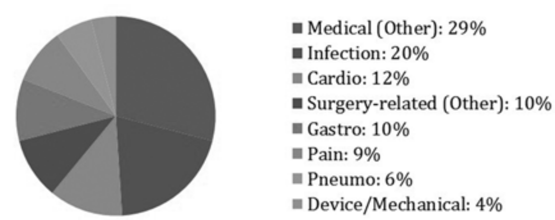



***Figure** - Diagram showing the main causes for 30-day readmissions after spinal arthrodesis. Infection was one of the most common and accounted for 20% of the total.*

## 247. The Feature of the Cardiac Function and Structure in Severe Thoracic Kyphoscoliosis Patients -- A Retrospective Study Based on the Echocardiographic and Holter Electrocardiograms

Yingsong Wang, MD; Jingming Xie, MD; Tao Li, MD; Zhiyue Shi, MD; Ni Bi, MD; Jie Zhang, MD; Zhi Zhao, MD; Ying Zhang, MD

**Summary**

The cardiac function and structure of 72 severe thoracic kyphoscoliosis were analyzed. Severe thoracic kyphoscoliosis had a limited impact on the cardiac function, structure, conduction, but the pulmonary artery pressure.

**Hypothesis**
Right now, data about cardiac function and structure in severe spinal deformity are quite rare.

**Design**
Retrospective study.

**Introduction**
Recently lots of researches have been showed that thoracic scoliosis with chest deformity obviously affect lung function, but a few studies focus on the impact on the heart.

**Methods**
A total of 72 severe thoracic kyphoscoliosis with major curve >90° were included in this study, patients with cardiac disease and lung disease were excluded. Those patients were divided into two subgroups according to the different directions of the major curve. Another 72 AIS with major curve < 90° were included in this study as control group. The demographic trait such age, sex, height, weight and Cobb angle were also analyzed. The echocardiographic and holter electrocardiograms data were analyzed based on different group.

**Results**
The echocardiographic showed that the left ventricular function and cardiac structure indicators were similar between severe group and control group (p>0.05). The pulmonary artery pressure in severe group were higher than control group (p<0.05). In subgroup analysis, the LVDd, LAD and RAD in left major curve were larger than them in right major curve(p<0.05), but the left ventricular function was similar between left and right major curve patients (p>0.05). The left ventricular function among different severity of deformity (90°-120°, 120°-150°, >150°) were similar (p>0.05). In severe group, Holter electrocardiograms showed that 59.7% patients had positive result, but there were no one case of malignant arrhythmias.

**Conclusion**
Severe thoracic kyphoscoliosis had a limited impact on the cardiac function, structure and conduction system. The real threat to the surgical safety is the poor lung function in severe thoracic kyphoscoliosis.

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## 248. Comparison of Adult Spinal Deformity Patients With and Without Rheumatoid Arthritis Undergoing Primary Fusion Surgery: A Nationwide Analysis of 43,177 Patients

*David N. Bernstein, MBA, MA; Emmanuel N. Menga, MD; Kenneth Foxx; Paul T. Rubery, MD; Addisu Mesfin, MD*

**Summary**
The Nationwide Inpatient Sample (NIS) was queried for RA and non-RA patients undergoing primary fusion surgery. Understanding any differences in comorbidities, post-surgical function, and mortality may improve care. RA patients had significantly higher rates of a number of comorbidities and worse initial post-surgical function but no difference in cost of care compared to the control group.

**Hypothesis**
Presenting comorbidities, post-surgical function, and mortality will differ between adult spinal deformity patients with and without RA undergoing a primary non-cervical fusion surgery.

**Design**
Retrospective nationwide database review.

**Introduction**
There is a paucity of literature available comparing presenting comorbidities, post-surgical function, and mortality in adult spinal deformity patients with and without RA undergoing a primary fusion surgery.

**Methods**
NIS data was analyzed from 2003-2013. Data was queried for spinal deformity patients (18+) undergoing primary non-cervical fusion surgery using ICD-9 and CPT codes. Patients with malignancy and/or trauma were excluded. Revision surgeries were excluded. Patients with RA (714.0) were included in the RA subgroup and removed from the control group. Chi-square and t tests were used.

**Results**
A total of 1,428 and 41,749 patients fit the inclusion criteria for the RA and control study groups, respectively. The mean age of the RA group was significantly older than the control group (66 vs. 61, p<0.001). A significantly higher percentage of women were in the RA group (80% vs. 67%, p<0.001). There was a significant difference in primary payers in each group with nearly two-thirds of the RA group (62%) compared to just under half (49%) of the control group (p<0.001) paying with Medicare. There was no difference in the cost of the care ($144,086 vs. $142.966; p = 0.72) A significantly higher percentage of patients in the RA group had the following comorbidities: iron deficiency anemia (p<0.001); congestive heart failure (p<0.001); chronic pulmonary disease (p<0.001); hypertension (p<0.001); and fluid & electrolyte disorders (p<0.001). No comorbidity analyzed was significantly higher in the control group. Post-surgical function rates were significantly worse in the RA group with 92% having at least moderate function loss compared to 87% in the control group (p<0.001). There was no difference in the mortality rate (p = 0.92).

**Conclusion**
Patients with RA undergoing primary non-cervical fusion surgery had significantly higher rates of a number of comorbidities and worse initial post-surgical function but no difference in cost of care compared to the control group.

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## 249. The Incidence of Short Term Morbidity and Complications after Surgery for Adolescent Idiopathic Scoliosis: Feedback and Process Improvement Impact Results

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**Summary**
ACS-NSQIP and a surgeon study group database registry each collected prospective data on AIS surgery and outcomes. When comparing data from the two observational cohorts during the same two years, we found different rates of 30- and 90-day infection, neurologic deficits, reoperation, and readmission. Complications were fewer in the group which incorporated feedback and performance improvement.

**Hypothesis**
Both databases will report similar rates of complications from prospectively collected cohorts.

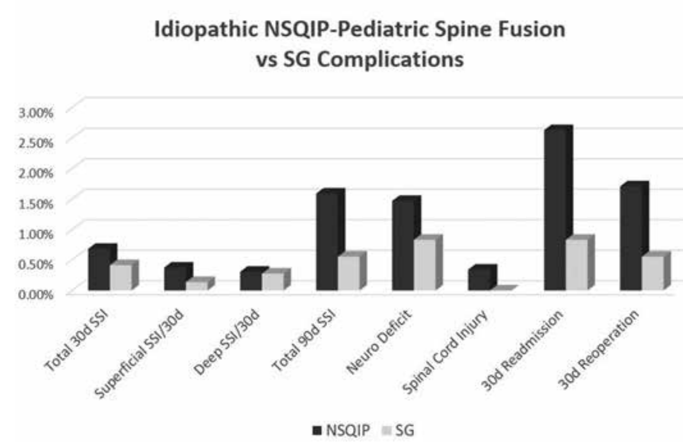
**Design**
Prospective Cohort

**Introduction**
The American College of Surgeon's National Quality Improvement Program (ACS-NSQIP) and a surgeon study group (SG) database collected prospective data on AIS surgery outcomes. However, NSQIP offers open enrollment to all institutions, and SG membership is limited by invitation to high-volume pediatric spine surgeons and carries out AIS-focused research and practice improvement initiatives. While both provide important outcome benchmarks, they may differ in their patient enrollment, outcomes and complications.

**Methods**
Prospective enrollment and a dedicated site coordinator with rigorous data quality assurance protocols existed for both registries. The ASC-NSQIP Pediatric Spine Fusion and SG database were queried for AIS 30- and 90-day complication data for 2014 and 2015. Outcomes were compared between groups with respect to superficial and deep surgical site infections (SSI), neurologic injury, readmission, and reoperation.

**Results**
There were a total of 2,927 AIS patients included in the ASC-NSQIP data and 721 in the SG database. At both 30 and 90 days, there were fewer surgical site infections reported by SG than ASC-NSQIP (30-day 0.42% vs. 0.68%; 90-day 0.55% vs. 1.59%, respectively). Similarly, there were less neurologic deficits (0.83% vs 1.47%), 30-day readmissions (0.83% vs. 2.63%), and 30-day reoperations (0.55% vs. 1.71%) in the SG cohort.

**Conclusion**
These two powerful sources of data suggest a range of complications/readmission rates that vary to some extent. Despite the strict data collection standards utilized in these two registries, some difference in the methods of data collection may explain some of the variance. A SG represents a collaborative cohort of surgeons with real time sharing and implementation of best practices that may also reflect the different rates of complications. Understanding the rate and ultimate risk factors for readmission and complications from big data sources has the potential to further drive quality improvement.




## 250. The S2AI Technique Has a Lower Complication Rate Compared to Iliac Screws: A Multicenter Study of 418 Adult Spinal Deformity Patients

*Micheal Raad, MD; Munish C. Gupta, MD; Hamid Hassanzadeh, MD; Amit Jain, MD; Brian J. Neuman, MD; Douglas C. Burton, MD; Gregory M. Mundis, MD; Virginie LaFage, PhD; Eric O. Klineberg, MD; Alan H. Daniels, MD; Richard Hostin, MD; Christopher P. Ames, MD; Shay Bess, MD; Daniel M. Sciubba, MD; Khaled M. Kebaish, MD; International Spine Study Group*

**Summary**
The S2AI and the iliac screw(IS) techniques are the two most commonly used pelvic fixation methods. They differ with respect to the extent of soft tissue dissection and ease of rod connection. They may also have varying biomechanical advantages. Our results indicate that the S2AI technique is associated with a 2.49-fold decrease in the risk of mechanical complications as well as a lower rate of surgical site infection(SSI).

**Hypothesis**
The S2AI and the IS techniques differ in several aspects; we hypothesize that there is a difference in mechanical complication rates and SSI.

**Design**
Prospective multicenter study.

**Introduction**
Sacropelvic Fixation has been historically associated with a high rate of complications. The S2AI and IS differ mainly with respect to the extent of soft tissue dissection and possible biomechanical differences. This study aims at comparing the rate of complications between the two techniques.

**Methods**
Multicenter prospective database of (ASD) surgery was analyzed for patients undergoing posterior fusion to the pelvis with S2AI or IS fixation with a 2 year follow-up. Primary outcomes were 1) mechanical complications (Instrumentation breakage at L5/S1-screw removal-L5/S1 nonunion) 2) occurrence of SSI. The S2AI & IS groups were compared with respect to age, gender, frailty index, number of levels fused, osteotomy type, operative time, type of interbody fusion(IBF) at L5/S1, BMP use at as well as radiographic parameters. T-test & chi-square test were used for

comparing continuous & categorical variables respectively. Those with p-value<0.1 were controlled for on multivariate regression.

**Results**

418 patients met the inclusion criteria. 74.4%(n=311) had complete data at 2 years. 23.68 (n=99) of the patients had S2AI fixation. The rate of mechanical complications was higher in the IS group (15.02% vs 7.07%, p=0.029). The IS broke in 3.76% (n=12) of the patients and the S2AI broke in 2.02% (n=2) (p=0.4). The two groups were similar with respect to all characteristics except for higher use of BMP at L5/S1 in the IS group (32.9% vs 20.2%, p=0.016) and a higher proportion of females (79.62% vs 68.69%, p=0.024) table1. After controlling for BMP use at L5/S1 and gender, S2AI fixation was associated with a lower rate of mechanical complications on multivariate analysis (OR=0.402, p=0.032). SSI rates were significantly higher in the IS group(0 vs 3.91%, p=0.021).

**Conclusion**

Our results show that although the S2AI & Iliac screw techniques have a similar rate of screw fracture, the S2AI technique is associated with lower SSI and overall lower rate of mechanical complications at the lumbosacral junction.

| Table 1 | Iliac Screws (n=319) | S2AI (n=99) | p-value |
|---|---|---|---|
| Age, mean(SD) | 62.08 (10.59) | 63.09 (10.08) | 0.2799 |
| **Female** | **79.62%** | **68.69%** | **0.024** |
| Frailty Index, mean(SD) | 3.73 (1.48) | 3.65 (1.57) | |
| Fused Levels, mean(SD) | 12.2(3.74) | 12.7 (3.55) | |
| No Osteotomy | 25.39% | 25.25% | |
| SPO | 43.57% | 52.53% | |
| 3CO | 31.03% | 22.22% | 0.69 |
| Operative Time in min, mean(SD) | 396.32, (128.3) | 411.76 (140.75) | 0.313 |
| No IBF at L5/SA | 46.70% | 53.54% | |
| ALIF at L5/S1 | 23.52% | 23.23% | |
| Posterioir TLIF at L5/S1 | 24.76% | 20.20% | |
| Other IBF at L5/S1 | 5.01% | 3.03% | 0.685 |
| **BMP use at L5/S1** | **32.90%** | **20.20%** | **0.016** |
| Baseline PI-LL, mean(SD) | 22.35 (20.67) | 22.45 (19.23) | 0.967 |
| Baseline SVA, mean(SD) | 106.8 (80.54) | 110.7 (76.74) | 0.6919 |
| Baseline PT, mean(SD) | 26.6 (10.31) | 27.05 (9.84) | 0.71 |

Bold Letter Interface indicates statistically significant difference, p<0.05

## 251. Planned Staged Surgery for Severe Pediatric Spinal Deformity does not Reduce Complications within 90 Days of Surgery: A Prospective Matched Cohort Study

*Sumeet Garg, MD; Nikki Bloch, BA; Patrick Carry; Mark A. Erickson, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Lawrence G. Lenke, MD; Brenda Sides, MA; Munish C. Gupta, MD*

**Summary**

Overall complications within 90 days of surgery between planned staged and planned unstaged procedures to treat severe pediatric spine deformity were similar.

**Hypothesis**

Incidence of complications within 90 days of corrective surgery to treat severe pediatric spine deformity will be lower among patients planned for a staged procedure vs planned unstaged procedure.

**Design**

Matched cohort study design from a prospective multi-center database

**Introduction**

Surgical correction of severe spine deformity (curve over 100° and/or planned VCR) is associated with high complications. Some surgeons advocate for staging complex cases as a safety measure to limit major complications. The purpose of this study was to compare the incidence of complications in the first 90 post-operative days among planned staged versus planned unstaged procedures.

**Methods**

Pediatric patients with severe spine deformity were enrolled prospectively in a multi-center database. Patients were categorized into the planned staged and planned un-staged groups based on preoperative surgical planning by individual surgeons. Complications within 90 days were categorized as major (return to the operating room or a permanent functional decline) or minor (managed non-surgically with return to baseline function). Propensity scores were used to match subjects that underwent a planned staged procedure to subjects that underwent a planned unstaged procedure based on preoperative factors including: age, gender, BMI, use of VCR, anterior procedure, etiology of deformity, % predicted FVC, total deformity angular ratio. Conditional logistic and negative binomial models were used to compare incidence of total complications as well as incidence of a major complication across the two groups.

**Results**

The demographics and clinical characteristics in the two groups (n=23 in each) were balanced by propensity matching. The total incidence of complications was 43% (10/23) in the planned unstaged group compared to 35% (8/23) in the planned staged group [Odds Ratio: 1.33, 95% CI: 0.46-3.84, p=0.5943]. Incidence of major complications was 9% (2/23) in the planned unstaged group compared to 22% (5/23) in the planned staged group [Odds Ratio 0.40, 95% CI 0.08-2.06, p=0.2734].

**Conclusion**

Overall and major complications between the two groups were similar. Staging procedures may not be an effective strategy to reduce the incidence of perioperative complications in the surgical treatment of severe spine deformity but may be indicated for other reasons.

## 252. A Comparison of Techniques to Measure MCGR Distraction Length.

*Michael J. Troy, BS; Patricia E. Miller, MS; Brian D. Snyder, MD, PhD*

**Summary**

Patients treated with magnetically controlled growing rods (MCGR) for early onset scoliosis undergo regular lengthenings. There is variability in the measurement of each MCGR rod distraction including: calculation by external controller (EC), ultrasound (US) before and after distraction, semi-annual radiographs. Distraction length calculated by the EC significantly overestimated the actual distraction measured by US or radiographs by nearly 10%. Distraction length measured by US was within 5% measured by radiographs, with differences over longer length intervals.

**Hypothesis**
Distraction length calculated using the external controller (EC) for MCGR rod lengthening is inherently inaccurate compared to actual measured distraction length using US or radiographs.

**Design**
Retrospective case series

**Introduction**
MCGR rods exemplify an alternative to traditional growing rod systems requiring surgical distraction, clinician variability remains as how to measure serial distraction lengths. The aim of this series was to compare the consistency of measured distraction length recorded by the EC, US pre and post distraction, and radiographs.

**Methods**
Forty-eight distraction lengths measured in 27 patients were analyzed for consistency among the monitoring methods. Assuming the interval change in total rod length measured on sequential spine radiographs to be the "gold-standard", the radiographic distraction length was compared to the calculated distraction length on the external controller and the change in length measured by US. Agreement among the modalities of distraction length was assessed using Bland-Altman analysis.

**Results**
Radiographic measurement of distraction length were slightly greater than US measurements by a systematic bias of 0.6 mm (p=0.02). The limits of agreement indicate that a measurement by radiograph is unlikely to exceed the US measurement by more than 4.4mm or less than 3.1 mm. The calculated length on the EC exceeded radiographic measures by an average bias of 1.2 mm (p=0.003). The limits of agreement indicate that the controller overestimated the distraction by < 6.3 mm and underestimated the distraction by <3.9mm. The EC exceeded the US length by an average bias of 1.8 mm (p<0.001). The limits of agreement indicate that that the controller overestimated the distraction length by <6.7 mm and underestimated the distraction length by < 3.0 mm.

**Conclusion**
Distraction lengths calculated by the EC during MCGR lengthening consistently overestimated the actual distraction measured directly by US or radiographs. Good agreement demonstrated by US and semi-annual radiographs, indicating that US provides a safe, non-ionizing radiation alternative for monitoring sequential change in rod lengths.

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### †253. Evaluation of a Novel Growth Guidance System for Early Onset Scoliosis Using Low Profile Gliding Implant with 5.5mm Titanium Rod in a Piglet Model

*Yingsong Wang, MD; Jingming Xie, MD; Zhiyue Shi, MD; Tao Li, MD; Ying Zhang, MD; Zhi Zhao, MD; Ni Bi, MD; Jie Zhang, MD*

**Summary**
We report an animal study to inspect availability and potential effect on adjacent segment in piglet using novel growth guidance (GG) system for early onset scoliosis(EOS).

**Hypothesis**
Adequate freedom of longitudinal growth provided by novel GG system might be the key role for avoiding auto-fusion.

**Design**
Animal study using immature piglet.

**Introduction**
Although growth friendly implants have presented generally accepted outcome in EOS, related problem such as auto-fusion, infection, or implant failure were same incidences as traditional technique.

**Methods**
We designed the novel GG system, included the features as low profile anchors, stiff rod, and without repeated surgeries. Multi-axial Double-ear screw for tightness connection and Fisheye screw for rod-axial sliding were selectively inserted into pedicle and linked by 5.5mm titanium rods. A total of 20 piglets with 3 months old were enrolled. Screws inserted by x-ray monitors and trance-muscle approach. Animals were divided into 1)control group, shame operation only, 2) fixation group, T5-L3 anchors with dual rods, 3)GG group A and B, combined fixation and gliding screws involved T5-L3(Fig.). Direct observation and measure during operation has been recorded. Radiography, computer tomography, and histological information have collected and compared between post-operation and 6 months after operation.

**Results**
Compared with fixation group, GG group both A and B shown significant spine growth tendency during post-op 6 months. The length of T5-L3 has extended average 56mm(42-68mm) in GG group A and 53mm(38-69mm) in GG group B, meanwhile, 58mm(48-63mm) in control group(P>0.05). Sagittal alignment sequenced following rod pre-bend in GG group. No skin ulceration encountered for each group, and no implant failure. Facet joint pathological change and fusion on fixation levels were obvious noticed through CT in fixation group but no one in GG group. Histological samples from capsule near gliding screw showed inflammation changes but negative from joint cartilage. Degenerative signs of adjacent endplate in fixation group were evidently more significant than in GG groups(P<0.05) and control group(P<0.05), and no difference between GG and control (P>0.05

**Conclusion**
The GG construct has been proved to allow spine longitudinal growth, either bilateral direction gliding or unidirection gliding, with sufficient stiffness from 5.5mm rods and implant low profile reliability. Rationally composition of fixated and slide anchors can induce adequate freedom of longitudinal spinal growth, then avoid auto-fusion or adjacent overload, regardless of neural plate bony tissue exposed.

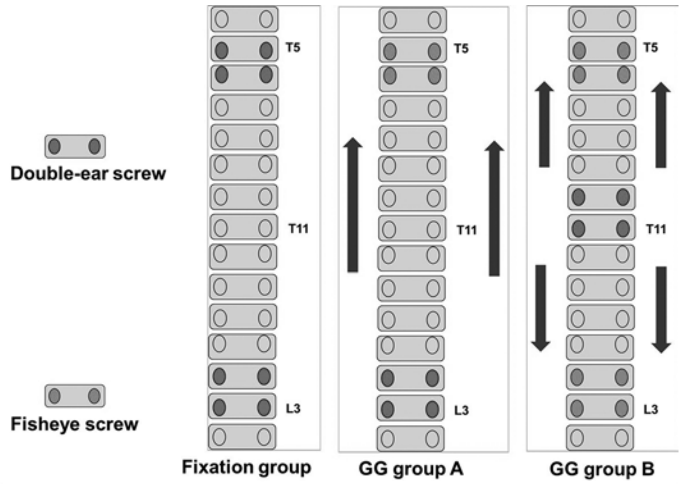


Fig. Composition of screws for fixation and gliding in each group

## 254. Proximal Rib-Based Constructs in Early Onset Scoliosis: Survivorship at or near Skeletal Maturity

*Alexandra Kondratyeva, DO; Nicholas Feinberg; Zachary Bloom, MD; Chun Wai Hung, MEng; Hiroko Matsumoto, MA; John T. Smith, MD; Joshua M. Pahys, MD; Sumeet Garg, MD; David Price Roye, MD; Michael Vitale, MD, MPH; Children's Spine Study Group*

**Summary**

In the surgical treatment of patients with EOS using proximal rib-based constructs, complication risks and reoperations are often high. While modern day rib-based constructs offer additional proximal fixation options, patient risk factors identified in this study need to be considered during preoperative planning.

**Hypothesis**

We hypothesized that the majority of proximal rib-based construct revisions and failures will occur within 2 years of implantation.

**Design**

Multicenter retrospective cohort study

**Introduction**

Rib-based constructs are a commonly employed type of instrumentation for the treatment of early onset scoliosis (EOS). This study aims to examine the longevity of such constructs and to identify risk factors associated with revisions.

**Methods**

This study queried an EOS registry of 15 major institutions for patients who had implantation of traditional rib-based growing constructs between 2002 and 2011 with 4 or fewer proximal anchors and a minimum of 5 years of follow-up. This yielded a total of 206 EOS patients. Constructs requiring removal or revision were evaluated. Statistical analysis was performed to evaluate the relationship between revision/failures and the following factors: age, Cobb, kyphosis, gender, unilateral vs bilateral constructs, BMI, ambulatory status, and etiology.

**Results**

Mean age at implantation was 5.8±2.8years. Mean follow-up 6.6±2.4years. Of 206 total patients, 140 required construct revision or removal and 66 reached final fusion. Risk of revision/removal per each year was calculated as: 26% (year 1), 18%(2), 17% (3-4), 16% (5), 13% (6), 11% (7), 0% (8-14). 90% of all revisions and removals occurred in the first 4 years. Severity of Cobb (P<0.006), kyphosis>50 (p<0.021), age at implantation ≤6 years old (p<0.001), and distal anchor fixation to the pelvis (p<0.02) were all found to be significant risk factors. Factors such as BMI, gender, unilateral vs bilateral architecture, and etiology did not demonstrate statistical significance.

**Conclusion**

Proximal hardware complication failures and reoperations are high although modern day rib-based constructs offer additional options. While proximal hardware complications decrease over time, overall rates of revision are quite high after traditional rib-based constructs. High revision rates persist throughout 5 years subsequently, but it should be noted that this study describes a historical cohort of patients with rib-based constructs, so these results may not be applicable to modern day constructs.

## 255. Spasticity is a Risk Factor of Complications and Surgical Outcome in the Management of Neuromuscular Early-Onset Scoliosis (EOS) with a Rib-Based Growing System (RBGS)

*Norman F. Ramirez-Lluch, MD; Gerardo Olivella, MPH; Omar Rodriguez, BS; Pablo Marrero, MD; Sumeet Garg, MD; John T. Smith, MD; Michael Vitale, MD, MPH; Randal R. Betz, MD; Children's Spine Study Group*

**Summary**

Spasticity is a risk factor for increased complications and decreased coronal plane correction in the management of neuromuscular Early-Onset Scoliosis with a RBGS.

**Hypothesis**

Neuromuscular patients with spasticity have poorer surgical outcomes and a higher complication rate compared to neuromuscular patients with hypotonicity treated with a RBGS.

**Design**

Retrospective cohort study of 131 neuromuscular EOS patients

**Introduction**

Neuromuscular EOS is difficult to treat and has high rate of complications. We hypothesized that neuromuscular patients with spasticity have poorer surgical outcomes and a higher complication rate compared to neuromuscular patients with hypotonicity treated with a RBGS.

**Methods**

This is an IRB approved, retrospective cohort study of 131 neuromuscular EOS patients, collected from an international multicenter database, treated with a RBGS. Patients were divided in 2 groups: spastic (SP) & hypotonic (HT). Pre-operative, intra-operative and post-operative data were compared between both groups. Complications were reported using a standardized scheme (Smith et al JPO, Dec 2015).

**Results**

32 ST and 99 HT patients were included. There were no significant differences in gender, age at surgery, weight, height, pre-op Cobb & kyphosis angles, and follow-up time (see Table 1). The immediate post-op Cobb angle % of correction in both groups were similar (37% SP & 40% HT). However, the most recent Cobb angle evaluation showed a low % of residual correction (16% SP & 11% HT) (p<0.05). The SP group had more complications (25 / 32 = 78%) than the HT group (55 / 99 = 56%) (P<0.05). The most common complications were infection (53% SP vs 39% HT), device migration (29% SP vs 36% HP), death (8% SP vs 1% HP), and implant failure (6% SP vs 13% HT), See Table 1. In 30% of spastic patients, the severity of their complications required instrumentation removal that altered the planned course of treatment compared with 10% of the hypotonic group.

**Conclusion**

There was no difference in surgical correction between groups. SP patients had more complications than those with HT in the management of neuromuscular scoliosis treated with a RBGS.

Table 1

| OUTCOME VARIABLES | Spastic | Hypotonic | P-Value |
|---|---|---|---|
| **Cobb Angle Data Comparison** | | | |
| Pre-Implant (Cobb1) - Post-Index (Cobb1) | 28.3 | 25.5 | P = 0.30 |
| Pre-Implant (Cobb1) - Most Recent (Cobb1) | 12.5 | 7.03 | P<0.05 |
| Post-Index (cobb1) - Most Recent (Cobb1) | -15.0 | -18.3 | P = 0.17 |
| Mean % Cobb Angle correction Immediate Post-op | 37% | 40% | P = 0.48 |
| Mean % Cobb Angle correction at Most Recent Follow-up | 16% | 11% | P<0.05 |
| **Kyph Angle Data Comparison** | | | |
| Pre-Implant (Max Kyph) - Post-Index (Max Kyph) | 23.2 | 16.2375 | P = 0.10 |
| Pre-Implant (Max Kyph) - Most-Recent (Max Kyph) | 12.9 | -2 | P<0.05 |
| Post-Index (Max Kyph) - Most-Recent (Max Kyph) | -10.2 | 0 | P = 0.14 |
| Mean % Kyph Angle correction Immediate Post-op | 34% | 32% | P = 0.18 |
| Mean % correction Most Recent Kyph | 19% | -4% | P<0.05 |
| **Complication Rate: Complicated Patient / n** | 25/32 = 78% | 55/99 = 56% | |
| Patient with no complications | 7/32 = 22% | 44/99 = 44% | P<0.05 |
| Patient with 1 complications | 12 | 23 | |
| Patient with 2 complications | 6 | 11 | |
| Patients with 3 complications | 2 | 9 | |
| Patients with 4 complications | 4 | 6 | |
| Patients with 5 or more complications | 1 | 7 | |
| Average complications per patient | 1.6 | 1.3 | |
| Total complications / n | 51 | 139 | |
| **Specific complications** | | | |
| Infection & wound dehisence * | 27 / 51 = 53% | 55 /139 = 39% | P<0.05 |
| Device Migration & related issues * | 15 / 51 = 29% | 50 / 139 = 36% | |
| Death | 4 / 51 = 8% | 2 / 139 = 1% | |
| Hardware Failure* | 3 / 51 = 6% | 18 / 139 = 13% | |
| Pain | 2 / 51 = 4% | 12 / 139 = 9% | |
| Pneumothorax* | 0 | 2 / 139 = 1% | |
| **Categories of Device Related Complications** | | | |
| Grade I | 2 | 11 | P = 0.13 |
| Grade IIA | 6 | 7 | |
| Grade IIB | 8 | 26 | |
| Grade III | 9 | 11 | |

## 256. Juvenile Idiopathic Scoliosis: Bracing to Skeletal Maturity

*Amanda T. Whitaker; Michael T. Hresko, MD; Alexandra Grzywna, BA; Daniel J. Hedequist, MD; Lawrence I. Karlin, MD; John B. Emans, MD; Michael P. Glotzbecker, MD*

**Summary**

Juvenile idiopathic scoliosis (JIS) is difficult to treat due to young age and high risk of curve progression. We reviewed 178 patients, 102 to skeletal maturity, treated with bracing. Our rate of progression to spinal fusion (46%) was lower with good brace compliance and strategic timing of brace wear changes during treatment to prevent brace fatigue. Risk factors are noncompliance, larger presenting curves, and medical comorbidities. Protective factors are lumbar modifier B, brace duration changes, and older age.

**Hypothesis**

Brace correction and age of the patient woudl correlate with brace success.

**Design**

Retrospective Case-control

**Introduction**

JIS brace treatment resutls are limited with poorly described protocols. Young age, long follow-up, and varying treatment methods make studying this population difficult.

**Methods**

Retrospective review of 178 patients with JIS who underwent brace treatment between the ages of 4-10, with 102 patients to skeletal maturity. Family history, MRI results, curve type, Cobb angle, brace type, duration of wear, number of brace changes, compliance by report, and surgical procedures were recorded.

**Results**

Standard protocol for a child with a Cobb angle >20° is treatment in a brace for 18-20hr a day. The most common curve characteristics at presentation were main thoracic and lumbar modifier B curves, average Cobb angle 29.8°, and age of 7.9 years. MRI was obtained in the majority (97%) of patients and demonstrated abnormalities in 29 patients (16%). Overall, patients who underwent surgical correction (46%, p<0.05) were noncompliant (OR 11.3), had a medical comorbidity not associated with scoliosis (OR 8.9), and greater major Cobb angle (OR 1.1). Protective factors (p<0.05) included lumbar modifier B (OR 0.17), more changes of duration of brace wear during their treatment (OR 0.26), and older age at bracing (OR 0.6). During brace treatment, 34% of curves did not progress (<5°).

**Conclusion**

This is the largest series of JIS patients with the lowest rate of spinal fusion and may be lower with good brace compliance and strategic timing of brace wear changes during treatment to prevent brace fatigue. Risk factors are noncompliance, larger presenting curves, and medical comorbidities. Protective factors are lumbar modifier B, brace duration changes, and older age at the start of bracing.

## 257. Traditional Growing Rod Instrumentation: Risk-Benefit Analysis of Surgical Intervention

*Christopher Migdal; Eric O. Klineberg, MD; Joel A. Lerman, MD; Max R. Haffner, MS; Blythe Durbin-Johnson; Rolando F. Roberto, MD*

**Summary**

We provide a risk-benefit analysis of each dual growing rod instrumentation (GRI) procedure that can aid in shared decision-making of initiating, continuing, and completing treatment with GRI.

**Hypothesis**
Each lengthening procedure will slightly reduce the patients' primary Cobb angle and will facilitate thoracic expansion. However, each lengthening procedure will require multiple radiographic studies and significant time under general anesthesia, and will be associated with a considerable complication rate.

**Design**
Retrospective review. We collected all data for this study from the patients' medical records.

**Introduction**
GRI has become a popular method of treatment for early-onset scoliosis (EOS). It requires a return to the OR and manual distraction every 6 months. This procedure is associated with significant risks that include instrumentation failure, infection, additional radiation dose, and additional time under anesthesia. The purpose of this study is to develop a model to determine the risks and benefits of each lengthening procedure.

**Methods**
A retrospective review of a single center's experience treating 29 patients with severe EOS with GRI. All patients treated at our institution who either completed their treatment course with GRI or were treated for a minimum of two years with GRI were selected for this study.

**Results**
10 of our 29 patients completed treatment with GRI and had definitive fusion. These 10 patients' primary Cobb angle reduced on average from 66 degrees to 37 degrees on final films. For the entire duration of their care, they had an average of 31 radiographs, 2 fluoroscopic exams, and 1 CT. They were under general anesthesia for an average of 1,312 minutes for routine scheduled procedures, and if there were implant or wound complications, they were under anesthesia for an additional 155 or 279 minutes, respectively. 60% of the patients had an implant complication and 30% had a wound complication. Our linear mixed effects model estimated that each lengthening procedure roughly decreased the patients' primary Cobb angle by 0.7 degrees and increased their T1-T12 height by 0.4 cm. However, each procedure was associated with a 20% instrumentation complication rate, 3% wound complication rate, 4 radiographic studies, and 104 minutes under general anesthesia.

**Conclusion**
While GRI is an effective treatment for EOS, there are additional risks associated with the repeated anesthetics and radiographic imaging. Our model can help weigh the potential risks and benefits in the shared decision-making of initiating, continuing, and completing treatment with GRI.

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### 258. Surgeon Survey Shows No Adverse Events with MRI in Patients with Magnetically Controlled Growing Rods (MCGR)

*Regina Woon; Lindsay M. Andras, MD; Hilali H. Noordeen, FRCS; Stephen Morris, MD; John Hutchinson; Suken A. Shah, MD; Jeff Pawelek; Charles E. Johnston, MD; David L. Skaggs, MD, MMM; Children's Spine Study Group; Growing Spine Study Group*

**Summary**
MRIs can be safely performed in patients with MCGRs, however, MRIs of thoracic and thoracolumbar spine may be of limited clinical benefit due to artifact.

**Hypothesis**
MRI following implantation of MCGR is not associated with any adverse events.

**Design**
Retrospective multicenter

**Introduction**
MCGRs have been shown to reduce the need for repeated surgical procedures and improve costs when compared to traditional growing rods but concerns about MRI compatibility exist. MRIs are often clinically indicated in the EOS population. The purpose of this study was to determine if MRI following implantation of MCGR is associated with any adverse events.

**Methods**
Pediatric spine surgeons who are members of the Growing Spine Study Group, Children's Spine Study Group, and early international users of this technology were surveyed regarding MRI use after performing MCGR surgery.

**Results**
118 surgeons were surveyed. Four surgeons reported 10 patients had an MRI with an implanted MCGR. Loss of fixation (0%, 0/10), movement of implants (0%, 0/10), unintended lengthening/shortening (0%, 0/10) or noticeable heating of MCGR (0%, 0/10) were not observed. No problems were observed with function of the MCGR following MRI and a mean of 2.1 mm was obtained at the next lengthening (range, 0.5-3.0mm). Two patients had brain MRIs, both of which could be interpreted. All cervical spine MRIs could be interpreted without excessive artifact (100%, 7/7). Six patients had MRIs of the thoracic or lumbar spine but these were considered uninterpretable as a result of artifact from the MCGR device (0%, 0/6).

**Conclusion**
These are the first reported cases of MRI use in humans with MCGR. There were no adverse events observed. MCGR rods lengthened as expected following MRI. MRIs of the brain and cervical spine were able to be interpreted, but MRIs of the thoracolumbar spine could not be interpreted due to MCGR artifact.

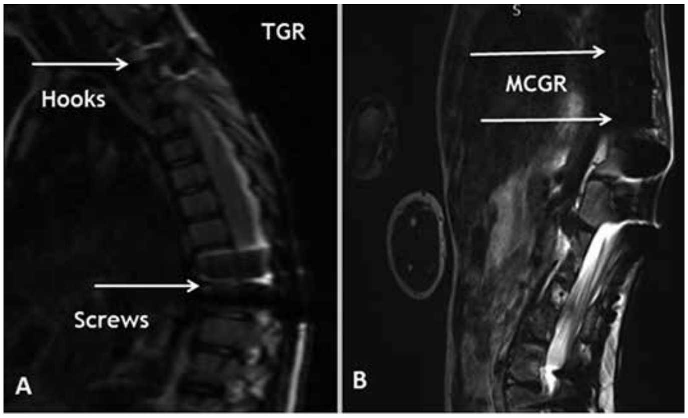


**Figure 1A & B:** Despite some artifact the intraspinal pathology can still be evaluated in a patient with TGR (A). In contrast figure B shows a patient with a MCGR where a large area of artifact prevented any of the images from being interpreted and intraspinal pathology in the thoracolumbar spine could not be evaluated.

## 259. Risk and Benefits of Definitive Fusion to Graduate Patients with Early Onset Scoliosis at the End of Distraction-Based Programs

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**Summary**
The decision on how to graduate an early onset scoliosis patient after a distraction-based program was analyzed in a prospective cohort of 32 patients. Deciding whether a definitive fusion or observation should be made depended on major curve deformity, sagittal misalignment, deformity etiology, or complication with previous implants. Definitive fusion effectively corrected coronal and sagittal deformity and increased trunk height; in exchange, patients had to undergo high surgical costs with limited coronal balance improvement.

**Hypothesis**
Definitive fusion leads to better correction but higher risks

**Design**
Prospective comparative analysis

**Introduction**
EOS is treated by growth-friendly techniques until skeletal maturity. Afterwards, they can be "graduated," either by definitive fusion (DF) or by retaining the previous implants (RPI) with no additional surgery. Criteria for this decision-making and the risks and benefits of definitive fusion are still to be determined.

**Methods**
We analyzed a prospective cohort of "graduated" patients after a distraction-based lengthening program. We gathered demographic, radiographic, and surgical data. Results of the two final treatment options were compared after 2-years' follow-up.

**Results**
32 patients were included. 4 patients dropped out, 13 underwent DF, and 15 underwent RPI. The mean age at initial treatment was 7.4 yrs, with a mean follow-up 8.3 years. Both groups had similar preoperative and final radiographic parameters (P>0.05). The criteria for undergoing DF were congenital etiology, implant-related complications, main curve magnitude (DF=63.2º±9 vs. RPI=47.9º±15;P=0.008), sagittal misalignment–SVA (DF=19.5±40mm vs. RPI=-17.3±35mm; P=0.29). During DF 12/13, patients underwent multiple osteotomies (average 5 SPO), one PVCR, and 3 costoplasties. Surgical time was 291.5±58min; blood loss was 946±375ml; and the number of levels fused was 13.7. Main Cobb was corrected by 19.7º±2.7 (31% correction); compensatory curve was corrected by 13.3º±6.3 (34%); T1-S1 length gained was 31±19.6mm and T1-T12 length gained was 9.3±39mm; Kyphosis was reduced by 10º±10.4 (22%); and SVA was reduced by 5.3±30mm. However, coronal balance worsened by 2.3±30.8mm. No major complications were encountered

**Conclusion**
Graduation by DF depended on unacceptable or progressive major curve deformity, sagittal misalignment, congenital etiology, or complication with previous implants. RPI on neuromuscular curves, Cobb<50º, and coronal misalignment <20 mm. Definitive fusion effectively corrected coronal and sagittal deformity and gained trunk height; in exchange, there was a high surgical cost without improvement in coronal balance.

## 260. Worsening Assisted Ventilator Rating (AVR) Correlates with Decreased Scores on Early Onset Scoliosis Quality of Life (EOSQ) in Patients Treated with Rib Based Growing Systems (RBGS): A Prospective Cohort Study

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**Summary**
Children with Early Onset Scoliosis (EOS) requiring RBGS implantation may have diminished pulmonary function and require supplemental oxygen or mechanical ventilation which influences quality of life (QOL). Our results correlate the level of ventilator assistance according to AVR with decreased QOL measures.

**Hypothesis**
Children with EOS undergoing RBGS implantation are expected to have AVR scores which correlate with QOL as measured by the EOSQ.

**Design**
Prospective cohort study

**Introduction**
Pulmonary function and QOL are outcome measures of interest for patients with EOS undergoing RBGS implantation. AVR is a scale used to measure ventilation needs in this population. A higher, or more severe, AVR has been suggested to imply negative changes in QOL. The EOSQ is a validated outcome measure developed for use in this population. We aimed to assess the correlation between EOSQ and AVR.

**Methods**
AVR and EOSQ scores were extracted from the Children's Spine Study Group database for patients under ten years old. Instances

were included if obtained after a minimum of two years after RBGS and excluded if the time between AVR and EOSQ assessment was greater than six months. Spearman Correlation Coefficient was performed to determine correlation between AVR and EOSQ.

**Results**
93 instances of concomitantly obtained EOSQ and AVR in 71 patients were analyzed. There was a statistically significant correlation between AVR and EOSQ in Child's Health Related Quality of Life and Family Impact sections in a total of five subsets (Table 1). Strength of correlation was weakly associated in descending order with: Physical Function (-0.40), Daily Living (-0.29), General Health (-0.26), Pulmonary Function (-0.25), and Financial Impact (+0.24).

**Conclusion**
A more severe AVR is negatively correlated with several domains of the EOSQ for patients with EOS after RBGS implantation. While the strength of this correlation was in some areas lower than expected, the results may reflect the reality that patients with childhood chronic disease adapt to their health status. The EOSQ responds as expected to increasing ventilator dependence, further validating the instrument.

Table 1. AVR/EOSQ Subset Correlation

| EOSQ Heading | AVR/EOSQ Correlation Coefficient | P-value |
|---|---|---|
| **General Health** | **-0.26** | **0.01** |
| Pain | 0.16 | 0.13 |
| **Pulmonary Function** | **-0.25** | **0.02** |
| Transfer | -0.19 | 0.07 |
| **Physical Function** | **-0.40** | **0.0002** |
| **Daily Living** | **-0.29** | **0.007** |
| Fatigue | -0.15 | 0.16 |
| Emotion | 0.11 | 0.33 |
| Parent Impact | 0.02 | 0.88 |
| **Financial Impact** | **0.24** | **0.02** |
| Child Satisfaction | -0.12 | 0.25 |
| Parental Satisfaction | -0.17 | 0.11 |

## 261. Conversion of Traditional Growth Friendly Instrumentation to Magnetically Controlled Growth Rods Does Not Affect Radiographic Outcomes Nor Increase Hardware Related Complications at Two Years Follow Up

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**Summary**
Patients undergoing primary magnetically controlled growing rod (MCGR) insertion have greater curve correction and lower complication rate than conversion patients in this largest reported cohort of patients in the early US experience. While conversion (CON) patients have a higher complication rate than primary insertion (INS) patients which were mainly medically-related, the wound/implant complication rates are lower than traditional growth friendly instrumentation (TGFI).

**Hypothesis**
CON patients will have higher complication rates than INS or TGFI patients with no additional radiographic correction.

**Design**
Retrospective cohort study using CSSG/GSSG EOS registries with historical control (TGFI).

**Introduction**
MCGR use has increased dramatically since the 2014 US release. Much of the early US experience involved conversion of TGFI to MCGR, even though the potential benefits/complications of CON are even less understood than INS. The purpose of this study is to compare outcomes and complications between INS and CON, with TGFI as control.

**Methods**
Major coronal curve/kyphosis and complications were compared at preop, postop, 1-yr, and 2-yr for INS and CON patients.

**Results**
57 patients (age 8.3y) were identified with no significant differences in age, gender, or C-EOS between INS and CON. There were 35 INS and 22 CON patients at a mean of 2.7yr after original implant (Rib-based 50%;Spine-based 50%). For INS, the major coronal/kyphosis angles were 70°/44° at preop, which corrected 39%/20% to 43°/35° at initial postop ($p<0.05$), and was stable at 2 yr (41°/37°). For CON patients, there were no significant changes from preop (56°/53°) to 2 yr (52°/55°) ($p>0.05$). 23 patients had 37 complications. Total complications were more frequent for CON (55%) than INS (31%) ($p=0.08$),but similar between CON (55%) and TGFI (58%). Wound complications were similar between INS (3%) and CON (5%), but lower than TGFI (16%). Medical complications for CON (14%) were higher than INS (6%), but similar to TGFI (12%). MCGR-specific complications were similar between INS (3%) and CON (5%).

**Conclusion**
Initial curve correction is greater following INS than CON,

which is maintained at 2 year follow-up. Complication rates are higher for CON than INS patients, which appear to be due to host/medical factors rather than device-related. This may reflect differences in comorbidities not accounted for by C-EOS classification. Device complications were similar in CON compared to INS patients, with both being lower than TGFI controls. MCGR-specific complications were low in both groups.

Comparison of Complications between Primary (INS) and Conversion (CON) MCGR with TGFI Control

| Complication Type | Primary MCGR (INS) | Conversion MCGR (CON) | Traditional Growth Friendly Instrumentation (TGFI) - Historical Control* |
|---|---|---|---|
| Total | 11/35 (31%) | 12/22 (55%) | 81/140 (58%) |
| Wound | 1/35 (3%) | 1/22 (5%) | 23/140 (16%) |
| Medical | 2/35 (6%) | 3/22 (14%) | 17/140 (12%) |
| Implant | 8/35 (23%) | 8/22 (36%) | 63/140 (45%) |
| MCGR-specific | 1/35 (3%) | 1/22 (5%) | N/A |

* Bess et al, 2010 - JBJS

## 262. Is Spine Flexibility Maintained with the Use of Semi-Constrained Growing Rods for Early Onset Scoliosis in Children?

Geoffrey N. Askin, FRACS; Maree T. Izatt; Robert D. Labrom, MD; Clayton J. Adam, PhD

**Summary**
Semi-constrained growing rods (GR) achieved 54% reduction in deformity and 11cm mean trunk height increase in a cohort of early onset scoliosis patients followed from GR insertion to final fusion.

**Hypothesis**
That semi-constrained GR will control deformity and allow ongoing growth during successive lengthening procedures, limiting auto-fusion and improving final correction in early onset scoliosis patients.

**Design**
Prospective single centre study of consecutive early onset scoliosis patients managed with the semi-constrained GR system.

**Introduction**
The GR surgical technique comprises fusionless instrumentation to reduce and control deformity whilst allowing the young spine to grow in early onset scoliosis. Original constrained GR designs result in spine auto-fusion which limits trunk lengthening and the degree of final correction possible. An earlier biomechanical study had shown that the semi-constrained GR allowed similar axial rotation ranges of the instrumented spine segments to that of an un-instrumented spine.

**Methods**
Semi-constrained GR were surgically inserted and lengthening procedures were performed at approximately six monthly intervals until the final definitive fusion surgery.

**Results**
Between 2007-2016, 27 patients with mean age of 8.1 years (1.5-10.5) underwent GR treatment. Diagnoses were neuromuscular (N=19), congenital (N=4), idiopathic (N=4) and the mean follow-up was 4.9 years (1.3-9.0). The mean pre-treatment Cobb angle was 73.6° (45-120); corrected to mean 39.3° (22-85) after GR insertion. To date 16 patients with mean age 12.5 years (7.2-16.0) have undergone definitive fusion surgery; mean pre-fusion Cobb angle of 54.6° (20-105) after having mean 6.8 (2-13) lengthening procedures. The trunk height increased by a mean 11.1 cm (5.5-19.6) between insertion of GR and the final fusion surgery. Mean Cobb angle after final fusion surgery was 34.0° (10-90) demonstrating a mean 37.8% curve correction relative to the pre-fusion curve and 53.8% reduction of deformity throughout the GR treatment. Eight of 27 patients experienced a complication: 3 infections, and in the 6 who had a single GR inserted there were 3 GR fractures and 3 failures of the cephalad hooks.

**Conclusion**
Results indicated the semi-constrained GR system was effective and allowed regular lengthening procedures. This new concept of GR may provide greater trunk lengthening compared to other systems by limiting the chance of auto-fusion with a minimum of implant complications.

## 263. Comparison of Weight Percentile Gain with Growth-Friendly Constructs in Early Onset Scoliosis (EOS)

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**Summary**
Underweight EOS patients (below the 20th weight percentile) gain a mean of 11 in weight percentile. There were similar gains with all types of growth friendly spine instrumentation.

**Hypothesis**
We hypothesize there is no significant difference in increase in weight percentile between growth friendly constructs in the treatment of EOS.

**Design**
Retrospective Multicenter

**Introduction**
Thoracic Insufficiency resulting from EOS can lead to severe cardiopulmonary disease. In this age group, pulmonary function tests are often difficult or impossible to perform. Weight gain has been used in prior studies as a proxy for improvement and has been demonstrated following prosthetic rib-based constructs and growing rod implantation. In this study, we aim to analyze weight gain of EOS patients treated with 4 different spinal implants (growing rods with spine anchors, growing rods with rib anchors, prosthetic rib-based constructs, guided growth constructs) to evaluate if significant differences in change in weight percentile exist between them.

**Methods**
Retrospective review of patients treated surgically for EOS was performed from a multicenter database. Exclusion criteria were index instrumentation at >10 years old and less than 2 year follow-up.

**Results**
287 patients met the inclusion criteria and etiologies were as follows: congenital=85; syndromic=79; neuromuscular=69; and

idiopathic=52. Average patient age at surgery was 5.4 years, with average follow-up of 5.8 years. Preoperatively, 55.4 % (162/287) fell below the 20th percentile. There was no significant difference in preoperative weight between implants (p=0.77), or diagnoses (p=0.25). Among this group, mean change in weight percentile was 10.5% (range: -16.7% to 88.7%) and all implant groups increased in mean weight percentile at final follow-up. Mean change in weight percentile was as follows: Growing rod spine anchors=13.4%; Growing rods rib anchors= 9.2%; Prosthetic rib-based constructs= 4.2%; Guided growth construct= 4.6%. There were no significant differences in weight percentile change by implant type (p=0.17).

**Conclusion**
Treatment of EOS with growth friendly constructs resulted in an increase in weight percentile for underweight patients (<20th percentile) with no significant difference between constructs.

## 264. Distraction-Based Surgeries Increase Spine Length for Patients with Non-Idiopathic Early Onset Scoliosis (EOS) - 5 Year Follow up

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**Summary**
At minimum 5 yr f/u, distraction-based surgeries are an effective way to increase spine length for non-idiopathic EOS. Final spine length is greater for neuromuscular than for congenital and syndromic patients.

**Hypothesis**
Distraction-based surgeries will increase spine length in patients with non-idiopathic EOS; although there may be differences between etiologies.

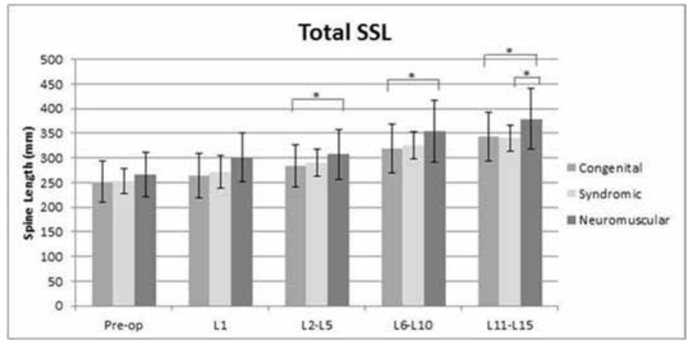
**Design**
Retrospective, comparative multi-center review.

**Introduction**
As EOS has many etiologies, it is unclear whether underlying etiology affects the spine length achieved with distraction-based surgeries. Since distraction may produce kyphosis, spine length should be assessed in the sagittal plane using the sagittal spine length (SSL - curved arc length of the spine in the sagittal plane). Our purpose was to determine if distraction-based surgeries will increase spine length in patients with non-idiopathic EOS and whether etiology affects final spine length.

**Methods**
Patients with non-idiopathic EOS treated with distraction-based systems (min 5 yr f/u, 5 lengthenings). Radiographic analysis pre-op, post-implant (L1) and after each lengthening (L2-5, L6-10, L11-15). Primary outcome was T1-S1 SSL.

**Results**
85 patients-63 congenital, 12 syndromic, 10 neuromuscular with pre-op age 4.1 yrs, scoliosis 73 degrees, kyphosis 46 degrees. After initial correction, scoliosis remained constant (62 degrees at L11-15) and kyphosis increased over time (40 degrees at L1 to 62 degrees at L11-15). SSL increased for the entire group from 253mm pre-op to 344mm at L11-15* and during distraction phase (270mm at L1 to 344mm at L11-15*). Pre-op SSL did not differ between etiologies; however, at final f/u, neuromuscular patients had greater SSL than the other etiologies* (Fig 1 with 1 std dev, *p<0.05).

**Conclusion**
At minimum 5 year follow up, distraction-based surgeries increased spine length for patients with non-idiopathic EOS; however, patients with neuromuscular etiology obtained greater final spine length than those with congenital and syndromic etiologies.




## 265. Does Mobility of the Chest Cage Affect the Pulmonary Function in Middle-Aged Patients with Idiopathic Scoliosis with Onset Before Age 10 Years?

*<u>Aina J. Danielsson, MD, PhD</u>; Kerstin Lofdahl Hallerman, MD, PhD; Andreas X. Socratous, MD; Åse A Johnsson, MD PhD*

**Summary**
Middle aged patients with reduced pulmonary function due to idiopathic scoliosis (IS) before the age of 10 had less mobility of the chest cage of the convex side.

**Hypothesis**
Middle-aged patients with IS who have reduced pulmonary function have less thoracic mobility compared to those with normal function.

**Design**
38 patients with IS, with onset before age 10 and braced or operated before maturity, were selected based on their PF at a mean 26-year follow-up (FU) after treatment. 19 had reduced PF (R, Forced Vital Capacity FVC <80% of the predicted) and 19 had normal PF (N, FVC >90 %). Patients were reexamined 4 years later.

**Introduction**
The knowledge is sparse concerning pulmonary function in adult patients with onset of IS before age 10. We aimed to evaluate wether PF is affected by the mobility of the chest cage.

**Methods**
Patients underwent spirometry and a computed chest tomography, which was performed in maximum inspiration and maximum expiration. Volumes of each lung were calculated and measures of the thoracic cage were calculated.

**Results**

The patients of the R group, compared to the N group, were significantly younger at onset (mean 5.5 vs. 7.2 years), had larger curves at start of treatment (mean 51° vs. 36°) and underwent surgery more often (mean 68 vs. 26%). Mean age (47 vs. 43 years) and curve size were similar (36°) at the FU. The thoracic cage (rotation to the sagittal plane, RAsag, and Rib Hump Index) was more distorted in the R group than the N group (mean 25.7° vs. 12.5°, p=0.0040 and mean 0.98° vs. 0.23°, p=0.0006 respectively). The increase of the total volume from expiration to inspiration did not differ between the N and R groups (142% vs. 117%, n.s.), while the ability to increase the lung volume on the convex side of the curve was significantly less for the R group than the N group (increased by 112 vs. 136 %, p=0.027).

**Conclusion**

The thoracic cage was significantly more distorted in the group with significantly reduced PF compared to the N group, despite similar curve sizes. The mobility of the thoracic cage on the convex side, as measured by the ability to increase the lung volume, was significantly lower in individuals with reduced PF.

## 266. Spine and Thoracic Length Measurements have Excellent Reliability in Patients with Early Onset Scoliosis

*Nicole Michael, BA; Patrick Carry; Mark A. Erickson, MD; Nikki Bloch, BA; Steven Gibbons; Courtney O'Donnell, MD; Sumeet Garg, MD*

**Summary**

This study assessed the reliability of pediatric spine and thoracic length radiographic measurements in the frontal plane. Excellent overall inter and intrarater reliability was observed for measuring both spine and thoracic length of patients with early onset scoliosis.

**Hypothesis**

There will be strong inter and intrarater reliability for spine and thoracic length in the frontal plane.

**Design**

Reproducibility of measurements

**Introduction**

Spine and thoracic length radiographic measurements are often used as a surrogate for pulmonary development in patients with early onset scoliosis (EOS). The purpose of this study is to investigate the reliability of spine and thoracic length measurements in the EOS population.

**Methods**

Using pilot data, it was determined that measuring 49 unique radiographs would provide 80% power to obtain a 95% confidence interval width of 0.05 for the interclass correlation coefficients (ICC). A random sampling strategy, stratified by underlying diagnosis according to EOS classification, was used to select subjects. Following institutional review board approval, 2 attending pediatric spine surgeons, 2 pediatric orthopaedic fellows, and 2 research assistants measured coronal spine (T1-S1) and thoracic (T1-L1) length on digital radiographs using a deformity measuring software program on two separate occasions at least three weeks apart. Order of images was randomized for the second iteration. Linear mixed model regression analyses were used to estimate inter and intrarater reliability.

**Results**

The study sample included subjects with idiopathic (N=17, 35%), congenital (N=16, 33%), neuromuscular (N=11, 23%), and syndromic (N=4, 8%) etiologies. Overall interrater reliability estimates for spine length [ICC: 0.894, 95% CI: 0.847-0.932] and thoracic length [ICC: 0.890, 95% CI: 0.844-0.929] were excellent. Intrarater reliability estimates for spine length [ICC: 0.906, 95% CI: 0.830-0.943] and thoracic length [ICC: 0.898, 95% CI: 0.817-0.938] were also excellent. The standard error of measurement (SEM) based on intrarater reliability was 1.95 cm for spine length and 1.31 cm for thoracic length. The SEM based on interrater reliability was 2.07 cm for spine length and 1.36 cm for thoracic length. Reliability estimates and SEM based on rater are shown in the figure.

**Conclusion**

There is excellent inter and intrarater reliability for digital radiographic measurements of spine and thoracic length in the EOS population at our institution. The measurement error is greater than the normal growth rate of a pediatric patient and introduces caution when evaluating treatments for scoliosis of the growing spine over a short duration of time.

| | InterRater Reliability | | | IntraRater Reliability | | |
|---|---|---|---|---|---|---|
| | ICC | 95% CI | SEM | ICC | 95% CI | SEM |
| Spine Length | | | | | | |
| Attendings | 0.968 | 0.940-0.982 | 1.124 | 0.982 | 0.969-0.990 | 0.832 |
| Fellows | 0.828 | 0.747-0.891 | 2.590 | 0.831 | 0.707-0.897 | 2.562 |
| RAs | 0.873 | 0.724-0.936 | 2.321 | 0.904 | 0.826-0.942 | 2.020 |
| Thoracic Length | | | | | | |
| Attendings | 0.941 | 0.907-0.965 | 0.986 | 0.962 | 0.931-0.978 | 0.798 |
| Fellows | 0.811 | 0.716-0.882 | 1.809 | 0.824 | 0.691-0.891 | 1.746 |
| RAs | 0.916 | 0.862-0.950 | 1.190 | 0.924 | 0.865-0.955 | 1.131 |

SEM = standard error of measurement; RA = research assistant rater

## 267. Rod Breakage in Growth Guidance Constructs: When, Where, and Why

*Kipp Cryar, MD; David B. Bumpass, MD; Frances McCullough, MNSc; Richard E. McCarthy, MD*

**Summary**

Growth guidance system (GGS) constructs using 5.5mm rods had a very low breakage rate, superior to constructs using 3.5mm or 4.5mm rods. Rods universally broke immediately adjacent to the apical fusion, or at a 3.5mm/4.5mm rod junction. Idiopathic EOS pts were most likely to experience rod breakage.

**Hypothesis**

Larger rod diameter in GGS constructs reduces overall breakage rate and improves rod longevity.

**Design**

Retrospective case series

**Introduction**

The GGS system, when implanted for early onset scoliosis (EOS), has the ability to decrease progression of scoliosis without the need for lengthening surgeries as required for other growing rod systems. However, rod breakage does occur in GGS pts. Detailed data reporting breakage rates and patterns in GGS constructs have not been published.

**Methods**
All pts (N=91) who underwent GGS placement for EOS at a single institution from 2004-15 were reviewed. Rod fractures were detected via serial radiographs and, in some cases, palpable prominence. Rates of rod breakage were compared for each rod size, and breakage patterns were noted.

**Results**
With an average of 6.2 years of follow up (0.94 to 12.2 yrs) 27/91 pts (30%) experienced rod breakage at a mean 2.9 yrs post-implantation (0.48 to 8.2 yrs). 8/23 pts (35%) with 3.5mm rods experienced rod breakage at a mean 1.4 yrs post-implantation (0.47 to 4.2 yrs). 24/59 pts (41%) with 4.5mm rods had a rod break at a mean 3.4 yrs after implantation (0.60 to 8.2 yrs). Only 1 of 34 pts (3%) with 5.5mm rods had a rod breakage, 2.3 yrs post-implantation. Breakage rate was significantly lower for 5.5mm rods when compared to 3.5mm and 4.5mm rods ($p<0.01$). Pts with idiopathic EOS had the highest rate of breakage at 36%, significantly greater than a 29% breakage rate for syndromic/neuromuscular pts and 25% for congenital EOS pts ($p=0.04$). Rods universally broke either just cephalad or caudal to the fused apex, or at the junction of a 3.5mm rod with a 4.5mm rod. The mean distance of the rod breakage from the fusion mass was 1.1cm (range 0-4.6 cm). Two pts had rods that migrated >4cm post-breakage.

**Conclusion**
Smaller-diameter GGS rods broke sooner and more frequently. Only 1 pt with 5.5 mm rods had rod breakage. 3.5mm rods broke at a similar rate as 4.5mm rods; however the 3.5mm rods broke an average of 2 years earlier than 4.5mm rods. Idiopathic EOS pts were more likely to break their rods, regardless of diameter. We recommend against using 3.5mm rods and suggest 5.5mm rods be used whenever possible in GGS treatment for EOS, and both rods should be replaced soon after identification of a rod break to prevent rod migration.

Table 1.

| % Likelihood of Subsequent Breakage Post-Implantation | 3.5 mm Rods | 4.5 mm Rods | 5.5 mm Rods |
|---|---|---|---|
| Within the 1st year | 22% | 2% | 0% |
| Between 1 and 2 years | 11% | 10% | 0% |
| Between 2 and 3 years | 6% | 10% | 3% |
| Between 3 and 4 years | 0% | 11% | 0% |
| Between 4 and 5 years | 7% | 14% | 0% |

Figure 1. 8 yo female 4 yrs after GGS implantation w/ 4.5 mm rod breakage immediately distal to fused apex.

## 268. The Impact of Convex Epiphysiodesis on Spinal Growth in Early Onset Scoliosis

*<u>Sleiman Haddad</u>; Luigi Aurelio Nasto, MD, PhD; Hossein Mehdian, MD, FRCS(Ed)*

**Summary**
Luque Trolley construct without convex epiphysiodesis (CE) could achieve significantly better growth and lung development in Early Onset Scoliosis (EOS) compared to a matched cohort treated with trombones and CE. Deformity was controlled equally well in both groups

**Hypothesis**
CE has a tethering effect on spinal growth and doesn't´t add any benefit in terms of deformity correction in EOS

**Design**
Matched cohort study of patients with EOS in our institution between 1990-2011 with two different guided growth techniques

**Introduction**
The aim in management of EOS is to correct the spinal deformity and maintain the correction while allowing the thoracic cavity and lungs to grow. Traditional growth rods require repeated surgeries and have high rate of complications. Guided growth techniques can avoid the problem of repeated surgeries and complications. Historically, CE was combined to guided growth construct to improve deformity correction. The utility of this additional anterior surgery was never studied properly. We studied two different guided growth constructs, one with CE, to compare results

**Methods**
Group 1: CE associated to Trombones. Group 2: Dual Growing Rod Technique with sublaminar wires and pedicular screws Matching was done based on age, sex, etiology, and severity of deformity Deformity parameters and growth measures as well as lung function were compared between both groups using fisher test

**Results**
We had 9 patients in each group (total 18 patients, 1:1 matching). Average age at surgery was 6yr (Range 2-10). Average f-up was 6yrs (2-11.5). 10 patients had Neuromuscular or syndromic curves whereas 4 were idiopathic EOS and 4 were due to a congenital vertebral malformation. Patients had similar preoperative curves (p 0,57) and achieved similar corrections (53% Vs 56% p 0,40) that was maintained at last f-up (p 0,20). Group 2 achieved significantly more growth (T1-S1 9.93mm/yr, 79% expected for age Vs.4.05mm/yr, 30% expected for age; $p<0{,}001$) during the first 5 years. X-rays between 5-year and 10-year f-up were available only for group 1 showing a growth r of 1.65mm/year. FVC at last f-up was done for neuromuscular and syndromic patients and was better in the group 2 without CE (60% Vs 50%, $p<0{,}001$). Full results are reproduced in Table 1. Growth in Group II is comparable to the published literature.

**Conclusion**
Our 5-year follow-up results show that Luque Trolley without epiphysiodesis achieves much better growth and respiratory function

than Luque Trolley with additional convex epiphysiodesis (2.79 times more growth) . Convex epiphysiodesis did not improve deformity control and seemed to have a tethering effect on growth. It should therefore be avoided when growing constructs are used

| Table 1: Results | | | | |
|---|---|---|---|---|
| | Group I | Group II | P | N=18 |
| Preopative Major Curve | 67° (45-95) | 65° (40°-91°) | 0.578 | 65° (40°-95°) |
| Immediate Postop Curve | 31.5°±6.0° (53% correction) | 29° ± 6.5° (56% correction) | 0.424 | 30° (0°-66°) |
| Major curve at 5yrs | 33.5°±7.1° | 30.4° ± 4.9° | 0.388 | 31° (0°-68°) |
| Major curve at Last follow-up | 34.2° ± 7.5° | 30.4° ± 4.9° | 0.278 | 32° (0°-69°) |
| Instrumented segment Growth/yr (<5yrs) | **2.27mm± 1.8** | **6.33mm±2.1** | **<0.001** | |
| T1-S1 Growth/yr (<5yrs) | **4.05mm ± 2.1** | **9.93mm± 2.3** | **<0.001** | |
| % Expected | **30%** | **79%** | **<0.001** | |
| Instrumented Segment Growth/yr (5-10yrs) | 1.65mm± 1.2 | -- | -- | |
| FVC* (5yrs) | **50.00%** | **60.75%** | **0.01** | |
| * Done for Neuromuscular and Syndromic patients only (N=10) | | | | |

### 269. Physician Collections are 71% Less for Early Onset Scoliosis Casting than for Growing Rod Instrumentation, but Hospital Collections are Similar

*Ena Nielsen, BA; Lindsay M. Andras, MD; Meghan Brown; David L. Skaggs, MD, MMM*

**Summary**
While hospital charges and collections per year were similar for patients treated with growing rods (GR) and serial elongation, derotation, and flexion casting (EDF), physician charges were 85% and physician collections were 71% less for casting patients per year. Sustaining a casting program may require hospital support for surgeons.

**Hypothesis**
The cost of EDF casting is less than the cost of GR instrumentation for the treatment of early onset scoliosis (EOS).

**Design**
Retrospective single-center

**Introduction**
GR instrumentation and the EDF casting technique are two options for treatment of progressive EOS. Our purpose was to investigate the cost of these two treatments for EOS.

**Methods**
Retrospective review of patients with EOS treated at our institution from 2007 to 2014 with either GR or EDF casting. Patients with <2 year follow up were excluded. Physician and hospital charges and collections until time of fusion were examined.

**Results**
20 patients met the inclusion criteria; there were 8 in the GR group and 12 in the EDF casting group. There were no significant differences between the groups in age (GR mean= 4.7 yrs; EDF casting mean= 3.5 yrs, p= 0.17), public vs private insurance (p= 0.71), or major curve (GR mean= 80.6 degrees; EDF casting mean= 66.7 degrees, p= 0.14) at the initiation of treatment. The two groups did differ significantly in length of follow-up (GR mean= 5.5 years; EDF casting mean= 2.6 years, p= 0.001). Excluding final fusion, the EDF casting patients had an average of 2.1 (range: 0.7-6.6) procedures/year while the growing rod patients had an average of 1.5 (range: 0.8-2.7) procedures/year. Average procedure time for the EDF group was 104.2 min; average procedure time for GR group, including initial fusion, was 93.0 min (p= 0.37). Physician charges were 85% less for the EDF group (EDF= $1,892.75, GR= $12,354.53, p<0.001). Physician collections were 71% less for the EDF group (EDF= $731.10, GR= $2,554.88, p= 0.001). The hospital charges and collections were similar between the 2 groups (p= 0.82, p= 0.42).

**Conclusion**
Although operative time was similar, the physician collections/year of treatment for EOS patients was significantly less with EDF casting than with GR treatment. The hospital charges and collections were similar between the two treatment groups.

Table 1. Comparison of physician and hospital charges and collections per year of treatment with either growing rods or EDF casting.

| Procedure | MD Charges/Year | MD Collections/Year | Hospital Charges/Year | Hospital Collections/Year |
|---|---|---|---|---|
| Growing rod | $12,354.53 | $2,554.88 | $46,958.12 | $13,388.27 |
| EDF casting | $1,892.75 | $731.10 | $52,315.55 | $10,213.00 |
| P-value | <0.001 | 0.001 | 0.82 | 0.42 |

### 270. The Effect of Different Lengthening Intervals of Dual Growing Rod Technique in the Treatment of Early Onset Scoliosis

*Jianguo Zhang, MD*

**Summary**
Dual growing rod technique has been considered as a safe and effective method in deformity correction and maintenance as well as in allowing spinal growth. But the lengthening intervals during the treatment period still remains controversial.

**Hypothesis**
Compared with lengthening intervals (<7m or >10m), a 7-10 month lengthening interval may be a better choice, considering the similar correction and spinal growth rate, relatively lesser surgeries, and lower complication rate.

**Design**
Retrospective study

**Introduction**
This is a retrospective study to evaluate the clinical outcomes of different lengthening intervals of dual growing rod in the treatment of early onset scoliosis, and try to find a better lengthening interval for clinical practice.

**Methods**
A total of 73 consecutive patients with intact follow-up information, receiving dual growing rod treatment in our hospital from 2004 to 2014, were enrolled. There were 56 females and 17

males, with an average age of 7.1 ± 2.6 years old at initial surgery. All patients had a minimum of 2-year follow-up. According to different lengthening interval, these patients were divided into 3 groups: 7 patients in Group 1 (< 7 months), 35 patients in Group 2 (7 - 10 months), and 31 patients in Group 3 (> 10 months). Number and frequency of lengthenings, and complications in each group were recorded. Radiographic evaluation included changes in Cobb angle, and T1-S1 length over the treatment period.

**Results**

The average lengthenings in Group 1, Group 2, and Group 3 was 4.9 ± 2.5, 5.1 ± 2.0, and 5.2 ± 2.7, respectively, with an average LI of 6.4 ± 0.4 months, 8.4 ± 0.8 months, and 11.3 ± 1.1 months, respectively. The post-initial and follow-up correction rate among 3 groups showed no significant difference (P>0.05). The annual T1-S1 growth in Group 1 and Group 2 was 1.76 ± 0.50 cm/year and 1.61 ± 0.48 cm/year, respectively, which was significantly higher than that in Group 3 (1.27 ± 0.47 cm/year, P<0.05). Twenty-six of 73 patients (35.6%) had 50 complications. The complication rate in both Group 1 and Group 3 was higher than that in Group 2.

**Conclusion**

With a 7-10 month lengthening interval, the correction rate was satisfying, and the complication rate and lengthening procedures was relatively lower. So, a 7-10 month lengthening interval may be a better and more practical solution for regular periodic lengthening in clinical practice.

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## 271. Contemporary Presentation and Recent Surgical Trends of Klippel-Feil Syndrome

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**Summary**

Klippel-Feil patients that presented with the classical Sprengel's deformity or congenital spinal fusion are rare. In contrast, patients were more likely to have other congenital abnormalities. Recent years show that KF patients are increasingly being treated with spinal fusion procedures and decreasingly with decompression only.

**Hypothesis**

KF diagnoses no longer follow traditional definitions.

**Design**

Retrospective analysis

**Introduction**

Historically, KF symptomology includes craniocervical anomalies, low posterior hairline, and brevicollis, with limited cervical range of motion. However, there remains no agreed-upon consensus on inheritance pattern. As a result, classification systems have been inadequate, and thus treatment algorithms have not been fully established.

**Methods**

KF patients ages 0-20 in the KID database were identified by ICD-9 code 756.16. Incidence was established using KID-supplied year- and hospital-trend weights. Demographics and secondary diagnoses commonly associated with KF were evaluated. Comorbidities, anomalies, and procedure type trends from the years 2003-2012 and assessed for likelihood to increase amongst the years studied using ANOVA tests.

**Results**

858 KF diagnoses were analyzed (51.1% female) and 475 patients with CF (50.3% female). Only 6.8% of KF patients were diagnosed with Sprengel's deformity and 1.4% with congenital fusion. Low hairline could not be queried in the database. 19.4% of KF patients presented with another spine abnormality, 3.0% presented with another musculoskeletal anomaly, and 13.6% presented with an anomaly of any other parts of body. 163 patients (12.6%) were treated surgically. Simple fusions were performed in 38.5% of patients (less than 3 levels, one approach), and more invasive fusion procedures were performed in 48.1% of patients. From 2003 to 2012, national trends revealed an increase in overall comorbidity burden (0.383 to 0.558, p=0.009). Eye (0% to 1.4%, p=0.043) and ear (0.7% to 4.0%, p=0.009) congenital anomalies increased over the years studied. Surgical treatment with any type of spinal fusion increased in popularity (6.7% to 18.4%, p-0.000), while decompression-only procedures decreased significantly (6.7% to 1.8%, p=0.009). Simple fusions increased from 0.7% to 7.9% (p=0.000) with both posterior and anterior approaches showing increased popularity (0% to 1.4% [p=0.043] and 0.7% to 4.3% [p=0.005]). Complex fusions similarly increased (0% to 10.4%, p=0.000) with only the posterior approach showing an increasing trend (0% to 6.8%, p=0.000).

**Conclusion**

KF patients are rarely diagnosed with traditional symptoms of KF. Operative techniques are recently moving towards fusions, and decreasing in complication incidence.

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## 272. The Use of Halo Gravity Traction in the Treatment of Severe Early Onset Scoliosis

*Sravisht Iyer, MD; Oheneba Boachie-Adjei, MD; Rufai Mahmud, MD; Irene Wulff, MD; Henry Ofori Duah, RN; Henry Osei Tutu; Kwadwo Poku Yankey MD, MD; FOCOS Spine Research Group*

**Summary**

Curves in severe early onset scoliosis (EOS) are sometimes not amenable to primary implantation of growing rod or guided growth (GR/GG) constructs. In such cases, pre-operative halo-gravity traction (HGT) provides ~30% correction and enables GR/GG implantation. Curves can be further corrected to ~40% following GR/GG implantation. HGT has a 30% complication rate but revision is only required in 6.7% of patients. HGT alone does not appear to significantly improve pulmonary function.

**Hypothesis**

Severe EOS curves that are not amenable to GR/GG implantation can be rendered treatable with pre-operative HGT

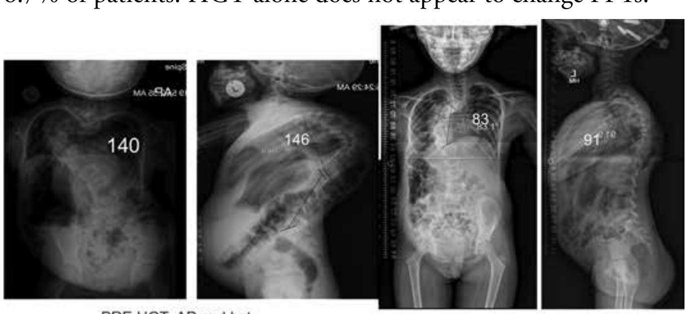
**Design**
Retrospective Review of Prospective Cohort

**Introduction**
In children with severe EOS, primary implantation of GR/GG constructs is not always possible (Figure 1). We describe patients who were treated in a staged fashion with HGT (stage 1) followed by GR/GG implantation (stage 2).

**Methods**
Pediatric patients (pts) with severe scoliosis treated with HGT prior to GR/GG implantation were included. HGT used traction up-to 50% body weight for 4 to 29wks (average 11wks). Pulmonary function tests (PFTs) were performed before and after HGT. Coronal Cobb (CC) and Sagittal Cobb (SC) angles were measured on the Pre-HGT, Post-HGT and 6 week post-op XR. Descriptive statistics are reported below. Pre-and post-operative PFTs were compared using a paired T-test.

**Results**
30 pts (15 female, 15 male) were included. Average age at GR/GG implantation was 9 years (range: 3-12). Most cases (n=24,80%) were idiopathic. Most pts had kyphoscoliosis (n=16, 53.3%) or scoliosis (n=11, 36.7%). Pre-HGT CC averaged 112±22° and SC averaged 106±26°. Following HGT, CC improved to 77±13° (29%) and SC to 74±17° (29%). After surgery, CC improved further to 70±14° (36% vs. pre-HGT) and SC to 63±21° (41%). HGT-related complications occurred in 9 pts (30%); 8/9 were pin site infections and 1 was a cranial abscess. Halo revision was required in 2 pts (6.7%). There was no change in PFTs following HGT (p>0.05 for all parameters). During surgery, an average of 14 levels were spanned; 2 pts required vertebral column resection. Surgical complications occurred in 9 (30%) of patients. By most recent follow up (average 16 months, range 1-38months), 7 pts (23.3%) had required reoperations; most commonly for broken implants (n=3,10%) and deep infection (n=2,6.7%).

**Conclusion**
In the setting of severe EOS not amenable to immediate GR/GG insertion, HGT can allow for ~30% correction of SC and CC. This improvement renders these curves treatable with GR/GG with further improvement to ~40% during implantation. While HGT has a 30% complication rate, revision is only required in 6.7% of patients. HGT alone does not appear to change PFTs.




PRE HGT AP and Lat

POST HGT HGT AP and Lat

## 273. No Acute Spine Infections in 1,380 Days: What We Have Done to Make This a Zero Event

*Amanda T. Whitaker; Crystal Seilhamer, MSN, RN, CNP, CNOR; Pamela L Horn, NP; Juan Mendoza, BS; Laura Gill, MD; Walter P. Samora, MD; Jan Klamar, MD; Allan C. Beebe, MD*

**Summary**
Acute spine infections are costly and preventable. We retrospectively reviewed our data from the institution before and after our spine infection protocol in May 2013. We have had zero acute spine infections with the adherence to our pre-operative and intra-operative protocol since its institution in 2013.

**Hypothesis**
We can identify unique factors that help to decrease acute spine infections to a zero-event.

**Design**
Retrospective case-control study

**Introduction**
Spine infections are devastating and costly. There is an effort to make post-operative infections a zero-event at our hospital through the "Zero Hero Program" instituted in 2009. Since that time, with the institution of pre-operative and intra-operative protocols we have made acute spine infections a zero event.

**Methods**
We retrospectively reviewed all spine surgeries with instrumentation from 2010-2016, before and after the establishment of our infection protocol in 2013. Age at fusion, BMI, ASA, comorbidities, type of surgery, length of surgery, adherence to the protocol, length of stay, max curve, previous procedures, short- (<90 days) and long-term infection rates, history of infection and complications were recorded.

**Results**
We have performed 381 spine surgeries after the protocol and 316 before the protocol, with an increased spine volume of 10 cases per year. We have had no acute spine infections since the institution of the protocol. Prior, we had a spine infection rate of 1.9%. Our compliance rate with our antibiotic and prep protocol is 95% compared with 92% prior (p=0.1). The largest improvement was in redosing of antibiotics (99% vs 95% p<0.05). Primary posterior spinal fusions comprised 74%, 4% were revisions, 14% growth-friendly devices and 6% conversions. Four had a history of previous infection. Most surgeries (99.7%) were completed by two attending surgeons. Average length of surgery was 4 hours and 32 minutes. Complicated diagnoses including congenital, neuromuscular, and syndromic, were 28% of our cases. Average number of comorbidities was 2.1. Changes to the protocol included skin prep (chloroprep, alcohol, duraprep, and ioban), cefazolin at 50mg/kg redosed every 3 hours, gentamycin for complex cases, limited traffic, no razors, positive pressure rooms, delayed instrumentation opening, no drains, and pre-operative lice and acne protocols.

**Conclusion**
Adherence to an aggressive antibiotic and skin prep protocol, preoperative screening for acne and lice, and dual attending surgeries have resulted in acute spine infections a zero event.

## †274. Development of a New Quaternary-Ammonium Bactericidal Coating with Anti-Biofilm Activity: Application on Covalently Grafted Titanium Surfaces

*Houssam Bouloussa, MD, MS; Charles Court, MD, PhD*

**Summary**
Quaternary-ammonium polymers (QAPs) are easily obtained and grafted on various surfaces to prevent bacterial adhesion and proliferation on surfaces. A QAP was synthesized and grafted on titanium surfaces to assess its bactericidal activity and visualize its killing mechanism and anti-biofilm activity.

**Hypothesis**
Quaternary ammium polymers may be of interest for titanium coating.

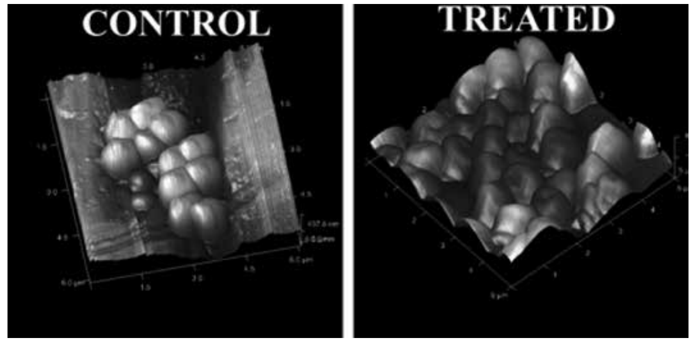
**Design**
Bacteriological studies on titanium surfaces

**Introduction**
Numerous in vitro studies showed the interest of biocidal polymers grafted on plastics or metals in the medical field. A polymer was synthesized and grafted on titanium for bacteriologic testing.

**Methods**
in vitro antibacterial activity: a MRSA strain isolated from a patient with a prosthetic joint infection was cultured in Brain Heart Infusion (BHI) at 37°C overnight. According to a modification of the 22196:2011 ISO norm, a 107CFU/mL bacterial suspension of 20 µL in rich medium (BHI) was simultaneously applied on pure titanium 1cm2 plates (control vs grafted with a QAP, mono-layer or thick coating) at 37°C. Cultures were sequentially stopped after 1h (bacterial killing) and 24h (growth inhibition), diluted in 0,9% saline and vortexed for detachment of live bacteria and bacterial counting. In vitro anti-biofilm activity: an in vitro biofilm was created on similar titanium plates with a 106 CFU/mL bacterial suspension of 500µL in BHI in each well. Cultures at 37°C were then stopped sequentially after 6h, 12h, 24h, 72h, and 7 days (medium was replaced every 24h). Plates were rinsed three times with PBS 5% and fixed in a 2,5% glutaraldehyde solution. AFM (Atomic Force Microscopy) of the biofilm after 3 hours and SEM-FEG (Scanning Electron-Microscopy with Field Emission Gun) from 6h to 7d days were obtained.

**Results**
A 1,6 log10 reduction of bacteria occurred on mono-layer coated surfaces in 1 hour, respectively 6,96 log10 UFC/mL vs 8,56 log10 UFC/mL, and 1,1 log10 in 24 hours, respectively 9,20 log10 UFC/mL vs 10,17 log10 UFC/mL, $p<0,0001$. Surfaces with thick coatings were sterilized, respectively 6,96 log10 UFC/mL vs 1 log10 UFC/mL, $p<0,0001$. An anti-biofilm effect was visualized on SEM-FEG up to 7 days. A specific effect on the 3D structure of killed bacteria was characterized using AFM: bacterial shrinkage and volume reduction as well as perforation were visualized.

**Conclusion**
The present study confirms the current body of evidence that bacterial membrane perforation is the primary mechanism by which bacteria are killed by QAPs. Such molecules could become promising candidates for coating on biomaterial implants provided further assessment using relevant in vivo models is performed.




## 275. Neurophysiologic Data for an Initial Series of Consecutive Lumbosacral Fusion Procedures Using Cortical Bone Trajectory (CBT) Screw

*George Rymarczuk, MD; Payman Vahedi, MD; John Gillick, MD; Jack Jallo; Joshua Heller; James S. Harrop, MD; Srinivas Prasad*

**Summary**
There is currently no published literature on the neurophysiologic data of CBT screws.

**Hypothesis**
The authors seek to define typical as well as concerning neurophysiologic parameters to enhance the safety of CBT screw insertion.

**Design**
Retrospective chart review of consecutive lumbosacral fusion patients using CBT screws.

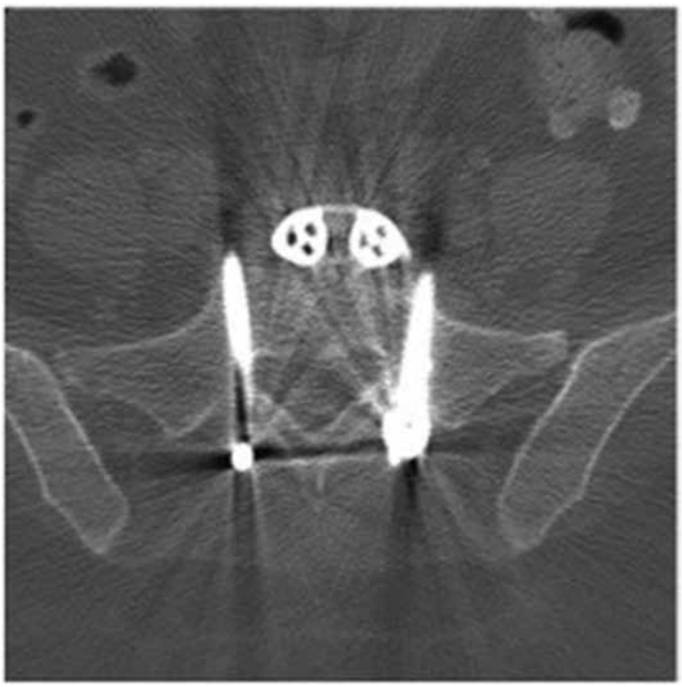
**Introduction**
CBT screws are an emerging means of spinal fixation. Potential advantages of CBT screws include improved screw purchase and pullout strength, less extensive soft-tissue dissection necessary for exposure of the screw insertion point, and less risk to neural and vascular structures. There is, however, no published literature regarding "typical" intra-operative neurophysiologic data findings for this new technique.

**Methods**
The records of 44 consecutive patients that underwent lumbosacral fusion procedures using CBT screws at a single institution were retrospectively analyzed for intraoperative neurophysiologic data.

**Results**
212 CBT screws were analyzed in 44 consecutive patients. Screws were placed from L2 to S1. Mean triggered electromyography (tEMG) stimulation threshold for all screws was 21.9 mA (range: 4-84 mA). After ROUT and ANOVA analysis, mean stimulation threshold was found to be 19.5 mA at L2, 24.3 mA at L3, 23.9 mA at L4, 19.5 mA at L5, and 13.9 mA at S1. Screws at S1 stimulated at a lower threshold than screws at all other levels ($p = 0.005$ vs L3; $p < 0.0001$ vs L4; $p = 0.025$ vs L5); screws at L5 stimulated at a lower threshold than L4 ($p = 0.009$). Intra-operatively, eight screws (3.7%) were felt to be potentially malpositioned based on fluoroscopic or tEMG findings. Six CBT screws were replaced after palpation of the tract confirmed no breach.

One screw was redirected, and one was unable to be salvaged and thus replaced with a traditional pedicle screw (0.9% revision rate).

**Conclusion**
As with traditional pedicle screws, concerning intra-operative findings that may indicate a breach include: too inferomedial of a trajectory noted on fluoroscopy, a stimulation threshold less than 8 mA, or a disproportionately low stimulation threshold compared to adjacent screws. Such findings intra-operatively should prompt investigation. CBT screws at S1 stimulate at significantly lower thresholds than at other levels, and screws at L5 stimulate at a lower threshold than L4. Reasons for this difference in stimulation threshold may be related to a shorter Euclidean distance from screw to nerve root at these levels, in addition to less available cortical bone within the sacrum, which decreases overall impedance to the applied current.



## 276. Pre-operative Halo-Gravity Traction: Can it Replace a Vertebral Column Resection?

*<u>Todd J. Blumberg, MD</u>; Susan Nelson, MD, MPH; Sumeet Garg, MD; Mark A. Erickson, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Munish C. Gupta, MD; Lawrence G. Lenke, MD; Patrick J. Cahill, MD*

**Summary**
Outcomes for pediatric patients with severe spinal deformity treated with pre-operative halo-gravity traction versus vertebral column resection were compared. HGT resulted in a 31% major curve correction pre-operatively and 49% after fusion, and was preferentially utilized in patients with more severe deformities and lower weight and BMI. Complication rates, length of stay, and estimated blood loss were similar between the cohorts. Improved curve correction was obtained in patients undergoing VCR, but it is unclear if this difference is clinically relevant.

**Hypothesis**
Patients treated with pre-operative halo-gravity traction (HGT) will have similar radiographic outcomes and lower complication rates compared to patients that undergo vertebral column resection (VCR) in the management of complex pediatric spine deformity.

**Design**
Prospective observational multicenter cohort.

**Introduction**
HGT can be an effective treatment to improve curve magnitude prior to surgery. However, severe deformities may still require VCR to achieve satisfactory correction. Treatment algorithms for complex pediatric spinal deformity are subject to surgeon preference and institutional bias. We seek to evaluate the role of HGT as an alternative to performing VCR in patients with complex deformity.

**Methods**
85 patients with severe spinal deformity undergoing operative management with either pre-operative HGT or intra-operative VCR and minimum 2-year follow-up were identified from a prospective multicenter database. Patients that received both HGT and VCR were excluded. Differences in patient characteristics, clinical, and radiographic outcomes were examined using bivariate statistics.

**Results**
42 patients underwent treatment with pre-operative HGT without VCR and 43 were treated with VCR alone. Patients treated with HGT had greater magnitude coronal (123° vs. 72°) and sagittal (124° vs. 101°) curves compared to patients treated with VCR alone ($p<0.01$). There was no difference between groups in regards to age, gender, or height, although patients with lower weight and BMI were selected for HGT more often ($p<0.01$). There was no difference in blood loss, complication rate, or postoperative length of stay. Mean HGT time was 83 days. Patients undergoing VCR had greater improvement in both coronal (69% vs. 48%, $p<0.01$) and sagittal curves (62% vs. 49%, $p<0.01$).

**Conclusion**
Surgeons preferentially utilized HGT in patients with more severe deformities and lower BMI. VCR results in greater correction of spinal deformity, but the clinical relevance of the difference in correction between groups is unclear. Pre-operative HGT is an effective adjuvant treatment in patients at higher risk for complication with VCR.

## 277. High Rate of Intraoperative Monitoring (IOM) Alerts in 176 Severe Pediatric Deformity Patients and its Relationship to the Deformity Angularity Ratio (DAR)

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**Summary**
IOM alerts are common (43%) in complex pediatric spinal deformity. Sagittal DAR is associated with any IOM and TCeMEP alerts; however, new permanent neurologic deficits are uncommon.

**Hypothesis**
Intraoperative monitoring alerts occur frequently in severe pediatric deformity cases, especially with severe angular deformity.

**Design**
Prospective observational multicenter cohort study.

**Introduction**
Severe pediatric deformity is technically challenging with higher complications. The surgical procedures were analyzed in terms of neurologic safety.

**Methods**
Patients with severe spinal deformity with a minimum curve of 100° or a planned VCR underwent operative treatment for their deformity and were followed for minimum 2 years. Logistic regression was used to evaluate associations of different procedures and radiographic parameters (VCR procedure, ant/post procedure, coronal C-DAR, sagittal S-DAR) with intraoperative neural monitoring alerts (SSEP, TCeMEP, and any IOM) and postoperative deficits.

**Results**
176/313 enrolled in the study met the inclusion criteria; we excluded patients with <2 yrs FU. 76/176 (43%) patients had a VCR procedure and one patient had a PSO. 162 (92%) had a posterior only approach; 14 (8%) were treated with a combined ant/post-surgery. 75 patients had 114 total intraop monitoring alerts. S-DAR was associated with any intraop alerts (p=0.04) and TCeMEP (p=0.04). C-DAR was associated with SSEP alerts (p=0.02). The 5 most common triggering events were correction maneuvers, 3-column osteotomy, implant and instrumentation placement, and hypotension. Some patients had multiple triggering events (N=26). 161 were neurologically normal preop. 150 pts remained normal neurologically postop and 11 had new deficits. However at 2 years postop, only 1/11 still had a deficit. 14 pts had a neurologic deficit preop. Postop 4 pts improved to a normal neurologic status, 9 pts continued to have a deficit, and 1 pt had partial recovery neurologically. At 2 years, out of the 14 neurologically abnormal pts preoperatively, 11 totally recovered, 2 partially recovered and 1 deficit did not improve.

**Conclusion**
Severe deformity pediatric patients have a high incidence of intraoperative neural monitoring alerts (43%); however, only 2 new permanent deficits were seen. 13 out of 14 patients improved or recovered from preoperative neurologic deficits. Sagittal DAR is associated with intraoperative monitoring alerts. Neural monitoring should be mandatory in these cases.

Table 1. Associations with neurological alert during surgery.

| | Bivariable Odds Ratio (95%CI) | P-value | Multivariable Odds Ratio (95% CI) | P-value |
|---|---|---|---|---|
| | | | | |
| S-DAR Any alert N=75 | 1.04 (1.00, 1.07) | 0.0579 | 1.04 (1.00, 1.08) | 0.0435 |
| C-DAR SSEP N=4 | 1.20 (1.02, 1.42) | 0.0275 | 1.19 (1.03, 1.38) | 0.0205 |
| S-DAR TCeMEP N=52 | 1.03 (1.00, 1.07) | 0.0792 | 1.04 (1.00, 1.09) | 0.0414 |

## 278. Structural Validity of the SRS-22 Questionnaire in Patients with Adult Spinal Deformity

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**Summary**
Designed for AIS patients, the SRS-22 is also widely used as an outcome instrument in ASD patients, although its structural validity has not been evaluated in this group. Confirmatory factor analyses on its 20 non-management items, using data from 245 US English, 428 Spanish, 229 Turkish, 95 French, and 195 German-speaking patients, revealed some consistently weak item-loadings. We recommend removal of 4 items (3,14,15,17), and standardization of others across language versions, to provide an improved 16-item version of the instrument.

**Hypothesis**
The four-factor structure of the SRS-22, originally designed for use in adolescent idiopathic scoliosis (AIS), is supported by data on patients with adult spinal deformity (ASD).

**Design**
Evaluation of invariance of the SRS-22 structure across different languages and sub-groups of ASD patients.

**Introduction**
Designed for AIS patients, the SRS-22 is now widely used as an outcome instrument in ASD patients. No studies have confirmed the four-factor structure (pain, function, self-image, mental health) of the SRS-22 in ASD and under different contexts.

**Methods**
Confirmatory factor analysis was performed on the 20 non-management items of the SRS-22 with data from 245 American English, 428 Spanish, 229 Turkish, 95 French, and 195 German speaking patients. Item-loading invariance was compared across languages, age groups, etiologies, treatment groups, and assessment times. A separate sample of 772 American SRS-22 data from surgical ASD patients was used for cross-validation.

**Results**
The SRS-22 factor structure fitted significantly better to the proposed four-factor solution than to a unifactorial solution.

However, items 14 (personal relationships), 15 (financial difficulties), and 17 (days off work) consistently showed weak item loadings within their factors across all language versions and in both baseline and follow-up datasets. Items 8 (back pain at rest), 11 (medication use), and 10 (trunk appearance) showed weak item loading in some languages. A trimmed SRS (SRS-16) that used the 4 least problematic items in each of the 4 domains yielded better-fitting models across all languages, but equivalence was still not reached. With the SRS-16 there was equivalence of item-loading with respect to treatment (surgery vs conservative), time of assessment (baseline vs 12 mo FU), and etiology (degenerative vs idiopathic), but not age (< vs ≥ 50y). All findings were confirmed in the cross-validation sample.

**Conclusion**

We recommend removal of the worst-fitting item in each domain of the SRS-22 (items 3, 14, 15,17), together with adaptation and standardization of other items across language versions, to provide an improved 16-item version of the instrument.

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## 279. Changes in Pulmonary Function Testing Following Halo Gravity Traction in Severe Deformity

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**Summary**

Severe spinal deformity causes limitations in baseline pulmonary function tests (PFTs) with both functional vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) being 53% of predicted. Pre-operative Halo Gravity Traction (HGT) improved FVC in ~20% of patients. Improvements were more likely to be seen in female patients, patients with more severe baseline deficits (i.e., those with FVC ~40% predicted) and those with improvements in FOCOS Score (FS) during HGT.

**Hypothesis**

There is a subset of patients that are more likely to respond to HGT with improvements in PFT.

**Design**

Retrospective Review of Prospective Cohort

**Introduction**

One theoretical advantage of HGT in the setting of severe deformity is the potential for improvement in pulmonary function prior to surgery. The impact of HGT on PFT, however, has not been previously described.

**Methods**

Patients (Pts) treated with HGT before undergoing primary surgery were included. HGT utilized traction up-to 50% body weight for 6 weeks to 8 months. PFTs were obtained both before and after HGT application. Pts without PFT data were excluded. A change of >15% in FVC was considered significant (improvement >=15%: FVC+, improvement < 15% or worsening: FVC-). FS, a previously-described risk stratification score, was used to quantify operative risk. FS was calculated before and after HGT. Groups were compared using chi-squared and t-test as appropriate. A multivariate logistic regression was used to determine independent predictors of PFT change.

**Results**

83 pts (32 female, 51 male) were included. Average age was 17.3 years (range 4 -32). Pre-HGT coronal CM was 130±22º and sagittal CM was 129±37º. Most cases were idiopathic (n=51,65.1%) and had kyphoscoliosis (n=66,79.5%). There was significant pulmonary disease prior to HGT (FVC: 53±21%, FEV1: 53±21%). However, there was no significant change in FVC or FEV1 following HGT (ΔFVC: 1±19%, p=0.581; ΔFEV1: -2±17%, p=0.371). 16 pts (19.3%) were FVC+. There was no difference in age, BMI or HGT duration between FVC+ and FVC-. FVC+ pts were more likely to be female (OR: 2.2, 95% CI: 1.05-4.6, p=0.006). FVC+ pts were more likely to have lower pre-op FVC (40% v 57%, p=0.006). FVC+ pts had a higher pre-op FS (92 v 86,p=0.035) but were also more likely to have improvement in FS (OR: 3.5, 95%CI: 1.1-11.1, p=0.030). Multivariate regression showed gender (p=0.004), pre-HGT FVC (p=0.009) and FEV1 (p=0.023) were independent predictors of FVC+ (R^2=0.447).

**Conclusion**

Although most pts have no changes in FVC following HGT, ~20% of pts see an improvement in FVC. Female pts, pts with lower baseline PFTs and those with improvements in FOCOS score after HGT are more likely to see improvements in FVC.

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## 280. Predictors of a Poor Response to Halo Gravity Traction in Severe Spine Deformity.

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**Summary**

We used the FOCOS score (FS), a modified version of a previously-described risk stratification score, to quantify pre-operative risk in patients with severe spinal deformity. Patients were treated with halo gravity traction (HGT) to reduce curve magnitude (CM) and optimize their risk profile. We found that patients with large sagittal CM and pure kyphotic deformities (e.g., patients with spinal tuberculosis) were the least likely to experience reductions in FS following HGT.

**Hypothesis**

While most patients have reductions in risk, there is a subset of patients that do not respond to pre-op HGT.

**Design**

Retrospective Review of Prospective Cohort

**Introduction**

The use of HGT can improve CM and reduce the pre-operative risk profile in patients undergoing surgery for severe spinal deformities. There are, however, a subset of patients who do not have any significant changes in risk profile following HGT.

**Methods**

Patients treated with HGT before undergoing primary surgery were included. HGT used traction up-to 50% body weight for 6 weeks to 8 months. FS, a previously-described stratification score, was used to quantify operative risk. FS was calculated using patient-factors, procedure-factors and CM. Scores ranged from 0-100 with higher scores indicating increased risk. HGT-responders (FS+) had a >=10pt drop in FS after HGT. HGT non-responders (FS-) had a <10pt drop. The two groups were compared using univariate chi-squared analysis or independent t-tests as appropriate. A multivariate binary logistic regression was performed to determine independent predictors of FS response.

**Results**

96 patients (42 female, 54 male) were included. The average age was 16.6 years (range 4-32 years). Average pre-HGT coronal and sagittal CM was 128°. Coronal CM improved by 32% and sagittal CM by 31% after HGT. The average drop in FS following HGT was 18±12pts. 25 patients (26%) were FS- and 71 (74%) were FS+. FS- patients had larger pre-operative sagittal CM (151º vs. 119º, p<0.001). There was no difference in coronal CM, age, gender or BMI. Curve etiology approached significance (p=0.051) with tuberculosis curves most likely to be FS-. Pure kyphotic curves were most likely to be FS- (p=0.018, 52.9% kyphotic FS- vs. 19.4% kyphoscoliosis and 28.6% scoliosis). Multivariate analysis showed curve type (p=0.008) and pre-op sagittal CM (p=0.002) were independent predictors of FS-.

**Conclusion**

Not all patients with spine deformity respond equally to HGT. Patients with large kyphotic deformities (e.g., patients with spinal tuberculosis) are the least likely to see improvements in FS and reduction of pre-operative risk profile following treatment with HGT. For such patients other reasons must indicate the need for HGT.

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## 281. Anterior Vertebral Tethering in the Treatment of AIS: A Comparison of Skeletally Immature vs More Mature Patients

*John T. Braun, MD*

**Summary**

Scoliosis correction was analyzed in 2 groups of AIS patients treated with anterior vertebral tethering (AVT). Although skeletally immature patients (R=0-1) had greater initial (59.6% vs 48.6%) and final (75.4% vs 45.5%) curve correction compared to more mature patients (R=2-5), the former required 3 (21.4%) additional procedures (2 tether removals for overcorrection and 1 PSF for lumbar decompensation below a tether) while the latter required none.

**Hypothesis**

Both skeletally immature and more mature AIS patients will demonstrate significant curve correction with AVT. Curve correction will be greater in skeletally immature patients.

**Design**

Retrospective review of consecutive patients (2010-2015).

**Introduction**

Although AVT has been used for the treatment of AIS in both skeletally immature and more mature patients, these 2 groups have never been compared. This study analyzed curve correction in these 2 groups initially and at 2-6 year F/U.

**Methods**

Twenty-two consecutive AIS patients were treated with AVT for T, TL and L curves in the 33-60° range. Patients were skeletally immature (R=0-1) or more mature (R=2-5). Cobb angles were used to compare curve magnitude pre-op, post-op and final.

**Results**

Twenty-two AIS patients were treated with AVT. Eleven (11F) skeletally immature patients with 17 curves (10T, 5TL, 2L) had an average curve of 38.3° (33-60°) at 12+5 years (9+2-15+2) and R=0.5 (0-1.5). Eleven (9F/2M) more mature patients with 16 curves (6T, 8TL, 2L) had an average curve of 46.1° (38-57°) at 15+6 years (13+9-17+10) and R=3.9 (2-5). Eight of 11 skeletally immature patients reached 2 year F/U with 3 patients requiring additional procedures at 2-2.5 years (2 removal of tethers for overcorrection and 1 PSF for lumbar decompensation below a tether). The remaining 5 skeletally immature patients demonstrated significant curve correction from 36.6° pre-op to 14.8° post-op (p=0.0009) with further improvement to 9.0° final (p=0.0008) at 4.2 years (2-6) with final R=3.7 (0-5). Six of 11 more mature patients reached 2 year F/U and demonstrated significant curve correction from 50.8° pre-op to 26.1° post-op (p=0.002) with little additional change at 27.7° final at 3.2 years (2-6) and R=4.7 (4-5). No additional procedures were required in the more mature patients.

**Conclusion**

AVT demonstrated significant curve correction in both skeletally immature and more mature AIS patients initially and at final 2-6 year F/U. Skeletally immature patients demonstrated greater initial (59.6% vs 48.6%) and final (75.4% vs 45.5%) curve correction compared to more mature patients but also required more additional procedures (21.4% vs 0%).

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## 282. Analysis of Complications with Staged Surgery for Less Invasive Treatment of Adult Spinal Deformity

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**Summary**

This multicenter review evaluated intra- and peri-operative complications after less invasive treatment of adult spinal deformity. After propensity matching, 19 hybrid (HYB) and 19 circumferential MIS (cMIS) treated patients were compared. Baseline demographic, radiographic, and surgical characteristics were similar. HYB (36.8%) staged patients had more peri-op complications than cMIS (5.3%) (p=0.044). Neurologic complications were higher in the HYB group (36.8% vs. 5.3%, p=0.017).

**Hypothesis**

Staging has the same impact on HYB and cMIS patients.

**Design**

A multi-center database of ASD patients treated with less invasive approaches was reviewed.

**Introduction**

Spinal deformity surgery is often exceedingly invasive and lengthy. Therefore, staging surgery over separate operative days has been advocated to reduce complications. Staging is often used in minimally invasive treatment of adult spinal deformity (ASD). The impact of staging on complication rate between hybrid (HYB) and circumferential MIS (cMIS) procedures has not been well studied.

**Methods**

Patients who underwent staging, ≥3 levels treated, ≥2 yr follow-up were analyzed. 99 patients underwent staging including 53 cMIS and 46 HYB. Propensity matching for levels fused resulted in 19 patients in each group. Intra- and peri-op (≤ 30days) complications were assessed.

**Results**

There were no significant difference in age, BMI, levels treated, OR time, LOS, VAS, ODI, CC, PT, PI-LL, SVA (Table 1). The overall complication rate was significant higher in HYB (89.5% vs 52.6%, p=0.012). Staged HYB patients were 7.6 times more likely to have a complication than staged cMIS patients. Three (15.8%) HYB (implant, fracture, durotomy) but no cMIS intra-op complications occurred (p=0.071). There were more HYB (52.6%) patients with peri-op complications than cMIS (21.2%; p=0.044). Peri-op neurologic complications were more frequent in HYB (36.8%) vs cMIS (5.3%) (p=0.017). Other complications did not differ significantly. 30 day re-operations were higher with cMIS (10.5%) vs HYB (0%) (p=0.046). The 2 cMIS patients requiring a return to the OR had revisions due to a superficial infection and 1 wound dehiscence.

**Conclusion**

In this propensity matched ASD cohort, MIS staged surgeries have fewer complications than HYB staged surgeries, but higher 30 day re-operations. Peri-op complications were significantly higher for HYB staged surgeries with neurologic adverse events being most common.

| | MIS | HYB | p |
|---|---|---|---|
| N | 19 | 19 | |
| Age | 67.3 | 62.8 | 0.075 |
| BMI | 28.5 | 27.9 | 0.954 |
| Follow-Up | 36.2 | 37.3 | 0.795 |
| Levels Instrumented | 6.6 | 7.3 | 0.817 |
| Total OR Time | 558.2 | 722.7 | 0.053 |
| Total EBL | 730.3 | 1461.3 | **0.004** |
| Total LOS | 10.7 | 11.3 | 0.544 |
| Pre-op Back Pain | 7.2 | 7.1 | 0.954 |
| Pre-op Leg Pain | 5.8 | 5.4 | 0.722 |
| Pre-op ODI | 55.6 | 49.6 | 0.201 |
| Pre-op Max Cobb | 33.2 | 40 | 0.644 |
| Pre-op PT | 22.5 | 22.1 | 0.908 |
| Pre-op PI-LL | 14.2 | 14.9 | 0.773 |
| Pre-op SVA | 35.1 | 63.8 | 0.203 |
| Complications | 10 (52.6%) | 17 (89.5%) | **0.012** |
| Intra-operative Complications | 0 (0.0%) | 3 (15.8%) | 0.071 |
| Implant | 0 (0.0%) | 1 (5.3%) | 0.311 |
| Operative | 0 (0.0%) | 2 (10.5%) | 0.146 |
| Peri-operative Complications | 4 (21.1%) | 10 (52.6%) | **0.044** |
| Infection | 1 (5.3%) | 4 (21.1%) | 0.15 |
| Surgical Site | 1 (5.3%) | 0 (0.0%) | 0.311 |
| Neurologic | 1 (5.3%) | 7 (36.8%) | **0.017** |
| Cardiopulmonary | 1 (5.3%) | 3 (15.8%) | 0.29 |
| Gastrointestinal | 0 (0.0%) | 3 (15.8%) | 0.071 |

Table 1. Comparison of matched MIS and HYB subgroups

## 283. Anterior Strut Bone Grafting via Concave Side Approach for Dystrophic Spinal Deformities in Neurofibromatosis type-1 Patients: A Case Series

_Takuto Kurakawa, MD, PhD_; *Koki Uno, MD, PhD; Teppei Suzuki, MD, PhD; Noriaki Kawakami, MD, DMSc*

**Summary**

Anterior fusion with strut bone grafts via concave side approach (concave side fusion) were performed for dystrophic spinal deformities in 12 neurofibromatosis type-1 (NF-1) patients. Solid fusion was obtained in all patients with 2 minor complications. Concave side fusion might be advantageous in respect to provide biomechanical stabilization for dystrophic spinal deformities in NF-1.

**Hypothesis**

Concave side fusion allows the surgeon to place the bone along the plumb line, and thereby it may provide biomechanical stabilization at the apex of dystrophic spinal deformities in NF-1 patients.

**Design**

A Case Series

**Introduction**

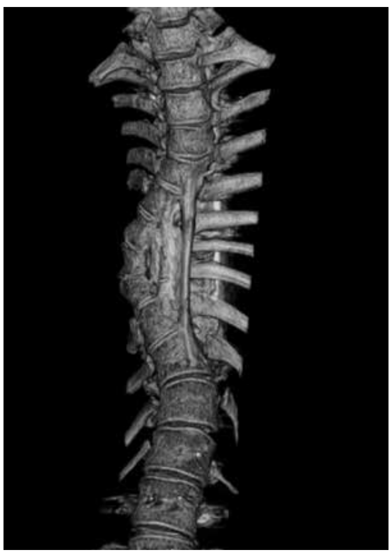
Combined antero-posterior fusion has been recommended for dystrophic spinal deformities in NF-1. However, theoretical biomechanical stability of common anterior fusion at the apex via convex approach was away from the plumb line and might not be an optimum candidate. Thus, the other approach from the opposite side remains to be validated.

**Methods**

A total of 12 dystrophic spinal deformities in NF-1 patients (9 female and 3 male) were included in the study. Mean age at surgery was 14 (range; 7-33) years and curve magnitude was 76 (42-105) degrees. Surgical procedure; from concave side approach under one-lung ventilation, proximal and distal end vertebrae were exposed and gutters for the fibular strut graft were made at the 2 vertebrae. After segmental vessels ligation, the fibular strut bone was grafted and additional ribs were placed along the fibular graft.

**Results**
Average fibular graft length was 120 mm, and 6.5 (range; 4-9) segments were fused anteriorly with 340 (231-479) minutes of operating time. Mean estimated blood loss was 670 (100-1620) ml and allogeneic transfusion was required in three patients. There were 2 perioperative minor complications; pulmonary atelectasis (1 patient), segmental vessels rupture at the time of strut bone placement (1 patient). Solid fusions were obtained and maintained in all patients with a mean follow-up of 4 years (1-11 years) after the surgery. However, osteolysis in the middle of strut graft was observed in one case with severe dystrophic changes.

**Conclusion**
Concave side fusion might be advantageous in respect to provide mechanical stabilization for dystrophic spinal deformities in NF-1.



## 284. Who Gets Staged Surgery in Severe Pediatric Spinal Deformity?

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**Summary**
Patient characteristics and imaging were compared for two groups of pediatric patients with severe spinal deformity that underwent either a single procedure or staged surgery from a prospective multicenter cohort. Patients undergoing combined anterior and posterior procedures or revision surgery were more often indicated by their surgeon for staged procedures. Almost all patients with primary kyphosis deformities had single stage procedures.

**Hypothesis**
Patients with more severe deformities, measured by preoperative major curve magnitude and deformity angular ratio (DAR), are more likely to have staged surgery.

**Design**
Prospective observational multicenter cohort.

**Introduction**
Reasons for staging severe spinal deformity correction may be related to surgeon preference and subject to the challenges of institutional logistics. We aimed to evaluate whether there are clinical or radiographic indicators associated with patients indicated for staged surgery.

**Methods**
177 pediatric patients with severe spinal deformity (major curve >100° or planned vertebral column resection) undergoing operative management with a minimum 2-year radiographic follow-up were identified from a prospective multicenter database. Differences in patient characteristics, as well as clinical and radiographic parameters were analyzed using bivariate statistics.

**Results**
147 patients underwent single stage deformity correction surgery, while 30 were staged (27 planned, 3 unplanned). There were no differences between groups in regards to patient gender, weight, height, BMI, underlying diagnoses, pulmonary function (% of FVC1 expected), number of levels fused, implant density, or highest level of Schwab osteotomy. Total and sagittal DAR were similar between groups (tDAR=27.9 for single stage vs. 26.3 for staged, sDAR=17.4 for single stage, 16.3 for staged). 97% of patients with isolated sagittal plane deformity had single stage surgery (p=0.003). Revision surgery accounted for 33% (10/30) of staged surgeries, compared to 14% (20/147) of single stage surgeries (p=0.01). Patients having staged surgery (6/30, 20%) were more likely to have a combined anterior and posterior procedure performed compared to patients having a single stage procedure (7/147, 5%; p=0.01).

**Conclusion**
Surgeons chose to stage procedures when a combined anterior and posterior procedure was undertaken and when performing revision surgery. Patients with isolated kyphosis deformity were most often addressed in a single stage procedure. These results may help with resource utilization, pre-operative counseling, and surgical planning for patients with severe spinal deformity.

## 285. The Use of Arm Span as a Substitute for Height in Calculating BMI for Spine Deformity Patients

*Harriet Opoku, MS; Theresa Yirerong, MPH; Belinda Osei-Onwona, MS; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group*

**Summary**
A comparative study of 93 pediatric Spine deformity pts and 64 normal children was done to assess the accuracy of using height or arm span with weight to calculate BMI. BMI calculation was adversely affected by the presence of a spine curvature when the arm span and height difference exceeded 3 centimeters. Clinicians should be aware of this measurement discrepancy in spine deformity patients.

**Hypothesis**
There is no difference in BMI values in spine deformity patients when using arm span or height.

**Design**
Prospective case control cohort

**Introduction**
Body Mass Index (BMI) value is based on weight to height ratio. In patients with spine deformities height does not reflect the true body size and the use of height in calculating BMI is likely to produce errors. A surrogate for height that is closest to a person's actual standing height such as the arm span will provide better values in nutritional assessment.

**Methods**
93 pediatric spine deformity pts (Grp1) were matched with 64 normal children (Grp 2). Anthropometric values (height, arm span and weight) and spinal curve were obtained. BMIs using arm span and height were calculated, and statistical analysis was done to assess the relationship between BMI /height and BMI /arm span in both groups as well as the relationship between these values and Arm span to Height difference (Delta AH) in the subjects.

**Results**
The avg age was 15.4 yrs (grp 1) vs 14.8yrs (grp 2). 46 M/47F: Grp 1 vs 33M/31F Grp 2. Major scoliosis in Grp 1 avg 104.9° (5° to 178°.) The Arm Span to Height difference (Delta AH) for Grp 1 was also calculated. A logistic regression showed that arm span could be used as a proxy to height (R2= 0.94) in persons with normal spines (Grp2) and that there was linearity in BMI scores (R2=0.97). There was a significant difference in the BMI values when comparing BMI/arm span vs BMI/height ($p<0.0001$). Mean BMI values using height was overstated by 2.81 (18.6%) i.e 18.1kgm2 instead of 15.3kgm2. The Delta AH threshold at which BMI score must be calculated using arm span as opposed to the height was 3 centimeters. Min P value=0.0312. Such was the case in 85(91%) of the study cohort.

**Conclusion**
Spine deformity pts experience height loss which can impact their true BMI values thereby giving erroneous impression of their nutritional status. Patients with Delta AH ≥ 3cm have a significant negative effect on the BMI calculation and should have the arm span used as substitute to height in BMI calculation and nutritional assessment.

| Delta AH | Population (n) | P-value |
|---|---|---|
| 0-2 | 8 | 0.1463 |
| 0-3 | 10 | 0.0312 |
| 0-4 | 15 | 0.0005 |
| 0 - >5 | 78 | 0.0001 |
| Total | 93 | |

## 286. The Use of Sublaminar Band Implants in Sagittal Curve Correction of Scoliosis in Marfan Syndrome

*Eugenio Dema, MD; Matteo Palmisani, MD; Stefano Cervellati, MD; Massimo Girardo, MD*

**Summary**
Marfan syndrome patients often require a spinal deformity surgery. There are differences in surgical principles to consider: atypical and rigid curve pattern, narrow pedicle, thin lamina and scalloping. The posterior instrumented spinal fusion should include all curves and extended to additional levels considering an alignment in sagittal and coronal planes. We report the use of sublaminar band or wires(old case)in addiction to implants (hooks/screw)to improve a sagittal curves in scoliosis surgery in patients with Marfan syndrome

**Hypothesis**
We analyze a min 2 y. postoperative results of posterior instrumented spinal fusion using hybrid/pedicle screws fixation with sublaminar band versus pedicle screws alone in scoliosis surgery in Marfan syndrome

**Design**
Prospective/comparative study in patients with scoliosis in Marfan

**Introduction**
Marfan syndrome is a systemic connective disorder

**Methods**
23 patients, 15 female and 8 male, with confirmed Marfan syndrome(Ghent criteria), mean age 16. y. (range 12-31y.) underwent to a posterior segmental instrumentation using pedicle screw alone (9) and pedicle screws or hybrid constructs with sublaminar band (14) between 1999 and 2015 in single center. Preoperative mean curve thoracic were 70.1(range 44-91) and 60(range 43-78) lumbar. In sagittal plane the curves decrease/reversed: 11(range 5-36) thoracic lordosis and mean thoracolumbar kyphosis 11.2(range 5-38). Mean FU was 5.7y.(range 2-16).

**Results**
All patients were followed for a minimum of 2 y. after surgery. The average curve correction to 32°(range 12-48) is 66% thoracic and 25°(10-35) 68% lumbar. The loss of coronal and sagittal correction at FU was 4% and 2% respectively. There is more correction rate in coronal plane with pedicle screw alone but in patients with sublaminar devices achieve a better correction in sagittal plane: decreasing a thoracic lordosis to kyphosis and thoracolumbar kyphosis to neutral. No significant differences between in blood loss, neurological deficit, hospital stay and infection rate. Four complications: 1 patient with intraoperatory dural tear, 2with a superior mesenteric artery syndrome associated with a significant correction and 1 loss of correction without instrumentation failure in correspondence of sublaminar band.

**Conclusion**
The scoliosis surgery in patients with Marfan syndrome require a particular attention to the altered bony anatomy. It's necessary to create a stable instrumentation using pedicle screws or hybrid construct to prevent curve decompensation. The use of sublaminar band, more than wires, in addition to implants may improve a sagittal curve correction and reduce difficulties of pedicle screw fixation in dismorphic Marfan spine

## 287. The Role of Pelvic Parameters on S2 Alar-Iliac (S2AI) Screw Trajectory

Jamal Shillingford, MD; Joseph L. Laratta, MD; James D. Lin, MD; Joseph M. Lombardi, MD; Comron Saifi, MD; Lawrence G. Lenke, MD; Ronald A. Lehman, MD

**Summary**
To date, no study has examined the relationship between spinopelvic sagittal parameters and screw trajectory.

**Hypothesis**
Pelvic tilt directly influences S2AI screw trajectory.

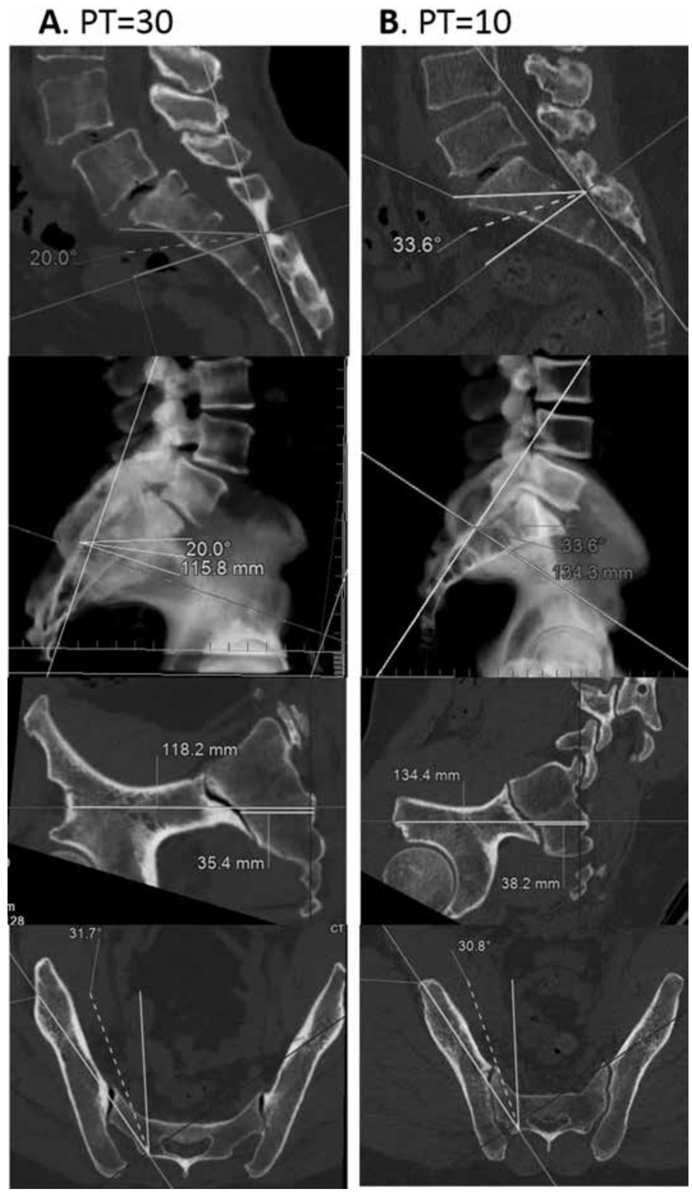
**Design**
Retrospective case series

**Introduction**
Spinopelvic fixation utilizing S2AI screws provides optimal fixation across the lumbosacral junction allowing for solid fusion, especially in long segment fusion constructs. Freehand placement of such screws relies heavily on the rich surrounding sacropelvic anatomy.

**Methods**
The medical records and preoperative CT scans of 33 consecutive patients with degenerative lumbar pathology between 2015-2016 were reviewed by two independent investigators. Preoperative standing X-rays were assessed to measure pelvic parameters including sacral slope, pelvic tilt, and pelvic incidence. Using 3-dimensional CT reconstructions, an ideal S2AI trajectory was defined as a start point between the S1 and S2 foramen with screw axis directed towards the anterior-inferior iliac spine on the sagittal plane. In the axial plane, the trajectory started at the lateral aspect of the S1/2 foramen and was directed through the narrowest portion of ilium. Sacral slope, horizontal angle, sagittal angle, intra-sacral distance and estimated screw lengths were recorded.

**Results**
The mean age at the time of surgery was 62.4+-12.5 years and there were 14 (42.4%) female patients in the cohort. The average sagittal angle measured in the sagittal plane was 27.3+-4.1°. The average horizontal angle measured in the axial plane using the posterior superior iliac spine as a reference was 35.9+-3.9°. Maximum screw length and intra-sacral screw length were 109.7+-16.4mm and 33.6+-6.4mm respectively. Pelvic tilt was found to have a moderate inverse correlation with sagittal screw trajectory (r=-0.467, p-value=0.006). Pelvic incidence and sacral slope had weak correlations with sagittal screw angle. In the subgroup analysis, patients with high pelvic tilt >20° had a significantly lower sagittal screw trajectory compared to those with a normal pelvic tilt (24.9+-3.7° versus 29.8+-2.8°, p-value = <0.001).

**Conclusion**
In this study, we found an inverse relationship between increased pelvic tilt and lower S2AI screw trajectory in the sagittal plane. This understanding of the pelvic parameters is imperative to safe and accurate placement of S2AI screws.




## 288. Gender Differences in the Recovery Experience Following Spinal Arthrodesis

Dennis G. Crandall, MD; Nina, J. Lara, MD; Andrew Chung; Jan Revella, RN; Michael S. Chang, MD; Jason Datta; Terrence Crowder; Lyle Young, MD; James Beauchamp, BSE

**Summary**
Prospective study of 1931 consecutive patients undergoing posterior spinal fusion analyzed the differences between men and women in the perception of pain and function. Women experienced more pain pre-op but improved pain (VAS) and function (ODI) more than men by 6 weeks and 1 year postop. Pain medicine use was similar by gender. Women were more likely to have comorbidities, and complications of adjacent level fracture and hardware failure. Gender differences exist in the recovery experience

**Hypothesis**
No significant difference in pain and function between male(M) and female(F) after spinal arthrodesis surgery

**Design**
Large prospective outcomes series

**Introduction**
Stereotypes exist regarding perceived gender differences involving the perception of pain. Some studies suggest that women have a lower tolerance to painful mechanical, electrical, and thermal stimuli than men. This study analyzed gender differences in pain and function after spinal fusion.

**Methods**
Prospective data from 1931 consecutive adults(F-1219; M-712) underwent posterior fusion by 5 surgeons, divided M vs F, followed 7 yrs(24-189mo). Outcomes analyzed by: diagnosis, single vs multilevel fusion, primary(1045) vs revision fusion(886), age(18-53yrs, 54-63yrs, 64-71yrs, 71-91yrs), comorbidities, BMI, revision vs no revision during follow-up, and complications. VAS, ODI, pain medication were collected pre-op, 6wks, 3mo, 6mo, 1yr. Complications were analyzed over average 7 years followup.

**Results**
Age 60 yrs(18–90yrs); 45% revision surgery. Predictors of preop pain: F, comorbidities, longer fusions, degen diagnosis, and BMI. F had more comorbidities(p<.002). M had higher pre-op BMI(29.7 vs 28.7;p<0.01). Preop VAS/ODI for F worse than M(6.5/49.7 vs 6.1/46.5;p=0.00005), 6 wks(4.3 vs 4.0;p=0.013), but was similar at 3mo(p=0.57), 6mo(p=0.61), 1yr(p=0.84). At 1 year, F had greater improvement(VAS p=0.002; ODI p=0.0007); pain medication use was similar(p=0.66). For degen group, F had lower function and higher pain preop: VAS/ODI 6.7/52 vs 6.2/47(p=0.00004); For deformity, F had more pain but similar function(6.3/46 vs 5.9/44;p=0.037, p=0.11). Older F(71-91yrs) had greater ODI improvement at 6wks and 1yr vs M(p=0.002). Degen spondy had the largest difference M vs F(p<0.0001). Of patients who required revision surgery, F improved VAS more than M(p=0.04); F had more adjacent fractures(p=0.07), hardware loosening(p=0.003).

**Conclusion**
Women had more pre-op pain but improved more at 6 wks and 1 year than men, regardless of diagnosis, age, or levels fused. F had more pre-op co-morbidities and M had higher BMI, both affecting outcomes. Gender differences exist in the recovery experience after spinal arthrodesis.

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## 289. Artificial Intelligence (AI) Can Predict Complications Better Than Traditional Statistical Testing Following Fusion for Anterior Lumbar Fusion (ALF)

*Jun S. Kim, MD; Deepak A. Kaji; Varun Arvind, MD; John M. Caridi, MD; Samuel K. Cho, MD*

**Summary**
AI Neural networks can "learn" from patient data, accurately forecast postoperative complications following ALF, and outperform logistic regression.

**Hypothesis**
AI better predicts post operative complications than logistic regression.

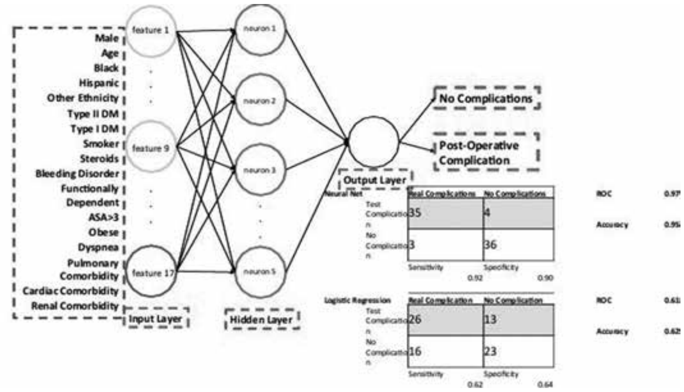
**Design**
Restrospective cohort

**Introduction**
Current clinical research relies on statistical models to identify independent risk factors of postoperative complications. However, complex interplay between risk factors is rarely accounted for, which can lead to inaccurate patient morbidity and mortality. Neural network is a machine learning classification system inspired by the human brain. Each network contains a large cluster of neurons which collectively but uniquely weigh the importance of input variables. Optimization of each individual neuron allows for the system to "learn" through repetitive epochs and minimizes error.

**Methods**
A retrospective cohort analysis was performed on national surgical data from 2011-14. Patients undergoing ALF surgery were separated into cohorts randomly. AI was trained on cases from 2011-2013 and subsequently tested on 2014 cases to simulate real world performance. A random under-sampling algorithm was chosen to account for class imbalance during training and testing. Bayesian regularization was also implemented to prevent overfitting during training and testing. Models were trained with 17 key demographic and operative variables as predictors. We defined postoperative complication as venous thromboembolism, surgical site infection, cardiac complications, or mortality. Feature selection was performed using principal component analysis. Model efficacy was assessed with area under the receiver-operator curve (AUROC) and accuracy.

**Results**
78 patients met the inclusion criteria, with 38 patients suffering from complications. The final model had a greater AUROC of 97% compared to the 61% of logistic regression and an accuracy of 95% compared to the 62% of logistic regression. The model also had a higher sensitivity and specificity (92% and 90%) compared to the sensitivity and specificity of logistic regression (62% and 64%).

**Conclusion**
This is the first case of using AI in spine literature with AUROC and accuracy values, which far exceed those of logistic regression. Although machine learning algorithms often succeed as classifiers, interpretability of its decision-making process may be obscured by the algorithm's complexity. The power of this network lies in its simplicity, with only one hidden layer comprised of five neurons. The combination of interpretability and accuracy suggests these algorithms can be applied to real time clinical workflow.




## 290. Scoliosis and Cardiopulmonary Outcomes in Osteogenesis Imperfecta Patients

Cathleen L. Raggio, MD; Rachel S. Bronheim, BA; Sobiah Khan, BA; Kate Citron, Ms.; Erin Carter, MS CGC

**Summary**
OI can result in decreased pulmonary function. Although scoliosis, commonly found in OI, has been correlated with decreased pulmonary function, it has been suggested that pulmonary function may be intrinsic to OI, rather than scoliosis.

**Hypothesis**
We hypothesized that reduction in pulmonary function is intrinsic to OI, rather than scoliosis.

**Design**
Retrospective chart review

**Introduction**
Osteogenesis imperfecta (OI) is characterized by a deficiency of type I collagen (Rauch, 2004). OI has been distinguished as a disorder of connective tissue, which can result in respiratory insufficiency—the leading cause of death in OI patients (McAllion, 1996). Correlations between scoliosis and decreased pulmonary function have been shown (Falvo, 1974; Wekre, 2014). However, it has been suggested that decreased pulmonary function may be an intrinsic component of OI, rather than a secondary effect of scoliosis (Widmann, 1999).

**Methods**
176 OI patient records were retrospectively reviewed to screen for scoliosis radiographs and PFTs. Anteroposterior radiographs were evaluated for scoliosis (curve >10°). Scoliosis curves were measured using the Cobb method by a single reviewer. If more than one curve was present, the largest curve was used for analysis. Pulmonary function was defined by FEV1/FVC ratio. Restrictive pulmonary disease was defined as FEV1/FVC >80%, while obstructive disease was defined as FEV1/FVC <70%. Bivariate correlation analysis was performed, using Spearman's rho correlation coefficient.

**Results**
57.2% of patients were female and 42.8% were male (ages 25-84). 43.4% of patients had OI Type I, 17.0% Type III, 23.3% Type IV, 1.3% Type V, 1.3% Type VIII, 1.3% Type IX, and 12.6% were unclassified or unknown recessive. 48.4% of patient charts had scoliosis radiographs, and 23.9% had PFTs. 18.9% of patient charts included radiographs and PFTs. 21.4% of patients had pulmonary comorbidity, while 18.9% had cardiac comorbidity present. The correlation between scoliosis and pulmonary function was weak (R=-0.059) and not statistically significant (p=0.747).

**Conclusion**
Pulmonary function (FEV/FVC) is weakly correlated with scoliosis. Therefore, decreased pulmonary function is most likely an intrinsic factor of OI, rather than scoliosis. Although respiratory insufficiency is known to be the leading cause of death in OI patients and regular PFTs are suggested as standard-of-care, most patients did not have PFTs done. This illustrates the need for greater emphasis on the importance of cardiopulmonary health and annual PFTs. We stress the medical importance of annual lung functions to better elucidate the underlying cause of cardiopulmonary insufficiency and minimize morbidity and mortality.

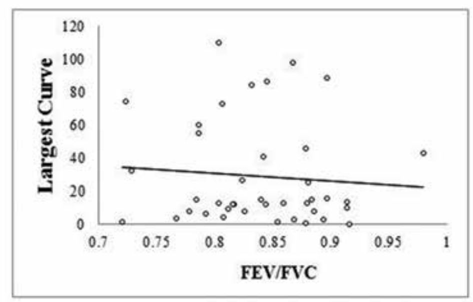



**Figure 1.** Weak correlation between scoliosis (largest curve >10 degrees) and pulmonary function (FEV/FVC); (R=-0.059; p=0.747).

## 291. The Influence of Coping Strategies on Pain Intensity & Quality of Life of Adult Idiopathic Scoliosis Patients

Johan L. Heemskerk, MD; Mark Altena, MD; B.E.E.M.J. Veraart, MD, PhD; René M. Castelein, MD, PhD; Diederik HR Kempen, MD, PhD

**Summary**
In some chronic conditions, quality of life & pain intensity are associated with coping strategies. This study found that catastrophizing and internalizing cognitions influence the QoL & pain intensity in adult patients with idiopathic scoliosis. Cognition training may be a helpful therapy in the overall treatment strategy of IS.

**Hypothesis**
Coping strategies have influence on pain intensity & QoL in adult patients with IS

**Design**
Cross-sectional

**Introduction**
Idiopathic scoliosis(IS) is a chronic deformity and may impact quality of life(QoL) in adulthood. In other chronic conditions, QoL is associated with coping strategies. Some strategies cause an exaggerated response to pain and decrease QoL. The objective was to explore the relationship between coping strategies and QoL in adult IS patients.

**Methods**
IS patients, treated during childhood between 1978-1996, were consecutive selected from a historic database and contacted to participate in this study. Patients were treated with Boston brace(n=136) or operated by Harrington spondylodesis(n=47) at least 20 years ago. All patients completed a set of questionnaires on pain coping and beliefs (pain coping and cognition list, PCCL), pain intensity (Oswestry Disability Index, ODI), & QoL (Rand-36). The PCCL describes four cognitions with a score 1 to 6: pain coping, internalizing, externalizing and catastrophizing. Analyses included non-parametric correlation and stepwise multiple regression.

**Results**
183 IS patients were recruited for this study and completed the questionnaires. Patients had a mean age of 43±3.6 years and a follow up of 28±4 years. 3 coping cognitions were almost the same between the braced and the operated group. However, braced patient had a significant higher score on pain coping (3.5±1.0 vs 2.9±1.0,P=0.029). Although the braced patients reported lower ODI scores than the operated patients(9±11 vs 19±19,P=0.059), these results were not significant. Results of the regression analyses showed that catastrophizing was associated with lower QoL & higher pain intensity and that internalizing was associated with higher QoL & lower pain intensity. Catastrophizing was the most important predictor for ODI score ( =0.451,P<0.000).

**Conclusion**
The results show that pain cognitions influence the QoL & pain intensity in patients with IS. Braced patients had a significant higher score for pain coping, which indicate that they use a better strategy to control their pain. In both treatment groups, catastrophizing showed the strongest association with QoL & pain intensity. Therefore, psychological training of positive coping styles could be a helpful complementary therapy in the overall treatment strategy of IS.

## 292. Does a Baclofen Pump Complicate Posterior Spine Fusion in Patients with Cerebral Palsy?

*Laura Lins, ATC; Anatoliy Nechyporenko, BS; Matthew A. Halanski, MD; Kenneth J. Noonan, MD*

**Summary**
Analyzing patients with Cerebral Palsy (CP) who undergo posterior spine fusion (PSF) for scoliosis revealed that patients with intrathecal baclofen (ITB) have increased surgical time, estimated blood loss (EBL), blood transfusion and need for neurosurgery consultation without increased post-operative complications.

**Hypothesis**
Patients with CP and pre-existing ITB have higher complication rates associated with PSF than similar patients without ITB.

**Design**
Retrospective comparative study of a consecutive series of CP patients undergoing PSF.

**Introduction**
In assessing outcomes following surgical procedures, appropriate risk stratification is important. Children with CP have higher rates of complications during spinal fusion compared with normal developing children. However, it is unknown whether the presence of a pre-existing ITB pump results in more difficult surgery and higher rates of complications in similarly affected children with CP.

**Methods**
Over a 15-year period, we retrospectively compared a consecutive series of CP patients undergoing posterior spine fusion (PSF); study groups included 19 patients with ITB and 49 patients without ITB. We compared demographics, comorbidities, and curve magnitude. Intraoperative measures included levels of PSF, fixation techniques, OR time, antifibrinolytics use, amount of blood loss/administration, spinal cord monitoring, and epidural placement. Post-operative measures of complications, including infection; length of ICU/hospital stay; drain utilization and drainage amount; and need for further surgery were also compared.

**Results**
ITB patients were more likely to have PSF with osteotomy and receive antifibrinolytics. A ten-fold increase in intra-operative neurosurgical consultations was found for patients with ITB. The average EBL was 1400ml for those with ITB and 900ml for those without. Average volume of blood administered was 1183 ml in those with ITB vs. 858 ml for those without. Mean surgical time was 1.2 hours greater in patients with ITB (6.7 vs. 5.5 hrs, p-value .039). Degrees of surgical correction were similar: 37.28 ±18.58 in patients with ITB and 40.45 ±17.65 for those without. Length of ICU/Hospitalization was similar between groups. Post-surgical complications were present in 78.9% of patients with ITB and 87.8% of those without ITB.

**Conclusion**
Almost half of the patients with ITB needed help from a neurosurgeon and the surgical time was over an hour longer. Although not statistically significant, those with ITB had higher EBL and blood transfused despite being significantly more likely to have antifibrinolytics. Despite the more challenging surgical course; there was no difference in complications or hospitalization time.

| Outcomes | No Pump (n=49) | Pump (n=19) | P-value |
|---|---|---|---|
| Cobb's Angle Pre-surgery | 64.79 ±21.52 | 62.62 ±21.53 | 0.6898 |
| Cobb's Angle Post-surgery | 24.34 ±14.75 | 25.34 ±13.90 | 0.7851 |
| Surgical Correction in Degrees | 40.45 ±17.65 | 37.28 ±18.58 | 0.4840 |
| Surgical Correction in Percentages | 62.12 ±19.36 | 58.39 ±18.11 | 0.4383 |
| Planned Neurosurgical Consult | 1 (2.0%) | 7 (36.8%) | < 0.001 |
| Unplanned Neurosurgical Consult | 1 (2.0%) | 1 (5.3%) | 0.484 |
| Volume of Blood Loss | 900 (250 - 7500) | 1400 (300 - 4500) | 0.093 |
| Volume of Blood Loss per Levels Fused | 61 (16 - 536) | 88 (20 - 300) | 0.158 |
| Volume of Blood Administered | 858 (0 - 4900) | 1183 (0 - 5400) | 0.074 |
| Volume of Blood Administered per Levels Fused | 55 (0 - 350) | 74 (0 - 386) | 0.111 |
| Fibrinolytics Use | 39 (81.2%) | 19 (100.0%) | 0.052 |
| Ponte Smith-Peterson Osteotomies | 7 (14.3%) | 8 (42.1%) | 0.022 |
| Nights in PICU | 2 (0-13) | 3 (0-4) | 0.362 |
| Nights in Hospital Total | 7 (3 - 26) | 6 (5 - 9) | 0.085 |
| Complications | 43 (87.8%) | 15 (78.9%) | 0.448 |
| Infection | 5 (10.2%) | 0 (0.0%) | 0.312 |
| Further Surgery Needed for PSF | 7 (14.3%) | 2 (10.5%) | 1 |
| Operating Room Time - hrs | 7.3 (4.9 - 14.7) | 8.5 (5.3 - 14.3) | 0.039 |
| Anesthesia Set Up Time - hrs | 1.4 (0.6 - 4.6) | 1.3 (1.0 - 5.0) | 0.757 |
| Surgical Time - hrs | 5.5 (3.4 - 10.7) | 6.7 (4.0 - 12.2) | 0.039 |

## 293. Intraoperative Halo Traction May Obviate the Need for Anterior Surgery in Severe Cerebral Palsy Scoliosis

*Taylor Jackson; Burt Yaszay, MD; Jahangir K. Asghar, MD; Joshua M. Pahys, MD; Anuj Singla, MD; Firoz Miyanji, MD, FRCSC; Suken A. Shah, MD; Paul D. Sponseller, MD, MBA; Peter O. Newton, MD; John M. Flynn, MD; Patrick J. Cahill, MD*

**Summary**
Cerebral palsy (CP) scoliosis patients treated with posterior spinal fusion (PSF) and intraoperative halo traction or anteroposterior (APSF) approach without intraoperative halo traction were compared. Both produced similar deformity correction and health related quality of life (HRQOL) outcomes, however APSF resulted in longer hospital stays, operative times, and more complications.

**Hypothesis**
Anterior surgery will produce similar deformity correction or HRQoL outcomes compared to intraoperative halo traction, but will result in longer hospital stays, operative times, and higher complication rate.

**Design**
A retrospective review of a prospective, multi-center database on spinal deformity associated with Cerebral Palsy.

**Introduction**
For large scoliosis, two strategies to increase correction include: intraoperative halo traction and/or anterior release surgery.

**Methods**
32 patients with a minimum two-years follow-up, major curves at least 100°, and in whom treatment included PSF were identified. 19 were treated with PSF and intraoperative halo traction and 13 with a APSF. The baseline characteristics, perioperative outcomes, and preoperative and two-year follow-up data for HRQOL and radiographic measures were compared.

**Results**
The groups had similar age, gender, nutritional and seizure status, GMFCS level, and change in CPCHILD scores. The groups had similar major curves (116.1° vs 111.6°, p=.223), but the APSF group had less flexible curves (27% vs 39%, p=.006) and less pelvic obliquity (POB) (29° vs 42°, p=.002). There was similar postoperative major curves (34.1° vs 42.3°, p=.136) and POB (8.4° vs 15.6°, p=.513), but more absolute change in POB (33.7° vs 15.7° of correction, p=.006) in the PSF group. The APSF group had longer surgeries (670 vs 350 minutes, p <.001) and hospital stays (16 vs 10 days, p=.010), but similar ICU and days intubated, EBL, cell saver and RBCs used. The APSF group had 27 complications in 10 patients compared to 9 complications in 4 PSF patients (p=.003).

**Conclusion**
Intraoperative halo traction and anterior surgery were used to aid correction in severe CP scoliosis. While anterior surgery was used in stiffer curves, this did not offer superior correction or better HRQOL, and was associated with increased hospital stay, operative times, and complications. Intraoperative halo traction may be a viable alternative to an anterior release in severe CP scoliosis.

| | | *Intraoperative Halo Traction* | *Anterior/Posterior Approach* | *P-Value* |
|---|---|---|---|---|
| ***Preoperative Radiographic Measures*** | Major Coronal Cobb Angle | 111.6° | 116.1° | 0.223 |
| | Curve Percent Flexibility | 39.2 | 26.6 | **0.006** |
| | Pelvic Obliquity (degrees) | 42.3° | 29.4° | **0.002** |
| | Lumbar Lordosis | 43.9° | 42° | 1 |
| | Deformity Angulation Ratio | 16 | 15.3 | 0.675 |
| ***Perioperative Outcomes*** | Anesthesia Time (minutes) | 424.4 | 895.2 | **< .001** |
| | Surgical Time (minutes) | 349.5 | 670.4 | **< .001** |
| | Total EBL (cc) | 1833.6 | 1896.5 | 0.577 |
| | Total Cell Saver (cc) | 346.3 | 497.7 | 0.419 |
| | Total RBCs transfused (cc) | 1336.3 | 607.3 | 0.149 |
| | Total Hospital Stay (days) | 10.4 | 16.1 | **0.014** |
| | ICU stay (days) | 5.8 | 8.1 | *0.055* |
| | Days Intubated | 4 | 3.5 | 0.215 |
| ***2-Year Postoperative Radiographic Measures*** | Major Coronal Cobb Angle | 34.1° | 42.3° | 0.136 |
| | Absolute Coronal Cobb Change | 77.5° | 73.8° | 0.536 |
| | Percent Coronal Cobb Correction | 69.5 | 63.4 | 0.204 |
| | Pelvic Obliquity | 8.4° | 15.6° | 0.513 |
| | Absolute Pelvic Obliquity Change | 33.7° | 15.7° | **0.006** |
| | Percent Pelvic Obliquity Correction | 79.5 | 60.5 | 0.924 |
| ***Complications*** | Overall | 9 | 27 | **0.006** |
| | Unique Patients | 4 (21.1%) | 10 (76.9%) | **0.003** |

## 294. Do all Patients with Cerebral Palsy Require Postoperative Intensive Care Admission After Posterior Spinal Fusion?

*Jaysson Brooks, MD; Burt Yaszay, MD; Carrie E. Bartley, MA; Tracey P. Bastrom; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Firoz Miyanji, MD, FRCSC; Peter O. Newton, MD; Harms Study Group*

**Summary**
Not all patients with CP undergoing spine surgery require ICU admissions. Lower surgical time, a higher Health Utilities Index score, and no past medical history of pneumonia decrease the odds of postoperative ICU admission.

**Hypothesis**
There are factors that decrease the likelihood of requiring a postoperative stay in the intensive care unit (ICU) after posterior spinal fusion (PSF) for spinal deformity associated with cerebral palsy (CP).

**Design**
Retrospective review of prospectively collected data

**Introduction**
Patients with CP requiring PSF have a higher morbidity than patients with idiopathic scoliosis. This contributes to the practice of sending patients to the ICU postoperatively for monitoring. ICU care is costly and little is known regarding which patients with CP truly need this higher level of care.

**Methods**
A prospective, multicenter database was queried for patients with CP who underwent PSF. Univariate and mulitivariate regression analysis was utilized to evaluate demographic and surgical characteristics associated with a length of stay (LOS) in the ICU of ≤ 1 day. Patients with an ICU LOS ≤ 1 day were assumed to not have required a postoperative ICU admission.

**Results**
324 patients met inclusion criteria. The mean ICU LOS was 4.7 days (range 0-47). 68 patients (21%) had an ICU LOS ≤ 1 day and 256 patients (79%) had an ICU LOS > 1 day. Univariate factors associated with an ICU LOS ≤ 1 day are seen in the table.

Of the factors found to be significant in the univariate analyses, three remained in the final multivariate model as predictive of an ICU stay ≤ 1 day: decreased surgical time, a higher Health Utility Index (HUI) score, and a negative history of pneumonia. The average surgical time for patients ≤ 1 was 323 ± 100 vs. 396 ± 122 in those > 1 day (OR 0.99, 95% CI 0.98-0.99, p < 0.001). The average HUI for patients ≤ 1 was 0.01 ± 0.3 vs. -12 ± 0.2 in those > 1 day (OR 11.3, 95% CI 2.3-54.5, p = 0.003). Of the patients with ≤ 1 day in the ICU, 60% had a negative history of pneumonia compared to 23% in those > 1 day (OR 2.8, range 1.2-6.4, p = 0.017).

**Conclusion**

Patients with CP who are less likely to require a postoperative ICU stay are those with no history of pneumonia, a higher HUI score, and shorter surgical times. Risk stratification may help avoid unneeded, costly ICU stays in patients with CP.

Table: Variables found to be significant between patients with ≤ 1 day ICU stay and those > 1 day (p < 0.05) on univariate analysis.

| | Variable | Least likely to stay in ICU |
|---|---|---|
| Patient Characteristics | *Cognitive impairment* | none |
| | *Verbal Communication* | able to communicate |
| | *GMFCS* | 1-3 |
| | *Seizure status* | no seizures |
| | *Previous History of Pneumonia* | negative |
| | *Weight* | heavier kids |
| | *Lordosis* | greater lordosis |
| | *CP Child communication domain* | higher score |
| | *CP Child health domain* | higher score |
| | *Health Utilities Index (HUI)* | more positive score |
| Surgical Characteristics | **Variable** | **Least likely to stay in ICU** |
| | *Lost Instrumented Vertebrae (LIV)* | lumbar/sacral level (not ilium) |
| | *Complication during procedure noted* | none |
| | *Surgical time* | shorter surgery |
| | *EBL (and EBL per blood volume)* | less blood loss |

## 295. Curve Rigidity is More Important than Curve Magnitude in Predicting Outcomes of Neuromuscular Spinal Deformity Surgery

*Ena Nielsen, BA; David L. Skaggs, MD, MMM; Tracy Kim Kovach Kovach; Lindsay M. Andras, MD*

**Summary**

Preoperative traction measurements correlated more strongly with estimated blood loss (EBL), transfusion, and post-operative Cobb angles than did preoperative Cobb angles, suggesting curve rigidity is a more important factor in predicting outcomes of spinal surgery in neuromuscular scoliosis.

**Hypothesis**

Preoperative traction measurements are more predictive of spinal surgery outcomes than preoperative Cobb measurements.

**Design**

Retrospective single center

**Introduction**

Prior studies have shown that larger preoperative Cobb angles correlate with intraoperative and postoperative complications in neuromuscular scoliosis surgery, but the influence of curve flexibility has not been evaluated. Our purpose was to determine how preoperative traction measurements correlated with outcomes for neuromuscular spinal deformity surgery.

**Methods**

A retrospective chart review was conducted of all patients undergoing spinal fusion for neuromuscular scoliosis >50 degrees at our institution between 2006-2012. Patients were excluded for <2 years follow-up. Radiographs were evaluated for Cobb angles and Cobb angles under traction.

**Results**

108 patients met the inclusion criteria, 57 patients had preoperative traction measurements. Average patient age was 14 years (range: 6.8-20.7 years). Average Cobb was 86.5 degrees (range: 50-129 degrees) and average traction Cobb was 59.1 degrees (range: 9-99 degrees), the average percent change in Cobb with traction was -33.7% (range: -82%-0%). Traction Cobb measurements correlated more strongly than preoperative Cobb angles for: EBL (traction: $r2= 0.13$ $p= 0.008$, Cobb: $r2= 0.05$ $p= 0.02$), amount transfused (traction: $r2= 0.28$ $p= 0.001$, Cobb: $r2= 0.05$ $p= 0.02$), percent deformity correction (traction: $r2= 0.1$ $p= 0.02$, Cobb: $r2= 0.004$, $p= 0.54$), and average postoperative Cobb measurements (traction: $r2= 0.33$ $p<0.001$, Cobb: $r2= 0.27$ $p<0.001$). With traction Cobb angles >60 degrees EBL increased 42%, mL transfused increased 55%, post-operative Cobb increased 45%, and LOS increased 62% versus those patients with traction Cobb angles <60 degrees (Table 1). While there was no difference in reoperation rate, hospital stays were nearly twice as long in those with traction Cobb angles >60 degrees.

**Conclusion**

Preoperative traction measurements correlate well with EBL, transfusion requirements, and residual post-operative deformity for neuromuscular spinal deformity surgery. Traction measurements are more predictive of outcomes than preoperative Cobb angle.

Table 1. Outcomes by traction category.

| | EBL (mL) | Amount Transfused (mL) | Post-op Cobb (degrees) | LOS (days) |
|---|---|---|---|---|
| Traction <60 degrees | 789.6 | 473.6 | 30.6 | 8.4 |
| Traction >60 degrees | 1215 | 832.7 | 48.4 | 16.0 |
| % difference | 42.4% | 55% | 45% | 62.3% |

## 296. Correction of Primary Kyphosis Involves More Reoperations and Complications than Primary Scoliosis in Patients with Cerebral Palsy

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**Summary**

We sought to compare surgical primary kyphosis (PK) and primary scoliosis (PS) patients with CP with respect to incidence of major complications, reoperation, and effect of surgery on health-related quality of life (HRQoL). We report a 33% reoperation rate among the PK group compared to 12% in the PS group (p=0.01). The major perioperative complication rate was 50% in the PK cohort and 31% in the PS cohort (p=0.12). Regardless, both cohorts achieved significant improvement in CPCHILD scores.

**Hypothesis**

Primary kyphosis patients will have similar complications, reoperations, and HRQoL as primary scoliosis patients with cerebral palsy.

**Design**

Retrospective review of a prospectively collected dataset.

**Introduction**

A paucity of data exists on primary kyphosis patients with CP undergoing surgical intervention. We sought to compare surgical PK and PS patients with CP with respect to incidence of major complications, reoperation, and effect of surgery on HRQoL.

**Methods**

Patients with CP who had undergone spinal fusion with minimum 2 year follow-up were identified. 221 patients (18 patients in the PK cohort and 203 patients in the PS cohort) were compared with respect to preoperative, intraoperative, and postoperative factors. Wilcoxon rank sum test and paired t-test analysis compared the groups.

**Results**

The groups differed with respect to pre-op kyphosis (PK=77°, PS=34°, p<0.01), major coronal Cobb (PK=44°, PS=86°, p<0.01) and pelvic obliquity (PK=13°, PS=24°, p<0.011). The cohorts were similar with respect to disease severity, demographics, and preoperative CPCHILD scores. The incidence of a major complication trended higher in the PK group (PK =50%, PS =31%, p= 0.12). The rate of reoperation was significantly higher in the PK group (PK=33%, PS=12%, p=0.01). The majority of reoperations in the PK cohort were implant related (PJK 4/6) while the majority of reoperations in the PS cohort were for infection (12/24). Regardless, surgical intervention in both groups resulted in a significant improvement in total domain CPCHILD scores (pre-op PK=55.2, post-op=PK 61.3, p=0.02 and pre-op PS=50.8, post-op PS=57.0, p<0.001).

**Conclusion**

A significant number of patients with CP undergoing surgical intervention for primary kyphosis require reoperation surgery, mainly for implant related issues. This is in contrast to those with primary scoliosis who demonstrate a lower reoperation rate with infection being the primary cause. Also, the major perioperative complication rate trends higher in the PK cohort. Regardless, surgical intervention significantly improves quality of life for these patients.

**Table 1:** Comparison Between Primary Kyphosis (PK) and Primary Scoliosis (PS).

| | PK (n=18) | PS (n=203) | p value |
|---|---|---|---|
| Age at Surgery | 14.4 ± 2.7 | 13.7 ± 2.7 | 0.30 |
| Males N (%) | 9 (50) | 109 (54) | 0.81 |
| Major Cobb Angle | | | |
| Pre-op (°) | 43.6 ± 22.8 | 86.0 ± 22.6 | **< 0.01** |
| 2 Years PO (°) | 15.5 ± 11.1 | 30.9 ± 15.1 | **< 0.01** |
| Pelvic Obliquity | | | |
| Pre-op (°) | 12.9 ± 11.0 | 23.6 ± 12.9 | **< 0.01** |
| 2 Years PO (°) | 4.5 ± 3.8 | 8.1 ± 6.6 | **0.04** |
| Kyphosis (T5-T12) | | | |
| Pre-op (°) | 76.6 ± 15.8 | 34.0 ± 19.7 | **< 0.01** |
| 2 Years PO (°) | 32.5 ± 11.5 | 21.2 ± 10.1 | **< 0.01** |
| Lordosis (T12-Sacrum) | | | |
| Pre-op (°) | 34.8 ± 21.9 | 42.1 ± 29.4 | 0.32 |
| 2 Years PO (°) | 49.5 ± 16.8 | 54.1 ± 16.0 | 0.26 |
| Estimated Blood Loss ± SD (cc) | 1701.9 ± 1288.7 | 1734.3±1287.0 | 0.92 |
| Surgical Time ± SD (minutes) | 372.1 ± 122.2 | 399.0 ± 124.4 | 0.38 |
| Length of Hospitalization (days) | 12.4 ± 8.9 | 11.7 ± 9.5 | 0.74 |
| Reoperation Rate (%) | 33 | 12 | **0.01** |
| Major Perioperative Complication Rate (%) | 50 | 31 | 0.12 |
| **2 Year Change in CPCHILD Scores** | | | |
| Personal Care – Activities of Daily Living | 5.9 ± 3.8 | **4.9 ± 1.6 †** | |
| Positioning, Transferring, & Mobility | 6.6 ± 3.5 | **10.4 ± 1.5 †** | |
| Comfort & Emotions | 6.8 ± 3.8 | **6.7 ± 2.2 †** | |
| Communication & Social Interaction | 3.8 ± 3.8 | 2.5 ± 1.8 | |
| Health | **8 ± 3.6 *** | **5.7 ± 1.6 †** | |
| Overall QoL | **11.7 ± 5.2 *** | **8.2 ± 2.2 †** | |
| Total Score | **6.1 ± 2.3 *** | **6.1 ± 1.2 †** | |

* significant difference ($p \leq 0.05$) from preoperative to postoperative using paired t-test
† significant difference ($p \leq 0.005$) from preoperative to postoperative using paired t-test
*All changes in mean CPCHILD scores were positive in both cohorts*

## 297. Radiological results of spinal fusion to L5 in flaccid type neuromuscular scoliosis

Wataru Saito, MD, PhD; Gen Inoue, MD, PhD; Eiki Shirasawa, MD; Masayuki Miyagi, MD PhD; Takayuki Imura, MD; Toshiyuki Nakazawa; Masashi Takaso, MD

**Summary**

We reviewed 49 flaccid type neuromuscular scoliosis patients fused to L5 and evaluated at least 2 years radiographic outcomes. Eighteen patients with over 10°correction loss of pelvic obliquity and/or over 20°pelvic obliquity at the last follow up were considered as failure group and they showed less flexibility and larger kyphotic deformity in thoracolumbar lesion preoperatively.

**Hypothesis**

Whether fusion should be extended to pelvis or stopped at L5 is still controversial in flaccid type neuromuscular scoliosis(fNMS). Evaluation of pre-and post-operative radiographic parameters(coronal, sagittal and pelvic) will indicate whether fusion should be stopped at L5 or not.

**Design**

Retrospective cohort study

**Introduction**

Posterior spinal correction in fNMS is one of the best solution to regain proper sitting balance. In our hospital, we have basically determined the lower instrumented vertebra(LIV) at L5 in all fNMS cases. The purpose of this study is to detect the indication and limitation of posterior spinal fusion to L5 in fNMS.

**Methods**

We retrospectively reviewed 49 fNMS patients with minimum 2 years follow up and evaluated their radiographical results of our procedure. Whole spine radiographs in sitting and supine position were evaluated preoperatively, immediately postoperatively and at the last follow up. Major Cobb angle, pelvic obliquity(PO), thoracic kyphosis(TK), thoracolumbar kyphosis(TLK) and lumbar lordosis(LL) were measured as parameters. Patients with correction loss of PO > 10° and/or PO at the last follow up > 20° were categorized as failure group(Group F) and patients with correction loss of PO ≦ 10°and PO at the last follow up ≦ 20° were categorized as success group (Group S). We statistically compared radiographical parameters in two groups.

**Results**
Duchenne muscular dystrophy, Spinal muscular atrophy and two other congenital muscular dystrophies were included. Eighteen patients were categorized as Group F and 31 patients as Group S. Group F had statistically larger preoperative Cobb angle and smaller LL in supine position than Group S (Cobb angle; 57.0±17.8°vs. 38.9±19.0°, p=0.002, LL; 13.1±24.3° vs. 30.8±19.5°, p=0.009). Immediately postoperative TLK in Group F was significantly larger and LL was smaller than Group S (TLK; 10.7±10.2° vs. 3.1±10.9°, p=0.023, LL; 0.5±22.8° vs. 15.0±23.0°, p=0.043).

**Conclusion**
In patients with preoperative large Cobb and PO and rigid lumbar kyphosis, residual 3-dimensional spinopelvic deformity may affect progression of deformity at the distal level of LIV after correction. When posterior spinal fusion to L5 in fNMS is indicated, sagittal alignment in thoracolumbar lesion should be considered not only coronal parameters.

## 298. Spinal Growth in Patients with Juvenile Idiopathic Scoliosis Treated with Boston Brace

*Johan L. Heemskerk, MD; Sebastiaan Wijdicks; Mark Altena, MD; René M. Castelein, MD, PhD; Diederik HR Kempen, MD, PhD*

**Summary**
The main goal of treatment in juvenile idiopathic scoliosis (JIS) is to control the spinal deformity while preserving spinal growth. This study shows that braced JIS patients are shorter due to their remaining curvature. However, bracing itself appeared not to influence spinal growth.

**Hypothesis**
Bracing does not affect spinal growth in JIS patients

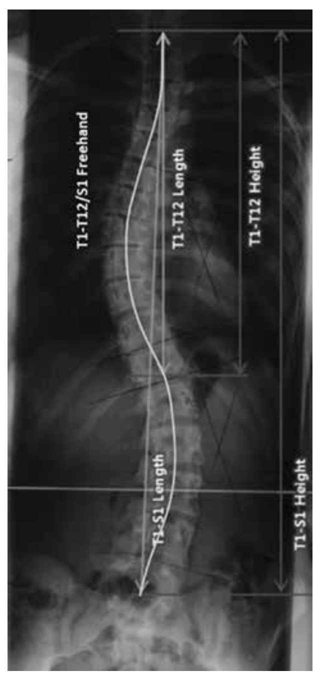
**Design**
Retrospective study

**Introduction**
In children with JIS, the spinal deformity can have serious consequences for lung development and may reduce life expectancy. The treatment goal in JIS is to maximize growth of the spine and thorax while controlling the spinal deformity. Bracing and spine surgery have been used to control the curve. Whereas surgery can decrease spinal growth, the effect of bracing on spinal growth is unknown. The aim of the study is to evaluate spinal growth in braced JIS patients.

**Methods**
50 braced JIS patients were selected from a database that was build since the 1970s. Three radiographs were selected: before brace initiation, after brace treatment and at final follow-up(FFU). The following variables were measured: T1-T12/T1-S1 height and freehand distance; an assessment of spinal length by drawing a line through midline of the spine following the curvature of the scoliosis. These measurements were compared with a sex matched control cohort of 77 patients without scoliosis.

**Results**
The mean age of diagnosis was 7.4±1.7 years. Brace treatment started at a mean age of 11.1±2.5 years and stopped at 14.6±1.8 years. The Cobb angle of the main curve before and after bracing were both 33°. At a mean age of 14,1±1.5 years, 14 patients were treated surgically with a mean angle of 57° before surgery. Freehand spinal growth during brace treatment was 1.08cm/year for the thoracic spine(total 4.30cm) and 1.75 cm/year for the full spine(total 7.11cm). The braced patients had at FFU a mean T1-T12 height of 289 mm, T1-T12 freehand of 293mm, T1-S1 height of 462 mm, T1-S1 of freehand 469mm and a standing height of 1721 mm. Spinal & standing height of the braced patients were at FFU significant different from the controls(p<0.05). However, there was no significant difference in freehand distance of the spine(p>0.2).

**Conclusion**
Bracing did not significantly influence spinal growth in this cohort of JIS patients. The height difference between scoliotic and control patients is caused by the spinal curve as freehand distances were similar. Spinal growth was similar to Dimeglio's data with a growth of 1.1 cm/year(T1-T12) and 1.8 cm/year(T1-S1) indicating that spinal growth during brace treatment was normal.




## 299. Bracing does not result in three-dimensional correction of the spine in adolescent idiopathic scoliosis

*Kenny Kwan, BMBCh(Oxon), FRCSEd; Hui Yu Koh, Miss; Kenneth MC Cheung, MD*

**Summary**

Although the coronal correction by bracing is well-established, its three-dimensional (3D) effect on the spine in adolescent idiopathic scoliosis (AIS) is not understood. This study reports on the sagittal and vertebral rotational changes during bracing in AIS. We found that coronal angle improvement was not associated with sagittal or vertebral rotational correction after bracing. This may have implications on brace efficacy and curve progression.

**Hypothesis**

Coronal deformity correction during bracing is coupled with spontaneous correction of the sagittal and rotational profiles. prospective clinical-radiographic study

**Design**

Prospective clinico-radiographic study.

**Introduction**

There is evidence to suggest that spontaneous synchronous derotation of the sagittal and transverse planes occur during coronal correction of AIS curves. The 3D effects of bracing on AIS is not understood. This study reports on the sagittal and rotational changes during bracing in AIS.

**Methods**

AIS patients whose apex was below T7 and fulfilled the SRS criteria for bracing were prospectively enrolled into the SRS supported study. All patients were given a custom-made Boston type thoraco-lumbo-sacral orthosis (TLSO). Low dose radiographs using biplanar imaging system with 3D capabilities were taken before bracing, and in-brace on first follow-up. Computerised reconstructions were performed to obtain a 3D image of the entire spine. Pre-bracing and in-bracing radiological parameters were analysed.

**Results**

30 patients with a mean age of 12 1.19 years were recruited into the study. Bracing reduced coronal Cobb angle of the main structural curve from 33.6 7.8o to 22.7 7.8o (p=0.00). There were no statistical significant differences between pre- and in-brace parameters for sagittal and transverse plane parameters. In subgroup analysis, a change in apical vertebral rotation (AVR) >3deg in-brace was associated with a decrease in lumbar lordosis compared with curves without AVR change in-brace.

**Conclusion**

Although bracing can correct the coronal deformity in AIS, its effects on vertebral rotation and transverse plane parameters are not necessarily reciprocal. Future studies are required to examine if the inability of bracing to correct the rotational profile has any implications on its efficacy and curve progression.

| | Pre-brace | In-brace | *P* value |
|---|---|---|---|
| Mean Cobb angle (°) | 33.6 ± 7.78 | 22.7 ± 7.8 | **0.000** |
| Mean AVR (°) | 1.33 ± 10.4 | 0.42 ± 8.65 | 0.232 |
| Mean T1/12 kyphosis (°) | 26.2 ± 8.51 | 27.9 ± 7.97 | 0.364 |
| Mean T4/12 kyphosis (°) | 19.6 ± 7.65 | 18.8 ± 6.37 | 0.463 |
| Mean L1/S1 lordosis (°) | 51.9 ± 12.7 | 47.4 ± 8.84 | **0.016** |
| Mean Sacral slope (°) | 43.8 ± 10.3 | 40 ± 9.45 | **0.008** |
| Mean Sagittal pelvic tilt (°) | 5.71 ± 8.9 | 8.21 ± 7.56 | **0.023** |
| Mean Lateral pelvic tilt (°) | 3.99 ± 2.97 | 3.94 ± 2.31 | 0.905 |
| Upper IAR (°) | 1.50 ± 3.49 | 1.57 ± 3.22 | 0.475 |
| Lower IAR (°) | -0.47 ± 2.45 | 0.21 ± 2.25 | 0.663 |
| Torsion index | 0.31 ± 1.49 | 0.39 ± 1.31 | 0.368 |

AVR = apical vertebral rotation
IAR = intervertebral axial rotation

## 300. Multicenter Evaluation of the Incidence of Pre- and Postoperative Malalignment in Degenerative Spinal Fusions

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**Summary**

A significant subset of degenerative lumbar fusion patients have malalignment that is unaddressed or worsened.

**Hypothesis**

Patients undergoing one- or two-level fusion for degenerative conditions may have malalignment of pelvic parameters not addressed by the fusion procedure

**Design**

Multicenter retrospective case series

**Introduction**

Postoperative spinopelvic malalignment (PI-LL > 10°) has been shown to be associated with lower postoperative quality of life and increased adjacent segment disease even in short-segment spinal fusions. The incidence of spinopelvic malalignment before and after degenerative spinal fusions in large-sample studies is previously unreported. The purpose of this study was to assess spinopelvic alignment pre and postoperatively in patients who underwent one- or two-level lumbar fusions for degenerative indications to determine the incidence of malalignment at each time point.

**Methods**

18 institutions enrolled 619 patients in a retrospective multicenter study. Inclusion required treatment with a 1 or 2-level lumbar spinal fusion for a degenerative indication with available pre and postoperative standing lateral xrays. Digital measurements for LL, PI, and pelvic tilt made at each time point. "Aligned" spinal alignment was considered when PI-LL was between -10° and 10° (inclusive), with "malaligned" thresholds being outside of that range. Single-level surgery was performed in 68% of cases and spondylolisthesis was present in a majority (51%) of patients.

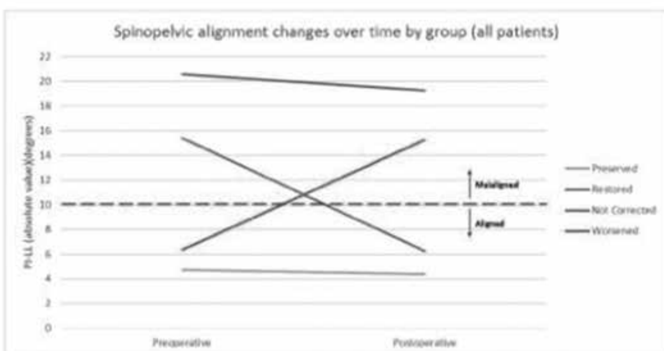
The most common levels treated were L4-5 (71%) followed by L5-S1 (66%). Fusion constructs included posterolateral only without interbody (90 cases, 15%) and cases with interbody fusion, including anterior or lateral interbody fusion (309 cases, 50%), posterior interbody fusion (192 cases, 31%), or combination (28 cases, 5%).

**Results**

229 patients (37.0%) were malaligned preop and 217 patients (35.1%) were malaligned postop. Alignment was preserved pre- to postop in 321 patients (51.9%) and 81 (13.1%) had their alignment restored postoperatively. In nearly a quarter of patients (148, 23.9%) alignment was not corrected (malaligned both pre and postop) while 69 patients (11.2%) worsened from aligned preop to malaligned postop.

**Conclusion**

This is the first multicenter study to evaluate spinopelvic alignment characteristics in degenerative lumbar fusion patients, finding over 1/3 of patients being malaligned pre and postop, and demonstrating a significant subset of patients whose fusion did not address or worsened alignment. These data suggest that alignment preservation/restoration considerations be incorporated into the decision making for all, not just deformity, spinal fusions.




Average PI-LL change from preop to postop by category

## 301. Anatomic Trajectory for Iliac Screw Placement: An Alternative to SAI Portal

Harry L. Shufflebarger, MD; Jahangir K. Asghar, MD

**Summary**

Iliac screw insertion may be accomplished by the PSIS or the SAI portals, the latter crossing the SI joint. The Anatomic Trajectory (AT) was reported in 2009 (Harrop et al. J Spinal Disord Tech, 2009;22:541-4), and is an attractive, viable alternative trajectory . The successful use is reported in a pediatric series of neuromuscular deformity and spondylolisthesis.

**Hypothesis**

The AT is equal or superior to the SAI portal, and does not cross the SI joint.

**Design**

Retrospective review of consecutive patients in whom the AT for iliac screw placement was employed.

**Introduction**

Iliac fixation is crucial in situations requiring fusion to the sacrum. Challenges includes complex anatomy, pelvic deformation, severe deformity, and previous surgery. The PSIS portal requires significant dissection, rod connectors, and complex bends. The SAI portal requires navigating the screw across the SI joint to the ilium. The Anatomic Trajectory (AT) is between PSIS and SAI entry, without prominence, connectors, or complex bends. See Figure for starting points.

**Methods**

A single institution IRB approved retrospective review of 54 consecutive patients requiring instrumentation to the ilium with a minimum 2 year follow-up (mean 44 mos, 26-78) were clinically and radiographically evaluated. All had bilateral iliac fixation via the AT. Parameter changes were assessed with Student t-test, significance at p<.05.

**Results**

28 severe cerebral palsy patients had initial coronal mean curve of 85 degrees (50-105) corrected to 23 degrees (15-30) at 2 years, p<.001. Pelvic obliquity was a mean 22 degrees (7-39) corrected to 4 degrees (1.5-10), p<.001. 20 had >50% spondylolisthesis (mean 60, 50-95), treated with reduction and interbody graft, improved to 10% (5-20, p<.001). 6 had other diagnoses (congenital, extension). In the CP group, 1 SSI occurred, 2 had implant fractures, and 12 had asymptomatic iliac screw loosening, none requiring revision. There were no neurological complications. In the spondy group, there were no neurologic complications and 1 prominent screw requiring removal. Of 104 iliac screws, 2 rod connectors were employed.

**Conclusion**

The advantages if the AT include no SI joint violation, low profile, rare use of lateral connectors, and results consistent with prior SAI results.


Radiographs demonstrating Anatomic iliac screw placement

Sacral and iliac starting points for placement of iliac screws

## 302. Marked Increase in Primary Atlantoaxial Spinal Fusion Surgeries in the United States from 2006-2014

Comron Saifi, MD; Alejandro Cazzulino, BA; Joseph L. Laratta, MD; Jamal Shillingford, MD; Ronald A. Lehman, MD; Steven C. Ludwig, MD; Howard S. An, MD; Frank Phillips

**Summary**

The number of primary atlantoaxial fusion procedures has increased while the number of revision procedures has decreased leading to a decreased revision burden. Outcomes for revision procedures were better than for primary.

**Hypothesis**
The revision burden for atlantoaxial fusion procedures has decreased in the U.S. from 2006-2014.

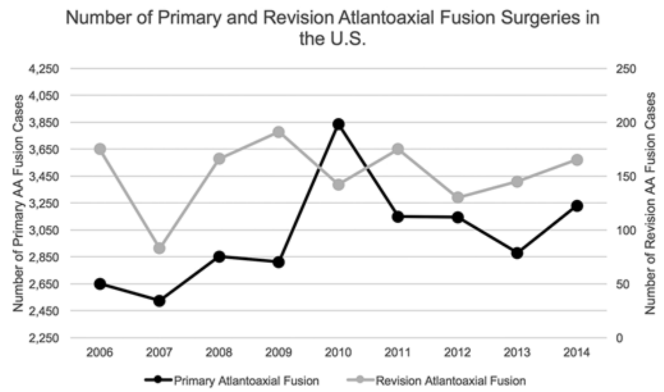
**Design**
Database study analyzing trends in rates and resource utilization.

**Introduction**
Hospital based data was analyzed for primary and revision atlantoaxial (AA) spinal fusion surgeries throughout the U. S. from 2006-2014. The prevalence of specific spinal surgeries and their economic impact can assist both providers and policy makers to improve healthcare cost-effectiveness. Data such as national rates, hospital costs, length of stay (LOS), routine discharge, mortality, and revision burden was analyzed based on patients treated with primary and revision AA fusion.

**Methods**
Patient data from the National Inpatient Survey (NIS) database for primary and revision AA fusion surgeries from 2006-2014 were obtained based on the ICD-9 CM codes 81.01 and 81.31, respectively. The NIS database represents a 20% sample of discharges from U.S. hospitals and was weighted to provide national estimates. Revision burden was defined as the ratio of revision procedures to the sum of primary and revision procedures.

**Results**
An estimated 27,079 primary and 1,372 revision AA fusions were done on patients in the U.S. from 2006-2014. Primary procedures per year increased 22% (mean: 3,009; range: 2,525-3,837), while revision procedures per year decreased 6% (mean: 152; range: 83-191). Mean LOS decreased for both procedures and revisions had a shorter mean LOS (5.7 days) compared to primary procedures (7.7 days). The mean percentage of routine discharge was higher for revision than primary cases, 65% and 50%, respectively. Mean hospital costs increased 28% and 27% for primary and revision cases, respectively. Mean costs were higher for primary cases (mean: $34,656; range: $29,583-$37,736) than revision cases mean: $31,032; range: $20,850-$40,449). Revision burden trended down over the study period with a mean of 4.9% (range: 3.2%-6.4%). The mean inpatient mortality rate for primary cases for years available was relatively unchanged at 2.2%.

**Conclusion**
Although the number of primary AA fusions has increased 22%, the number of revision procedures has decreased 5% over the same nine-year period throughout the U.S. This disparity is denoted by the decreasing revision burden, which may imply an improvement in fusion rates. The inpatient mortality rate of 2% is a reminder that patients who are indicated for AA fusion have a real risk of death postoperatively.




## 303. Outcomes and Cost-Minimization Analysis of Cement Spacers and Expandable Cages for Posterior-Only Reconstruction of Metastatic Spine Corpectomies

*Yusef, J Jordan; Jacob M. Buchowski, MD, MS; Mahati Mokkarala, BS; Eric Feuchtbaum; David B. Bumpass, MD*

**Summary**
Outcomes and Cost-Minimization Analysis of Cement Spacers and Expandable Cages for Posterior-Only Reconstruction of Metastatic Spine Corpectomies

**Hypothesis**
The rate of complications and revision surgery when using PMMA spacers to reconstruct the spine after corpectomy for MSD would be equivalent to use of an EC, with lower implant and operating room (OR) costs.

**Design**
Single-center retrospective cohort study/cost-minimization analysis.

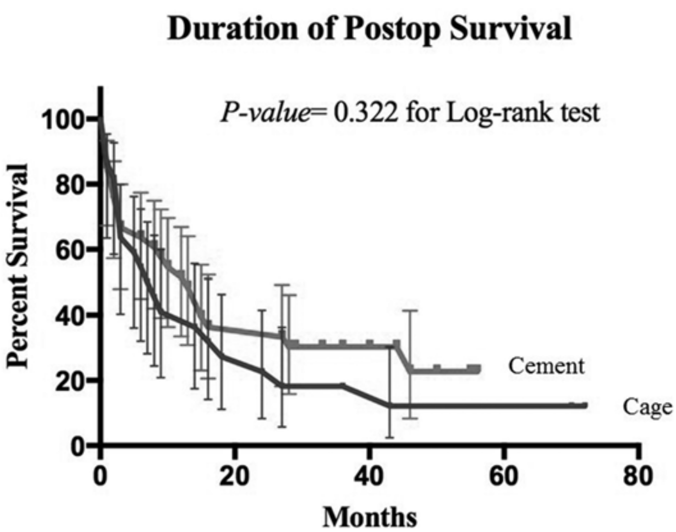
**Introduction**
Reconstruction of the thoracic/lumbar spine after tumor corpectomy can be achieved using either an EC or a PMMA spacer. Few studies have compared the relative successes between these two forms of reconstructions in the management of metastatic spine disease. The objective of this study was to compare both the outcomes and costs of EC and PMMA spacers in the treatment of MSD.

**Methods**
A single surgeon performed 65 vertebral corpectomies for MSD requiring anterior column reconstruction from 2007-14. All charts were retrospectively reviewed and no patients were excluded. All resections were single-stage resections/reconstructions of the vertebral body through a posterior-only approach. Lumbar nerve roots were preserved in all cases. Revised Tokuhashi scores were recorded. Radiographs were reviewed to evaluate for implant failure or progressive malalignment. Other outcomes of interest included intraoperative time, perioperative complications, postoperative survival, and subsequent reoperations.

**Results**
36 patients were treated with PMMA spacers, and 29 were treated with EC. Baseline age, BMI, and disease severity were equivalent

between treatment groups. The cohorts had no significant differences in operative complications, EBL, postoperative survival, number of subsequent reoperations, or changes in radiographic alignment. The PMMA patients had a significantly shorter mean operative duration (328 min vs. 241 min, p<0.001). Institutional implant cost savings were $4925 favoring the PMMA cohort ($75 vs. $5000). Assuming a published OR time cost of $23/min, mean OR savings were $2000 for the PMMA cohort. Total cost minimization per PMMA case was $6925, which was robust in 2-way sensitivity analyses varying both implant costs and time costs by 30%.

**Conclusion**
In the largest series to date of posterior-only tumor corpectomies, PMMA spacers and EC were both reliable techniques for spinal reconstruction. PMMA showed excellent durability while minimizing costs by $6925 per case, an important consideration as reimbursement pressures increasingly influence surgical decision-making.




## 304. Hypoalbuminemia as an Independent Risk Factor for 30-Day Morbidity and Mortality in Cervicothoracic Spinal Tumor Excision

*Awais K Hussain; Khushdeep S Vig; Deepak A. Kaji; Parth Kothari; William A Ranson; Samantha Jacobs, BA; Chierika, O Ukogu; Jun S. Kim, MD; Varun Arvind, MD; Samuel K. Cho, MD*

**Summary**
A retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) found that preoperative hypoalbuminemia is an independent risk factor for certain postoperative adverse outcomes.

**Hypothesis**
Hypoalbuminemia can serve as a marker for malnutrition and be used to assess risk of post operative complications

**Design**
Retrospective cohort study

**Introduction**
:Malnutrition has been shown to be associated with postoperative morbidity and mortality. It is a particularly prevalent comorbidity in cancer patients. This study aims to explore the prognostic implication of hypoalbuminemia in patients undergoing laminectomy and excision for thoracic and lumbar spinal tumors.

**Methods**
This was retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database between 2010 and 2014 for patients undergoing laminectomy and excision of thoracic spinal tumors. CPT codes 63276 and 63275 were used to query patients undergoing laminectomy for thoracic and cervical spinal tumors. These patients were then divided into two cohorts, malnourished (<3.5g/dL preoperative albumin) and nourished. Patient baseline factors, perioperative data, and postoperative course were analyzed by univariate analysis. Multivariate logistic regression was used to compare the two albumin cohorts to determine the effect of malnourishment on short term postoperative morbidity and mortality.

**Results**
A total of 1138 patients with thoracic and cervical tumors were identified. Of these patients 404 (35.5%) were malnourished (albumin <3.5g/dL). Multivariate logistic regression (Table 1) found malnutrition to be an independent risk factor for 30-day mortality (OR=4.34, CI: 2.70-6.97, p<0.001), discharge to a facility other than home (OR=2.45, CI: 1.84-3.25, p<0.001), length of stay greater than or equal to five days (OR=3.11, CI: 2.11-4.59, p<0.001), transfusion (OR=5.57, CI: 1.10-1.87, p=0.008), and sepsis (OR=4.07, CI: 2.28-7.24, p=0.002).

**Conclusion**
Hypoalbuminemia in the preoperative setting is a risk factor for 30-day mortality, non-home discharge, prolonged LOS, pulmonary complications, bleeding requiring intra or postoperative transfusion, and sepsis. Albumin levels can be used as a prognostic tool and for risk stratification for adverse outcomes.

# AUTHOR INDEX

SCOLIOSIS RESEARCH SOCIETY

52ND ANNUAL MEETING & COURSE

The Scoliosis Research Society gratefully acknowledges Globus Medical for their overall support.

# Author Index



**PRESENTATION KEY**

1-129 = Paper/ Podium Presentations, E-Presentations = 150-164, 200-304 = E-Posters, PMC= Pre-Meeting Course, CASE= Case Discussion LTS= Lunchtime Symposium, HDC= Half-Day Course

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# About SRS

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 37 orthopaedic surgeons to an international organization of more than 1,250 health care professionals.

## MISSION STATEMENT

The purpose of Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

## MEMBERSHIP

SRS is open to orthopaedic surgeons, neurosurgeons, researchers and allied health professionals who have a practice that focuses on spinal deformity.

**Active Fellowship** (membership) requires the applicant to have fulfilled a five-year Candidate Fellowship and have a practice that is 20% or more in spinal deformity. Only Active Fellows may vote and hold elected offices within the Society.

**Candidate Fellowship** (membership) is open to all orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice which includes at least 20% spinal deformity. Candidate Fellows stay in that category for five years, during which time they must meet all of the requirements and demonstrate their interest in spinal deformity and in the goals of the Society. After five years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Candidate Fellowship does not include the right to vote or hold office. Candidate Fellows may serve on SRS committees.

**Associate Fellowship** (membership) is for distinguished members of the medical profession including nurses, physician assistants, as well as orthopaedic surgeons, neurosurgeons, scientists, engineers and specialists who have made a significant contribution to scoliosis or related spinal deformities who do not wish to assume the full responsibilities of Active Fellowship. Associate Fellows may not vote or hold office, but may serve on committees.

See website for membership requirement details and printable membership applications: http://www.srs.org/professionals/membership

## SRS MEMBERSHIP INFORMATION SESSION

Thursday, September 7, 12:30-1:30pm in Salon HIJ

Join us and learn more about the Scoliosis Research Society

- How to Apply
- Benefits of Membership
- Leadership Opportunities
- Scholarships
- Networking
- Education

## PROGRAMS AND ACTIVITIES

SRS is focused primarily on education and research and include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Hands-On Courses, Worldwide Conferences, a Global Outreach Program, the Research Education Outreach (REO) Fund which provides grants for spine deformity research, and development of patient education materials.

## WEBSITE INFORMATION

For the latest information on SRS meetings, programs, activities and membership please visit www.srs.org. The SRS Website Committee works to ensure that the website information is accurate, accessible and tailored for target audiences. Site content is varied and frequently uses graphics to stimulate ideas and interest. Content categories include information for medical professionals, patients/public, and SRS members.

Visit the SRS website at www.srs.org.

## SOCIAL MEDIA

Follow SRS online. Join the conversation online about the 52nd Annual Meeting & Course. Share your experience and stay up-to-date with SRS during and after the meeting.

Share and search public posts with: #SRSAM17

@srs_org

@srs_org

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If you need assistance finding the SRS social media or using the hashtag (**#SRSAM17**), please see Shawn at the registration desk

# About SRS

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**Committee & Taskforce (TF) Chairs**
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Translation – Andre Luis F. Andujar, MD
Website – Todd Milbrandt, MD, MS
Worldwide Conference – Benny T. Dahl, MD, PhD, DMSci

# Notes

# MEETING OUTLINE

| | |
|---|---|
| **Monday, September 4, 2017** | |
| 8:00 - 16:00 | Board of Directors Meeting |
| 17:00 - 19:00 | Incoming Committee Chair Reception (by invitation only) |
| **Tuesday, September 5, 2017** | |
| 7:00 - 17:00 | SRS Committee Meetings |
| 13:00 - 18:15 | Hibbs Society Meeting |
| 14:00 - 17:00 | Registration Open |
| 19:00 - 22:00 | SRS Leadership Dinner (by invitation only) |
| **Wednesday, September 6, 2017** | |
| 6:30 - 18:00 | Registration Open/ E-Posters Open |
| 7:45 - 12:20 | Pre-Meeting Course – Morning Sessions |
| 12:35 - 13:35 | Lunchtime Symposia |
| 13:45 - 16:30 | Pre-Meeting Course – Afternoon Sessions |
| 16:45 - 17:45 | Case Discussions |
| 18:00 - 19:15 | Opening Ceremonies |
| 19:15 - 21:00 | Welcome Reception |
| **Thursday, September 7, 2017** | |
| 6:30 - 16:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 12:30 | Scientific Program |
| 12:35 - 13:30 | Half-Day Course Lunch |
| | Member Information Session |
| 13:30 - 16:30 | Half-Day Courses |
| **Friday, September 8, 2017** | |
| 6:30 - 17:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 11:50 | Scientific Program |
| 12:05 - 13:05 | Lunchtime Symposia |
| 13:15 - 17:15 | Scientific Program |
| 19:00 - 22:00 | Farewell Reception |
| **Saturday, September 9, 2017** | |
| 6:30 - 12:00 | Registration Open/ E-Posters Open |
| 6:30 - 7:45 | Members Business Meeting |
| | Non-Members Continental Breakfast |
| 7:30 - 10:00 | Guest Hospitality Suite |
| 7:55 - 13:30 | Scientific Program |
| 13:45 - 15:30 | Board of Directors Meeting |

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