Scoliosis Research Society

54th Annual Meeting

SEPTEMBER 18-21, 2019

Montréal, Canada

Palais des congrès de Montréal
1001 Jean Paul Riopelle Pl, Montréal, QC H2Z 1H5, Canada

Final Program

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President's Message

On behalf of the Scoliosis Research Society (SRS), it is my great pleasure to welcome you to the 54th Annual Meeting in Montréal, Canada.

The Annual Meeting serves as the gathering place for those surgeons and scientists who want to know the latest information for the optimal treatment for all patients with spinal deformity for the past 53 years. This year there were 1745 submitted abstracts (46% from outside of the US indicating that we truly are a global society); 171 were accepted for podium presentation, 75 for e-posters, and 12 for case discussions. Firoz Miyanji, MD and the Program Committee have done masterful work in reviewing all of the submissions and putting together a truly outstanding program.

I want to personally thank Stefan Parent, MD, PhD, our local host in Montréal. He has enthusiastically showed us this beautiful city, so please take some time during the meeting and enjoy the spectacular sites in Montréal.

The Education Committee, led by Committee Chair Burt Yaszay, MD, have put together an excellent program, beginning on Wednesday morning with the Pre-Meeting Course, "Improving Patient Outcomes through Peak Surgeon Performance." After the Pre-Meeting Course on Wednesday there will be two abstract sessions featuring Adolescent Idiopathic Scoliosis papers. Following the abstract sessions will be case discussion sessions and the Opening Ceremonies featuring the Steel Lecture, presented by Normand Laprise, Grand Chef Relais & Châteaux at TOQUÉ! Restaurant and co-owner of BRASSERIE T! and BEAU MONT, who will share with us his perspective on Quebec's culinary tradition. The E-Posters will also be available for viewing on the kiosk located in the foyer, outside of the General Session room Wednesday through Saturday.

Thursday morning begins the scientific program with the excellent papers selected for podium presentations; as well as the presentation of the Harrington Lecture, "Dropping the "I" in AIS, What will it Take?" presented by René M. Castelein, MD, PhD, and the Lifetime Achievement Awards to Juergen Harms, MD and Alberto L. Ponte, MD. New this year will be the Industry Workshops, from 12:50-14:20, delegates are encouraged to attend one of the five concurrent workshops highlighting topics and technologies selected by the companies. The Half-Day Courses will follow the workshops, on the topics "Growth and Scoliosis" and "Adult Spinal Deformity: Case Based Debates." Also included in the Half-Day Courses will be abstract presentations. Thursday evening will be a wonderful opportunity for you to sightsee around Montréal on your own or with friends.

Friday will be a full day of scientific sessions. The Members Business Meeting & Lunch will be held from 12:00-13:30; during this time there will also be a Non-Members Lunch Session on, "Leveraging Social Media to Improve Your Practice." Following the day of educational sessions will be the Farewell Reception in the evening at the St. James Theater. Tickets are required; if you have not purchased a ticket with your registration, please check at the registration desk, as there may be tickets still available. Cocktail attire is appropriate for the Farewell Reception.

Saturday will be a half day of scientific sessions and then your chance to enjoy Montréal, your friends from around the world and then say good bye until next year!

The SRS staff, led by Executive Director, Tressa Goulding, deserve 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 our great Society. I want to especially thank my fellow Presidential Line colleagues who have made this year great for me and have advanced our Society; Past President II, Kenneth MC Cheung, MD; Immediate Past President, Todd J. Albert, MD; President-Elect, President Paul D. Sponseller, MD; and Vice President, Muharrem Yazici, MD.

Best wishes to all for a great meeting!

Peter O. Newton, MD
Scoliosis Research Society President 2018-2019

General Meeting Information

The Scoliosis Research Society gratefully acknowledges DePuy Synthes for their Educational Grant support of the Annual Meeting.

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General Meeting Information

VENUE INFORMATION

Palais des congrès de Montréal
1001 Place Jean-Paul-Riopelle, Montréal

ABSTRACT VOLUME

All abstracts accepted for presentation at the 54th Annual Meeting have been published in the Final Program (pages 161-370). Each attendee will receive one copy of the program along with their registration materials. Abstracts have also been posted online to the Program page of the SRS Annual Meeting website (http://www.srs.org/am19/program) and are available in the Annual Meeting mobile app.

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 congress center, 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 St. James Theater, at an additional $50 fee per ticket for registered delegates and a $175 fee for 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 all Annual Meeting 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 Palais des congrès de Montréal 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 75 E-Posters available for your review on the E-Poster kiosks in the Registration Foyer outside of the general session room, 517CD, on Level 5 of the Palais des congrès de Montréal. The E-Posters are also available on the USB included with your registration materials.

The E-Poster Kiosks and E-Poster USBs are supported, in part, by a grant from NuVasive.

INDUSTRY WORKSHOPS

Delegates are encouraged to attend the industry workshops from 12:50-14:20 on Thursday, September 19. Each workshop is programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Boxed lunches will be available during the workshops. See page 64 in the Meeting Agenda, for additional workshop details.

*Please note: CME credits are not available for workshops.

EVALUATIONS

Please take time to complete the online evaluations for each session you attend. Evaluations are available online at www.srs.org/am19/cme-evaluations or on the mobile app. Your input and comments are essential in planning future Annual Meetings.

WIRELESS INTERNET

Wireless Internet access is available throughout the meeting space, to log on use:

Network: SRS2019
Password: SCOLIOSIS

Wireless Internet is supported, in part, by Zimmer Biomet.

LANGUAGE

English will be the official language of the SRS Annual Meeting.

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.

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 NuVasive.

PRINTING STATIONS

Delegates are welcome to use the complimentary printing stations, located next to the Exhibit Hall, to print their certificate of attendance and CME certificates (pre-registered delegates only; onsite registrants will have access to their certificates beginning October 24, 2019).

Printing Stations are supported, in part by, a grant from NuVasive.

CHARGING STATION

Delegates are welcome to use the complimentary charging station in the back of the General Session room (517CD) to recharge smartphones and small tablets. Please do not leave your electronic devices or any personal belongings at the charging station unattended.

The Charging Station is supported, in part, by a grant from NuVasive.

General Meeting Information

MEMBERS BUSINESS MEETING

Room: 517A

All SRS members are invited to attend the Members Business Meeting, at the following time:

- Friday, September 20 – 12:00-13:30 *(hot lunch buffet)*

Agendas will include reports from the various SRS committees, presentations by the 2019 Travelling Fellows and updates on SRS activities and programs.

SRS MEMBERSHIP INFORMATION

Prospective members and new candidate members are invited to attend a membership information session Thursday, September 19 from 17:35-18:00 in Room 517A.

REGISTRATION DESK

Location: 517 Foyer, Level 5 – Palais des congrès de Montréal

Tuesday, September 17	12:00-17:00
Wednesday, September 18	6:00-19:00
Thursday, September 19	6:30-16:30
Friday, September 20	7:00-17:00
Saturday, September 21	7:30-11:00

SPEAKER UPLOAD AREA

Room: 523A

Presenters may upload their PowerPoint presentations in the Speaker Ready Room, located in room 523A

Presentations may not be uploaded in individual rooms but must be uploaded in the Speaker Ready Room

Tuesday, September 17	13:00 – 18:00
Wednesday, September 18	6:30 – 20:00
Thursday, September 19	6:30 – 18:00
Friday, September 20	6:30 – 18:00
Saturday, September 21	6:30 – 12:30

SMOKING POLICY

Smoking is not permitted during any meeting activity or event.

PHOTOGRAPHY POLICY

SRS will be taking photographs throughout the Annual Meeting. 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.

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 recordings 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.

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 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, including the main ballroom 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!

Evaluations

We Need Your Feedback!

Complete the session and overall meeting evaluations on the app or online.

If you have questions, contact SRS at cme@srs.org

On the App: *Session Evaluations:*
1. Select "Agenda" from the home screen
2. Select the Session you want to evaluate
3. Scroll to the bottom of the session description to find the evaluation

Overall Meeting Evaluation:
1. Select "Polls & Voting" from the home screen
2. Select the Annual Meeting Evaluation

Online: https://www.srs.org/am19/cme-evaluation

SRS Annual Meeting Mobile App

A mobile app will be available to all delegates during the 54th Annual Meeting. The app is designed to enhance the attendee experience by providing all the information about the Annual Meeting in one convenient location that can be accessed from any smart phone or tablet with an internet connection.

To download the 54th Annual Meeting Mobile App:

1. Search for "SRS AM 2019" in the App Store or Google Play Store and install
2. Open the downloaded app to begin using the app right away
3. To take full advantage of the app, login with your email address

Once downloaded, delegates can access all static content on the app without an internet connection, including:

- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule (must login with an email address)
- Maps of the meeting space
- An alert system for real-time updates from SRS – program changes and breaking news as it happens
- Session and overall meeting evaluations
- Session handouts created by faculty and Abstracts
- Live polls and the "Ask a Question" feature allowing attendees to submit questions during sessions

ASK A QUESTION IN THE APP

Delegates will be able to ask questions, directly through the mobile app, during all the Annual Meeting sessions.

To ask a question:

1. Click on "Agenda" and select the session you are in with the "Ask a Question" feature enabled.
2. Scroll to the bottom of the session information and click "Ask a Question" under Session Engagement. Questions already asked by attendees will be listed.
3. Click "Ask a Question" again and a text box will appear.
4. Type your question in the text box and click "Submit Question". Your question will appear within the question list.
5. If someone has asked a question you would also like answered, you can "up vote" the question by clicking the circular up arrow button to the right of the question in the list. When questions get up voted they will be pushed higher up on the page as the number of votes increase.

PARTICIPATE IN LIVE SESSION POLLS

Live polls can be found at the bottom of session pages. To participate in one, click "Join Live Poll" at the bottom of the page under Session Engagement. Once you've started a session poll, you can move from question to question by selecting your answers and clicking "Submit" or by clicking on the navigation arrows to the left and right of the Submit button. Moderators will display the live results on screen for the entire audience to view.

Sessions featuring live polls include:

Lunchtime Symposium C: Navigation Options for Spinal Surgeons: State of the Art 2019 (Room: 517A)

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: SRS2019 Password: SCOLIOSIS

Stay up to date with SRS during the Annual Meeting and share your experiences.

#SRSAM19

@srs_org Scoliosis Research Society @srs_org ® Scoliosis Research Society

CME Information

Meeting Description

The Scoliosis Research Society (SRS) Annual Meeting is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Over 170 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:

- Evaluate the indicators and radiographic measures to estimate growth and improve clinical decisions
- Critically analyze the value and refine the indications for the effective use of navigation and robotics
- Adopt dashboards to improve physician performance and patient outcomes
- Demonstrate a thorough understanding of the parameters that change with the aging spine
- Optimize the selection of anterior, posterior, combined, or minimally invasive approaches and differentiate the benefits of appropriate surgical techniques
- Evaluate and appropriately apply new surgical techniques
- Integrate the available evaluation tools and treatment of comorbidities to improve patient outcomes

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.

Credit Designation

SRS designates this live activity for a maximum of *27.5 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 are 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 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 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.

CME Certificates and Evaluations

CME certificates will be available to pre-registered delegates upon the opening of the meeting at www.srs.org/am19. Delegates who registered onsite may access their certificates after October 24, 2019. Certificates are NOT available to delegates registering onsite until October 24.

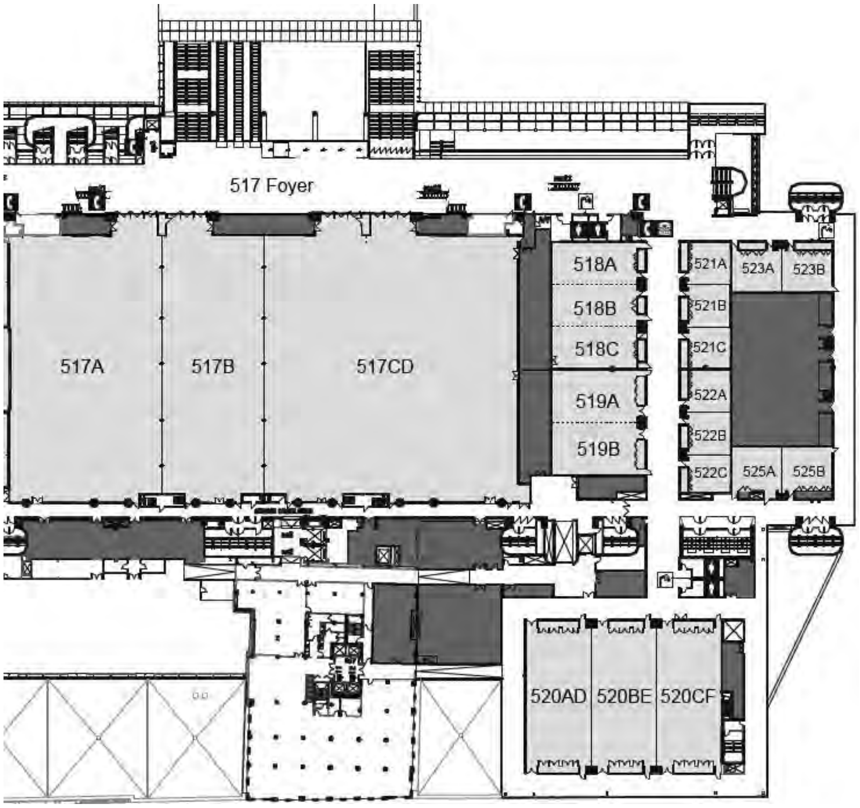
Delegates should log on to the website listed above and enter their last name and the ID# listed at the top of their registration confirmation form or badge. The system will ask delegates to indicate which sessions they attended, and then will generate a PDF certificate which may be printed or saved to the delegate's computer. Session attendance is saved in the database, and certificates may be accessed again, in the event the certificate is lost or another copy is required.

Please note that certificates will not be mailed or emailed after the meeting. The online certificate program is the only source for this documentation. Please contact SRS at cme@srs.org for any questions. SRS asks that all CME certificates be claimed no later than December 31, 2019.

Certificates of attendance will be emailed to each delegate upon checking in at the registration desk at the meeting. Delegates will not receive a paper copy of the certificate in their registration materials. If you would like a paper copy, please stop at the printing stations before the close of the meeting. Evaluations are available to all attendees at the commencement of the meeting. Evaluations are available in the SRS AM 2019 mobile app.

Meeting Space Floorplans

Level 5:



517CD – General Session

517A – Concurrent Sessions & Member Business Meeting

517B – Concurrent Sessions & Hibbs Society Meeting

517 Foyer – Registration Desk, E-Posters

525A – Pop-up Committee Room

525B – Pop-up Committee Room

521A, B, C & 522A, B, C – Committee Meeting Rooms & Corporate Hospitality Rooms

518, 519, 520 – Industry Workshops

Meeting Outline

Monday, September 16, 2019	
8:00-16:00	Board of Directors Meeting*
Tuesday, September 17, 2019	
7:00-8:00	2019-2020 Committee Chair Breakfast & Education Session*
8:30-16:30	SRS Committee Meetings*
12:00-17:00	Registration Open
13:00-18:00	Speaker Ready Room Open
13:00-17:00	Hibbs Society Meeting*
19:00-22:30	SRS Leadership Dinner* (by invitation only)
Wednesday, September 18, 2019	
6:00-19:00	Registration Open/ E-Posters Open*
6:30-20:00	Speaker Ready Room Open
8:00-12:00	Pre-Meeting Course
12:15-13:15	Lunchtime Symposia
13:30-17:05	Scientific Program
17:15-18:15	Case Discussions
18:30-19:35	Opening Ceremonies*
19:35-21:30	Welcome Reception*
Thursday, September 19, 2019	
6:30-16:30	Registration Open/ E-Posters Open*
6:30-18:00	Speaker Ready Room Open
8:00-12:30	Scientific Program
12:30-12:50	Boxed-lunch Pick-up*
12:50-14:20	Industry Workshops*
14:35-17:35	Half-Day Courses
17:35-18:00	Membership Info Session*
Friday, September 20, 2019	
6:30-18:00	Speaker Ready Room Open
7:00-17:00	Registration Open/ E-Posters Open*
8:00-11:45	Scientific Program
12:00-13:30	Member Business Meeting & Lunch*
12:15-13:30	Non-Member Lunch Session*
13:40-17:30	Scientific Program
19:00-22:00	Farewell Reception*
Saturday, September 21, 2019	
6:30-12:30	Speaker Ready Room Open
7:30-11:00	Registration Open/ E-Posters Open*
8:00-12:30	Scientific Program
13:00-16:30	Board of Directors Meeting*

** Denotes Non-CME*

Guest Lecturers and Award Recipients

Howard Steel Lecture

Wednesday, September 18, 2019

Normand Laprise

Grand Chef Relais & Châteaux – TOQUÉ! Restaurant
Co-owner of BRASSERIE T! and BEAU MONT

Normand Laprise was born in 1961 in Kamouraska, near the St. Lawrence River. At an early age he developed great respect for freshly harvested products from the farm on which he grew up. In 1981, after finishing school at the *Charlesbourg Hotel School* in Québec City, he worked alongside great chefs such as Jacques Le Pluart and then Jean-Pierre Billoux at the *Hôtel de la Cloche* near Dijon. He returned to Montréal in 1989 as chef de cuisine at restaurant *Citrus* where he was quickly noticed for his creativity.

In 1993, he opened *Toqué!* with his associate, Christine Lamarche. By building strong relationships with small producers and providing their customers with the finest local and inseason products, *Toqué!* contributed to the development of Québec gastronomy and even became a staple of it. A *Relais & Châteaux* member since 2006 and part of the exclusive *Les Grandes Tables du Monde* since 2014, *Toqué!* is one of the top 2 restaurants in Canada according to *Canada's 100 Best*, including no. 1 in 2015 and 2016, since the creation of this list. It is also the only Canadian restaurant to be ranked, since the last four years, amongst the top 100 restaurants in the world by *Elite Traveler Magazine*.

In 2010, Normand Laprise and Christine Lamarche opened *Brasserie T!,* a second restaurant in the heart of *Quartier des spectacles* of Montréal. A French-inspired brasserie set in a contemporary décor, *Brasserie T!* democratizes the access to high-quality local products while being more accessible than its sister restaurant. In winter 2019, he will pursue even further his philosophy by opening Beau Mont, restaurant and a grocery-counter. The space will also serve as a commissary kitchen for research and development of the Signé Toqué group. Thus, making it possible to support the expansion of Brasserie T!'s footprint in the Montréal metro area (starting with a second location opening near Hotel ALT in Brossard's DIX30 district), as well as in ensuring an increased volume to producers.

In acknowledgement of his work and his contribution to Québec gastronomy, Normand Laprise received the *Order of Québec* in 2009 and the Order of Canada in 2014. In 2012, Macleans named him Chef of the year and he and Christine Lamarche received a *doctorat honoris causa* from the *Institut de Tourisme et d'Hôtellerie du Québec.* He was awarded the *Prix-Hommage Renaud Cyr* 2018 to honour his involvement with Quebec's gardeners, farmers and fishermen and the Hommage Chapeau restaurateurs prize! 2017 given by the Association des restaurateurs du Québec (ARQ). Chef Laprise also published the book *Toqué! : Creators of a New Quebec Gastronomy* for which he received, in 2013, a *James Beard Foundation Award* and a *Prix Marcel-Couture.*

Normand Laprise is the only Canadian ambassador of the prestigious International Chef Advisory Board of the Paul Bocuse Institute. Chef Laprise is often invited to cook abroad, where he is happy to introduce others to Québec gastronomy.

Harrington Lecture

Thursday, September 19, 2019

Dropping the "I" in AIS, What will it take?
René Castelein, MD, PhD

René Castelein is a professor of orthopedic surgery and chairman of the department of orthopedics at the University Medical Center Utrecht, The Netherlands. He trained as a general orthopedic surgeon in the Netherlands but was also formed by a fellowship at the the Alfred I du Pont Hospital for Children (Head at that time: Dr. Dean MacEwen), in Wilmington, Delaware. He started his professional life in general practice, but since joining the academic practice in Utrecht has mostly focused on spinal deformity, both clinically and scientifically, especially in the field of etio-pathogenesis of idiopathic scoliosis. He has published over 150 scientific peer reviewed papers, a number of book chapters, has supervised around 30 PhD Theses and presented Key Note Lectures, mostly on scoliosis, at international society meetings. He has been a visiting professor at a number of prestigious international universities, has been the president of the Nordic Spinal Deformities Society (NSDS), of the International Research Society of Spinal Deformities (IRSSD), is a board member of the International Group for Advancement in Spinal Science (IGASS) and was the vice president and scientific secretary of the Dutch Orthopaedic Society. He is a member of, and has received research support from, a number of international scientific societies like SRS, Eurospine, AO-Spine, and the Fondation Yves Cotrel.

Walter P. Blount Humanitarian Award Recipient

The 2019 Walter P. Blount Humanitarian Award will be presented on Wednesday, September 18, acknowledging outstanding service to those with spinal deformity, and for generosity to the profession and society.

Theodore A. Wagner, MD

Dr. Theodore Anstey Wagner was born in Philadelphia. His formal training includes the Haverford School, Trinity College, and Temple Medical School. His advanced training included an internship at the Royal Victoria Hospital in Montréal, an orthopaedic residency at the University of Washington, and a spine fellowship at the University of Hong Kong. He served in the United States Navy as a Lieutenant Commander.

Guest Lecturers and Award Recipients

He began his practice in Seattle with two of the original members of the SRS: Dr. James Tupper and Dr. Marr Mullen. His first presentation to the SRS (1973) was on the correction of Scheuermann's kyphosis, which was reviewed by Dr. Paul Harrington. He has remained active on the Instrument Committee and the Global Outreach Committee, which he headed. As a member of the World Wide Committee, and with then-President Kamal Ibrahim, he traveled to Aleppo, Syria in 2013 to explore the possibility for a teaching center in the Middle East. The country's civil war began on the day the team was in the operating room.

Fifteen years ago, he joined the University of Washington as a Clinical Professor and was rewarded by the residents with the "Best Teaching Award" in 2011. Since then, he has expanded his involvement to become an Adjunct Professor in the departments of Neurosurgery and Global Health.

Dr. Wagner's international traveling and surgical teaching began with a family sabbatical to Tanzania in 1980. He has since led a series of annual teaching events in Indonesia with Drs. Subroto and Saleh which continue to this day. Dr. Wagner began making trips to Bangladesh with Dr. George Bagby in 2008 and continues to visit Nalta Hospital, Dr. Shah Alam at NITOR Hospital, and to attend the country's annual spine meetings.

In response to an urgent email from Dr. Rohit Pokharel, Dr. Wagner joined a rapid response team to aid with the recovery effort following a 7.8 magnitude earthquake in Nepal 2015. His involvement extended beyond medical care to include the distribution of food and medicine to the country's isolated communities.

Dr. Wagner is most proud of introducing and recommending three surgeons, from Bangladesh, Indonesia, and Nepal, to be members of the SRS. They represent 450 million people whose care and surgery will be influenced by open discussion with the SRS community.

Lifetime Achievement Award Recipients

The 2019 Lifetime Achievement Awards will be presented on Thursday, September 19. 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.

Juergen Harms, MD

Juergen Harms, born in February 1944 in Darmstadt, Germany, is among the best known and influential spine surgeons worldwide. After having studied human medicine at the University of Frankfurt/Main, Germany, and at the University of Saarland, Homburg, Germany, he specialized into the field of orthopedic surgery and finished in 1974. He became professor at the University of Saarland in 1978. In 1980, he started to work within the field of spine surgery in Karlsbad-Langensteinbach. Here, in a small village in the region of the rural northern Black Forest, he founded one of the most important spine centers in Europe, supported for more than 25 years by his first senior consultant Dieter Stoltze. Harms gave valuable influence to spine surgery up to now. He influenced modern spine surgery of today within the fields of spinal biomechanics adopted to spine surgery and spinal function, development of spinal implants, techniques in spine surgery, teaching, interdisciplinary character of spine surgery and networks.

Some of his major key point accomplishments include the following: He constructed the first artificial spinal spacer ever and created the polyaxial pedicle screw. He gave tremendous influence to new spine surgical techniques, as TLIF, C1-C2 fixation, spinal transoral surgery, and correction of deformity with special emphasis in young individuals. He realized as early as 1980, that an interdisciplinary cooperation is essential to optimize spine surgery with respect to outcome and complications.

The Harms Study Group was initiated in 1995, as a small group of collaborative surgeons came together under the leadership of Randal Betz and Harms. The initial objective of the group was to evaluate the outcomes of the anterior approach for thoracic adolescent idiopathic scoliosis (AIS) popularized by Harms in comparison to the posterior approach that was the standard. The group was named after Harms in honor of the contributions he made to the development of the anterior procedure. Over the past 23 years the group has grown to 38 surgeon members at 15 research sites. The group has published 210 peer-reviewed papers and has shared 812 scientific presentations at annual societies meetings. The study group is supported by industry research grants and charitable donations made to the associated non-profit: Setting Scoliosis Straight foundation. Patient education is supported by the foundation through annual educational events, education videos and handbooks. The group has developed a Quality Improvement program for surgeons, utilizing comparative dashboard reporting, with a goal of improving patient outcomes worldwide. Harms meets regularly with the leadership of the Study Group as his vision to support discoveries in spinal deformity treatment continues to inspire the group. Finally, Lenke`s classification of AIS [32] raised from collaboration with the Harms study group.

Juergen Harms was driven by an enormous passion to improve skills, knowledge and understanding of spine mechanics and surgery. He is one of the most innovate and influential spine surgeons worldwide who gave tremendous impact to modern spine surgery.

The words in this article were taken from, *Tribute for Juergen Harms 75 Birthday*, written by Tobias Pitzen, Dezsö Jeszenszky, Klaus Dieter Stoltze, Christiane Pöckler- Schöninger, Rita Huber, Gregor Ostrowski, and Michael Ruf.

Alberto L. Ponte, MD

Graduating in 1953 with his medical degree from the University of Turin, Italy, Prof. Ponte stayed in Italy the next six years afterwards completing his Orthopedic Residency in the University Hospital in Florence, Italy. During that time he did however spend two years as an exchange fellow in some of the most important orthopedic or trauma hospitals in Great

Britain, Germany, Austria and Switzerland. It is easy to see that Prof. Ponte started his medical career off on an ambitious foot.

Shortly after, he moved to the United States where he completed a one year spine fellowship with John Cobb at the Hospital for Special Surgery in New York, where he performed 60 surgeries for scoliosis, a few of them at the Hospital in Orange New Jersey. At the Hospital for Special Surgery he made an experimental study on vertebral growth in rabbits by inserting 51 medical markers into the vertebral bodies of thirteen 8-9 weeks old rabbits and following them until the end of growth. The result was that the lower epiphysis contributes twice as much to the growth in height of the vertebral body. Other feats while in the States included a seven month fellowship at the Bone tumor Service of Memorial Hospital in New York where he could use a new bone glue to stabilize pathologic fractures of the femur in patients with a short life expectancy and to recuperate and examine them post mortem. He participated in further training in spine deformities with John Moe, Joe Risser and Walter Blount. Shortly after, he returned to Florence where he founded the first spine ward in Italy and performed the very first scoliosis surgeries there, introducing the methods he learned in the United States. In Florence he made a study on long term outcomes of vertebral body fractures occurring in infantile and adolescent age.

His membership with the SRS began in 1968. It was around that time where he also became founder and chief of the first independent Spine Center in Italy (Pietra Ligure), soon becoming one of the busiest in the world, with patients, visiting spine surgeons and fellows coming from all continents. It was at Pietra Ligure that during a 13 year period 3,025 patients with thoracic hyperkyphosis were treated by corrective plaster casts.

It was in 1987 that the Ponte Osteotomy was developed; the first technique to permit correction of thoracic hyperkyphosis by major shortening of the posterior spine, preserving the anterior column load sharing capacity. Now the osteotomy is widely applied to gain flexibility in various types of spine deformities. It was in that same year where Prof. Ponte was the first one to correct severe thoracic hyperkyphosis from ankylosing spondylitis. In the nearly 24 years as Chief of the Spine Center in Pietra Ligure, he performed between 200-220 major spine surgeries for scoliosis, kyphosis and spondylolisthesis per year. He also operated on a great number of herniated discs. Prof. Ponte has attended numerous national and international spine meetings around the world as an invited guest lecturer or on a visiting professorship. He has attended 40 meetings of the SRS with several presentations and discussions as well as had several articles published in orthopedic journals including an article published in Spine Deformity in 2018 titled, “The True Ponte Osteotomy: By the One Who Developed It”.

Prof. Ponte can be found enjoying the outdoors. When he was able to sneak away from his bustling career, he could be found mountain climbing, downhill skiing or swimming.

Social Event Information

Opening Ceremonies & Welcome Reception

Wednesday, September 18, 2019, 18:30-21:30
Location: 517CD & 517 Foyer

Open to all registered delegates at no additional fee. Guest registration is mandatory for guests to attend the Opening Ceremonies & Welcome Reception. Name badges are required.

The Annual Meeting will officially begin with the Opening Ceremonies and this year's Howard Steel Lecture, presented by Chef Normand Laprise. The evening will include an introduction of the SRS officers and the presentation of the Walter P. Blount Humanitarian Award. 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, plenty of lively conversations and reunions with colleagues and friends.

See page 60 in the Final Program for the Opening Ceremonies agenda.

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

Farewell Reception

Friday, September 20, 2019, 19:00-22:00

The 54th Annual Meeting will culminate with a Reception at the St. James Theater located walking distance from the Palais des congrès de Montréal in old Montréal. The building was constructed as the main Montréal branch of the Canadian Bank of Commerce from 1907 to 1909 and features impressive marble and stone interiors and stained glass windows.

The Farewell Reception is open to all registered delegates and registered guests. Tickets are $50 each for registered delegates and $175 each for guests, and should be purchased in advance. A limited number of tickets may be available onsite. Tickets are required. Cocktail dress is appropriate for the Farewell Reception.

St. James Theater

265 St Jacques St, Montréal, Canada

Walking Directions from the Westin:
1. Exit the Westin from the front entrance onto Rue Saint-Antoine
2. Turn left towards Rue Saint-Pierre
3. Turn left onto Rue Saint-Pierre
4. Turn left onto Rue Saint-Jacques
5. St. James Theater will be on your left

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3. Turn right onto Rue Saint-Pierre
4. Turn left onto Rue Saint-Jacques
5. St. James Theater will be on your left

Restaurant Recommendations

From Local Host, Stefan Parent, MD, PhD.

Montréal boasts unparalleled culinary diversity. From local specialties to international cuisine, there's more than one restaurant to appeal to everyone. The list below represents some of Montréal's most highly rated and beloved restaurants. Distances are measured in miles from the Palais des congrès de Montréal.

Bouillon Bilk
1595 Boul St-Laurent, (514) 845-1595, 0.7 miles

Chez Sophie
1974 Rue Notre-Dame Ouest, (438) 380-2365, 1.6 miles

La Chronique
104 Avenue Laurier O, (514) 271-3095, 2.5 miles

Leméac
1045 Avenue Laurier O. (514) 270-0999, 2.6 miles

Club Chasse et Pêche
423 Rue Saint-Claude, (514) 861-1112, 0.9 miles

Ferreira Café
1446 Rue Peel, (514) 848-0988, 0.9 miles

Graziella
116 Rue McGill, Montréal, (514) 876-0116, 0.4 miles

Jatoba
1184 Place Phillips, (514) 871-1184, 0.4 miles

Maison Boulud (inside the Ritz-Carlton)
1228 Rue Sherbrooke Ouest, (514) 842-4224, 1.6 miles

Le Mousso and Petit Mousso
1023 Rue Ontario E, Montréal, (438) 384-7410, 1.4 miles

Le Serpent
257 Rue Prince, (514) 316-4666, 0.6 miles

Toqué
Co-owned by Chef Normand Laprise, 2019 Steel Lecturer
900 Place Jean-Paul-Riopelle, (514) 499-2084, located across the street

Monarque
406 Rue Saint-Jacques, (514) 875-3896, 0.2 miles

Henri Brasserie Française
1240 Phillips Square, (514) 544-3674, 0.5 miles

Notes

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The Scoliosis Research Society gratefully acknowledges Medicrea for their support of the Annual Meeting Welcome Reception.

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Conflict of Interest Disclosures

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Meeting Agenda

The Scoliosis Research Society gratefully acknowledges Medtronic for their support of the Annual Meeting Pre-Meeting Course and Live Webcast.

SRS
Scoliosis Research Society

Tuesday, September 17, 2019

12:00-17:00

REGISTRATION OPEN

13:00-17:00

HIBBS SOCIETY MEETING

An additional registration fee of $50 applies for the Hibbs Society Program.

The Sacro Pelvic Unit

Session 1

13:00-14:10
Moderator: Kai Cao, MD, PhD

13:00-13:05 **Introduction**
Peter O. Newton, MD

13:05-13:20 **Is Scoliosis a Problem of the Sacropelvic Unit? Implications from a Mouse Model**
Kenneth MC Cheung, MD

13:25-13:40 **Sacral Fixation Application in Lumbosacral Junction Deformities of Young Children**
Jiangguo Zhang, MD

13:40-13:55 **Hip and Spine Dilemma in Neuromuscular Scoliosis: Decision Making and Management**
Lori A. Karol, MD

13:55-14:10 **Case Discussion 1: Congenital Sacro Pelvic Malformation**
Kariman Abelin-Genevois, MD, PhD

Session 2

14:10-15:20
Moderator: Zezhang Zhu, MD, PhD

14:10-14:25 **The Hip Spine Dilemma: Hip or Spine First?**
Pierre Roussouly, MD

14:25-14:40 **Coronal Imbalance and the Strategies to Defend Depending on the Orientation of the Sacro Pelvic Imbalance**
Yong Qiu, MD

14:40-14:55 **How to Build the Correction Strategy from the Sacro Pelvic Unit**
Jean Charles Le Huec, MD, PhD (Presented by Kariman Abelin-Genevois, MD, PhD)

14:55-15:10 **How to Build the Implant Strategy in Order to Move the Sacro Pelvic Unit**
Munish C. Gupta, MD

15:10-15:20 **Case Discussion 2: The Hip Spine Dilemma in Ankylosing Spondylitis**
Kai Cao, MD, PhD

15:20-15:40 Break

Tuesday, September 17, 2019

Session 3

15:40-17:00
Moderator: Kariman Abelin-Genevois, MD, PhD

15:40-15:55 **PJK in Long Spinal Constructs: Which Role Plays the Sacro Pelvic Unit?**
Han Jo Kim, MD

15:55-16:10 **Sacro Iliac Joint Disease: What are the Options Then?**
Gregory M. Mundis Jr., MD

16:15-16:30 **Does the Sacro Pelvic Arrangement Play a Role in the Surgical Outcomes of Spinal Deformity Surgery?**
Michael P. Kelly, MD

16:30-16:45 **The Role of the Sacro Pelvic Sagittal Orientation in the Achievement of a Good Surgical Outcome: Considerations on the Relative Role of Sagittal Alignment using the GAP Score**
Francisco Javier Perez Grueso, MD

16:45-16:55 **Case Discussion 3: Sagittal Alignment is Not All: The Dilemma of Coronal Malalignment**
Zezhang Zhu, MD, PhD

16:55-17:00 **Conclusion - Acknowledgements**

Wednesday, September 18, 2019

6:00-19:00

REGISTRATION OPEN

8:00-12:00

PRE-MEETING COURSE

Room: 517CD
The Pre-Meeting Course is sponsored, in part by, Medtronic.
See page 85 for Pre-Meeting Course Handouts.

Improving Patient Outcomes through Peak Surgeon Performance

Chair: Burt Yaszay, MD
Co-Chairs: Charles H. Crawford III, MD; Michael D. Daubs, MD; Benny T. Dahl, MD, PhD, DMSci; Baron S. Lonner, MD

Session 1: Understanding Surgeon Performance

Moderators: Serena S. Hu, MD & Paul D. Sponseller, MD, MBA

8:00-8:05	**Introduction: The What and Why of Surgeon Performance?** *Burt Yaszay, MD*
8:05-8:15	**Blue Angels: The Perfect Demonstration** *Chris Collins*
8:15-8:21	**Does Improving Physician Performance Lead to Improved Patient Outcomes?** *Rajiv K. Sethi, MD*
8:21-8:28	Discussion
8:28-8:34	**The Role Of Dashboards in Maintenance of Certification** *John (Jack) M. Flynn, MD*
8:34-8:40	**Hospital/Payor Dashboards on Surgeon Performance** *Stephen L. Ondra, MD*
8:40-8:46	**AIS Dashboard: How has it Improved My Practice?** *Suken A. Shah, MD*
8:46-8:52	**Adult Deformity: Is it Ready for Dashboarding?** *Ferran Pellisé, MD, PhD*
8:52-8:59	Discussion
8:59-9:05	**Getting to Peak Performance for the Early Career Surgeon** *Han Jo Kim, MD*
9:05-9:11	**Maintaining Peak Performance for the Later Career Surgeon** *John R. Dimar II, MD*
9:11-9:17	**Addressing Poor Surgeon Performance Before it Leads to Patient Morbidity** *Michael D. Daubs, MD*
9:17-9:23	**Optimizing Surgeon Performance Around the Globe: What are the Limitations/Barriers?** *Muharrem Yazici, MD*
9:23-9:30	Discussion

Wednesday, September 18, 2019

Session 2: Improving Surgeon Performance Parameters

Moderators: Carol C. Hasler, MD & Baron S. Lonner, MD

9:31-9:37 **Risk Stratification and Predictive Analytics in Adult Spinal Deformity**
Christopher P. Ames, MD

9:37-9:43 **Presurgical Optimization**
Benny T. Dahl., MD, PhD, DMSci

9:43-9:49 **Preoperative Planning: Planning Software and Advanced Imaging**
Stefan Parent, MD, PhD

9:49-9:55 **Building OR Teams**
Firoz Miyanji, MD, FRCSC

9:55-10:02 Discussion

10:02-10:08 **Decreasing Blood Loss**
Justin S. Smith, MD, PhD

10:08-10:14 **Decreasing Risks of Infection: Best Practice Guidelines**
Michael P. Glotzbecker, MD

10:14-10:20 **Minimizing Neuro Complications: Checklists and IONM Teams**
Michael G. Vitale, MD, MPH

10:20-10:27 Discussion

10:27-10:45 Refreshment Break

Debates

Moderators: Michael P. Kelly, MD & A. Noelle Larson, MD

Debate 1: Navigation/Robotics

10:45-10:50 **Navigation/Robotics is Worth the Cost and Improves Performance**
Ronald A. Lehman Jr., MD

10:50-10:55 **Navigation/Robotics Increases Cost and Worsens Performance**
Khaled M. Kebaish, MD

Debate 2: Surgeon Density

10:55-11:00 **Two Surgeon Teams Improve Performance Parameters**
Gregory M. Mundis Jr., MD

11:00-11:05 **Two Surgeon Teams Dilute the Training Experience**
Charles H. Crawford III, MD

11:05-11:15 Discussion

Session 3: Surgeon Performance in Complex Cases

Moderators: Munish C. Gupta, MD & Burt Yaszay, MD

11:15-11:30 **Adult Cases**
Panel: Marinus de Kleuver, MD, PhD; Robert A. Hart, MD; Tyler Koski, MD; Kota Watanabe, MD

11:30-11:45 **Pediatric Cases**
Panel: Saumyajit Basu, MS(orth), DNB(orth), FRCSEd; Patrick J. Cahill, MD; Brice Ilharreborde, MD, PhD; Ilkka J. Helenius, MD, PhD

11:45-12:00 **Complications Cases**
Panel: Laurel C. Blakemore, MD; Meric Enercan, MD, Eric O. Klineberg, MD; Yong Qiu, MD

12:00-12:15

BOXED LUNCH PICK-UP & WALKING BREAK

Wednesday, September 18, 2019

12:15-13:15

LUNCHTIME SYMPOSIA (THREE CONCURRENT SESSIONS)

LTSA: Importance of Sagittal Contour in the Young and the Old
Room: 517CD
Chairs/Moderators: Ahmet Alanay, MD & David W. Polly Jr., MD

12:15-12:20 **Key Sagittal Contour Parameters, How to Measure Them and How Do They Affect HRQoL?**
Christopher I. Shaffrey, MD

12:20-12:25 **Options for Correcting Sagittal Contour Including Osteotomies and Table Based Correction Along with Intra-operative Assessment**
Kristen E. Jones, MD

12:25-12:30 **Planning Desired Surgical Correction: A Biomechanical Approach**
Kariman Abelin Genevois, MD, PhD

12:30-12:35 **Planning Desired Surgical Correction: A Mathematical Approach**
Caglar Yilgor, MD

12:35-12:45 **How to Reliably Execute Surgical Correction in AIS**
Suken A. Shah, MD

12:45-12:50 **When Do You Really Need a PSO or VCR?**
Lawrence G. Lenke, MD

12:50-12:55 **Adult Case Presentation**
David W. Polly Jr., MD

12:55-13:00 **Pediatric Case Presentation**
Ahmet Alanay, MD

13:00-13:15 Discussion

LTSB: Practical Biomechanics for Spine Surgeons
Room: 517B
Chair/Moderator: Brian D. Snyder, MD, PhD

12:15-12:30 **SAFETY: Avoiding Construct Failure**
Brian D. Snyder, MD, PhD

12:30-12:35 Discussion

12:35-12:50 **Let's Get This Straight**
Peter O. Newton, MD

12:50-12:55 Discussion

12:55-13:10 **EFFICACY: Avoiding Unexpected Outcomes**
James O. Sanders, MD

13:10-3:15 Discussion

LTSC: Navigation Options for Spinal Surgeons: State of the Art 2019
Room: 517A
Chairs/Moderators: Sumeet Garg, MD & Rajiv K. Sethi, MD

12:15-12:17 **Introduction/Overview**
Sumeet Garg, MD

12:17-12:23 **Intra-Op CT/Stealth**
Vedat Deviren, MD

12:23-12:29 **Robotics**
Ronald A. Lehman Jr., MD

12:29-12:35 **Patient Specific Navigation (3D Printed Guides)**
Sumeet Garg, MD

12:35-12:40 Discussion

12:40-12:45 **Radiation Consideration**
A. Noelle Larson, MD

12:45-12:51 **Comparison of Navigation Technology in Spine Surgery**
Rajiv K. Sethi, MD

12:51-12:56 Discussion

12:56-12:58 **Introduction of Panel**
Rajiv K. Sethi, MD

12:58-13:04 **Adult Case**
Rajiv K. Sethi, MD

13:04-13:10 **Pediatric Case**
Sumeet Garg, MD

13:10-13:14 Discussion

13:14-13:15 **Final Remarks**
Sumeet Garg, MD

13:15-13:30

WALKING BREAK

13:30-15:00

SESSION 1: ADOLESCENT IDIOPATHIC SCOLIOSIS I

Room: 517CD
Moderators: Firoz Miyanji, MD, FRCSC & Peter O. Newton, MD

13:30-13:35 **Welcome Remarks**

13:35-13:39 **Paper #1 The Benefits of Sparing Lumbar Motion Segments in Spinal Fusion for Adolescent Idiopathic Scoliosis are Evident at 10 Years Postoperatively**
Masayuki Ohashi, MD, PhD; Tracey P. Bastrom, MA; Michelle Claire Marks, MS, PT; Carrie E. Bartley, MA; Peter O. Newton, MD; Harms Study Group

13:39-13:43 **Paper #2 Residual Curve and Truncal Shift Impact Patient Satisfaction after Surgery for AIS**
Majd Marrache, MD; Paul D. Sponseller, MD, MBA; Baron S. Lonner, MD; Aaron J. Buckland, MBBS, FRACS; Michael P. Kelly, MD, MS; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Amit Jain, MD; Harms Study Group

13:43-13:47 **Paper #3 Greater Residual Thoracic Curve at 10 years after Surgery in Primary Thoracic Adolescent Idiopathic Scoliosis is Associated with Below Normal SRS-22 Pain Scores**
Tracey P. Bastrom, MA; Masayuki Ohashi, MD, PhD; Carrie E. Bartley, MA; Michelle Claire Marks, MS, PT; Burt Yaszay, MD; Peter O. Newton, MD; Harms Study Group

13:47-13:56 Discussion

13:56-14:00 **Paper #4 Thoracoscopic Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Minimum 2 Years Results of Patients Reaching Skeletal Maturity**
Ahmet Alanay, MD; Altug Yucekul, MD; Peri Kindan; Hatice Hatun Tanriover; Tais Zulemyan, MSc; Gokhan Ergene, MD; Sahin Senay, MD; Binnaz Ay, MD; Yasemin Yavuz, PhD; Caglar Yilgor, MD

14:00-14:04 **Paper #5 Impact of Prematurity on Immediate Postoperative Outcomes Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis**
Neil V. Shah, MD, MS; Marine Coste, BA; Saad Tarabichi, BS; David J. Kim, BS; Sirish Khanal, BS; George A. Beyer, MS; Neil Patel, BS, BA; Amanda M. Dave, MD, MS; Ashish Patel, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD; Bassel G. Diebo, MD

14:04-14:08 **Paper #6 Do Patients with Anterior Vertebral Body Growth Modulation Have a Better Quality of Life than Patients with a Posterior Spinal Fusion?**
Marjolaine Roy-Beaudry, MSc; Julie Joncas, RN; Isabelle Turgeon, BS; Abdulmajeed Alzakri, MD, MS; Stefan Parent, MD, PhD

14:08-14:17 Discussion

14:17-14:21 **Paper #7 What Are Parents Willing to Accept? A Prospective Study of Risk Tolerance for AIS Surgery**
Baron S. Lonner, MD; Amit Jain, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Michael P. Kelly, MD, MS; Andrea Castillo, BS; Majd Marrache, MD; Christopher P. Ames, MD; Suken A. Shah, MD

14:21-14:25 **Paper #8 Impact of Poor Mental Health on Clinical Outcomes in Surgically Treated Adolescents Idiopathic Scoliosis Patients**
Majd Marrache, MD; Caleb Gottlich, MS, BS; Paul D. Sponseller, MD, MBA; Baron S. Lonner, MD; Aaron J. Buckland, MBBS, FRACS; Michael P. Kelly, MD, MS; Suken A. Shah, MD; Amer F. Samdani, MD; Michelle Claire Marks, MS, PT; Peter O. Newton, MD; Amit Jain, MD; Harms Study Group

14:25-14:29 **Paper #9 The Ultimate Patient Reported Outcome Tool: Patient Generated Index in Adolescent Idiopathic Scoliosis**
Baron S. Lonner, MD; Andrea Castillo, BS; Amit Jain, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Michael P. Kelly, MD, MS; Christopher P. Ames, MD; Majd Marrache, MD; Suken A. Shah, MD

14:29-14:38 Discussion

14:38-14:42 **Paper #10 Shoulda Gone to L4: Risk Factors for Poor Outcome Following L3 LIV Selection in Adolescent Idiopathic Scoliosis (AIS)**
Scott M. LaValva, BA; Jason Brett Anari, MD; John (Jack) M. Flynn, MD; Harms Study Group

14:42-14:46 **Paper #11 Does a Leveled Lowest Instrumented Vertebra (LIV) Lead to Better Outcomes at 5 Years Following PSF When Ending at L3 vs. L4?**
Stefan Parent, MD, PhD; Burt Yaszay, MD; Tracey P. Bastrom, MA; John (Jack) M. Flynn, MD; Michael P. Kelly, MD, MS; Michael P. Glotzbecker, MD; Peter O. Newton, MD; Harms Study Group

14:46-14:50 **Paper #12 Pregnancy Outcomes and C-Section Rates in Operative vs. Nonoperative AIS Patients at Mean 30-year Follow-up**
Lauren Swany, BS; A. Noelle Larson, MD; Suken A. Shah, MD; Pawel Grabala, MD; Todd Milbrandt, MD, MS; Michael J. Yaszemski, MD, PhD

14:50-15:00 Discussion

15:00-15:20

REFRESHMENT BREAK

15:20-17:05

SESSION 2: ADOLESCENT IDIOPATHIC SCOLIOSIS II

Room: 517CD
Moderators: Lawrence G. Lenke, MD & B. Stephens Richards, MD

15:20-15:24 **Paper #13 The 'Touched Vertebra' Method and Trunk Shift in Patients with Lenke Type I in AIS: A Prospective Randomized Study**
Giedrius Bernotavicius, MD, PhD; Kestutis Saniukas, MD, PhD; Rimantas Zagorskis, MD; Vykintas Sabaliauskas, MD; Kestutis Saniukas, MD, PhD

15:24-15:28 **Paper #14 Thoraco-lumbar Junction Alignment is Critical for Surgical Planning in Lenke Type 1A Curve Pattern: Analysis Using Segmental 3-D Measurements**
Stephen G. George, MD; Subaraman Ramchandran, MD; Harry L. Shufflebarger, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Harms Study Group

15:28-15:32 **Paper #15 How to Select the Lowest Instrumented Vertebra in Lenke Type 5 Adolescent Idiopathic Scoliosis Patients?**
Qianyu Zhuang, MD; Jianguo Zhang, MD; Wang Shengru, MD

15:32-15:41 Discussion

15:41-15:45 **Paper #16 Reliable Skeletal Maturity Assessment without Added Radiographs: External Validation of the Proximal Humerus Ossification System and Relevant Learning Methodology**
Theodor Di Pauli von Treuheim, BS; Don Li, MS; Christopher Mikhail, MD; Daniel Cataldo, DO; Daniel R. Cooperman, MD; Brian G. Smith, MD; Baron S. Lonner, MD

Wednesday, September 18, 2019

15:45-15:49 **Paper #17 Idiopathic Scoliosis Cobb Angle Prediction from Clinical Measures: A Geometrical Study of a 7591 Subjects Cohort**
Francesco Negrini, MD; Sabrina Donzelli, MD; Giulia Angela Antonella Rebagliati, MD; Francesca Di Felice, MD; Fabio Zaina, MD; Stefano Negrini, MD

15:49-15:53 **Paper #18 Dynamic Spinal Posture Changes 2 Years After Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Patients**
Sebastien Pesenti, MD, PhD; Solène Prost, MD; Guillaume Authier; Elke Viehweger, MD, PhD; Benjamin Blondel, MD, PhD; Jean-Luc Jouve, MD

15:53-16:02 Discussion

16:02-16:06 **Paper #19 The Importance of Lumbar Curve Flexibility in the Prediction of Spontaneous Lumbar Curve Correction for Selective Thoracic Fusion in Lenke Type 1-2-3-4 C Curves**
Sinan Kahraman, MD; Yunus Emre Akman, MD; Onur Levent Ulusoy, MD; Ayhan Mutlu, MD; Tunay Sanli, MA; Huseyin Ozturk, MD; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

16:06-16:10 **Paper #20 Does Postoperative Thoracic Hypokyphosis Affect Cervical Disc Degeneration at 10 Years Postoperatively? A Comparison to Controls**
Ayato Nohara, MD; Ryoji Tauchi, MD; Toshiki Saito, MD; Tetsuya Ohara, MD; Kazuki Kawakami, B.Kin; Noriaki Kawakami, MD

16:10-16:14 **Paper #21 Flexibility of Thoracic Curve and Three-dimensional Thoracic Kyphosis can Predict Pulmonary Function in Nonoperatively Treated Adult Patients with Adolescent Idiopathic Scoliosis**
Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Naoto Endo, MD, PhD

16:14-16:23 Discussion

16:23-16:27 **Paper #22 Do You Really Want to Know? How Contaminated is the Wound Before Closure in Pediatric Spinal Surgery**
Lara L. Cohen, BS, MPH; Richard M. Schwend, MD; John (Jack) M. Flynn, MD; Daniel J. Hedequist, MD; Michael T. Hresko, MD; Lawrence I. Karlin, MD; John B. Emans, MD; Brian D. Snyder, MD, PhD; Patricia E. Miller, MS; Michael P. Glotzbecker, MD

16:27-16:31 **Paper #23 Can We Reduce the Infection Rates Associated with High Implant Density in Deformity Surgeries?**
Aakash Agarwal, PhD; Boren Lin, PhD; Hossein Elgafy, MD, FRCS, FRCS(C); Hossein Elgafy, MD, FRCS, FRCS(C); Vijay K. Goel, PhD; Anand K. Agarwal, MD; Chris Karas, MD; Steven R. Garfin, MD; Jeffrey C. Wang, MD; Neel Anand, MD

16:31-16:35 **Paper #24 Promising but Imperfect: The Effectiveness of Quality Programs for Surgical Site Infections in Pediatric Spinal Surgery Diminishes Over Time**
Michael G. Vitale, MD, MPH; Bradley Hammoor, MS; Hiroko Matsumoto, PhDc; Gerard F. Marciano, BS; Lucas K. Dziesinski, BS; David Price Roye, MD; Benjamin D. Roye, MD, MPH

16:35-16:44 Discussion

16:44-16:48 **Paper #25 Is it Growth or Natural History? Increasing Spinal Deformity after Sanders Stage 7 in Females with AIS**
Olivia Grothaus, BA; Domingo Molina IV, MD; Cale Jacobs, PhD; Vishwas R. Talwalkar, MD; Henry J. Iwinski, MD; Ryan D. Muchow, MD

16:48-16:52 **Paper #26 Untreated Adolescent Idiopathic Scoliosis in Adulthood: How Often Do These Patients Require Surgery?**
Jace Erwin, BS; Brandon B. Carlson, MD, MPH; Joshua Bunch, MD; Robert Sean Jackson, MD; Marc Asher, MD; Douglas C. Burton, MD

16:52-16:56 **Paper #27 Risk of Progression of Larger AIS Curves After Maturity: What Should We Be Telling Our Patients?**
Kevin M. Neal, MD; Gary M. Kiebzak, PhD

16:56-17:05 Discussion

17:05-17:15

WALKING BREAK

Wednesday, September 18, 2019

17:15-18:15

CASE DISCUSSIONS

(Three Concurrent Sessions)

Case Discussion 1

Room: 517CD
Moderator: Burt Yaszay, MD

17:15-17:30 **1A Screw vs Aorta: A Vertebral Body Tether Case Report Illustrating Approach to Diagnose and Treat Periaortic Screws**
Michael S. Warren, MD; Lawrence L. Haber, MD; Michael A. Nammour, MD; Taylor A. Smith, MD; Heather Taillac, MD; Vincent R. Adolph, MD

17:30-17:45 **1B A Case Series on Pectoralis Major Muscle Flap for Esophageal Perforation after Revision ACDF**
Michael A. Nammour, MD; Heather Taillac, MD; Michael S. Warren, MD; Bhumit R. Desai, BS; Paul C. Celestre, MD, Lawrence L. Haber, MD

17:45-18:00 **1C Intraoperative Anaphylaxis from Intraosseous Gelatin Administration Leading to Surgery Abandonment in AIS Patients**
Vishal Sarwahi, MD; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Melanie A. Smith, cPNP; Terry D. Amaral, MD

18:00-18:15 **1D Don't Underestimate the Hazard of Thoracolumbar Kyphosis in Skeletal Dysplasia**
William Giles Stuart Mackenzie, MD; Anthony Dinardo, DC; Rameez Qudsi, MD, MPH; Colleen Ditro, RN, BSN, DNP,CPNP; Suken A. Shah, MD; William G. Mackenzie, MD, FRCS(C)

Case Discussion 2

Room: 517B
Moderator: Daniel J. Sucato, MD, MS

17:15-17:30 **2A The Management of Scoliosis Following an Infantile Hemipelvectomy for Ewings Sarcoma**
Otis C. Shirley, MD; Robert Rowan, FRACS

17:30-17:45 **2B En Bloc Spondylectomy of Primary Chondrosarcoma Arising within a Previous Spinal Fusion: A Case Report and Discussion**
Floreana N. Kebaish, MD; Andrew B. Harris, BS; Khaled M. Kebaish, MD, FRCS(C)

17:45-18:00 **2C Supplementary Thoracoscopic Anterior Rib Strut Grafting Following Posterior Spinal Fusion and Instrumentation for Dystrophic Kyphoscoliosis in Neurofibromatosis**
William Z. Morris, MD; Karl E. Rathjen, MD; Daniel J. Sucato, MD, MS

18:00-18:15 **2D Facilitation of Transcranial Motor-evoked Potentials in Spinal Muscular Atrophy with Intrathecal Nusinersen: A Case Report**
Suken A. Shah, MD; William Giles Stuart Mackenzie, MD; Scott S. Furstenau, BS, CNIM; Alier J. Franco, PhD; William G. Mackenzie, MD, FRCS(C)

Case Discussion 3

Room: 517A
Moderator: Paul D. Sponseller, MD, MBA

17:15-17:30 **3A The Utility of Virtual Reality in Surgical Planning for Fixed Cervical Deformity: A Case Illustration**
Joshua Hanna, MD; Jonathan Riffle, DO; Caleb Stewart, BS; Edna Gouveia, MD; James Kalyvas, MD

17:30-17:45 **3B Treatment of Congenital Spinal Deformity under the Guidance of Mixed Reality Navigation: A Case Report**
Baoguo Mi, PhD; Dingjun Hao, MD, PhD; Lequn Shan, MD, PhD

17:45-18:00 **3C Concomitant Congenital Cervicothoracic/Upper Thoracic Deformity Associated with Sprengel Deformity and Klippel-Feil Syndrome: A Rare Condition**
Huseyin Ozturk, MD; Yunus Emre Akman, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

18:00-18:15 **3D Missed Cervical Myelopathy: An Unusual Presentation of Erbs Palsy in a Child with C5 Hemivertebrae with Complete Subluxation of C4 on C6**
Michael S. Warren, MD; Michael A. Nammour, MD; Heather Taillac, MD; Bhumit R. Desai, BS; Paul C. Celestre, MD

Wednesday, September 18, 2019

18:15-18:30

WALKING BREAK

18:30-21:30

OPENING CEREMONIES & WELCOME RECEPTION

Room: 517CD

18:30-18:35 **Welcome to Montréal**
Stefan Parent, MD, PhD, Local Host

18:35-18:42 **Presidential Message**
Peter O. Newton, MD

18:42-18:45 **Announcement: Biedermann Award**
Peter O. Newton, MD & Lutz Biedermann

18:45-18:55 **Presentation of Blount Humanitarian Award**
Theodore A. Wagner, MD
Presentation by Matthew E. Cunningham, MD, PhD, Awards & Scholarships Committee Chair

18:55-19:05 **Acknowledgement of Corporate Supporters**
Presentation by Todd J. Albert, MD, Past President & Corporate Relations Committee Chair

19:05-19:10 **Introduction of Howard Steel Lecturer**
Stefan Parent, MD, PhD

19:10-19:30 **Howard Steel Lecture**
Normand Laprise

19:30-19:35 **Closing Remarks**
Peter O. Newton, MD

19:35-21:30

WELCOME RECEPTION

Location: 517 Foyer

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

Thursday, September 19, 2019

6:30-16:30

REGISTRATION OPEN

8:00-9:50

SESSION 3: ADULT SPINAL DEFORMITY I

Room: 517CD
Moderators: Douglas C. Burton, MD & Jeffrey L. Gum, MD

8:00-8:04 **Welcome Remarks**

8:04-8:08 **Paper #28 Outcome of Multilevel Spinal Deformity Surgery in Patients Over 60 Years of Age: A Multicenter International Prospective Study**
Stephen J. Lewis, MD, FRCS(C); Sigurd H. Berven, MD; Yukihiro Matsuyama, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Christopher I. Shaffrey, MD; Benny T. Dahl, MD, PhD, DMSci; Marinus de Kleuver, MD, PhD; Maarten Spruit, MD, PhD; Ferran Pellisé, MD, PhD; Kenneth MC Cheung, MD; Ahmet Alanay, MD; David W. Polly Jr., MD; Jonathan N. Sembrano, MD; Yong Qiu, MD

8:08-8:12 **Paper #29 Patient Factors Affect Outcomes in Operative Treatment of Adult Symptomatic Lumbar Scoliosis (ASLS)**
Michael P. Kelly, MD, MS; Elizabeth L. Yanik, PhD, MS; Christine Baldus, RN, MS; Christopher I. Shaffrey, MD; Jon D. Lurie, MD; Leah Yacat Carreon, MD, MS; Oheneba Boachie-Adjei, MD; Jacob M. Buchowski, MD, MS; Charles H. Crawford III, MD; Charles Cannon Edwards, MD; Thomas J. Errico, MD; Steven D. Glassman, MD; Lawrence G. Lenke, MD; Stephen J. Lewis, MD, FRCS(C); Han Jo Kim, MD; Tyler Koski, MD; Stefan Parent, MD, PhD; Frank J. Schwab, MD; Justin S. Smith, MD, PhD; Keith H. Bridwell, MD

8:12-8:16 **Paper #30 Mechanical Complications Following 3-Column Osteotomy Surgery: A Competing Risk Analysis in 193 Consecutive Adult Spinal Deformity Patients**
Tanvir J. Bari, MD; Dennis W. Hallager, MD, PhD; Lars Valentin Hansen, MD; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

8:16-8:25 Discussion

8:25-8:29 **Paper #31 Artificial Intelligence-based Adult Spinal Deformity Risk-benefit Classification: Hierarchical Clustering of 1245 Patients and Surgeries with Machine-based Learning and Simplified Decision Trees**
Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Ferran Pellisé MD, PhD; Michael P. Kelly, MD, MS; Ahmet Alanay, MD; Emre R. Acaroglu, MD; Francisco Javier Sanchez Perez-Grueso, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD, MS; Alba Vila-Casademunt, MS; Douglas C. Burton, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Miquel Serra-Burriel, PhD; European Spine Study Group; International Spine Study Group

8:29-8:33 **Paper #32 Decision Analysis in Quest of the Ideal Treatment in Adult Spinal Deformity Revisited**
Emre R. Acaroglu, MD; Selcen Yuksel, PhD; Can Ates, PhD; Selim Ayhan, MD; Sinan Bahadir, MD; Vugar Nabiyev, MD; Alba Vila-Casademunt, MS; Ferran Pellisé, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Ibrahim Obeid, MD, MS; Frank S. Kleinstueck, MD; Ahmet Alanay, MD; European Spine Study Group

8:33-8:37 **Paper #33 Development and Expanded Validation of an Individualized Preoperative Predictive Risk Calculator for Major Complications Following Adult Spinal Deformity Surgery: A Step Forward to Improve Shared Decision Making in a Value-driven Economy**
Ferran Pellisé, MD, PhD; Miquel Serra-Burriel, PhD; Justin S. Smith, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Michael P. Kelly, MD, MS; Alba Vila-Casademunt, MS; Francisco Javier Sanchez Perez-Grueso, MD; Shay Bess, MD; Jeffrey L. Gum, MD; Douglas C. Burton, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Virginie Lafage, PhD; Ibrahim Obeid, MD, MS; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Ahmet Alanay, MD; Christopher P. Ames, MD; International Spine Study Group; European Spine Study Group

8:37-8:46 Discussion

8:46-8:50 **Paper #34 The 5-item Modified Frailty Index is Predictive of Severe Adverse Event in Patients Undergoing Surgery for Adult Spinal Deformity**
Mitsuru Yagi, MD, PhD; Takehiro Michikawa, MD, PhD; Naobumi Hosogane, MD, PhD; Nobuyuki Fujita, MD, PhD; Satoshi Suzuki, MD, PhD; Eijiro Okada, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD; Takashi Asazuma, MD, PhD; Shinjiro Kaneko, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD

Thursday, September 19, 2019

8:50-8:54 **Paper #35 Prognostic Nutritional Index Less than 50 Indicate High Possibility of Medical Complications After Adult Spinal Deformity Surgery**
Shin Oe, MD; Daisuke Togawa, MD, PhD; Tomohiko Hasegawa, MD, PhD; Yu Yamato, MD, PhD; Go Yoshida, MD, PhD; Sho Kobayashi, MD, PhD; Tatsuya Yasuda, MD; Tomohiro Banno, MD, PhD; Hideyuki Arima, MD, PhD; Yuki Mihara, MD; Hiroki Ushirozako, MD; Tomohiro Yamada, MD; Yukihiro Matsuyama, MD, PhD

8:54-8:58 **Paper #36 Assessing the Five-year Baseline Prevalence of Metabolic Bone Diseases in the Adult Spinal Deformity Surgical Patient Population: A Call to Own the Bone**
George A. Beyer, MS; Neil V. Shah, MD, MS; Alexander Rompala, BS; Saad Tarabichi, BS; Adam J. Wolfert, BA; Ishaan Jain, BS; Mikhail Tretiakov, MD; Ahmed M. Eldib, MD; Michael Malekan, DO; Qais Naziri, MD; Vincent Challier, MD; Renaud Lafage, MS; Elian Shepherd MD, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD; Bassel G. Diebo, MD

8:58-9:08 Discussion

Meeting Agenda

9:08-9:12 **Paper #37 Lateral Lumbar Interbody Fusion for Adult Spinal Deformity: Is it Superior to the Conventional Posterior Spinal Fusion for Correcting Sagittal Imbalance?**
Hyeong Joo Lee, MD; Chang Ju Hwang, MD, PhD; Dong-Ho Lee, MD, PhD; Choon Sung Lee, MD, PhD; Jae Hwan Cho, MD, PhD; Jae Woo Park, MD

9:12-9:16 **Paper #38 Clinical Implications of Lateral Access to the Concavity Side for Adult Spinal Deformity**
Joshua T. Wewel, MD; Alp Ozpinar, MD; Nikolay L. Martirosyan, MD, PhD; Corey T. Walker, MD; Gregory M. Mundis Jr., MD; Adam S. Kanter, MD; Juan S. Uribe, MD

9:16-9:20 **Paper #39 Does Interbody Fusion Protect Against Rod Failure in the Lower Lumbar Spine after Long Fusions to the Sacrum: A Comparative Analysis of Adult Spinal Deformity Patients**
Mostafa H. El Dafrawy, MD; Keith H. Bridwell, MD; Owoicho Adogwa, MD; Maksim A. Shlykov, MD, MS; Thamrong Lertudomphonwanit, MD; Michael P. Kelly, MD, MS; Munish C. Gupta, MD

9:20-9:29 Discussion

9:29-9:33 **Paper #40 Combined Anterior-posterior Vs All-posterior Approaches for Adult Spinal Deformity Correction: A Matched Control Study**
Sleiman Haddad, MD, PhD, FRCS; Alba Vila-Casademunt, MS; Oscar Enrique Ramirez Ramirez, MD; Antonia Matamalas, PhD; Juan Bago, MD, PhD; Caglar Yilgor, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Ibrahim Obeid, MD, MS; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Ferran Pellisé, MD, PhD; European Spine Study Group

9:33-9:37 **Paper #41 Adult Spinal Deformity Patients Who Undergo Staged Surgery Within 3-months Have Equivalent Timeline to Functional Recovery as Those with Non-staged Surgery**
Andrew B. Harris, BS; Micheal Raad, MD; Varun Puvanesarajah, MD; Majd Marrache, MD; Mark Ren, BS; Barry R. Bryant, BS; Lee H. Riley, MD; David B. Cohen, MD, MPH; Khaled M. Kebaish, MD, FRCS(C); Brian J. Neuman, MD

9:37-9:41 **Paper #42 Multiple Rod Construct and PSO: A Survival Analysis with Minimum 2 Year Follow-up**
Munish C. Gupta, MD; Renaud Lafage, MS; Mostafa H. El Dafrawy, MD; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Robert A. Hart, MD; Christopher I. Shaffrey, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Richard Hostin, MD; Han Jo Kim, MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

9:41-9:50 Discussion

9:50-10:10

REFRESHMENT BREAK

10:10-12:30

SESSION 4: QUALITY/SAFETY/VALUE/COMPLICATIONS I

Room: 517CD
Moderators: S. Rajasekaran, MD, PhD & Suken A. Shah, MD

10:10-10:14 **Paper #43 The Risks, Reasons, and Costs for 30- and 90-day Readmissions After Adolescent Idiopathic Scoliosis Surgery**
Nathan J. Lee, MD; Jalen D. Dansby, BS; James D. Lin, MD, MS; Alex Ha, MD; Paul J. Park, MD; Meghan Cerpa, BS, MPH; Eric Leung, BA; Ronald A. Lehman Jr., MD; Lawrence G. Lenke, MD

10:14-10:18 **Paper #44 Forecasting Spinal Deformity Healthcare Burden and Operative Utilization in the United States from 2015 to 2040: An Epidemiological-based ARIMA Computation Modeling**
Piyush Kalakoti, MD; Nathan R. Hendrickson, MD, MS; Joshua M. Eisenberg, MD; Andrew Pugely, MD

10:18-10:22 **Paper #45 Cost-effectiveness of Operative vs Nonoperative Treatment of Adult Symptomatic Lumbar Scoliosis: An Intent-to-Treat Analysis with Five Year Follow-up**
Leah Yacat Carreon, MD, MS; Steven D. Glassman, MD; Jon D. Lurie, MD; Christopher I. Shaffrey, MD; Michael P. Kelly, MD, MS; Christine Baldus, RN, MS; Kelly R. Bratcher, RN; Charles H. Crawford III, MD; Elizabeth L. Yanik, PhD, MS; Keith H. Bridwell, MD

10:22-10:31 Discussion

10:31-10:35 **Paper #46 Postoperative Spinal Injection Reduces Length of Stay and Postoperative Narcotic Use Following AIS Fusion Surgery**
Daniela Galeano-Garces, MD; Fady Baky, MD; William J. Shaughnessy, MD; Anthony A. Stans, MD; Dawit T. Haile, MD; A. Noelle Larson, MD; Todd Milbrandt, MD, MS

10:35-10:39 **Paper #47 Factors Associated with Chronic Opioid Use in Preoperative Opioid Nonusers Following Adult Spinal Deformity Surgery**
Andrew B. Harris, BS; Brian J. Neuman, MD; Alex Soroceanu, MD, FRCS(C), MPH; Richard Hostin, MD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Jeffrey L. Gum, MD; Munish C. Gupta, MD; Alan H. Daniels, MD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Shay Bess, MD; Khaled M. Kebaish, MD, FRCS(C); International Spine Study Group

10:39-10:43 **Paper #48 Preemptive Opioid-sparing Medication Protocol Decreases Pain and Length of Hospital Stay in Children Undergoing Posterior Spinal Instrumented Fusion for Scoliosis**
Selina C. Poon, MD; De-An Zhang, MD; Frederick R. Bushnell, MD, MBA; Ronen S. Sever, MD; Robert H. Cho, MD

10:43-10:52 Discussion

10:52-10:56 **Paper #49 Intraoperative Red Blood Cell Salvage in Posterior Spinal Fusions for Idiopathic Scoliosis: Guidelines for Selective Use**
Garrett E. Wahl, BS; Scott John Luhmann, MD

10:56-11:00 **Paper #50 Randomized, Controlled Trial of Two Tranexamic Dosing Protocols in Adult Spinal Deformity Surgery**
Michael P. Kelly, MD, MS; Mostafa H. El Dafrawy, MD; Lawrence G. Lenke, MD

11:00-11:04 **Paper #51 Is Fresh Whole Blood Better than Components in Major Spine Surgery: A Prospective Randomized Study**
S. Rajasekaran, PhD; Keerthivasan Panneerselvam, MBBS, MS; Ajoy Prasad Shetty, MS, DNB

11:04-11:13 Discussion

11:13-11:17 **Paper #52 New Neurologic Deficit and Recovery Rates in Treatment of Complex Pediatric Spine Deformities Exceeding 100 Degrees or Treated by 3CO**
Oheneba Boachie-Adjei, MD; Henry Ofori Duah, RN, MPH; Kwadwo Poku Yankey, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Amer F. Samdani, MD; Peter O. Newton, MD; Suken A. Shah, MD; Mark A. Erickson, MD; Harry Akoto, MD, MB ChB; Brenda A. Sides, MS; Munish C. Gupta, MD; Fox Pediatric Spinal Deformity Study Group

11:17-11:21 **Paper #53 Deformity Angular Ratio is Associated with Intraoperative Neuromonitoring Changes without a VCR: Spinal Deformity is More Influential than Type of Surgery**
Ali Siddiqui, BS; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM; Lindsay M. Andras, MD

11:21-11:25 **Paper #54 Is the Axial Spinal Cord Classification Predictive of Intraoperative Neurologic Alert for Pediatric Scoliosis Patients? A Validation Study**
Smitha E. Mathew, MBBS; A. Noelle Larson, MD; William J. Shaughnessy, MD; Anthony A. Stans, MD; Todd Milbrandt, MD, MS

11:25-11:34 Discussion

11:34-11:39 **Harrington Lecture Introduction**
Peter O. Newton, MD

11:39-11:59 **Harrington Lecture: Dropping the "I" in AIS, What will it Take?**
René M. Castelein, MD, PhD

12:00-12:30 **Presentation of Lifetime Achievement Awards**
See page 14 for additional information

12:30-12:50

BOXED LUNCH PICK-UP & WALKING BREAK

12:50-14:20

INDUSTRY WORKSHOPS – NON-CME

DePuy Synthes
Room: 520BE

Optimizing Patient Outcomes in Adult and Pediatric Spinal Deformity: Case Discussions
Faculty: Randal Betz, MD; Michael Daubs, MD; Munish Gupta, MD; Suken Shah, MD; Joshua Pahys, MD; Stefan Parent, MD; Baron Lonner, MD
This workshop will provide the opportunity to hear several case discussions with Key Thought Leaders on the complex demands of spinal deformity surgery with emphasis on diagnosis and treatment options. The faculty panel for this workshop will be composed of Adult and Pediatric surgeons specializing in Spinal Deformity.

Globus Medical, Inc.
Room: 519

Harnessing the Power of Patient Growth with REFLECT™
Faculty, Ahmet Alanay, MD
Join the Globus Medical industry workshop session to discuss Harnessing the Power of Patient Growth with REFLECT™: A Non-Fusion Technique for Adolescent Idiopathic Scoliosis (AIS). Stop by to learn more about the REFLECT™ system, the surgical technique, and the instrumentation using a bone model. You will also hear about case examples, indications, complications, and results. We hope you can join us for this informative workshop.

Medtronic
Room: 520CF

Constructs for Challenging Deformities: How Technology is Impacting My Practice
Faculty: Christopher Shaffrey, MD; Avery Buchholz, MD; and Darrell Hanson, MD
In this workshop we'll review the latest technologies being used in high-demand spinal deformity cases, highlighting how pre-op planning, navigation, robotics, and innovative implants can facilitate enhanced biomechanical performance and construct tailoring.

NuVasive
Room: 518

Are You Leaving Correction on the Table? Using Surgical Intelligence Technology to Address Alignment in Pediatric Spinal Deformity
Faculty: David Clements, MD; Tenner Guillaume, MD; and Greg Mundis, MD
Come learn about the integration of enabling technologies aimed at helping you reproducibly achieve proper kyphosis, restoration, and coronal balance in every patient. When used with the powerful Reline® 5.0-6.0 fixation system, the Pulse® platform provides real-time feedback to help objectively measure and dial in your correction.

Thursday, September 19, 2019

Stryker

Room: 520AD

Advanced Techniques and Options for Treating Complex Spinal Pathologies: An Interactive Case-Based Discussion

Moderator: John Kostuik, MD
Faculty: Christopher P. Ames, MD; Shay Bess, MD; Jeffrey Gum, MD; Ronald A. Lehman Jr., MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD
Join our faculty panel for a case-based discussion addressing advanced correction techniques when faced with complex pathologies.

14:20-14:35

WALKING BREAK

14:35-17:35

HALF-DAY COURSES (TWO CONCURRENT SESSIONS)

HDCA: Growth and Scoliosis

Room: 517CD
Chairs/Moderators: Peter F. Sturm, MD & G. Ying Li, MD
See page 115 for Half-Day Course Handouts.

14:35-14:40 **Growth Indicators"**
James O. Sanders, MD

14:40-14:45 **How Growth Modulation Allows for Curve Correction**
Peter O. Newton, MD

14:45-14:50 **Long Term Results of Fusion: EOS**
Dominick A. Tuason, MD

14:50-14:55 **Long Term Results of Fusion: AIS**
William A. Phillips, MD

14:55-15:05 Discussion

15:05-15:09 **Paper #55 Morphological Analysis of 112 Resected Hemivertebrae from a Developmental Perspective**
Tianhua Rong, MD; Jianxiong Shen, MD; Ningyi Jia, MD; Zheng Li, MD; Chong Chen, MD; Youxi Lin, MD; Haining Tan, MD; Yang Jiao, MBBS

15:09-15:13 **Paper #56 Benefits of Best Practice Guidelines in Spine Fusion: Comparable Correction with Higher Density and Fewer Complications**
Pedro M. Fernandes, MD; Joaquim Soares do Brito, MD; Isabel Flores, PhD; Jacinto Manuel Monteiro, PhD

15:13-15:19 Discussion

15:19-15:24 **Functional Outcomes: Pulmonary**
Jwalant S. Mehta, FRCS, MS (Orth), D (Orth), MCh (Orth)

15:24-15:29 **Functional Outcomes: Psychological**
Colin Nnadi, FRCS(Orth)

15:29-15:34 **Available Techniques**
Brandon A. Ramo, MD

15:34-15:44 Discussion

15:44-15:48 **Paper #57 Rib Cage Deformity and Pulmonary Function After Surgery in Adolescent Idiopathic Scoliosis**
Raphael Pietton, MD; Houssam Bouloussa, MD, MS; Tristan Langlais, MD; Romain Laurent, MD; Wafa Skalli, PhD; Claudio Vergari, PhD; Raphael Vialle, MD, PhD

15:48-15:52 **Paper #58 A 10-year Study for Lung Function in Patients with Severe Rigid Spinal Deformities (SRSDs) Treated by Posterior Vertebral Column Resection (PVCR)**
Jingming Xie, MD; Ni Bi, MD; Yingsong Wang, MD; Qiuan Lu, MD; Ying Zhang, MD; Zhiyue Shi, MD; Quan Li, MD; Zhi Zhao, MD, PhD; Tao Li, MD

15:52-15:56 **Paper #59 Thoracoscopic Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Mid-term Results of 24 Patients**
Tuna Pehlivanoglu, MD; Ender Ofluoglu, MD; Ismail Oltulu, MD; Ender Sarioglu, MD; Guray Altun, MD; Mehmet Aydogan, MD

15:56-16:00 **Paper #60 Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS: An Eight Year Experience**
John T. Braun, MD; Daniel P. Croitoru, MD

16:00-16:12 Discussion

16:12-16:17 **When is the Optimal Time to Intervene: Clinical**
Amer F. Samdani, MD

16:17-16:22 **When is the Optimal Time to Intervene: Basic Science**
Stefan Parent, MD, PhD

16:22-16:27 **Best Practice Guidelines**
Judson W. Karlen, MD

16:27-16:32 **Avoiding Complications**
Masood Shafafy, FRCS(Orth)

16:32-16:42 Discussion

16:42-16:46 **Paper #61 Long Term Follow up of Patients with Infantile Idiopathic Scoliosis: Is Rib Vertebral Angle Difference a Reliable Indicator of Progression?**
Adam Lloyd, MBBS, MS; Morgan E. B. Jones, MBBS, FRCS; Jwalant S. Mehta, FRCS, MS (Orth); D (Orth); MCh (Orth); Adrian C. Gardner, MBBS, FRCS; Jonathan Spilsbury; David S. Marks, FRCS; Matthew P. Newton Ede, FRCS

16:46-16:50 **Paper #62 Current Use in Growth-friendly Implants for Early Onset Scoliosis: A Ten-year Update**
Walter Klyce, BA; Stuart L. Mitchell, MD; Jeff Pawelek, BS; David L. Skaggs, MD, MMM; James O. Sanders, MD; Suken A. Shah, MD; Richard E. McCarthy, MD; Scott John Luhmann, MD; Peter F. Sturm, MD, MBA; John (Jack) M. Flynn, MD; John T. Smith, MD; Michael G. Vitale, MD, MPH; Behrooz A. Akbarnia, MD; Paul D. Sponseller, MD, MBA; Children's Spine Study Group; Growing Spine Study Group

16:50-16:54 **Paper #63 Magnetically-controlled Growing Rod Patients Have Similar HRQOL Scores Compared to Traditional Growing Rod Patients After Two Years of Treatment**
David L. Skaggs, MD, MMM; Behrooz A. Akbarnia, MD; Jeff Pawelek, BS; Hiroko Matsumoto, PhDc; Tricia St. Hilaire, MPH; Peter F. Sturm, MD, MBA; Francisco Javier Sanchez Perez-Grueso, MD; Scott John Luhmann, MD; Paul D. Sponseller, MD, MBA; John T. Smith, MD; Klane K. White, MD, MS; Michael G. Vitale, MD, MPH; Children's Spine Study Group; Growing Spine Study Group

16:54-17:03 Discussion

17:03-17:13 **Case 1**
Ron El-Hawary, MD

17:13-17:23 **Case 2**
Sumeet Garg, MD

17:23-17:33 **Case 3**
Per D. Trobisch, MD

17:33-17:35 **Closing Remarks**
Peter F. Sturm, MD

Thursday, September 19, 2019

HDCB: Adult Spinal Deformity: Case Based Debates

Room: 517A
Chairs/Moderators: Eric O. Klineberg, MD & Ferran Pellisé, MD, PhD
See page 138 for Half-Day Course Handouts.

14:35-14:40 **Case Introduction for Alignment Goals and Proximal Junctional Kyphosis**
Ferran Pellisé, MD, PhD

14:40-14:45 **Adult Alignment Targets Provide Improved Outcomes and Decreased Complications (Schwab-ISSG)**
Virginie Lafage, PhD

14:45-14:50 **Alignment Targets Need to Include Age, Location of Lordosis to Decrease Complications (GAP-ESSG)**
Caglar Yilgor, MD

14:50-14:55 **Alignment Parameters in India**
Saumyajit Basu, MS(orth), DNB(orth), FRCSEd

14:55-15:05 **Case Conclusion and Discussion**
Ferran Pellisé, MD, PhD

15:05-15:10 **Case Introduction for Predictive Analytics and Avoiding Complications**
Eric O. Klineberg, MD

15:10-15:15 **Predictive Analytics are the Future and Can Help Surgeons Avoid Complications**
Christopher P. Ames, MD

15:15-15:20 **Let's be Cautious with Predictive Analytics**
Marinus de Kleuver, MD, PhD

15:20-15:25 **Are Current Western Predictive Models Applicable in Asia?**
Kota Watanabe, MD, PhD

15:25-15:35 **Case Conclusion and Discussion**
Eric O. Klineberg, MD

15:35-15:39 **Paper #64 Benefits of Medical Optimization Before Thoracolumbar Three-column Osteotomies: An Analysis of 618 Patients**
Andre M. Samuel, MD; Noor M. Maza, BS; Avani S. Vaishnav, MBBS; Francis C. Lovecchio, MD; Yahya A. Othman; Steven J. Mcanany, MD; Sravisht Iyer, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

15:39-15:43 **Paper #65 The 5-factor Modified Fragility Index (MFI-5) is Predictive of 30-day Postoperative Complications and Readmission in Patients with Adult Spinal Deformity (ASD)**
Neil V. Shah, MD, MS; George A. Beyer, MS; David J. Kim, BS; Neil Patel, BS, BA; Douglas A. Hollern, MD; Saad Tarabichi, BS; Daniel E. Suarez, ; Dan Monessa, BS; Suriya Baskar, BA; Peter L. Zhou, MD; Ahmed M. Eldib, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD; Bassel G. Diebo, MD

15:43-15:47 **Paper #66 Surgical Risk Stratification Based on Preoperative Risk Factors in Adult Spinal Deformity**
Mitsuru Yagi, MD, PhD; Takehiro Michikawa, MD, PhD; Naobumi Hosogane, MD, PhD; Nobuyuki Fujita, MD, PhD; Eijiro Okada, MD, PhD; Satoshi Suzuki, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD; Takashi Asazuma, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD Kota Watanabe, MD, PhD

15:47-15:51 **Paper #67 Predictive Risk Calculators for Unplanned Readmissions and Reoperations Following Adult Spinal Deformity (ASD) Surgery**
Ferran Pellisé, MD, PhD; Miquel Serra-Burriel, PhD; Justin S. Smith, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Michael P. Kelly, MD, MS; Alba Vila-Casademunt, MS; Francisco Javier Sanchez Perez-Grueso, MD; Shay Bess, MD; Jeffrey L. Gum, MD; Douglas C. Burton, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Virginie Lafage, PhD; Ibrahim Obeid, MD, MS; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Ahmet Alanay, MD; Christopher P. Ames, MD; International Spine Study Group; European Spine Study Group

15:51-16:10 Discussion

16:10-16:15 **Case Introduction for Correction Options for Adult Deformity**
Ferran Pellisé, MD, PhD

16:15-16:20 **Anterior/Posterior Yields Superior Correction and Outcomes**
Munish C. Gupta, MD

16:20-16:25 **Posterior Only Correction is Effective in Achieving Alignment Goals**
Lawrence G. Lenke, MD

16:25-16:30 **MIS is the Only Option for Achieving Superior Outcomes**
Juan S. Uribe, MD

16:30-16:40 **Case Conclusion and Discussion**
Ferran Pellisé, MD, PhD

16:40-16:45 **Case Introduction for Cervical Deformity: Does Alignment Matter**
Eric O. Klineberg, MD

16:45-16:50 **Cervical Alignment is as Important as Thoracolumbar Alignment**
Justin S. Smith, MD, PhD

16:50-16:55 **Cervical Alignment is Less Critical, and Here is Why**
Jean-Charles Le Huec, MD, PhD

16:55-17:00 **Cervical Deformity, Approach Considerations**
Christopher I. Shaffrey, MD

17:00-17:10 **Case Conclusion and Discussion**
Eric O. Klineberg, MD

17:10-17:14 **Paper #68 Increasing Cost Efficiency in Adult Spinal Deformity Surgery: Identifying Predictors of Lower Total Costs**
Peter G. Passias, MD; Avery Brown, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Christopher P. Ames, MD; Douglas C. Burton, MD; Jeffrey L. Gum, MD; Robert A. Hart, MD; Richard Hostin, MD; Khaled M. Kebaish, MD, FRCS(C); Brian J. Neuman, MD; Shay Bess, MD; Breton G. Line, BS; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Eric O. Klineberg, MD; International Spine Study Group

17:14-17:18 **Paper #69 Predicting ASD Surgeries That Exceed Medicare Allowable Payment Thresholds: A Comparison of Hospital Costs to What the Government Will Actually Pay**
Jeffrey L. Gum, MD; Miquel Serra-Burriel, PhD; Breton G. Line, BS; Themistocles S. Protopsaltis, MD; Alex Soroceanu, MD, FRCS(C), MPH; Richard Hostin, MD; Peter G. Passias, MD; Michael P. Kelly, MD, MS; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Eric O. Klineberg, MD; Han Jo Kim, MD; Andrew B. Harris, BS; Khaled M. Kebaish, MD, FRCS(C); Frank J. Schwab, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group

17:18-17:22 **Paper #70 How Much Correction is Possible? Minimally Invasive Multilevel Lateral Lumbar Interbody Fusion Combined with Posterior Column Osteotomy using Stiff Rod (6.35 mm Cobalt Chrome) in Adult Spinal Deformity Surgery as Compared with Pedicle Subtraction Osteotomy**
Jung-Hee Lee, MD, PhD; Ki-Young Lee, MD; Won-Ju Shin, MD; Dong-Gune Chang, MD, PhD; Sang Kyu Im, MD; Seong Jin Cho, MD

17:22-17:35 Discussion

17:35-18:00

MEMBERSHIP INFORMATION SESSION

Room: 517A

Friday, September 20, 2019

7:00-17:00

REGISTRATION OPEN

8:00-8:46

SESSION 5A: HIBBS BASIC RESEARCH AWARD NOMINEES

Room: 517CD
Moderators: Lawrence L. Haber, MD & Ronald A. Lehman Jr., MD

8:00-8:04 **Welcome Remarks**

8:04-8:08 **Paper #71 A Multi-ethnic Meta-analysis Defined the Association of rs12946942 with Progression of Adolescent Idiopathic Scoliosis***
Kazuki Takeda, MD, PhD; Nao Otomo, MD; Anna Grauers, MD, PhD; Yan-Hui Fan; Yoji Ogura, MD; Youhei Takahashi, MD; Elisabet Einarsdottir; Juha Kere; Morio Matsumoto, MD, PhD; Yong Qiu, MD; You-Qiang Song, PhD; Paul Gerdhem, MD, PhD; Shiro Ikegawa, MD, PhD; Kota Watanabe, MD, PhD

8:08-8:12 **Paper #72 Exploring Predictive Model of Plasma miRNAs on Curve Progression in Adolescent Idiopathic Scoliosis (AIS): A 6 Years Longitudinal Study***
Jiajun Zhang, PhD; Ka Yee Cheuk, PhD; Tsz-Ping Lam, MBBS; Yong Qiu, MD; Jack CY Cheng, MD; Wayne Y.W. Lee, PhD

8:12-8:16 **Paper #73 Genome-wide Association Study Identifies Novel Genetic Locus Associated with Curve Progression in AIS Patients***
Lei-Lei Xu, PhD; Zhichong Wu, PhD; Xu Sun, MD; Zhen Liu, MD; Yong Qiu, MD; Zezhang Zhu, MD

8:16-8:25 Discussion

8:25-8:29 **Paper #74 LBX1 May Play a Role in the Development of AIS via Regulating the Proliferation and Differentiation of Myosatellite Cells***
Lei-Lei Xu, PhD; Zhichong Wu, PhD; Xu Sun, MD; Zhen Liu, MD; Yong Qiu, MD; Zezhang Zhu, MD

8:29-8:33 **Paper #75 Are Serum Ion Levels Elevated in Pediatric Patients with Spinal Implants vs. Controls?***
Smitha E. Mathew, MBBS; A. Noelle Larson, MD; Matthew P. Abdel, MD; Andre J. van Wijnen, PhD; Todd Milbrandt, MD, MS; Geoffrey F. Haft, MD

8:33-8:37 **Paper #76 TBX6-associated Congenital Scoliosis (TACS) as a Clinically Distinguishable Subtype of Congenital Scoliosis: Further Evidence Supporting the Compound Inheritance and TBX6 Gene Dosage Model***
Nan Wu, MD; Jiaqi Liu, MD; Kazuki Takeda, MD, PhD; Sen Zhao, BS; Terry Jianguo Zhang, MD; Feng Zhang, PhD; Zhihong Wu, MD; Shiro Ikegawa, MD, PhD; James R. Lupski, MD, PhD, DSc (hon); Guixing Qiu, MD; Deciphering Disorders Involving Scoliosis and COmorbidities Study (DISCO)

8:37-8:46 Discussion

Key: * = Hibbs Award Nominee for Best Basic Research Paper, † = Hibbs Award Nominee for Best Clinical Research Paper
Cast your vote for the Hibbs Awards on the Mobile App: 1. Select "Polls & Voting" from the app home screen 2. Select the Hibbs Awards voting Polls 3. Cast your vote!

Friday, September 20, 2019

8:47-9:50

SESSION 5B: HIBBS CLINICAL RESEARCH AWARD NOMINEES

Room: 517CD
Moderators: Kenneth MC Cheung, MD & Muharrem Yazici, MD

8:47-8:51 **Paper #77 Tranexamic Acid In Pediatric Scoliosis Surgery (TRIPSS): A Prospective Randomized Trial Comparing High Dose And Low Dose Tranexamic Acid In Adolescent Idiopathic Scoliosis (AIS) Undergoing Posterior Spinal Fusion Surgery†**
Mohd Shahnaz Hasan, MBBS, MAnes; Chris Yin Wei Chan, MD, MS; Siti Nadzrah Yunus, MBBS; Ching Choe Ng, MD, MAnaes; Chee Kidd Chiu, MBBS, MS; Mun Keong Kwan, MBBS, MS

8:51-8:55 **Paper #78 Prospective Randomized Controlled Trial of Implant Density in AIS: Results of the Minimize Implants Maximize Outcomes Study†**
A. Noelle Larson, MD; David W. Polly Jr., MD; Paul D. Sponseller, MD, MBA; B. Stephens Richards, MD; Sumeet Garg, MD; Hubert Labelle, MD, FRCS(C); Stuart L. Leslie Weinstein, MD; Suken A. Shah, MD; Charles H. Crawford III, MD; Matthew E. Oetgen, MD; James O. Sanders, MD; Nicholas D. Fletcher, MD; Laurel C. Blakemore, MD; Ann M. Brearley, PhD; Mark A. Erickson, MD; Stefan Parent, MD, PhD; Carl-Eric Aubin, PhD, ScD (h.c.), P.Eng.; Daniel J. Sucato, MD, MS; Minimize Implants Maximize Outcomes Study Group

8:55-8:59 **Paper #79 The Analgesic Effect of Dexmedetomidine in Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Double Blinded Prospective Randomized Study†**
Ajoy Prasad Shetty, MS, DNB; Ankith NV, MS; Rishi M. Kanna, MBBS, MS; S. Rajasekaran, PhD

8:59-9:08 Discussion

9:08-9:12 **Paper #80 Health Related Quality of Life in Non-operated Patients with Adolescent Idiopathic Scoliosis in the Middle Years: Mean 25 Years Follow-up Study†**
Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD, PhD; Kazuhiro Hasegawa, MD, PhD

9:12-9:16 **Paper #81 Scheuermann Kyphosis 39 Year Follow-up from Diagnosis in Non-operated Patients†**
Lærke C. Ragborg; Casper Dragsted, MD; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

9:16-9:20 **Paper #82 Quantitative Risk Analysis of Adolescent Idiopathic Scoliosis Patients Who Deferred Surgery†**
Gabriel KP Liu, MD, FRCS; Gerald Fung; Si Jian Hui, MBBS; Jun Hao Tan, MBBS; Leok-Lim Lau, FRCS; Hee-Kit Wong, FRCS

9:20-9:29 Discussion

9:29-9:33 **Paper #83 Prospective Follow-up of Anterior Vertebral Body Tethering (AVBT) for Idiopathic Scoliosis: Interim Results from an FDA IDE Study†**
Amer F. Samdani, MD; Joshua M. Pahys, MD; Robert J. Ames, MD; Harsh Grewal, MD; Glenn Pelletier, MD; Randal R. Betz, MD; Steven W. Hwang, MD

9:33-9:37 **Paper #84 Clinical, Radiological and HRQoL Outcomes after Selective Thoracic Fusion with Minimum 15 Years Follow-up†**
Sinan Kahraman, MD; Yunus Emre Akman, MD; Ayhan Mutlu, MD; Onur Levent Ulusoy, MD; Tunay Sanli, MA; Huseyin Ozturk, MD; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

9:37-9:41 **Paper #85 Using Humerus Ossification and Cobb Angle to Predict Progression to Surgery in Scoliosis Patients†**
Don Li, MS; Jonathan Cui, MD, BS; Stephen G. DeVries, BS; Joseph Kahan, MD; Logan Petit, MD; Ronan Talty; Daniel R. Cooperman, MD; Brian G. Smith, MD

9:41-9:50 Discussion

9:50-10:10

REFRESHMENT BREAK

Key: * = Hibbs Award Nominee for Best Basic Research Paper, † = Hibbs Award Nominee for Best Clinical Research Paper
Cast your vote for the Hibbs Awards on the Mobile App: 1. Select "Polls & Voting" from the app home screen 2. Select the Hibbs Awards voting Polls 3. Cast your vote!

Friday, September 20, 2019

10:10-11:45

SESSION 6: HEALTH-RELATED QUALITY OF LIFE IN SPINAL DEFORMITY

Room: 517CD
Moderators: Michael P. Kelly, MD, MS & Justin S. Smith, MD, PhD

10:10-10:14 **Paper #86 Core Outcome Set for Adult Spinal Deformity: An Initiative of the Scoliosis Research Society**
Marinus de Kleuver, MD, PhD; Sayf S.A. Faraj, MD; Miranda L. Van Hooff, PhD; Tjitske M. Haanstra, PhD; Anna K. Wright, PhD; David W. Polly Jr., MD; Steven D. Glassman, MD

10:14-10:18 **Paper #87 Defining a Surgical Invasiveness Threshold for Major Complications Following Adult Spinal Deformity Surgery**
Brian J. Neuman, MD; Andrew B. Harris, BS; Eric O. Klineberg, MD; Robert A. Hart, MD; Richard Hostin, MD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Jeffrey L. Gum, MD; Michael P. Kelly, MD, MS; Alan H. Daniels, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Khaled M. Kebaish, MD, FRCS(C); International Spine Study Group

10:18-10:22 **Paper #88 Normalization of Worst Preoperative PROMIS Domain Predicts Patient Satisfaction with ASD Management After Fusion Surgery**
Nicholas S. Andrade, BS; Alvaro Ibaseta, MS; Rafa Rahman, BS; Richard L. Skolasky, Sc.D.; Daniel M. Sciubba, MD; Lee H. Riley, MD; David B. Cohen, MD, MPH; Khaled M. Kebaish, MD, FRCS(C); Brian J. Neuman, MD

10:22-10:31 Discussion

10:31-10:35 **Paper #89 Long-term Follow-up Surgical Outcome of Young Adult Idiopathic Scoliosis: Comparison with Adolescent Idiopathic Scoliosis Ten or More Years of Follow-up**
Dong-Ju Lim, MD, PhD; Se-Il Suk, MD, PhD; Sung-Soo Kim, MD, PhD; Dong-Gune Chang, MD, PhD

10:35-10:39 **Paper #90 Patient-related and Radiographic Predictors of Inferior Health-related Quality of Life Measures in Non-operative Adult Spinal Deformity Patients**
Peter G. Passias, MD; Haddy Alas, BS; Shay Bess, MD; Breton G. Line, BS; Virginie Lafage, PhD; Renaud Lafage, MS; Christopher P. Ames, MD; Douglas C. Burton, MD; Michael P. Kelly, MD, MS; Richard Hostin, MD; Khaled M. Kebaish, MD, FRCS(C); Khoi D. Than, MD; Christopher I. Shaffrey, MD; Robert A. Hart, MD; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; International Spine Study Group

10:39-10:43 **Paper #91 Lower Satisfaction after Adult Spinal Deformity Surgery in Japan Compared with the US Despite Similar SRS22 Pain and Function Scores: A Propensity Score Matched Analysis**
Mitsuru Yagi, MD, PhD; Christopher P. Ames, MD; Naobumi Hosogane, MD, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Morio Matsumoto, MD, PhD; Shay Bess, MD; Kota Watanabe, MD, PhD; International Spine Study Group

10:43-10:52 Discussion

10:52-10:56 **Paper #92 Effects of Post-operative Complications in Complex Pediatric Spine Deformity on SRS Scores: Does Complication Adversely Affect Quality of Life of Patients?**
Oheneba Boachie-Adjei, MD; Kwadwo Poku Yankey, MD; Henry Ofori Duah, RN, MPH; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Amer F. Samdani, MD; Peter O. Newton, MD; Suken A. Shah, MD; Mark A. Erickson, MD; Harry Akoto, MD, MB ChB; Brenda A. Sides, MS; Munish C. Gupta, MD; Fox Pediatric Spinal Deformity Study Group

10:56-11:00 **Paper #93 Surgical Standardization Improves Safety, Efficiency, and Outcomes in AIS Surgery and is Reproducible**
Vishal Sarwahi, MD; Jesse Galina, BS; Sayyida Hasan, BS; Chhavi Katyal, MD; Marina Moguilevtch, MD; Beverly Thornhill, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

11:00-11:04 **Paper #94 Health-related Quality of Life of Idiopathic Scoliosis: Comparison of Untreated Patients, Surgically Treated Patients and Normal Controls**
Duygu Kuzu, PhD; Tunay Sanli, MA; Huseyin Ozturk, MD; Yunus Emre Akman, MD; Sinan Kahraman, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

11:04-11:13 Discussion

Friday, September 20, 2019

11:13-11:20 **2020 Meetings Previews**

11:20-11:25 **Introduction of the President**
Paul D. Sponseller, MD, MBA

11:25-11:45 **Presidential Address**
Peter O. Newton, MD

11:45-12:00

MEMBERS: WALKING BREAK TO MEMBER BUSINESS MEETING & LUNCH

11:45-12:15

NON-MEMBERS: BOXED LUNCH PICK-UP

12:00-13:30

MEMBER BUSINESS MEETING & LUNCH – NON-CME

Room: 517A
An agenda will be provided at the meeting.

12:15-13:30

NON MEMBER LUNCH SESSION – NON-CME

Room: 517B

Leveraging Social Media to Improve Your Practice

Chair/Moderator: Joshua M. Pahys, MD

12:15-12:20 **Introduction**
Joshua M. Pahys, MD

12:20-12:30 **Using Social Media to Build Your Practice**
Robert H. Cho, MD

12:30-12:40 **How to Build and Manage Your Personal Webpage**
Lloyd A. Hey, MD

12:40-12:55 Discussion

12:55-13:05 **How to Handle Negative Comments on Social Media**
Amer F. Samdani, MD

13:05-13:15 **Staying HIPAA Compliant**
Jaysson T. Brooks, MD

13:15-13:30 Discussion

13:30-13:40

WALKING BREAK

13:40-15:25

SESSION 7: MISCELLANEOUS/KYPHOSIS/NON-OPERATIVE TREATMENT STRATEGIES

(Runs Concurrently with Session 8)
Room: 517A
Moderators: Hubert Labelle, MD, FRCS(C) & David W. Polly Jr., MD

13:40-13:44 **Paper #95 Concomitant Low-grade Isthmic Spondylolisthesis Does Not Affect the Course of AIS**
Dietrich Schlenzka, MD, PhD; Mauno Ylikoski, MD, PhD; Mikko Poussa, MD, PhD; Timo A. Yrjonen, MD; Leena Ristolainen, PhD

13:44-13:48 **Paper #96 How Does Pelvic Incidence Change in Low-Grade Spondylolisthesis in Association with Listhesis Progression?**
Abdulmajeed Alzakri, MD, MS; Julie Joncas, RN; Hubert Labelle, MD, FRCS(C); Stefan Parent, MD, PhD; Soraya Barchi, BS; Jean-Marc Mac-Thiong, MD, PhD

13:48-13:52 **Paper #97 Opportunities to Improve the Outcome of Surgical Treatment in High-Grade Spondylolisthesis**
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, MS, PT; Hubert Labelle, MD, FRCS(C)

13:52-14:01 Discussion

14:01-14:05 **Paper #98 Spinal Deformity in Long-term Survivors of Childhood Sarcoma**
Felipe A. Garcez de Campos, MD; Israel Fernandez-Pineda, MD; Rodrigo B. Interiano, MD; Kirsten K. Ness, PhD; Andrew Davidoff, MD; Melissa Hudson, MD; Leslie L. Robison, PhD; Derek M. Kelly, MD; Jeffrey R. Sawyer, MD; William C. Warner Jr, MD

14:05-14:09 **Paper #99 Vertebra Plana in Children Can Be Due to Etiologies Other than Eosinophilic Granuloma**
Fady Baky, MD; Todd Milbrandt, MD, MS; Matthew T. Houdek, MD; A. Noelle Larson, MD

14:09-14:13 **Paper #100 Neurologic Deficit Improved with the Correction of Rotatory Subluxation using Pre-operative Halo-gravity Traction in Severe Neurofibromatosis Type 1 and Congenital Scoliosis**
Benlong Shi, PhD; Yang Li, PhD; Zhen Liu, MD; Xu Sun, MD; Zezhang Zhu, MD; Junyin Qiu; Yong Qiu, MD

14:13-14:22 Discussion

14:22-14:26 **Paper #101 Degenerative Paraspinal Muscles Impact Thoracic Spine Compensation in ASD Patients**
Mathieu Bannwarth, MD; Jonathan Charles Elysée, BS; Renaud Lafage, MS; Bryan Ang, BS; Alex Liu Huang; Cole Bortz, BA; Jessica Andres-Bergos, PhD; Peter G. Passias, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Virginie Lafage, PhD

14:26-14:30 **Paper #102 Association of Higher Frailty Score and Lower Self-care Activity with Sagittal Spinopelvic Malalignment in the Elderly Population**
Tae Woo Kim, MD; Jae Keun Oh, MD; Jong Joo Lee, MD; Yoon Ha, MD

14:30-14:34 **Paper #103 Does Clinical Photography Influence Satisfaction with Surgery in Adult Patients Operated on Spinal Deformity?**
Cristina Madrid de la Serna, MD; Alejandro Gomez-Rice, MD; Felisa Sanchez-Mariscal, PhD; Iria Vazquez Vecilla, MD; Lorenzo Zuniga, MD; Enrique Izquierdo, PhD

14:34-14:43 Discussion

14:43-14:47 **Paper #104 What is the Optimal Postoperative Sagittal Alignment in Ankylosing Spondylitis-related Thoracolumbar Kyphosis Following One-level Pedicle Subtraction Osteotomy?**
Jichen Huang, MD; Bangping Qian, MD; Yong Qiu, MD; Bin Wang, MD; Yang Yu, MD; Feng Zhenhua, MS; Junyin Qiu; Hongbin Ni, MD

14:47-14:51 **Paper #105 Clinical and Radiographic Outcomes in Patients with Severe and Rigid Kyphoscoliosis (>100 degrees) Treated without a 3-Column Osteotomy (3CO)**
Isaac O. Karikari, MD; Kwadwo Poku Yankey, MD; Henry Ofori Duah, RN, MPH; Harry Akoto, MD, MB ChB; Irene Wulff, MD; Oheneba Boachie-Adjei, MD

14:51-14:55 **Paper #106 Are We Neglecting Long Term Effects of Vertebral Shortening on Pulmonary Function in Spinal Tuberculosis?**
Tushar Narayan Rathod, MBBS, MS, FCPS D Ortho; Nandan A. Marathe, MS

14:55-15:04 Discussion

15:04-15:08 **Paper #107 3D-Printed Spinal Orthosis in Management of Adolescent Idiopathic Scoliosis: A Randomized Controlled Trial**
Yang Min Lin, MS; Jason Pui Yin Cheung, MBBS, FRCS, MS; Kenneth MC Cheung, MD; M S. Wong, PhD

15:08-15:12 **Paper #108 Curve Correction is Significantly Greater with Braces Optimized Using CAD/CAM and FEM after 2 Years of Treatment: A Randomized Controlled Trial**
Aymeric Guy, MS; Elisabeth Audet-Duchesne; Soraya Barchi, BS; Hubert Labelle, MD, FRCS(C); Carl-Eric Aubin, PhD, ScD (h.c.), P.Eng

15:12-15:16 **Paper #109 Effectiveness of Providence Night-time Bracing compared to Full-time Boston Bracing for Adolescent Idiopathic Scoliosis. A Matched Cohort Study**
Ane Simony, MD, PhD; Mikkel ø. Andersen, MD; Stig Mindedahl Jespersen, MD, PhD; Leah Yacat Carreon, MD, MS

15:16-15:25 Discussion

13:40-15:25

SESSION 8: ADULT SPINAL DEFORMITY II – SAGITTAL ALIGNMENT AND PJK

(Runs Concurrently with Session 7)
Room: 517CD
Moderators: Stephen J. Lewis, MD, MSc, FRCSC & Pierre Roussouly, MD

13:40-13:44 **Paper #110 The Impact of Sagittal Balance and Spinopelvic Parameters on the Development of Proximal Junctional Kyphosis Following Posterior Spinal Fusion for Adult Spinal Deformity**
Bryce A. Basques, MD; Michael T. Nolte, MD; Philip K. Louie, MD; Jannat Khan, BS; Kamran Movassaghi, MS, BS; Dennis P. McKinney, BS; Joseph F. Michalski, MS, MPH; Howard S. An, MD; Christopher J. DeWald, MD

13:44-13:48 **Paper #111 Are We Better at Preventing PJK Today? A Comparison of Incidence 5-7 Years Later**
Han Jo Kim, MD; Jingyan Yang, MHS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD; Peter G. Passias, MD; Jeffrey L. Gum, MD; Shay Bess, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Renaud Lafage, MS; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

13:48-13:52 **Paper #112 Cement Augmentation at UIV and Prophylactic Vertebroplasty at UIV+1 for the Prevention of PJK and PJF in Adult Spinal Deformity Surgery with Osteoporosis: A Retrospective Analysis of 161 Patients with a Mean Follow-up of 6 Years**
Yunus Emre Akman, MD; Huseyin Ozturk, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Meric Enercan, MD; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

13:52-14:01 Discussion

14:01-14:05 **Paper #113 Comparing and Contrasting the Clinical Utility of Sagittal Spine Alignment Classification Frameworks: Roussouly vs. SRS-Schwab**
Peter G. Passias, MD; Cole Bortz, BA; Renaud Lafage, MS; Bassel G. Diebo, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Munish C. Gupta, MD; Daniel M. Sciubba, MD; Shay Bess, MD; Richard Hostin, MD; Christopher I. Shaffrey, MD; Breton G. Line, BS; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; International Spine Study Group

14:05-14:09 **Paper #114 Restoring the Ideal Roussouly Sagittal Profile in Adult Scoliosis Surgery Decreases the Risk of Mechanical Complications**
Javier Pizones, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Luc Moreno-Manzanaro, BS; Alba Vila-Casademunt, MS; Caglar Yilgor, MD; Nicomedes Fernández-Bao, MD; Jose Miguel Sánchez-Márquez, MD, PhD; Gloria Talavera, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD, MS; Ahmet Alanay, MD; Ferran Pellisé, MD, PhD; European Spine Study Group

14:09-14:13 **Paper #115 Outcomes of Surgical Treatment for 138 Patients with Severe Sagittal Deformity at a Minimum 2-Year Follow Up**
Justin K. Scheer, MD; Lawrence G. Lenke, MD; Justin S. Smith, MD, PhD; Peter G. Passias, MD; Han Jo Kim, MD; Shay Bess, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

14:13-14:22 Discussion

14:22-14:26 **Paper #116 Comprehensive Alignment Planning (CAP) for Adult Spinal Deformity (ASD) More Effectively Predicts Surgical Outcomes and Proximal Junctional Kyphosis than Previous Classifications**
Renaud Lafage, MS; Justin S. Smith, MD, PhD; Jonathan Charles Elysée, BS; Peter G. Passias, MD; Shay Bess, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Richard Hostin, MD; Gregory M. Mundis Jr., MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

14:26-14:30 **Paper #117 Does the Global Alignment and Proportion Score Overestimate Mechanical Complications after Adult Spinal Deformity Correction?**
Griffin R. Baum, MD, MS; Alex Ha, MD; Meghan Cerpa, BS, MPH; James D. Lin, MD, MS; Joseph A. Osorio, MD, PhD; Richard P. Menger, MD, MPA; Simon Morr, MD, MPH; Eric Leung, BA; Ronald A. Lehman Jr., MD; Zeeshan M. Sardar, MD, MS, FRCS(C); Lawrence G. Lenke, MD

14:30-14:34 **Paper #118 Modified Global Alignment and Proportion Scoring with Body Mass Index and Bone Mineral Density (GAPBB) for Prediction of Mechanical Complication after Adult Spinal Deformity Surgery: Retrospective Analysis of 203 Patients**
Kyung Hyun Kim, MD; Sung Hyun Noh, MD; UnYong Choi, MD

14:34-14:43 Discussion

14:43-14:47 **Paper #119 The Impact of Segmental Kyphosis in the Upper Thoracic Motion Segments of Instrumented Posterior Spinal Fusions for Idiopathic Scoliosis on the Development of Proximal Junctional Kyphosis**
Justin S. Roth, DO; Scott John Luhmann, MD

14:47-14:51 **Paper #120 Thoracolumbar Junction Orientation: A Novel Guideline for Sagittal Correction to Reduce Proximal Junctional Kyphosis in Adult Spinal Deformity Patients with UIV at the Thoracolumbar Junction**
Hong Joo Moon, MD, PhD; Michael P. Kelly, MD, MS; Thamrong Lertudomphonwanit, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Munish C. Gupta, MD

14:51-14:55 **Paper #121 Vertebral Column Resection Improves the Sagittal Plane Greater than Other Techniques but Risks Symptomatic Junctional Kyphosis**
Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Sumeet Garg, MD; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Mark A. Erickson, MD; Daniel J. Sucato, MD, MS; Amer F. Samdani, MD; Burt Yaszay, MD; Joshua M. Pahys, MD; Peter O. Newton, MD; Brenda A. Sides, MS; Michael P. Kelly, MD, MS; Fox Pediatric Spinal Deformity Study Group

14:55-15:04 Discussion

15:04-15:08 **Paper #122 Evaluation of Global Alignment and Proportion Score in an Adult Spinal Deformity Database**
Munish C. Gupta, MD; Caglar Yilgor, MD; Hong Joo Moon, MD, PhD; Thamrong Lertudomphonwanit, MD; Ahmet Alanay, MD; Michael P. Kelly, MD, MS; Lawrence G. Lenke, MD; Keith H. Bridwell, MD

15:08-15:12 **Paper #123 Global Alignment and Proportion (GAP) Scores in an Asymptomatic Nonoperative Cohort**
Adam M. Wegner, MD, PhD; Sravisht Iyer, MD; Han Jo Kim, MD; Lawrence G. Lenke, MD; Brenda A. Sides, MS; Michael P. Kelly, MD, MS

15:12-15:16 **Paper #124 The Impact of Lordosis Distribution and Sagittal Harmony on Postoperative Mechanical Complications after a Lumbar PSO**
Javier Pizones, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Luc Moreno-Manzanaro, BS; Alba Vila-Casademunt, MS; Louis Boissiere, MD; Caglar Yilgor, MD; Nicomedes Fernández-Bao, MD; Jose Miguel Sánchez-Márquez, MD, PhD; Gloria Talavera, MD; Frank S. Kleinstueck, MD; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Ferran Pellisé, MD, PhD; Ibrahim Obeid, MD, MS; European Spine Study Group

15:16-15:25 Discussion

15:25-15:50

REFRESHMENT BREAK

15:50-17:30

SESSION 9: QUALITY/SAFETY/VALUE/COMPLICATIONS II

Room: 517CD
Moderators: James O. Sanders, MD & Nicholas Spina, MD

15:50-15:54 **Paper #125 Preop Opioid Use is Associated with Worse Postop Outcomes and Chronic Opioid Use in Non-Revision Adult Scoliosis Patients: Corroboration of Two Independent Multi-center Studies**
Shay Bess, MD; Breton G. Line, BS; Michael P. Kelly, MD, MS; Christine Baldus, RN, MS; Christopher P. Ames, MD; Douglas C. Burton, MD; Elizabeth L. Yanik, PhD, MS; Robert K. Eastlack, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Khaled M. Kebaish, MD, FRCS(C); Han Jo Kim, MD; Jeffrey L. Gum, MD; Richard Hostin, MD; Gregory M. Mundis Jr., MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Keith H. Bridwell, MD; International Spine Study Group

15:54-15:58 **Paper #126 Preoperative Opioid Therapy Poorly Controls Pain in Non-revision Adult Spinal Deformity (ASD) and Increases Risk for Chronic Postoperative Opioid Usage**
Shay Bess, MD; Breton G. Line, BS; Michael P. Kelly, MD, MS; Jeffrey L. Gum, MD; Richard Hostin, MD; Khaled M. Kebaish, MD, FRCS(C); Christopher P. Ames, MD; Douglas C. Burton, MD; Gregory M. Mundis Jr., MD; Robert K. Eastlack, MD; Robert A. Hart, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group

15:58-16:02 **Paper #127 Post-op Opioid Cessation in ASD Patients Using Opioids Pre-op is Associated with Improved Outcomes and Satisfaction**
Alex Soroceanu, MD, FRCS(C), MPH; Jeffrey L. Gum, MD; Khaled M. Kebaish, MD, FRCS(C); Andrew B. Harris, BS; Munish C. Gupta, MD; Breton G. Line, BS; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Shay Bess, MD; Douglas C. Burton, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Richard Hostin, MD; International Spine Study Group

16:02-16:11 Discussion

16:11-16:15 **Paper #128 Complications of Posterior Vertebral Column Resection for Severe Spinal Deformity with More Than Two-year Follow-up: A Single-center Experiences**
Qianyu Zhuang, MD; Jianguo Zhang, MD; Wang Shengru, MD

16:15-16:19 **Paper #129 Comprehensive Complication Classification for Adult Spinal Deformity: Complication Timing and the Impact on Outcomes at 2 Years**
Eric O. Klineberg, MD; Renaud Lafage, MS; Munish C. Gupta, MD; Robert A. Hart, MD; Gregory M. Mundis Jr., MD; Shay Bess, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; International Spine Study Group

16:19-16:23 **Paper #130 Incidence and Risk Factors for Rod Fracture after Three-column Osteotomy in Severe Spinal Kyphoscoliosis**
Yong Qiu, MD; Sanqiang Xia, PhD; Zezhang Zhu, MD; Benlong Shi, PhD; Zhen Liu, MD; Junyin Qiu; Feng Zhenhua, MS; Hongbin Ni, MD

16:23-16:32 Discussion

16:32-16:36 **Paper #131 Safety and Efficacy of Osteotomy for Congenital Spinal Deformity Associated with Split Spinal Cord Malformation**
Hua Hui, MD; Dingjun Hao, MD, PhD

16:36-16:40 **Paper #132 Efficacy of Halo-femoral Traction after Posterior Spinal Release in Correction Surgery of Severe Kyphoscoliosis: A Comparison with Pre-operative Halo-gravity Traction**
Bo Shi, MD, PhD; Zezhang Zhu, MD; Benlong Shi, PhD; Zhen Liu, MD; Bin Wang, MD; Junyin Qiu; Feng Zhenhua, MS; Yong Qiu, MD

16:40-16:44 **Paper #133 Does Thoracoplasty Adversely Affect Long Term Lung Function in Complex Pediatric Spine Deformity?**
Oheneba Boachie-Adjei, MD; Arthur Sackeyfio, MD; Henry Ofori Duah, RN, MPH; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Amer F. Samdani, MD; Peter O. Newton, MD; Suken A. Shah, MD; Mark A. Erickson, MD; Irene Wulff, MD; Brenda A. Sides, MS; Munish C. Gupta, MD; Fox Pediatric Spinal Deformity Study Group

16:44-16:53 Discussion

16:53-16:57 **Paper #134 Is Postoperative Imaging Prior to Discharge Necessary Following Idiopathic Scoliosis Surgery?**
Terrence G. Ishmael, MBBS; Daniel J. Sucato, MD, MS; Kiley Frazier Poppino, BS; Chan-Hee Jo, PhD

16:57-17:01 **Paper #135 Surgeon Volume Affects Short- and Long-term Surgical Outcomes in Idiopathic Scoliosis**
Vishal Sarwahi, MD; Alexander M. Satin, MD; Dean C. Perfetti, MD; Jesse Galina, BS; Sayyida Hasan, BS; Jeffrey Goldstein, MD; Terry D. Amaral, MD

17:01-17:05 **Paper #136 Risk Factors that Decrease Complete Recovery in Idiopathic Scoliosis Surgery Associated Neurological Injuries**
Swamy Kurra, MBBS; Harman Chopra, BS; Jinhui Shi, MD; Stephen A. Albanese, MD; Elizabeth A. Demers Lavelle, MD; William F. Lavelle, MD

17:05-17:14 Discussion

17:14-17:18 **Paper #137 Pedicle Screw Plowing in Adolescent Idiopathic Scoliosis: How Common is it, and is it a Problem?**
Walter Klyce, BA; Amit Jain, MD; Stefan Parent, MD, PhD; Suken A. Shah, MD; Patrick J. Cahill, MD; Stephen G. George, MD; David H. Clements III, MD; Vidyadhar V. Upasani, MD; Burt Yaszay, MD; Firoz Miyanji, MD, FRCS(C); Michael P. Kelly, MD, MS; Baron S. Lonner, MD; Michelle Claire Marks, MS, PT; Peter O. Newton, MD; Paul D. Sponseller, MD, MBA; Harms Study Group

17:18-17:22 **Paper #138 Hounsfield Units Value is a Better Predictor of Pedicle Screw Loosening than the T-score of DXA in Patients with Lumbar Degenerative Diseases**
Da Zou, MD; Weishi Li, MD

17:22-17:30 Discussion

19:00-22:00

FAREWELL RECEPTION

Location: St. James Theater
Tickets required; additional information on page 16.

Saturday, September 21, 2019

7:30-11:00

REGISTRATION OPEN

8:00-10:50

SESSION 10: EOS/NEUROMUSCULAR DEFORMITY

Room: 517CD
Moderators: Meric Enercan, MD & Amer F. Samdani, MD

8:00-8:04 **Welcome Remarks**

8:04-8:08 **Paper #139 Is Performing a Definitive Fusion for Scoliosis in Juvenile Cerebral Palsy (CP) Patients a Good Long-term Surgical Option?**
Roland Howard, MD; Tracey P. Bastrom, MA; Madeline Cross, MPH; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Firoz Miyanji, MD, FRCS(C); Amer F. Samdani, MD; Peter O. Newton, MD; Burt Yaszay, MD

8:08-8:12 **Paper #140 Posterior Spinal Fusion in Children with Cerebral Palsy Moves Underweight Children Up the CP Growth Chart**
Keith Baldwin, MD; Joshua M. Pahys, MD; David A. Spiegel, MD; John (Jack) M. Flynn, MD; Paul D. Sponseller, MD, MBA; Mark F. Abel, MD; Harms Study Group; Patrick J. Cahill, MD

8:12-8:16 **Paper #141 Postoperative Enteral Feeding in Cerebral Palsy Patients After Spinal Fusion: How Long Should We Wait?**
Bram Verhofste, MD; Jay Berry, MD; Nicholas D. Fletcher, MD; Patricia E. Miller, MS; Brigid Garrity, MS, MPH; Michelle Claire Marks, MS, PT; Suken A. Shah, MD; Burt Yaszay, MD; Peter O. Newton, MD; Amer F. Samdani, MD; Firoz Miyanji, MD, FRCS(C); Mark F. Abel, MD; Paul D. Sponseller, MD, MBA; Michael P. Glotzbecker, MD

8:16-8:25 Discussion

8:25-8:29 **Paper #142 An Enhanced Surgical Protocol Can Drastically Reduce Surgical Site Infections in NM Patients**
Vishal Sarwahi, MD; Sayyida Hasan, BS; Michelle Kars, MD; Jesse Galina, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD

8:29-8:33 **Paper #143 Standardizing Surgical Approach With a Dedicated Team Improves Surgical Outcomes in Neuromuscular Scoliosis**
Vishal Sarwahi, MD; Jesse Galina, BS; Benita Liao, MD; Sayyida Hasan, BS; Melanie A. Smith, cPNP; Aaron M. Atlas, BS; Michelle Kars, MD; Alexa Vetere, PA-C; Terry D. Amaral, MD

8:33-8:37 **Paper #144 Residual Lumbar Hyperlordosis is Associated with Worsened Hip Status 5 Years after CP Scoliosis Correction**
Aaron J. Buckland, MBBS, FRACS; Herbert Kerr Graham, MD, FRCS; Dainn Woo, BS; Dennis Vasquez-Montes, MS; Michelle Claire Marks, MS, PT; Peter O. Newton, MD; Thomas J. Errico, MD; Paul D. Sponseller, MD, MBA

8:37-8:46 Discussion

8:46-8:50 **Paper #145 Proximal Anchor Fixation in Magnetically Controlled Growing Rods (MCGR): What is the Impact of Anchor Selection & Density?**
Blake C. Meza, BS; John T. Smith, MD; Michael G. Vitale, MD, MPH; Jason Brett Anari, MD; Children's Spine Study Group

8:50-8:54 **Paper #146 Risk Factors for Proximal Junctional Kyphosis (PJK) in Children with Neuromuscular Scoliosis**
Brandon J. Toll, BA; Shashank V. Gandhi, MD; Amir Amanullah, BS; Amer F. Samdani, MD; M. Burhan Janjua, MD; Joshua M. Pahys, MD; Steven W. Hwang, MD

8:54-8:59 **Paper #147 Consider these Factors to End Fusion Short of the Pelvis in Children with CP Scoliosis**
Francisco Eguia, BA; Brian T. Sullivan, MD; Patrick J. Cahill, MD; David A. Spiegel, MD; Keith Baldwin, MD; Suken A. Shah, MD; Burt Yaszay, MD; Peter O. Newton, MD; Paul D. Sponseller, MD, MBA

8:59-9:08 Discussion

9:08-9:12 **Paper #148 Mortality in Pediatric Spinal Deformity: 242 Patients with 40-year Follow-up**
Casper Dragsted, MD; Soren Ohrt-Nissen, MD, PhD; Lærke C. Ragborg; Thomas Andersen, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

9:12-9:16 **Paper #149 Influence of Surgical Treatment on Pulmonary Function in Congenital Spinal Deformity: A Long-term Follow-up Study**
Noriaki Kawakami, MD; Toshiki Saito, MD; Ryoji Tauchi, MD; Kazuki Kawakami, B.Kin; Tetsuya Ohara, MD

9:16-9:20 **Paper #150 Neurological Deficit in Delayed Presentation of Congenital Vertebral Deformities (CVD): An Analysis of Risk Factors and Surgical Outcome**
S. Rajasekaran, PhD; Rajesh Rajavelu, MS, MS (ortho); Ajoy Prasad Shetty, MS, DNB

9:20-9:29 Discussion

9:29-9:33 **Paper #151 Spinal MRI Utilization in Patients with Early Onset Scoliosis Review of a Large Multi-Center Database**
Brendan A. Williams, MD; Anna McClung, BSN; Laurel C. Blakemore, MD; Suken A. Shah, MD; Jeff Pawelek, BS; Paul D. Sponseller, MD, MBA; Stefan Parent, MD, PhD; John B. Emans, MD; Peter F. Sturm, MD, MBA; Burt Yaszay, MD; Behrooz A. Akbarnia, MD; Growing Spine Study Group

9:33-9:37 **Paper #152 Surgery for Severe Pediatric Spinal Deformity has a Significant Rate of Revision: A Prospective Multi-center Cohort Study**
Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Richard E. McCarthy, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Peter O. Newton, MD; Burt Yaszay, MD; Joshua M. Pahys, MD; Harry L. Shufflebarger, MD; Amer F. Samdani, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Suken A. Shah, MD; Brenda A. Sides, MS; Michael P. Kelly, MD, MS; Fox Pediatric Spinal Deformity Study Group

9:37-9:41 **Paper #153 Outcomes of Definitive Spine Fusion Using All Pedicle Screw For Borderline Immature Patients With Severe Idiopathic Early Onset Scoliosis**
Hany Abdel Gawwad Soliman, MD; Sarah Y. Abozaid, MD; Faisal El-Sherief, MD; Ashraf Abdelaziz, PhD

9:41-9:50 Discussion

9:50-9:54 **Paper #154 Comparison of Serial Casting vs. Brace Treatment for Early Onset Scoliosis**
Ying Li, MD; Chelsea K. Graham, BS; Christopher B. Robbins, PhD; George H. Thompson, MD; Peter F. Sturm, MD, MBA; John B. Emans, MD; Paul D. Sponseller, MD, MBA; Michael P. Glotzbecker, MD; Children's Spine Study Group; Growing Spine Study Group

9:54-9:58 **Paper #155 Comparison of Surgical Outcomes Between Early Definitive Spinal Fusion and Growing Rod in Patients with Early Onset and Dystrophic Scoliosis in Neurofibromatosis Type 1: A Multicenter Study**
Ryoji Tauchi, MD; Noriaki Kawakami, MD; Koki Uno, MD, PhD; Teppei Suzuki, MD, PhD; Toshiaki Kotani, MD, PhD; Takuya Yamamoto, MD, PhD; Hideki Murakami, MD, PhD; Satoru Demura, MD; Kazuki Kawakami, B.Kin

9:58-10:02 **Paper #156 Law of Temporary Diminishing Distraction Gains: The Phenomenon of Temporary Diminished Distraction Lengths with Magnetically Controlled Growing Rods that is Reverted with Rod Exchange**
Jason Pui Yin Cheung, MBBS, FRCS, MS; Bow H. Cora, PA-C, BS; Kenneth MC Cheung, MD

10:02-10:11 Discussion

10:11-10:15 **Paper #157 Awake Serial Body Casting for the Management of Infantile Idiopathic Scoliosis (IIS)**
Scott M. LaValva, BA; Noriaki Kawakami, MD; Jigar S. Gandhi, PharmD; Kazuaki Morishita; Peter F. Sturm, MD, MBA; Sumeet Garg, MD; Michael P. Glotzbecker, MD; Jason Brett Anari, MD; John (Jack) M. Flynn, MD; Children's Spine Study Group; Growing Spine Study Group; Patrick J. Cahill, MD

10:15-10:19 **Paper #158 Elevated Serum Titanium Levels in Children with Early Onset Scoliosis Treated with Growth-sparing Instrumentation**
Ying Li, MD; Chelsea K. Graham, BS; Christopher B. Robbins, PhD; Michelle S. Caird, MD; Frances A. Farley, MD

10:19-10:23 **Paper #159 Bigger is Better: Larger Thoracic Height is Associated with Increased Health Related Quality of Life at Skeletal Maturity**
Hiroko Matsumoto, PhDc; Matthew E. Simhon, BS; Sumeet Garg, MD; Amer F. Samdani, MD; John T. Smith, MD; Paul D. Sponseller, MD, MBA; Michael G. Vitale, MD, MPH; Benjamin D. Roye, MD, MPH; Children's Spine Study Group; Growing Spine Study Group

10:23-10:32 Discussion

10:32-10:35 **Presentation of Hibbs Awards for Best Basic Research and Clinical Research Papers**
Firoz Miyanji, MD, FRCSC

10:35-10:50 **Transfer of the Presidency**
Peter O. Newton, MD & Paul D. Sponseller, MD, MBA

10:50-11:05

REFRESHMENT BREAK

11:05-12:30

SESSION 11: CERVICAL DEFORMITY/BIOMECHANICS/BASIC SCIENCE

Room: 517CD
Moderators: Ilkka J. Helenius, MD, PhD & Rick C. Sasso, MD

11:05-11:09 **Paper #160 Outcomes of Instrumented Cervical Spinal Fusion in Children with Os Odontoideum**
Ilkka J. Helenius, MD, PhD; Jennifer M. Bauer, MD, MS; Bram Verhofste, MD; Paul D. Sponseller, MD, MBA; Walter F. Krengel, III, MD; Daniel J. Hedequist, MD; Patrick J. Cahill, MD; A. Noelle Larson, MD; Joshua M. Pahys, MD; John T. Anderson, MD; Jeffrey E. Martus, MD; Burt Yaszay, MD; Jonathan H. Phillips, MD, MBBS

11:09-11:13 **Paper #161 Cervical Spine Fusion in Children: A Retrospective Analysis of Complication Free Survivorship**
Sean M. Kelly, MD, DO; Denise R. Lopez, MSNARNP; Jonathan H. Phillips, MD, MBBS

11:13-11:17 **Paper #162 Are Posterior Osteotomies Warranted when Managing Mild Flexible Cervical Deformity?**
Robert K. Eastlack, MD; Stacie Tran, MPH; Alex Soroceanu, MD, FRCS(C), MPH; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Justin S. Smith, MD, PhD; Eric O. Klineberg, MD; Virginie Lafage, PhD; D. Kojo Hamilton, MD; Han Jo Kim, MD; Gregory M. Mundis Jr., MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

11:17-11:26 Discussion

11:26-11:30 **Paper #163 Risk Factors for Progression of Osseous Cervical Congenital Scoliosis**
Amir Amanullah, BS; Brandon J. Toll, BA; Joshua M. Pahys, MD; Amer F. Samdani, MD; Steven W. Hwang, MD

11:30-11:34 **Paper #164 The Influence of Spinopelvic Morphologies on Sagittal Spinal Alignment: An Analysis of the Incidence Angle of Inflection Points**
Sung Hoon Choi, MD; Chang Ju Hwang, MD, PhD; Jae Hwan Cho, MD, PhD; Seung Min Son, MD, PhD; Tae Sik Goh, MD, PhD; Jung Sub Lee, MD, PhD; Dong-Ho Lee, MD, PhD

11:34-11:38 **Paper #165 Sagittal Cervical Alignment After Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: Five-year Follow-up**
Joshua M. Pahys, MD; Steven W. Hwang, MD; Suken A. Shah, MD; Patrick J. Cahill, MD; Peter O. Newton, MD; Harms Study Group; Amer F. Samdani, MD

11:38-11:47 Discussion

11:47-11:51 **Paper #166 The Effect of Different Strategies and Correction Maneuvers in AIS Surgery**
Tom P. Schlösser, MD, PhD; Kariman Abelin Genevois, MD, PhD; Jelle Frederik Homans, MD; Saba Pasha, PhD; Pierre Roussouly, MD; Suken A. Shah, MD; René M. Castelein, MD, PhD

11:51-11:55 **Paper #167 Impact of Lowest Instrumented Vertebra Selection on Trunk Range of Motion after Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis**
Joshua M. Pahys, MD; Ross Chafetz, PhD, DPT; Spencer Warshauer, MS; Amer F. Samdani, MD; John P. Gaughan, PhD; Steven W. Hwang, MD

11:55-11:59 **Paper #168 Pathologic Sagittal Alignment is Already Present in Early Stages of Adolescent Idiopathic Scoliosis (AIS)**
Tom P. Schlösser, MD, PhD; René M. Castelein, MD, PhD; Pierre Grobost, MD; Suken A. Shah, MD; Kariman Abelin Genevois, MD, PhD

11:59-12:08 Discussion

12:08-12:12 **Paper #169 Penetration into the Intervertebral Disc of Antibiotics Used for Perioperative Prophylaxis in Spine Surgery: Implications for the Current Standard and for the Treatment of Disc Infections**
Manu Capoor, MD; Andrew McDowell, PhD; Martin Solansky; Martina Zapletalova, PhD; Todd Alamin, MD; Michael F. Coscia, MD; Steven R. Garfin, MD; Radim Jancalek, MD, PhD; Filip Ruzicka, PhD; Jeffrey C. Wang, MD; Christof Birkenmaier, MD; Ondrej Slaby, PhD

12:12-12:16 **Paper #170 LncRNA SULT1C2A Regulates Foxo4 in Vitamin A Deficiency Induced Congenital Scoliosis by Targeting rno-miR-466c-5p through PI3K-ATK Pathway**
Chong Chen, MD; Haining Tan, MD; Jiaqi Bi, PhD; Tianhua Rong, MD; Youxi Lin, MD; Jinqian Liang, MD, PhD; Jianxiong Shen, MD

12:16-12:20 **Paper #171 Effects of Cyclic Loading on Polyester Tethers for Prophylactic Treatment of Proximal Junctional Kyphosis**
Damon Mar, PhD; Steven J. Clary, BS; Brant Stephen Ansley, MS, PA; Joshua Bunch, MD; Douglas C. Burton, MD; Terence E. McIff, PhD, MBA

12:20-12:30 Discussion

12:30 Adjourn

Notes

Pre-Meeting Course & Half-Day Course Handouts

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

Pre-Meeting Course Program Handouts

IMPROVING PATIENT OUTCOMES THROUGH PEAK SURGEON PERFORMANCE

Scoliosis Resarch Society • Pre-Meeting Course

Wednesday, September 18, 2019

8:00-12:00
Palais des congrès de Montréal, Montréal, Canada

Course Chair

Burt Yaszay, MD

Co-Chairs:

Charles H. Crawford III, MD
Michael D. Daubs, MD
Benny T. Dahl, MD, PhD, DMSci
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Yong Qiu, MD

The Pre-Meeting Course is supported, in part, by Medtronic.

Pre-Meeting Course Handouts

IMPROVING PATIENT OUTCOMES THROUGH PEAK SURGEON PERFORMANCE

Chair: Burt Yaszay, MD
Co-Chairs: Charles H. Crawford III, MD; Michael D. Daubs, MD; Benny T. Dahl, MD, PhD, DMSci; Baron S. Lonner, MD

Session 1: Understanding Surgeon Performance

Moderators: Serena S. Hu, MD & Paul D. Sponseller, MD, MBA

8:00-8:05 **Introduction: The What and Why of Surgeon Performance?**
Burt Yaszay, MD

8:05-8:15 **Blue Angels: The Perfect Demonstration**
Chris Collins

8:15-8:21 **Does Improving Physician Performance Lead to Improved Patient Outcomes?**
Rajiv K. Sethi, MD

8:21-8:28 **Discussion**

8:28-8:34 **The Role Of Dashboards in Maintenance of Certification**
John (Jack) M. Flynn, MD

8:34-8:40 **Hospital/Payor Dashboards on Surgeon Performance**
Stephen L. Ondra, MD

8:40-8:46 **AIS Dashboard: How has it Improved My Practice?**
Suken A. Shah, MD

8:46-8:52 **Adult Deformity: Is it Ready for Dashboarding?**
Ferran Pellisé, MD, PhD

8:52-8:59 **Discussion**

8:59-9:05 **Getting to Peak Performance for the Early Career Surgeon**
Han Jo Kim, MD

9:05-9:11 **Maintaining Peak Performance for the Later Career Surgeon**
John R. Dimar II, MD

9:11-9:17 **Addressing Poor Surgeon Performance Before it Leads to Patient Morbidity**
Michael D. Daubs, MD

9:17-9:23 **Optimizing Surgeon Performance Around the Globe: What are the Limitations/Barriers?**
Muharrem Yazici, MD

9:23-9:30 **Discussion**

Pre-Meeting Course Handouts

Session 2: Improving Surgeon Performance Parameters

Moderators: Carol C. Hasler, MD & Baron S. Lonner, MD

9:31-9:37 **Risk Stratification and Predictive Analytics in Adult Spinal Deformity**
Christopher P. Ames, MD

9:37-9:43 **Presurgical Optimization**
Benny T. Dahl., MD, PhD, DMSci

9:43-9:49 **Preoperative Planning: Planning Software and Advanced Imaging**
Stefan Parent, MD, PhD

9:49-9:55 **Building OR Teams**
Firoz Miyanji, MD, FRCSC

9:55-10:02 **Discussion**

10:02-10:08 **Decreasing Blood Loss**
Justin S. Smith, MD. PhD

10:08-10:14 **Decreasing Risks of Infection: Best Practice Guidelines**
Michael P. Glotzbecker, MD

10:14-10:20 **Minimizing Neuro Complications: Checklists and IONM Teams**
Michael G. Vitale, MD, MPH

10:20-10:27 **Discussion**

10:27-10:45 **Refreshment Break**

Debates

Moderators: Michael P. Kelly, MD & A. Noelle Larson, MD

Debate 1: Navigation/Robotics

10:45-10:50 **Navigation/Robotics is Worth the Cost and Improves Performance**
Ronald A. Lehman Jr., MD

10:50-10:55 **Navigation/Robotics Increases Cost and Worsens Performance**
Khaled M. Kebaish, MD

Debate 2: Surgeon Density

10:55-11:00 **Two Surgeon Teams Improve Performance Parameters**
Gregory M. Mundis Jr., MD

11:00-11:05 **Two Surgeon Teams Dilute the Training Experience**
Charles H. Crawford III, MD

11:05-11:15 **Discussion**

Session 3: Surgeon Performance in Complex Cases

Moderators: Munish C. Gupta, MD & Burt Yaszay, MD

11:15-11:30 **Adult Cases**
Panel: Marinus de Kleuver, MD, PhD; Robert A. Hart, MD; Tyler Koski, MD; Kota Watanabe, MD

11:30-11:45 **Pediatric Cases**
Panel: Saumyajit Basu, MS(orth), DNB(orth), FRCSEd; Patrick J. Cahill, MD; Brice Ilharreborde, MD, PhD; Ilkka J. Helenius, MD, PhD

11:45-12:00 **Complications Cases**
Panel: Laurel C. Blakemore, MD; Meric Enercan, MD, Eric O. Klineberg, MD; Yong Qiu, MD

Does Improving Physician Performance Lead to Improved Patient Outcomes?

Rajiv Sethi MD
Executive Director of Neuroscience Institute
Director of Spine Center of Excellence Programs at Virginia Mason
Director of Complex Spine Research and Clinical Fellowships
Clinical Professor of Health Services Research
Virginia Mason Medical Center
University of Washington Department of Health Services Research
Schools of Medicine and Public Health
Seattle, Washington, USA

- How do we know what "improving physician performance" means? This is a fairly objective statement, so we must first take a look at what it actually means before determining what strategies to use.
- Improving physician performance can refer to improved patient outcomes, making care more affordable, reducing unnecessary patient visits, or having more engaged and productive physicians. Realistically, all of these are in play when considering physician performance.
- Over the last 10 years, there has been an incredible amount of literature showing that these metrics are all at play when assessing physician performance.
- One of the most common ways to assess physician performance is with quality measures. However, there is a struggle between caring for patients and reporting these quality measures.
- In 2016, more than $15.4 billion was spent on the reporting of quality measures in the United States alone. Reporting was supposed to become easier, better, and more meaningful, instead the number of measures has grown to over 1,000.
- This level scrutiny and time commitment has led to higher levels of physician dissatisfaction and burnout – not exactly motivators for improving performance. A particular point of interest is the discrepancy between the amount of effort needed to report on the measures and the quality of care represented by the measures.
- Adding more and more quality measures clearly isn't the answer when we look to improve physician performance, so what can we do instead?
- One of our first steps was to define what quality meant at Virginia Mason. This equation defines quality as appropriateness times a good outcome with a high degree of services divided by an elimination of waste.
- We use two main improvement pathways with VMPS. The first step is to truly understand your current state or situation, then either improve incrementally with Kaizen or completely reinvent using Kaikaku.
- In a paper published in Spine Deformity late last year, we took a look how to improve care in complex spine cases while embracing the value equation.
- Some of the approaches we've used include standardization and standard pathways, team-based approaches, continuous mentorship, dual-attendings, and tracking and monitoring outcomes.
- Much of the research we've conducted within the spine team at Virginia Mason has included the importance of standardized protocols and pathways. With less variability in care comes improved patient outcomes.
- Using a team-based approach has been associated with lower surgical site infection rates, fewer surgical errors, fewer operating room delays, and improvements in surgical unit culture. CUSP, the framework developed by the Agency for Healthcare Research and Quality, emphasizes improving safety culture by improving teamwork and engaging staff at all levels in safety efforts.
- The continuous mentorship model allows early career surgeons the responsibility of their patients while providing a senior surgeon "safety net" to facilitate patient safety during the junior surgeon's learning curve.
- In another study published in the Journal of the American Academy of Orthopaedic Surgeons late last year, we look at the dual-attending approach, which can improve safety and outcomes, decrease complications, and may give junior surgeons an accelerated learning curve. Both improving physician performance and improving patient outcomes – a win-win!
- Utilizing dashboards to track and monitor outcomes can be vital in improving physician performance. These dashboards can also help to identify high performers who can further refine best practice guidelines to improve patient outcomes.
- Our Spine Safety Improvement Model provides a conceptual framework and breaks down each aspect of achieving quality and safety in complex spine surgery.
- Quality improvement work requires buy-in: involve physicians from the beginning, make the QI tools easy to use and access, report on conditions most relevant to their field and community, and include all stakeholders in the development of reports.
- In conclusion, yes, improving physician performance does lead to improved patient outcomes. However, this work must be led by the physicians, in order to avoid suboptimal solutions from regulatory bodies or payer groups. Getting ahead of improving physician performance can allow for solutions that work best for your team.

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The Role of Dashboards in Maintenance of Certification

John (Jack) Flynn, MD
Philadelphia, Pennsylvania, USA

ABOS MOC requirements

- 240 CME credits per Recertification cycle
- At least 40 of these credits coming from self-assessment examinations (SAE)
- Participation in Registries that are approved by the ABOS may be used for SAE credits

Requirements for a Registry to be approved by ABOS

- Includes 4 basic components of practice improvement: measure, assess and educate, plan improvement and re-measure.
- Allows a diplomate to review outcome of treatment and/or performance data from his/her own practice collected over a relevant period of time
- Allows assessment of performance in practice for an orthopaedic topic, procedure, or diagnosis, and defines an appropriate time frame or volume of patient interaction to provide relevant information to assess performance
- Focuses on defined metrics. Options for assessment include clinical outcome, patient reported outcome, process improvement, improvement in patient experience, or other quality improvement activity. Cost reduction measures may be employed if in conjunction with quality measures.
- Includes a mechanism for the Diplomate to receive performance data and apply the results to improvement in practice
- Includes a mechanism for assessing performance or comparing the diplomate's performance with peers or relevant benchmarks, and educational resources to support performance in practice

Registries approved by ABOS (so far)

1. Function and Outcomes Research for Comparative Effectiveness in Total Joint Replacement (FORCE TJR)
2. Michigan Arthroplasty Registry Collaborative Quality Initiative (MARCQI)
3. American Academy of Orthopaedic Surgery-The AAOS Registry Program
4. St. Francis Hospital & Medical Center's Orthopedic Registry, Data Acquisition & Information Search Engine (D.A.I.S.E.)
5. **Setting Scoliosis Straight Foundation-Setting Scoliosis Straight-Surgeon Performance Program**

Setting Scoliosis Straight Foundation-Setting Scoliosis Straight-Surgeon Performance Program

- QI registry designed to assess patient and surgeon variables and practice patterns associated with the surgical treatment of Adolescent Idiopathic Scoliosis
- Patient-level data is submitted by participating surgeons on a quarterly basis to the Setting Scoliosis Straight central infrastructure
- The primary aims of this AIS QI registry are to promote health care quality improvement by allowing clinicians to identify ways to improve treatment processes and patient outcomes by tracking their surgical cases
- The secondary aim of the AIS QI registry is to serve as a source of data for outcomes and comparative effectiveness quality improvement programs
- For more info: http://hsg.settingscoliosisstraight.org/surgeon-performance-program/

Hospital/Payer Dashboards on Surgeon Performance

Stephen L. Ondra, MD
Williston, Florida, USA

Introduction:

Dashboards on surgeon performance are increasingly common and serve a two primary purposes:

- o Assessment and optimization of quality
- o Efficiency of financial and other resource utilization

Both are typically assessed relative to peer benchmarks and offer a means of assessing individual surgeons and group performance. Such assessment can inform surgeons in order to allow self-assessment and practice improvement but increasingly, these measures are tied to compensation, whether in fee-for-service (FFS) incentives or penalties that are tied to performance measures or even more directly in the evolving value-based-reimbursement (VBR) models.
While surgeons are justifiably skeptical of such instruments and concerned about the data that populates them, use will continue to grow as healthcare continues to evolve into increasingly managed business structures. With this in mind, it is incumbent upon surgeons to understand and shape dashboard construction and the data used to populate them, in order to create instruments that accurately assess surgeon performance and improve patient care.

In this handout, we will review the major drivers and directions of dashboards for quality and financial performance and then, how they are being brought together to assess individual and group value performance, with value defined as:

In addition to the high level review of surgeon dashboards, some specific examples and use cases will be provided to aid in understanding and influencing dashboards from the point of view of individual surgeons, institutions and systems and professional organizations.

Quality Dashboards

There is an old saying that the best thing about quality measures is that there are so many of them for the same thing.

Quality dashboards have been around for decades, beginning with pay-for-performance (P4P) initiatives and are increasingly been tied to reimbursement rewards and penalties. While the goal is to improve care consistency and patient outcome, the dashboards can only drive care improvement if the data included is accurate.

This has been a difficult proposition due to patient variability but also getting organizational agreement on and consistency between measures.

As MACRA (Medicare Access and CHIP Reauthorization Act) continues to implement, dashboards will be driven by MIPS (Merit Based Incentive Payment System) and the shift to APMs (Alternative Payment Models).

In 2019 under MIPS, 45% of payment increases or penalties (+/- 4% in 2019 and +/- 9% by 2025) will be tied to quality reporting measures.

Given the importance of quality measures to patient care, improvement in the practice of surgery and surgeons, and the economic interests of everyone, there is no more important effort in healthcare than developing meaningful, risk adjusted, clinically relevant, easily collectable and consistent quality measures.

There is no activity more important for professional societies to engage in and all physicians to contribute to. Without this, measures will continue to be developed too slowly and remain too process driven.

To create better quality and risk adjustment measures more quickly, we need to not just continue the current approaches as the only path to quality measure development but instead, develop new and more nimble approaches. Approaches that accept surrogate outcome measures, use Bayesian statistical algorithms and AI tools on big data, as alternative ways to develop clinically relevant and meaningful outcome measures with minimal collection burden.

Lastly, the inconsistency between which quality measures are used by different payors and other organizations in their dashboards make their utility in comparing and bench marking physician performance difficult.

When looked at by the AHIP (American Health Insurance Plans) CMO group, only 5% of all quality measures were consistent between payors.

As a result, these dashboards are under performing relative to their potential. Physicians and physician groups should work with payors but even more so, the purchasers of care who influence them, to create consistency in the measures used.

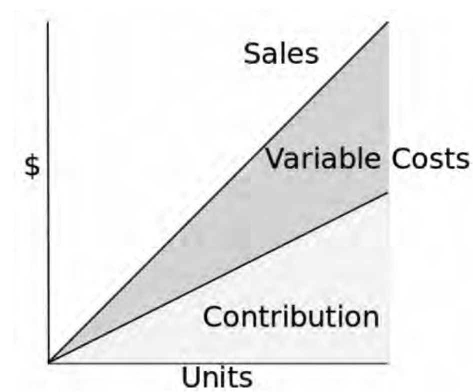
Financial Utilization Dashboards

Whether aware or not, surgeons are increasingly assessed by a variety of financial and resource utilization dashboards.

In hospitals, dashboards for operating room performance of individual surgeons, groups and product/service lines are commonly measured by Contribution Margin dashboards.

These tools assess the cost/volume/profitability of the individual components of a service but not the overall value of the entire line to the organization. As such, it is a useful tool to optimize performance of each aspect of a delivered service but will not reflect the complete value.

To do this, the various Contribution Margin calculations would need to be combined and have fixed costs added.



Surgeons should engage with management in using these dashboards to assess how to optimize the efficiency of each aspect of their practice and in doing so, increase the value of the service to the institution, which ultimately benefits everyone in the healthcare delivery team in either direct or indirect ways. It is also important that the surgeon does not let this happen in isolation but within the context of the overall service line value. Without understanding that and only looking at the component being assessed in the Contribution Margin calculation, the actual value the surgeon service brings to the institution can be overestimated but is more commonly underestimated. Especially when ancillary and other services generated by the operative event are considered.

Another common dashboard model relates to general resource utilization such as length of stay, days in the ICU, OR time, blood loss and ancillary service utilization such as imaging. These are typically shown relative to peers and the accuracy of this is heavily dependent on how patients are grouped, inclusion and exclusion criteria and risk adjustment. Many of these measures are also used in surrogate measures of quality when specific quality measures are lacking.

It is imperative that surgeons engage in and help shape how the data fields are chosen, measured and collected.

While none of these measures will be perfect, the better the measures are and the more they are refined over time, the more accurately surgeons will be assessed and the less often surgeons will be unfairly penalized or rewarded due to data errors and dashboard inaccuracy.

Surgeon Value Dashboards

As quality and financial dashboards become more common and more sophisticated, they are being combined to assess individual surgeon value.

Additionally, data that is used to populate dashboards is also being used with sophisticated AI algorithms to assess the overall value of care delivered by individuals, groups and institutions.

One example is the company Roadmap, which creates value assessment for individual surgeons by taking CMS and other publicly available data. It does this by specialty, subspecialty, and practice type. This information is used by payors to shape networks, benefit design guidance of beneficiaries and other purposes. Increasingly, such information is now beginning to be used by health systems and provider networks to improve physician performance, in order to meet and succeed in the various forms of VBR models. Models such as Bundled Payment for Care Improvement (BPCI), Accountable Care Organizations (ACOs), Patient Centered Medical Homes (PCMH), Capitation and others. All of these are a part of the MACRA APM pathways that provide an option to MIPS reporting.

Conclusion

Quality, Financial and Value performance dashboards are already a part of the healthcare landscape and physicians will increasingly be measured by and have compensation tied to them.

As difficult as it is to untangle the financial webs of our complex health system, it is far easier to do this than it is to develop and implement quality measures.

Unless we commit to partnering with payers, purchasers (employers and small groups), government and others to develop new ways to quickly develop clinically meaningful, risk adjusted, easily collectable and consistent quality measures, we will only have a race to the bottom on cost and that is not in either patient or provider interests.

There is no more important imperative for the medical profession to engage in, lead and push forward as quickly as possible.

AIS Dashboard: How It Has Improved My Practice

Suken A. Shah MD
Nemours / Alfred I duPont Hospital for Children
Wilmington, Delaware, USA

Affordable care act

- Patient Protection and Affordable Care Act (ACA) 2010
- Better stewards of data
- Funding for electronic medical record
- Incentivizes good quality care
- Quality improvement – part of the new model of reimbursement by CMS
- Reduce overall health care costs

Affordable care act

- Recent healthcare reforms in United States, optimization of independent clinical and ***PROs***
- Performance Improvement Modules (PIMs) ~ identify validated metrics to improve results
- Mick et al. *J Nurs Adm.* 2011 & Render et al. *BMJ Qual Saf.* 2011
- NASS Collaborative Initiative with ABOS 2012 (Subcommittee Chairman)
- Lehman, Shufflebarger, Marks et al SRS 2014 (Hibbs Award Finalist)
- Utilizing PIMs across Healthcare Systems
- Recognize variations in management/outcomes
- Promote normalization of perioperative protocols
- Establish Best Practice Guidelines (BPGs)

Various forms of technology / databanks

- Database
- Administrative
- Population specific
- Internal
- Registries
- Collect data for assessment of long term outcomes
- Improve follow up
- Develop best practice

Pitfalls of Big data

- Misclassification bias
  - Lumping
  - Confounders
  - Proxy outcomes
  - Adequate power
  - What questions do we ask?
  - Who is capable of figuring it out?

Pitfalls of Big data

- Electronic Medical Record (EMR)
- Should be robust
- …not too involved
- Physician burnout
- Minimum data needed to answer the question
- Quality of data

Pre-Meeting & Half-Day Course Handouts

- Efficiently collected
- Not burdensome
- Accurate
- Reliable
- Predictive analytics (PA): Uses technology and statistical methods to search massive data
  - o Analyzes it to predict outcomes for individual patients
  - o Increase the accuracy of diagnoses
  - o Help preventive medicine and public health
  - o Targeted treatments for individual patients
  - o Researchers can develop predictive models
  - o Patients have potential benefit of better outcomes

Patient centered care vs. population health

- Integrating both concepts into practice can facilitate required outcome-measure reporting and potentially improve patient outcomes. [Harwood et al]

Risk stratification in medicine

- Total joint arthroplasty (AAHKS) – patient checklist for known risk factors
- Scoliosis Research Society M&M Database
- HSG / ISSG Database
- Cardiac surgery
- Non-cardiac major surgery
- Deep venous thrombosis
- Key elements: data, population health and predictive analytics
- Early identification of complications (based on risk stratification)

American College of Surgeons National Surgical Quality Improvement Program (NSQIP)

Feeding outcomes back to providers with real-time comparisons with other hospitals leads to:
Quality improvement
Better patient outcomes
Cost savings
Overall improved patient safety

Variation in Outcomes and Resource Utilization in Pediatric Spinal Deformity Surgery

Shah, Sethi, Brighton: NSQIP database query for perioperative resource utilization and outcomes in spinal deformity surgery
>1500 patients

Benchmarking / Dashboarding

- Helps patients
- Peer to peer comparison
- Differentiates surgeons / programs (…in effect, stratifies risk)
  - o Best practice sharing
  - o Prospectively collected data regarding intraoperative variables in PSF for AIS
- Reduced blood loss, improved operative time and reduced length of stay

Harms Study Group Database

10 centers
>15 surgeons
Largest ongoing prospectively collected database for AIS
Quality assurance
Vigilant follow up
Group can assist *__negative surgeon outliers__* in improvement of their deficiencies, thereby improving overall patient reported outcomes

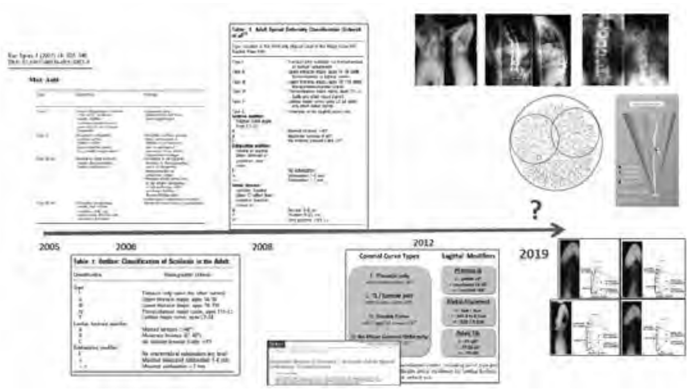
BENCHMARKING AND DASHBOARDS

- Dashboard reporting and Performance Improvement Modules (PIMs) result in "real-time" information
- Allows surgeons' to compare their outcomes with other surgeons performing the same operations
- Enables the development of Best Practice Guidelines (BPGs)
- Internal queries / audits
- Not costly, fairly easy to perform
  - o Identify problem areas
- May lack sufficient power or generalizability

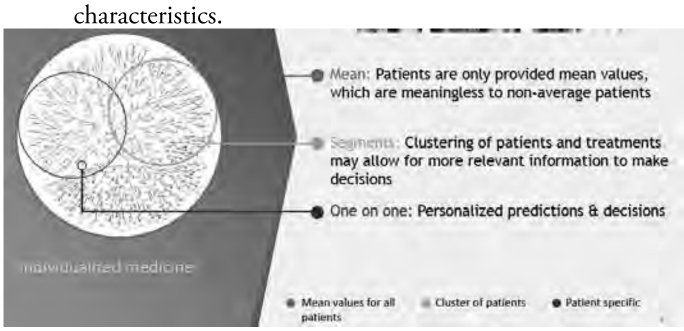
Adult Deformity: Is it Ready for Dashboarding?

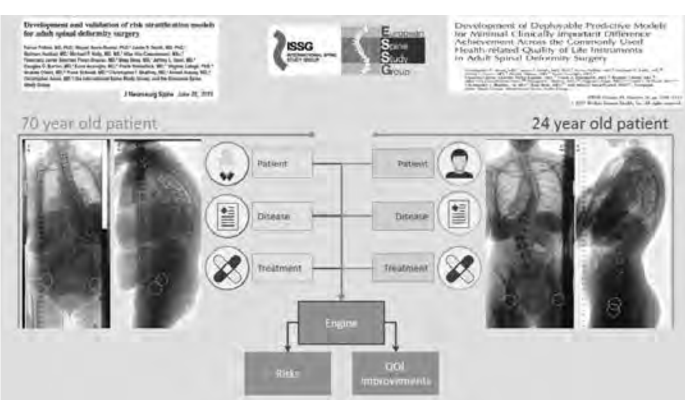
Ferran Pellisé, MD, PhD
Chief of Spine Unit Hospital Vall Hebron
Director Barcelona Spine Institute Hospital Quiron
Barcelona, Spain

- **Adult Spine Deformity (ASD), where are we?**
  - o Aging populations, the high prevalence of ASD, and an increasing demand to remain independent without significant disability in older age have together resulted in a significant increase in ASD surgery during recent decades. ASD is becoming increasingly recognized as a disease that could easily reach epidemic proportions.
  - o The global burden of ASD in patients seeking specialized medical attention is huge compared with other chronic conditions. When compared with individuals reporting no medical conditions, SF-36 scores from the population with self-reported chronic conditions range from -2.5 to -14.1. Comparable scores for patients with ASD range from -10.9 to -45.0. Physical function, role physical and pain domains show the worst scores. Surgical candidates with ASD display the worst HRQL scores (-17.4 to -45.0).
  - o Nonoperative care has not shown a significant impact on health-related quality of life (HRQL), while surgery is associated with HRQL improvements that are maintained over time.
  - o The rate of major complications following ASD surgery is hardly acceptable. Postoperative major complications increase healthcare costs and deteriorate patient HRQL scores.
- **ASD represents a very heterogeneous group of patients** including adult pediatric spinal deformities, iatrogenic deformities and late onset degenerative spinal deformities. Multiple classifications have been suggested over the last decade illustrating lack of consensus and understanding of the "disease".

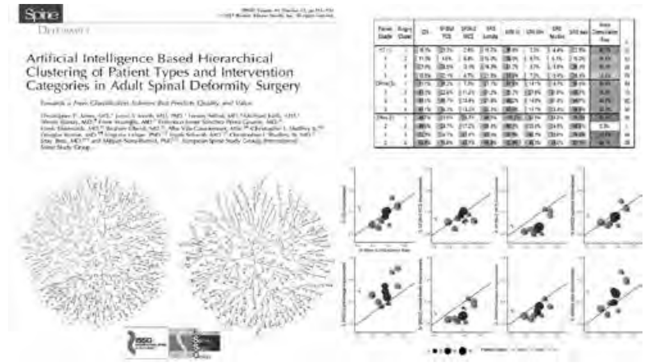


- **ASD patient heterogeneity does not allow the use of ASD mean values**. The level of heterogeneity of clinical presentation and treatment options for adult spinal deformity (ASD) is one of the most salient features of the condition. A more focused or individualized patient analysis seem essential to improve overall ASD management and surgical outcomes.
  - o Knowledge about individual prognostic factors for ASD provides limited information about complex interactions between patient and treatment characteristics. Analysis based upon simultaneous interaction among many variables may define previously unrecognized associations between outcomes and complication risk.
  - o Artificial intelligence and predictive modelling allow an individualized / cluster risk-benefit analysis and helps to establish personalized standards based on relevant patient characteristics.

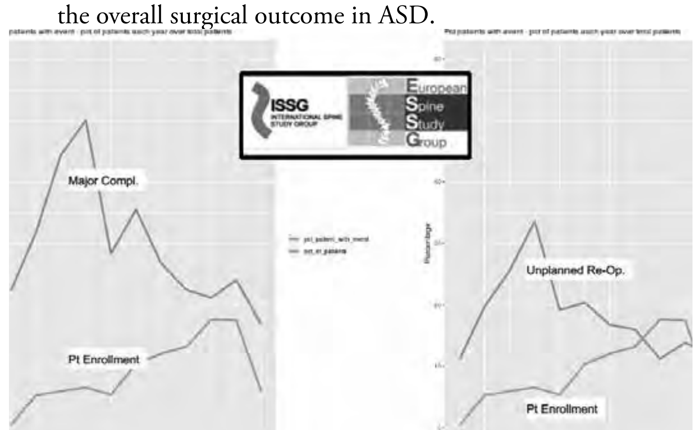




  - o Through the novel application of AI to ASD, unsupervised hierarchical clustering can identify subtle data patterns and classify patients and treatments according to observable characteristics.
  - o Use of AI-based hierarchical clustering enables inclusion and simultaneous analysis of significantly more overall patient demographic characteristics, frailty factors, radiographic and functional status measures than existing ASD classification schemes.
- **Performance benchmarking should not be based on averages.** Performance standards should consider patient specific factors, procedure details and site-specific variations among others.



- **Key parameters to be included in an ASD dashboard:**
  - o Individualized /Cluster risk-benefit analysis (HRQL vs Complications) based on:
    - ▪ Patient characteristics (age, frailty)
    - ▪ Deformity characteristics (magnitude, shape, location, flexibility)
    - ▪ Treatment options (surgical invasiveness)
  - o Preoperative optimization of modifiable risk factors
  - o Definition of individualized, quantitative and qualitative, surgical alignment goals
  - o Definition of Intraoperative strategies to minimize postoperative complications
    - ▪ Surgical & OR team characteristics
    - ▪ Bleeding
    - ▪ Infection
    - ▪ Surgical time
    - ▪ Mechanical complications: PJK, Pseudoarthrosis.
  - o Definition of postop protocols to optimize treatment outcomes.
- **Progress over the last decade has been evident.** A better understanding of the deformity and alignment goals along with a refinement of surgical techniques have been associated with a significant decrease in the rate of complications, improving the overall surgical outcome in ASD.



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Getting Peak Performance for the Early Career Surgeon

Han Jo Kim, MD
New York, New York, USA

- Defining Peak Performance - Balance in Work and Life
- Setting up your Mentorship Network
- Opportunistic Decision Making
- Developing Focus and Developing New Skills
- Self- Awareness and Personal Feedback
- Handling Pressure and Learning from Complications

Maintaining Peak Performance for the Later Career Surgeon

John R Dimar II, MD
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A. Aging Spine Surgeon [1]

1. The Surgeon Work Force is Aging, 1/3 Are >55 Years Old [2]
2. Surgeons Suffer the Same Medical Problems as the General Population
3. Physical Aging & Cognitive Demand of Surgery Raises Concerns About Timely Retirement; a Potential Public Health Issue
4. Many Professions Require Mandated Retirement
   a. Pilots 65
   b. Air Traffic Controllers: 56
   c. British Surgeons: 70 Private Practice
   d. FBI: 57
   e. NPS: 57
   f. Lighthouse Operator: 55

"No Standards for a Surgeons Retirement!"

B. Why Surgeons Resist Retirement

1. Irrelevance
2. Loss of Self – Esteem/Value
3. Financial Need
4. Fear of Death/Immortality
5. Indispensability
6. Inability to Perceive Their Decline
7. Poor Post-retirement Activity Planning

C. Physiology: Varies with the Individual

1. Predictable Decline in Neurocognitive Function
2. Deterioration of Fluid Intelligence
3. Decreased Cognitive Speed
4. Declining Short Term Memory
5. Problem/Diagnostic Solving Decline
6. Loss of Manual Dexterity
7. Chronic Medical Illnesses
   a. Cardiovascular Disease

b. Diabetes
c. Hypertension
d. MI & Stroke
e. Dementia
f. **Alcohol & Drug Abuse (29%)*****
8. Vision Changes: 100% More Light, Cataracts, Myopia
9. Neurodegenerative Disease
10. Depression & Suicidal Ideation [1] [2]

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[2] Olsen KD, Mayo Clinic Proceedings, Challenges Facing the Aging Surgeon, Dec.: 2017: 92 (92 (12): 1741 - 1742

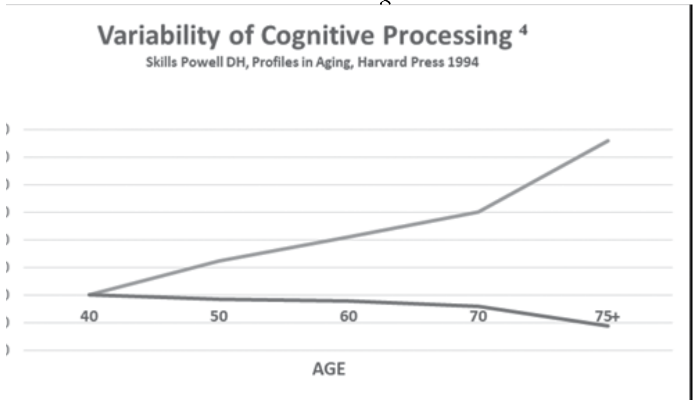
D. Greater Experience: Does it Lead to Better Clinical Performance?
1. Experience Leads to Quality Care & Outcomes: *Paradox*
2. Longer Practice Risk Providing Lower Quality Care [3]
3. Older Surgeons Consistently Have Poorer Recertification Performance
4. Older Surgeons in Fact are Less Likely to Adhere to Practice Standards (74%)
5. Less Likely to Incorporate New Treatment Protocols
6. More Likely to Prescribe Inappropriate Medications
7. More *Experienced Surgeons Have Worse Outcomes*
8. Older Physicians Do Not Exhibit Higher Mortality, Just Longer LOS

[3] Choudhry NK, et.al., Systematic Review: The Relationship Between Clinical Experience & Quality of Healthcare, Ann Intern Med 2005; 142:260-73.

E. Legal Considerations: Assessing the Aging Orthopedic Surgeon [4]
1. Rehabilitation Act of 1973
2. American with Disabilities Act (ADA)
3. Age Discrimination in Employment Act (ADEA)
4. Health Care Improvement Act (HCQIA) – Peer Review Protection
5. Cognitive Assessment for Impairment: 4 Areas
   a. Visual Spatial Perception
   b. Fine Motor Skills
   c. Short Term Memory
   d. Verbal Intelligence

[4] Hickson GB, et.al., Cognitive Skills Assessment for the Aging Orthopedic Surgeon, AOA Critical Issues, J Bone Joint Surg Am., 2019; 101: e7(1-5)

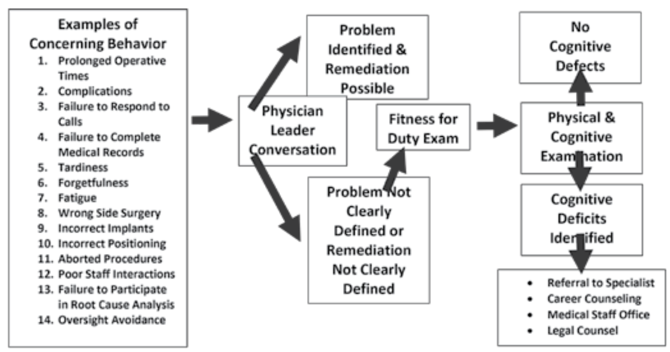
F. Variability of Cognitive & Physical Decline: There's Hope
1. Impressive Variability Amongst Older Physician [5]
2. Variability Increases with Aging
3. Many Older Physicians Meet or Exceed Younger Counterparts
4. Senior Surgeons Perform within the Range of Younger Surgeons: 61% on Testing
5. Only 7/108 Performed Significantly Worse
6. No Many are Still Excellent at Age 73
7. *"Age Alone is Not a Sufficient Predictor of Cognitive Performance"*
8. *"There Should Be No Mandatory Retirement Age for Surgeons: Need to Evaluate Functional Age"*



[5] Katlic, MR, et.al., The Aging Surgeon, Advances in Surgery, 50 (2016) 93-103

Evaluation of Cognitive Function When Required

1. Evaluating the Performance of a Surgeon [4]



[4] Hickson GB, et.al., Cognitive Skills Assessment for the Aging Orthopedic Surgeon, AOA Critical Issues, J Bone Joint Surg Am., 2019; 101: e7(1-5)

H. Physical Aging in the Surgeon: Compensations [6]
1. Deterioration of Physical Skills Begins at 28
   a. Vision: 100% More Illumination by Age 55 & Loops Hearing: Hearing Aids
   b. Dexterity: Training
   c. Reaction Time: OT & PT
   d. Endurance: Improve General Health Status
2. Two Decades of Experience Compensate for Loss Skills
3. Cognitive Skills Decline After Age 60
   a. 25% by Age 75

"Maximum Strength is Generally Achieved During the Third Decade of Life, With a 25% Loss of Strength by Age 65"

"There is No Question That Technology Has Extended the Ability of the Spine Surgeon to Practice"

[6] Blasier RB, The Problem with the Aging Surgeon, When Surgeon Age Becomes a Surgical Risk Factor, Clin Orthop Relat Res (2009) 467: 402-411

I. Mandatory Continuous Professional Development (CPG): **It's What We All Should be Doing** [7]

1. Most Physicians Believe That to Provide the Best Possible Care to Their Patients, They Must Commit to Continuous Learning
2. Current Continuing Medical Education (CME) Provides Little More Than Documentation of Attendance
3. CME Must Provide Opportunities for Formative Assessment During CME activities by Incorporating Practice & Feedback Sessions

J. Professional Societies That are Ensuring Competence: Ramping Up Compliance Regardless of Age [7]

1. The American Board of Medical Specialties (ABMS): Maintenance of Certification - **MoC Program.** To maintain specialty board certification, physicians must demonstrate that they are participating in practice-based
2. The Federation of State Medical Boards (FSMB): Maintenance of Licensure - **MoL Program.** To qualify for re-licensure, physicians have to demonstrate a commitment to life-long learning and practice improvement.
3. Accreditation Council for CME (ACCME): Revised its accreditation standards to focus on improvement of physician competence, physician performance, and patient health status
4. Hospitals & Health Systems: Competency-based credentialing, in which physicians would have to demonstrate specific competencies to obtain and maintain privileges to practice.

"As a Surgeon I (You) Have to Take Every Opportunity to Participate in Lifelong Learning Both as a Provider & Receiver of Knowledge"

[7] Moore DE, et.al., Achieving Desired Results and Improved Outcomes: Integrating Planning and Assessment Throughout Learning Activities, Journal of Continuing Education in the Health Profession, 29(1):1–15, 2009

K. Lifelong Intellectual Curiosity: Learn, Embrace, Incorporate!

1. Start Your Practice with Life Long, Unbridled Curiosity
   a. Read
   b. Write
   c. Research
   d. Teach
   e. Educate
2. Participate in Lifelong Learning
   a. Grow Your Knowledge Base
   b. Practice Clinical Decision Algorithms
   c. Attend Current Concept Meetings Often
   d. Stay Current on New Technology: Grow Your SKILLS!
   e. Tap into you Societies Educational Resources
3. Maintain Your Health & Work on Fitness
   a. Avoid Excessive ETOH, Drugs, Smoking
   b. Get an Annual Physical
   c. Avoid a Dangerous Lifestyle
4. Continuous Professional Development (CPG)
   a. Lead & Participate in the Process
   b. Embrace New Knowledge Throughout Your Practice

"There is No Sadder Picture Than the Professor Who has Outgrown His Usefulness, and the Only One Unconscious of the Fact, Insists with a Praiseworthy Zeal, Upon the Performance of Duties for Which Circumstances of the Time Have Rendered Him Unfit" [4] William Osler, 1892

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Addressing Poor Surgeon Performance Before It Leads to Patient Morbidity

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Issue: How do we detect and intervene when a surgeon is under-performing?

Background: Patient reported outcomes have become the primary measure for quality in our medical system. Treatment outcomes are affected by every aspect of patient care. Individual surgeon performance has been highlighted publicly and privately as a major factor in surgical morbidity and mortality. Surgeon performance is a complex subject that is impacted by a multitude of factors. As we improve the accuracy of our methods for gathering data and metrics for surgeon performance, the goal is shifted toward intervening and improving under-performing surgeons.

Facts:

- Peer group comparisons can modify surgeon behavior
- Performance grades are variable depending on factor being measured
- Institutional performance can affect the individual surgeon's performance measures
- Peers are the first to know of diminishing performance
- Peer intervention is difficult in many institutions and can be very political
- Fear of legal repercussions for peer reporting impacts system
- The best model for addressing poor performance has not been established
- Surgeon coaching may be an option

Best Model: Complication reporting and discussion is part of the ACGME program requirements for Neurosurgery and Orthopaedic Surgery residency training programs. Surgeons of all ages are familiar with the process of quality improvement or morbidity and mortality (M&M). Peer review is critical to any process aimed at impacting surgeon performance. Many academic medical centers use transparent, non-pejorative reporting systems, conferences, and modification methods to address under-performing physicians, however the quality of these systems is variable. Many Departments are thwarted by hesitancy of faculty members to voluntarily report complications and an overall culture of fear in disclosing bad outcomes. In most private practice groups there is very little peer interaction and reporting. The hospital becomes the only reporting body that detects major morbidities and death. The cases are graded and filed without any real intervention unless there are multiple issues in a very short time period.

Opinion: Individual surgeon report cards should be the standard. The data points should be agreed upon through the use of national standards as well as locally pertinent conditions. All of the surgeons involved should be involved in the development process. The process has to be transparent and non-pejorative. Skilled leadership is critical in obtaining buy-in to the process. The policies for intervention and quality improvement programs should be clear. Surgeons identified as under-performing should have the opportunity to discuss their cases with their peers in a non-threatening environment. Pre-operative case discussion and planning should be included as part of any performance improvement plan. The ABOS and ABNS should make a practice peer review process a requirement for certification and recertification. The performance improvement process should be legally protected as a quality improvement process and not discoverable. Failure to comply in the PI program should be met with possible loss of privileges with rights of due-process.

Summary: Addressing under-performing surgeons early is critical to protecting patients and improving outcomes. Report cards and peer review are critical to modifying behavior and improving performance. The process must be transparent and non-pejorative to obtain broad participation. The ideal model has not yet been developed. We all must be active in the development of the best model.

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Optimizing Surgeon Performance Around the Globe: What are the Limitations/ Barriers?

Muharrem Yazici, MD
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Risk Stratification and Predictive Analytics

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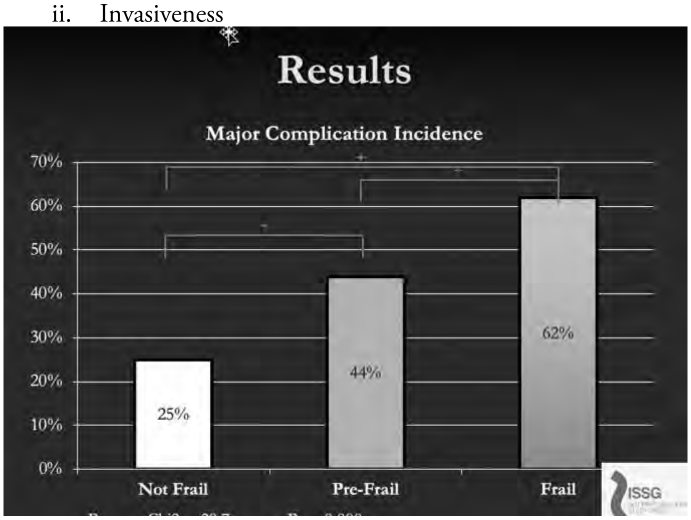
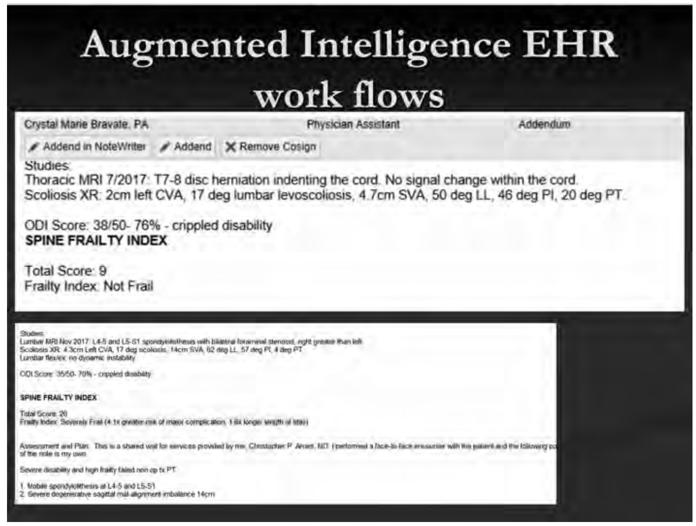
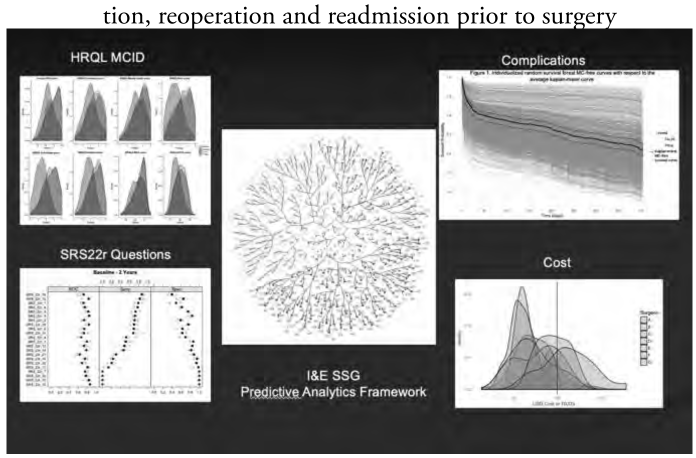
UCSF ISSG Global Spinal Analytics
San Francisco, California, USA

1. Our population is aging and the US healthcare system is running out of money
   a. 80 million over 65 by 2050
   b. Medicare out of funds by 2026
   c. Spinal Deformity Surgery > $100 billion annual cost in US
2. Older population is demanding higher levels of function as they age
   a. ASD surgery results in significant disability improvement in many cases
   b. ASD surgery more expensive as patients age
   c. Increased complications with increased frailty
   d. Improved disability improvement with increased age and Frailty
3. Solutions
   a. Collective intelligence – focus on the complication side—ration care to those who will be cheaper and less at risk of major complications
   b. Risk Stratification using datification of the patient and the procedure
      i. Frailty
      ii. Invasiveness

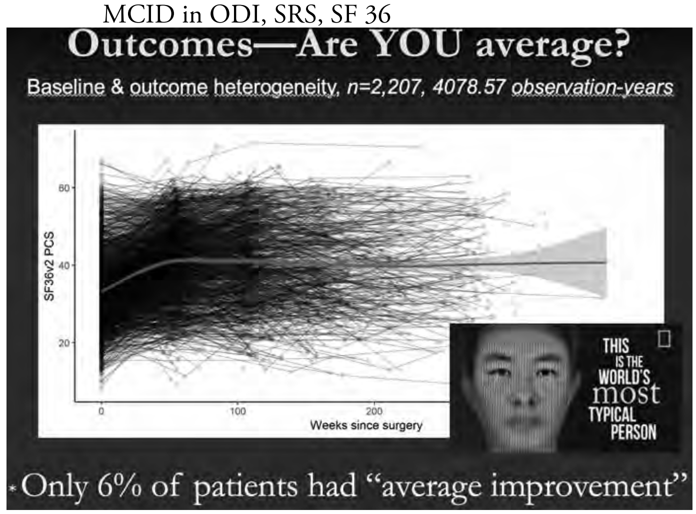




   c. Artificial Intelligence Predictive models that consider both outcomes and complications
      i. ISSG ESSG Models accurately predict major complication, reoperation and readmission prior to surgery



      ii. ISSG ESSG Models predict any improvement and MCID in ODI, SRS, SF 36



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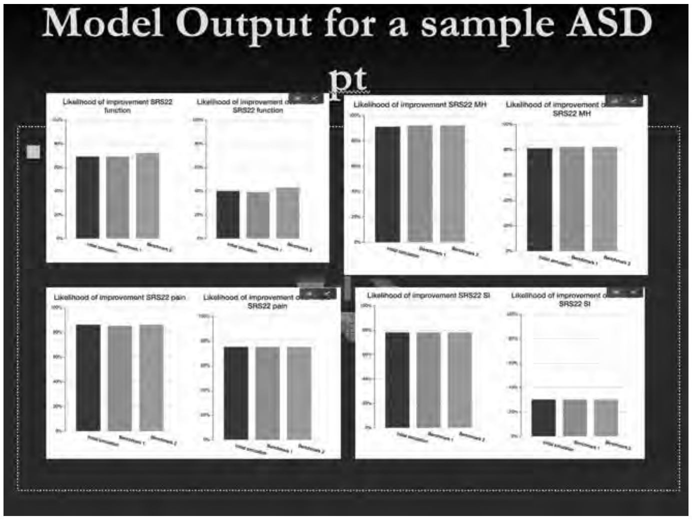


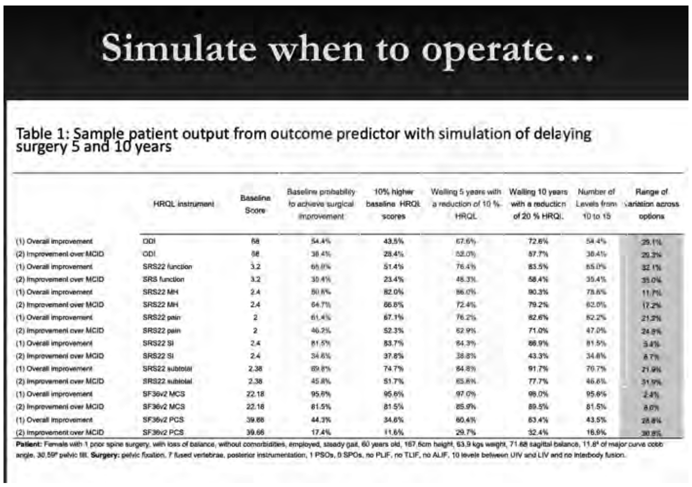
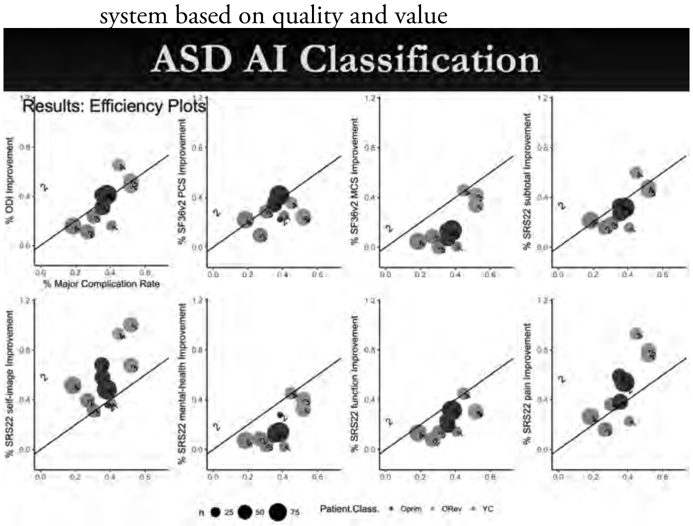

Simulate when to operate…

Table 1: Sample patient output from outcome predictor with simulation of delaying surgery 5 and 10 years

	HRQL instrument	Baseline Score	Baseline probability to achieve surgical improvement	10% higher baseline HRQL scores	Waiting 5 years with a reduction of 10 % HRQL	Waiting 10 years with a reduction of 20 % HRQL	Number of Levels from 10 to 15	Range of variation across options
(1) Overall improvement	ODI	68	54.4%	43.5%	67.6%	72.6%	54.4%	29.1%
(2) Improvement over MCID	ODI	68	38.4%	28.4%	52.0%	87.7%	38.4%	29.3%
(1) Overall improvement	SRS22 function	3.2	65.0%	51.4%	76.4%	83.5%	65.0%	32.1%
(2) Improvement over MCID	SRS function	3.2	30.4%	23.4%	48.3%	58.4%	35.4%	35.0%
(1) Overall improvement	SRS22 MH	2.4	80.6%	82.0%	86.0%	90.3%	78.6%	11.7%
(2) Improvement over MCID	SRS22 MH	2.4	64.7%	66.8%	72.4%	79.2%	62.0%	17.2%
(1) Overall improvement	SRS22 pain	2	61.4%	67.1%	76.2%	82.6%	62.2%	21.2%
(2) Improvement over MCID	SRS22 pain	2	46.2%	52.3%	62.9%	71.0%	47.0%	24.8%
(1) Overall improvement	SRS22 SI	2.4	81.5%	83.7%	84.3%	86.9%	81.5%	5.4%
(2) Improvement over MCID	SRS22 SI	2.4	34.6%	37.8%	38.8%	43.3%	34.6%	8.7%
(1) Overall improvement	SRS22 subtotal	2.38	69.8%	74.7%	84.8%	91.7%	70.7%	21.9%
(2) Improvement over MCID	SRS22 subtotal	2.38	45.8%	51.7%	65.8%	77.7%	46.6%	31.9%
(1) Overall improvement	SF36v2 MCS	22.18	95.6%	95.6%	97.0%	98.0%	95.6%	2.4%
(2) Improvement over MCID	SF36v2 MCS	22.18	81.5%	81.5%	85.9%	89.5%	81.5%	8.0%
(1) Overall improvement	SF36v2 PCS	39.66	44.3%	34.6%	60.4%	63.4%	43.5%	28.8%
(2) Improvement over MCID	SF36v2 PCS	39.66	17.4%	11.6%	29.7%	32.4%	16.9%	20.8%

Patient: Female with 1 prior spine surgery, with loss of balance, without comorbidities, employed, steady gait, 60 years old, 167.6cm height, 63.9 kgs weight, 71.68 sagittal balance, 11.8° of major curve cobb angle, 30.59° pelvic tilt. **Surgery:** pelvic fixation, 7 fused vertebrae, posterior instrumentation, 1 PSOs, 0 SPOs, no PLIF, no TLIF, no ALIF, 10 levels between UIV and LIV and no interbody fusion.

d. Precision Medicine
   i. Unsupervised AI clustering based new ASD classification system based on quality and value



   ii. Surgery for specific goals –ISSG ESSG models predict chance of improvement in each SRS 22 question. e.g. Will my walking improve?

Frailty and Invasiveness Index

Spine, 2018 vol. 43(20) pp. 1426-1431
External Validation of the Adult Spinal Deformity (ASD) Frailty Index (ASD-FI) in the Scoli-RISK-1 Patient Database
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Miller, EK; Vila-Casademunt, A; Neuman, BJ; Sciubba, DM; Kebaish, KM; Smith, JS; Alanay, A; Acaroglu, ER; Kleinstück, F; Obeid, I; Sánchez Pérez-Grueso, FJ; Carreon, LY; Schwab, FJ; Bess, S; Scheer, JK; Lafage, V; Shaffrey, CI; Pellisé, F; Ames, CP; European Spine Study Group; International Spine Study Group

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An assessment of frailty as a tool for risk stratification in adult spinal deformity surgery
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Passias, PG; Horn, SR; Soroceanu, A; Oh, C; Ailon, T; Neuman, BJ; Lafage, V; Lafage, R; Smith, JS; Line, B; Bortz, CA; Segreto, FA; Brown, A; Alas, H; Pierce, KE; Eastlack, RK; Sciubba, DM; Protopsaltis, TS; Klineberg, EO; Burton, DC; Hart, RA; Schwab, FJ; Bess, S; Shaffrey, CI; Ames, CP; International Spine Study

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Study Group

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Presurgical Optimization

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The primary goal of presurgical optimization is to minimize the risk of complications associated with the surgical procedure. This has traditionally been done through identification of pre-surgical risk factors. Some of these are not modifiable, whereas other factors can be modified to reduce the risk related to the surgery.

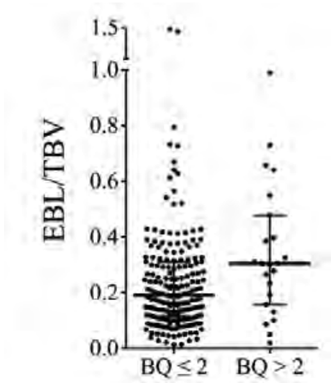
Traditional definition of presurgical optimization
Assessment of individual patient related risk factors:

- Age
- Gender
- BMI
- Co-morbidity

Especially in pediatric deformity spine surgery, the underlying diagnosis highly affects the risk of deep infection. Where the infection risk in surgical treatment of adolescent idiopathic scoliosis is less than 1%, the risk is significantly higher in surgery for neuromuscular scoliosis.

Low BMI is typically a risk factor described in patients undergoing surgery for neuromuscular scoliosis, and the nutritional aspect is now a cornerstone of presurgical optimization in these patients since both low and high BMI are modifiable risk factors *(Malik et al. 2019).*

An example of pre-surgical optimization is the identification of patients at risk for high blood loss. Although, the risk for blood loss may be challenging to modify, organizational changes can be implemented to reduce the that risk as much as possible (cell saver, tranexamic acid, two attending surgeons, planned staged procedure)



Estimated blood loss (EBL) in relation to total blood volume (TBV) depending on scores on a pre-operative blood screening questionnaire (BQ) (Anadio et al. 2017).

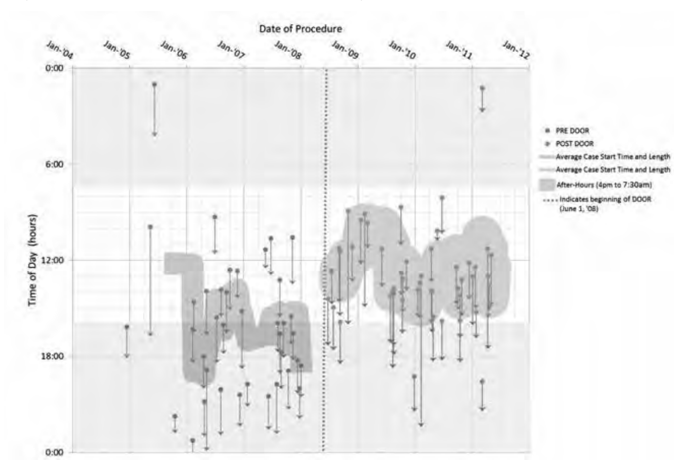
Extended definition of presurgical optimization

- Organizational factors
- Preoperative patient information
- Surgeon training

Organizational factors

Although not directly related to the optimization of the individual patient, several studies have found that the organization of the healthcare system can play a role in the presurgical optimization and risk reduction; both on a regional and a local level.

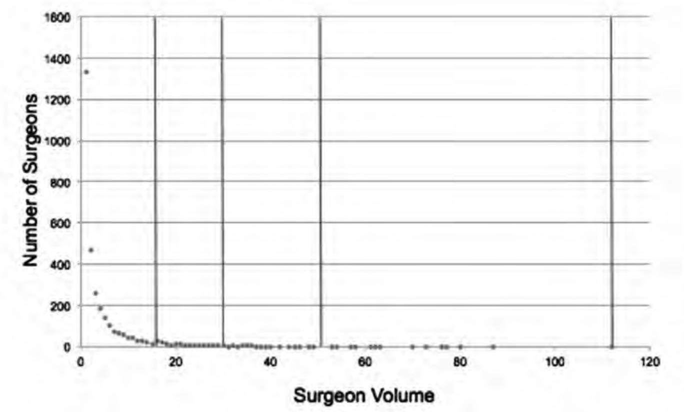
The introduction of dedicated orthopaedic operating rooms (DOORS) in the treatment of patients with femoral neck fractures has been shown to reduce the risk of ICU-admission, infection, myocardial infarction and mortality:



Blue lines and dots indication procedure start and duration before DOOR was implemented, and red lines and dots indicates the variables after DOOR was implemented (Roberts et al. 2015).

In relation to surgical treatment of adolescent idiopathic scoliosis it has been demonstrated that the volume of procedures, both in relation to the hospital but also in relation to number of procedures performer per surgeon, affects the risk of complications *(Menger et al. 2017)*. This is an example of how presurgical optimization should include assessment of regional and possibly national organization of spine surgery.

Similar findings have been reported in adult deformity surgery:



Surgeon volume of revision adult deformity spine surgery showing that the majority of surgeons performed 0 to 40 procedures per year (Paul et al. 2015)

At the local level the multidisciplinary conferences can serve as a forum to discuss the indication for surgical treatment, and to identify patients who should undergo preoperative optimization prior to surgery *(Sethi et al. 2014).*

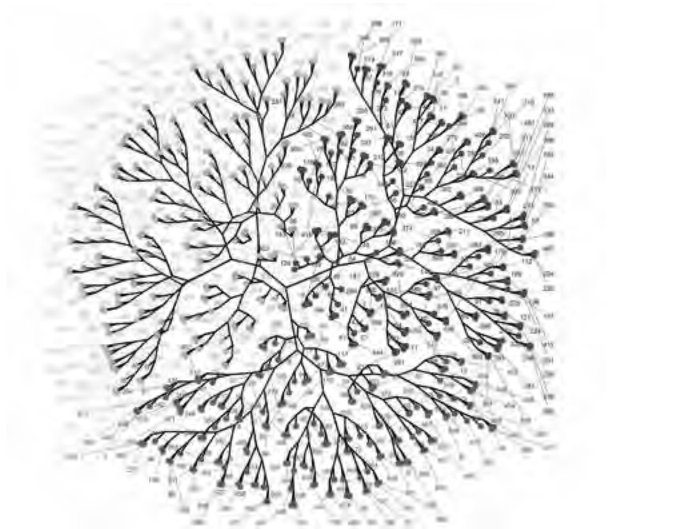
Multidisciplinary spine conference at Texas Children's Hospital.

Preoperative patient information

Patients and their families expect information about the risk of complications associated with the planned procedure. However, patients also expect a realistic expectation regarding the change in health-related quality (HRQL) of life after their treatment.

Within the last two decades the use of PROM's has been accepted as a way of informing the patient about the expected outcome of the procedure. In most cases, PROM's can provide an average of expected gain in HRQL, but with the introduction of personalized medicine, future patients will expect a more specific assessment of HRQL, closely linked to their own wishes.

This may require a whole new paradigm of assessing HRQL, using artificial intelligence to math individual patients to other patients with the same risk profile, allowing the patient to consider the likelihood of obtaining a sufficient improvement in HRQL.



Hierarchical clustering of patient types based on artificial intelligence (Ames et al. 2019)

Surgeon training

- Non-technical skills
- Pre-operative planning
- Learning-curve
- Virtual simulation training

Surgical training should be included as a factor that the be modified, and "surgical training" should be widely defined, and also include training in so-called "non-technical skills" *(Cameron AJ. 2019):*

- Situation awareness
- Decision making
- Communication
- Teamwork
- Leadership

There is little doubt that virtual and augmented reality will be an integral part of future surgeons training, but there is still a lack of studies demonstrating a clinical benefit to the patients *(Pfandler et al. 2017).*

Conclusion

Besides the traditional patient related variables, future presurgical optimization will include factors like organizational structure of the health care system, a wide variety of surgeon related factors, as well as artificial intelligence to improve patient selection and decrease the risk of complications.

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Preoperative Planning: Planning Software and Advanced Imaging

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Introduction and Background

Spinal deformities both in the adolescent and the adult population pose several challenges to the treating surgeon. Spinal deformity surgery remains a complex procedure that involves many decisions that can have an impact on the patient's outcome. Level selection, location and selection of implants (screws/hooks), number of implants, osteotomy use and localisation and rod material and shape. Good understanding of normal spinal balance and alignment is a key factor to include in the surgical planning and must therefore be tailored to each patient's specific anatomy. Recent advances in pre-operative planning software and advanced imaging have improved the pre-operative planning for these complex procedures. This presentation will focus on the use of these softwares, their advantages and disadvantages and on the pre-operative advanced imaging available to better understand the spinal deformities.

Pre-operative planning software

A variety of pre-operative planning softwares exists that can be used for assessing the patient pre-operatively. They range from the simple angle calculator that will propose a surgical plan based on the patient's pelvic balance and geometry to the more advanced software capable of generating a personalized pre-contoured rod. Most programs are based solely on angular measurements and don't integrate biomechanical aspects while simulating the outcome. More recently, a new generation of programs have started integrating Finite Element Modeling or flexible multi-body models. These simulations are thought to better reflect the spinal unit behaviour and can provide a better assessment of the forces involved in both the surgical correction and the residual forces in the spine/instrumentation at the end of the procedure. A surgical plan could therefore be reviewed by the surgeon with a better understanding of the forces involved in attaining the desired correction. The surgeon could also modify the surgical plan by adding different types of osteotomies or by adding a cage anteriorly.

Advanced pre-operative planning for growth-friendly procedures

Growth-friendly methods have been used to prevent fusion or to delay final fusion in children with spinal deformities with significant growth remaining. Many factors have to be taken into account including the size of the deformity, the surgical approach, the timing of the intervention and the remaining growth available. In an ideal world, a single surgical event providing timely reversal of the deformity without over-correction would be ideal. Growth modulation of the spine through the use of an anterior vertebral tether has shown promising results but it remains to determine which levels to instrument and when to intervene to harness enough growth to correct the deformity without risking overcorrection of the curve. The optimal timing for intervention is based on several factors that are often not under the control of the treating physician. How much growth remains, how much deformity must be corrected, what growth-friendly method is planned will all affect the final outcome.

For these reasons, patient-specific Finite Element Model (FEM) growth modulation planning tools have been developed to better predict the outcome of surgical correction. These models use patient-specific 3D anatomy through 3D reconstruction of the spine and personlaize these models by using patient characteristics such as spine flexibility to personalize the simulations. The surgical procedure is then simulated through the imposition of different boundary conditions simulating each step of the surgical procedure (lateral decubitus, screw and tether installation, application of gravity in the upright position and growth). Depending on the predicted amount of growth, the patient's curve behaviour can predicted over a perior of one, two or three years. D

The surgeon can then be presented with a list of implant configurations that will help determine the optimal procedure (figure 1)

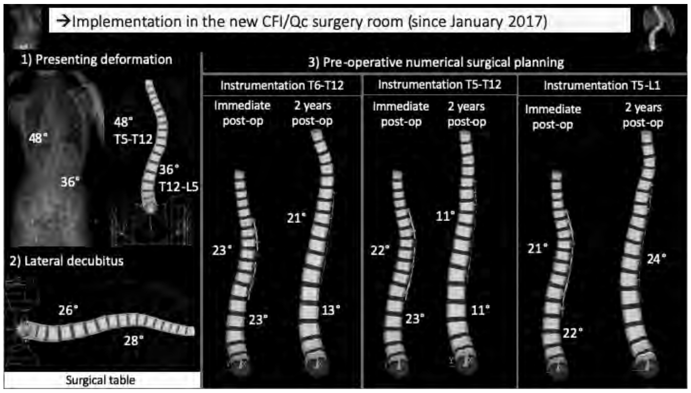

Figure 1: pre-operative planning of growth modulation procedure

In a recent review of the first 54 patients treated with AVBGM using this planning software, 2year post-operative results showed good to excellent correspondence to simulated outcomes. A 32% correction of the actual thoracic Cobb angle was found between the presenting deformation and the intra-operative patient positioning in lateral decubitus (p-value<0.005). The correction was increased to 43% at immediate post-operative correction (p-value<0.005), while an additional 18% correction was measured after 1 year of growth (p-value<0.005) and an additional 5% correction after 2 years of growth (p-value=0.22). The lumbar Cobb angle correction was of 22%, 33%, 49% (p-value<0.05) and 55% (p-value=0.29) respectively for the same time points. The simulated immediate, 1- and 2-year post-operative corrections were predicted within a precision of 4° and 5° as compared to the actual thoracic and lumbar Cobb angles, while the updated simulation reduce this difference to 3° and 4° for all time points. Tables 2 and 3 show a summary of the actual and simulated results for each correction indices.

The actual T4-T12 kyphosis and L1-L5 lordosis angles were both slightly modified by 2° and 4° respectively on average immediately after surgery, and after 1-year and 2-year (p-values≥0.4). The simulated kyphosis and lordosis angles were predicted within 5° for each time point. The actual apical rotation was corrected on average by 6° immediately after surgery (p-value=0.05), while after 1 and 2 years of growth, the correction was of 8° and 9° respectively (p-values≥0.4). Simulated correction in the transverse plane was within 4° of the actual measurements for each time point. Finally, the actual T1-L5 height was of 350 mm immediately after surgery, 366 mm after 1 year of growth and 381 mm after 2 years of growth. Simulated spinal T1-L5 height was within 8 mm of the actual reference measurement at each time point.

Advanced imaging

Recently, clinicians have had access to an innovative biplanar imaging technology that utilizes two orthogonal beams of X-rays directed towards a particle detector (Charpak 1992; Nobel prize), intersecting to create two simultaneous linked orthogonal images of an object (in this case, the full length of the spine of a patient), one postero-anterior (PA) and one lateral (LAT). This technique significantly decreases radiation exposure: 8 to 10 times that of conventional X-rays and 800-1000 times that of CT-scan. The digital images can then be imported in a software to create an accurate full-length 3D reconstruction of the spine. This technology allows for low radiation acquisition of cross-sectional and longitudinal data for this comprehensive 3D reference data set of spine growth in normal spines.

From the 3D reconstructions of the above described system, it is then possible to calculate and visualize a series of regional (maximum Cobb, frontal Cobb, sagittal alignment, orientation of the plane of maximum curvature) and local parameters (vertebral and disk wedging, vertebral transverse plane rotation, and several pelvic indices) characterizing the spinal deformity. One such parameter that has been described in recent years is the "True Kyphosis" that represents the segmental sagittal alignment after the coronal and axial deformities have been normalized resulting in a representation of the summed sagittal relationships between each vertebra. This representation allows the surgeon to better understand the segmental deformity and how to correct it surgically.

3D models

For more complex deformities, it may be usefull to directly observe the spinal anatomy prior to performing a surgical procedure. Multi-slice 3D Ct-Scanner can provide high resolution reconstructions of the spine permitting 3D printing of actual-size resin models. These models can be used to observe the anatomy and to plan a more complex surgery such as a VCR. Although not advisable for routine cases due to the added radiation dose, these models are very helpful in difficult cases/congenital cases.

Conclusions

Pre-operative planning has progressed drastically in recent years with the advent of more sophisticated planning softwares. The added time needed for the planning of the procedure can often be gained intra-operatively by shifting the decision making pre-operatively instead of intra-operatively. More realistic models are becoming available and will probably result in better surgical execution and improved surgical outcomes. For growth-friendly procedures, the best time to intervene varies from patient to patient based on the growth remaining and the severity of the deformity to treat. Over-correction or insufficient correction can be evaluated pre-operatively using a patient-specific FEM planning software. This tool can help the clinician to determine the optimal time to intervene. Advanced imaging allows surgeon to better understand local and regional deformity prior to addressing the deformity surgically improving pre-operative planning and surgical strategy.

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Building OR Teams

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Rationale for Building an OR Team:

Simple - Surgeon's duty to patient and families to optimize patient outcomes and minimize complications

- Mid Staffordshire Public Inquiry – increased focus on medical professionalism and *collegiality*, as well as patient safety and the role of *culture and behavior* in promoting safe patient care[1]
- Growing evidence about direct links between medical errors and behavior in OR - *specifically* team working and communication[2,15]
- Effective teams are more innovative and have greater job satisfaction - reduce "burn-out"[3,15]

Steps to Consider:

1. Buy-In

- Important to identify early which individuals are good but *more importantly* which enjoy spine procedures
- Don't be shy to spark interest:
  - o Explain and take time in OR to display anatomy, key steps in procedure
  - o Invite anesthesia/nursing involved in the case to post-op spine clinics to meet patients/families so they feel part of total patient care and can see the difference *they* made – not simply the "technical" but the impact on QoL and allows patients to thank the team in person.
  - o Share the success stories with all involved and let them know that it was only made possible by *working together* – not a "surgeon's show"

2. Stakeholders

- Administration/Policy-makers generally are responsive to "ROI" concept, therefore important to *identify metrics* early to stakeholders that improvements on patient outcomes/quality of care *will be measured and presented*
- Important to collect data and add to pool of literature on QSVI[4-7,9,16,17,18]
- Consider aligning with other centers that have teams and do comparison of QSVI variables (ORT/LOS/URO/Transfusion rates/etc) that help educate "naysayers"

3. Critical Culture

- Membership:
  - o Define common goal: *to provide high quality patient care*
  - o Redefine goal(s) as time goes on: "aim to be best at high quality patient care" – compete with other institutional teams…cardiac, MTD, etc to help keep members engaged
  - o Need "critical mass" and level of skill[7]
  - o Each member should understand other member roles and responsibilities…eg. "motor loss" should spark same concern in RN, anesthesia, as it does in surgeon[13]
  - o All to respect role, expertise, competence, and contributions of each other - share goal of high quality care for patient[11,13]
  - o Commitment to team work is in best interest of patient
  - o Recognize that all members are important to outcome of the task - feel confident to raise their voice and intervene[6,19-22]
- Leadership:
  - o Leader to provide clear guidance and whom team members look for guidance
  - o Teams led by non-threatening style learn new procedures more quickly and effectively[12]
  - o Continue to solicit input from team members and engage in team-based decision making – critical when new technologies (navigation, OR suite re-design, etc) are being negotiated[6]
  - o Invert the "triangle"
- Communication:
  - o Communication[8,10,11] – *both content and skills – what is said and how it is delivered…*
    - o *Timely, clear, open, and respectful*
    - o "Information sharing" – team understands why certain actions are being taken and can calibrate their own actions accordingly
    - o Coordination of tasks and *knowledge of tasks* of "others"[14] - invite anesthesia/nursing to pre-op counseling sessions…will understand patient positioning, need for special equipment, room set-up, etc well in advance of simple "OR huddle"
- Safe Interpersonal Climate[19-22]:
  - o *"First-name" basis*, eliminate the prefixes: Dr., Nurse, Scrub Tech, etc; this can be enhanced further by identifying on a social level with members outside of work environment… explore hobbies together
  - o Always end a case by a "thank you" to all in the OR
  - o Can "agree to disagree"
- Review, Reflect, Learn1[5,18]:
  - o Seek and accept feedback
  - o Review team's performance – NSQIP Spine Pilot study[18]/HSG Surgeon Performance Program
  - o Listen to ideas for process/procedure improvement
  - o Celebrate successes – highlight annual achievements of all –

academic and non-academic

- Have Fun

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Decreasing Blood Loss

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Incidence of excessive blood loss in complex spine surgery and potential consequences:

- A recent study based on a multicenter prospective cohort of 291 patients treated surgically for adult spinal deformity, reported an 11% incidence of "excessive blood loss", which was defined as >4 L.[1] This was considered a complication.
- Whether "excessive blood loss" should be considered a complication and, if so, at what threshold it should be a complication remains unclear.
- Significant blood loss can have consequences, including hypotension, end organ damage and coagulopathy.
- Allogenic blood can present additional risks, including hemolytic transfusion reactions, transfusion-related acute lung injury, infection transmission, and immune modulation effects

Surgical considerations/techniques for reducing intraoperative blood loss:

- Multiple techniques can be used intraoperatively to help reduce and address blood loss, including:
  - Positioning prone patients to allow abdomen to hang free to decrease abdominal/venous pressure (e.g. open-frame table)
  - Using subperiosteal dissection techniques
  - Waxing bony edges
  - Decorticating for arthrodesis at the end of the procedure

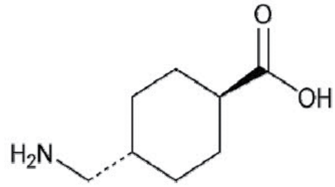
- Use of topical hemostatic agents
- Use of cell salvage devices
- Use of less invasive techniques

Anesthetic considerations/techniques for reducing intraoperative blood loss:

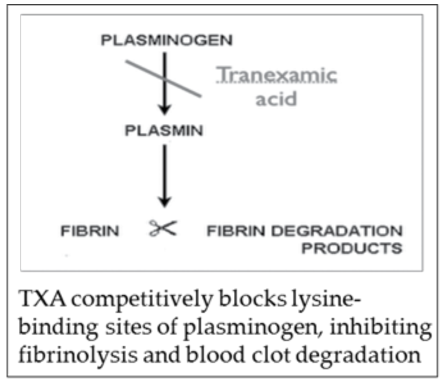
- Acute normovolemic hemodiluton: Not commonly used in spine surgery, but has been shown to be safe and effective.[2] Blood is drained in the OR into bags, replaced with crystalloid, and given back to patient at end of procedure. Hemodilution up to 30% may induce mild hypercoagulable state and decrease bleeding.
- Maintenance of normothermia: Hypothermia can lead to hemostatic impairment (platelets). Multiple joint arthroplasty studies have reported decreased blood loss with normothermia.
- Controlled hypotension: Not commonly used in spine surgery, but has been used in orthopedic procedures for decades. Although may reduce blood loss, concerns of risk of postop vision loss and compromised perfusion of end organs (renal, spinal cord).
- Intrathecal morphine: Multiple prospective RCTs report preop intrathecal morphine reduced intra-op blood loss.[3] Does not impact neuro assessment and can also provide pain relief. Mechanism for blood loss reduction remains unclear.
- Rotational thromboelastometry (ROTEM): Functional visco-elastometric method for dynamic real-time assessment for specific coagulation pathway abnormalities. Can be used intraoperatively to assess coagulation deficiencies and reduce blood product utilization. Has been predominantly used in cardiac, trauma, and major visceral surgery. Recent studies have reported successful use in spine surgery:
  - Guan et al.[4] assessed transfusion requirements between 15 surgically-treated adult spinal deformity patients who received ROTEM-guided therapy who were matched with 15 who did not receive ROTEM-guided therapy. Non-ROTEM patients required significantly more total blood products (8.5 vs 3.7 units, p=0.001). This remained significant after adjusting for number of levels of fused, TXA use, and preop hct/INR (p=0.016).
  - Buell et al.[5] assessed transfusion requirements between 17 adult spinal deformity patients treated with pedicle subtraction osteotomy (PSO) who received ROTEM-guided therapy who were matched with 17 who did not receive ROTEM-guided therapy. ROTEM-guided therapy enabled reduction in blood loss and total blood product transfusion volume.

Antifibrinolytics:

- Aprotinin: Reduces fibrinolysis by inhibiting plasmin activity. Effectively reduces blood loss in cardiac surgery but results in spine had mixed results. In 2007, FDA suspended use (except for investigational use) due to concerns of increased risk of acute renal failure and DVT.
- Epsilon-aminocaproic acid: Lysine analogue with antifibrinolytic action. Conflicting data regarding efficacy in decreasing blood loss in spine surgery.
- Tranexamic acid (TXA): Synthetic lysine analogue with antifibrinolytic action; inhibits binding of lysine residues on fibrin to plasmin or plasminogen thereby preventing fibrinolysis. Established efficacy for reducing blood loss in knee/hip arthroplasty and growing evidence or spine surgery.



TXA molecular structure



TXA mechanism of action

- Cheriyan et al performed a meta-analysis of TXA efficacy on surgical bleeding in spine surgery based on 11 RCTs.[6]
  - Found a very wide range of dosing protocols and applications to a broad range of spinal pathologies (adult, pediatric, deformity, degenerative disease, cervical, lumbar).
  - Overall, TXA reduced intraop blood loss by average of 219 mL (range: 116 to 322 mL) compared with placebo. Included broad range of procedure complexities.
  - Overall, TXA reduced allogenic blood transfusion requirement by average of 33% compared with placebo.
  - Only identified occurrence of 1 DVT (in placebo group), no PEs, and only 1 MI (in TXA group). Ker et al also found no increased risk of thromboembolic events with based on a meta-analysis of 129 RCTs with 10,488 surgical patients (not limited to spine).[7]
  - Found greater benefit for larger blood loss surgeries. Those with average blood loss of >1,500 mL had average reduction in intraop and postop blood loss of 676 and 161 mL, respectively.
- Karimi et al performed a systematic review and meta-analysis of TX efficacy for pediatric scoliosis surgery based on 5 RCTs.[8]
  - TXA reduced intraop blood loss by average of 812 mL compared with control
  - TXA reduced postop blood loss by average of 245 mL compared with control
  - TXA significantly reduced fresh frozen plasma requirements
- Raman et al performed a retrospective review of 319 adult spinal deformity patients with differing TXA dosing proto-

cols.[9]

- 258 had "low-dose" TXA (10 or 20 mg/kg load then 1 or 2 mg/kg/hr infusion)
- 60 had "high-dose" TXA (40 mg/kg load then 1 mg/kg/hr infusion)
- High-dose TXA (compared with low-dose) was predictive of:
  - 515 cc less EBL (p=0.002)
  - 11.4% less blood volume lost (p=0.004)
  - 1 U pRBC less transfused intraop (p<0.001)
- High-dose TXA had higher rate of:
  - postop atrial fib (5% vs 0%, p<0.001)
  - postop MI (1.7% vs 0%, p<0.01)
  - But the MI patient (also had atrial fib) had major risk factors

- Lin et al performed an assessment of the safety of high-dose TXA in complex adult spinal deformity based on 100 consecutive cases.[10]
  - High-dose TXA = 50 mg/kg load then 5 mg/kg/hr infusion
  - Only noted 1 (1%) PE and 2 (2%) DVTs, all successfully treated with anticoagulation
  - Suggests that high-dose TXA may be safe but no control group
- Xie et al performed an assessment of the safety of very high-dose TXA in complex spinal deformity surgery based on 59 deformity patients (age range 7-46 y/o).[11]
  - High-dose TXA = 100 mg/kg load then 10 mg/kg/hr infusion until skin closure
  - 26 patients (8 of whom had a VCR) had high-dose TXA; 33 patients (9 of whom had a VCR) had no TXA (control group)
  - High- and low-dose TXA patients had similar demographics and surgical parameters; subset of VCR patients with and without TXA also had similar parameters
  - Overall, TXA group had significantly less blood loss (2.4 L vs 4.8 L, p=0.020) and had less blood transfusion (p=0.022)
  - Patients undergoing a VCR had the greatest reduction in blood loss with TXA (4.2 L vs 9.9 L, p=0.012; 57% reduction) compared with non-VCR patients (1.4 L vs 2.4 L, p=0.013; 40% reduction)
  - No lower limb DVT, symptomatic MI, symptomatic PE, seizures, or acute renal failure in the TXA group
  - Concluded that high-dose TXA appears to be effective (especially with VCR) in this relatively young population but future assessments should be performed to assess safety in older patients
- Situations in which TXA use may have increased risk (contra-indicated?):
  - History of DVT or PE
  - History of TIA
  - History of stroke
  - History of subarachnoid hemorrhage
  - Treatment with anticoagulants
  - Renal impairment
  - Chronic liver disease
  - Cardiac stents
- Conclusions:
  - Several surgical and anesthetic considerations that may help to reduce blood loss
  - Very good evidence that TXA reduces surgical bleeding and transfusion requirements in patients undergoing spine surgery
  - TXA does not appear to be associated with increased risk of PE, DVT, or MI (but should consider contra-indications/relative contra-indications when deciding which patients to treat with TXA)
  - TXA use may be most advantageous in cases with expected high blood loss
  - Appropriate dosing of TXA remains unclear and needs further study

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Decreasing Risks of Infection: Best Practice Guidelines

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Outline
- o Why is It So Hard?
- o You Need a Good Team
- o Assess Risk
- o Routine…Create a Plan
- o Can We Move the Needle?
- o Track Outcomes and Improve

Why is It So Hard?
- o Many medical comorbitities
- o Preoperative evaluation challenging
- o How do you optimize?
- o Data Poor

Have a Good Team
- o Miyanji (SRS 2016):
  - o Team-based approach led to significant decline in:
    - – SSI (8.5à0.7%)
    - – OR time (404.5 minà351 min)
    - – LOS (14.3 daysà8.9 days)
    - – Unplanned staged procedures (6.2à2.9%)
  - o Adult experience similar

Engage Your Local Team
- o Orthopaedics
- o Neurosurgeon
- o Anesthesia
- o ID
- o OR/Floor Nursing
- o Medical Service
- o Complex Care Service (CCS)
- o ICU

National Team
- o Join forces, share data
- o Multicenter research collaborative
  - – SSI
  - – CSSG, GSSG, HSG
  - o Collaboration in Quality Space Is Key

Assess Risk
- o Patient related
- o Surgery related
- o Difficult to assess risk
- o Tools available to estimate
  - o EOS
  - o NM/CP
  - o Non-idiopathic

Create a System/Routine
- o Reduce Uncertainty
- o Makes you/others more comfortable
- o Is Variability Bad?
- o Studies have shown that reducing variability
  - - Improves outcomes
  - - Reduces cost
- o Where to Start?
  - o Published best practice guidelines/literature review
    - - SSI
    - - Neuromonitoring
    - - Postoperative AIS care
    - - Others
  - o Use/create checklists
  - o Create institution specific pathways
- o How do we keep them updated?

Can We Move the Needle?
- o BCH initiative led to lower infection rate
- o Hawthorne effect?

Track Outcomes and Improve
- o Dashboards
  - o National and local benchmarks
  - o Monitor protocol compliance
  - o ACS, NSQIP, NSPS
    - o Be willing to change behavior
    - o We all want to get better

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Minimizing Neuro Complications: Checklists and IONM Teams

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IOM Standards for CPG

- Approaches to care are variable; decreasing variability will improve care
- Standards include transparency, management of conflict of interest, guideline development group should be multidisciplinary and balanced, including a patient or patient/consumer organization, utilize formal systematic review of evidence, strong recommendations worded in accordance with evaluation, external review, updating

Appropriate Use Criteria (2011)

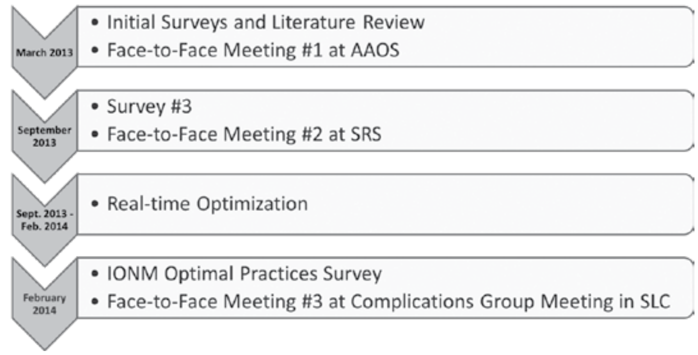
- Integrate clinician expertise and experience with evidence to find appropriate treatment for patients
- Need for development of best practice guidelines identified to synthesize evidence and experience
  - o BPG for SSI in High Risk Spine Patients
    - Systematic literature review discovered *no Grade A evidence* for patient-related risk factors in pediatric scoliosis surgery
    - *Sparse Grade A* evidence for perioperative interventions in scoliosis surgery

Hawthorne Effect: Making Outcomes Transparent and Visible

Response to Intraoperative Neuromonitoring Changes

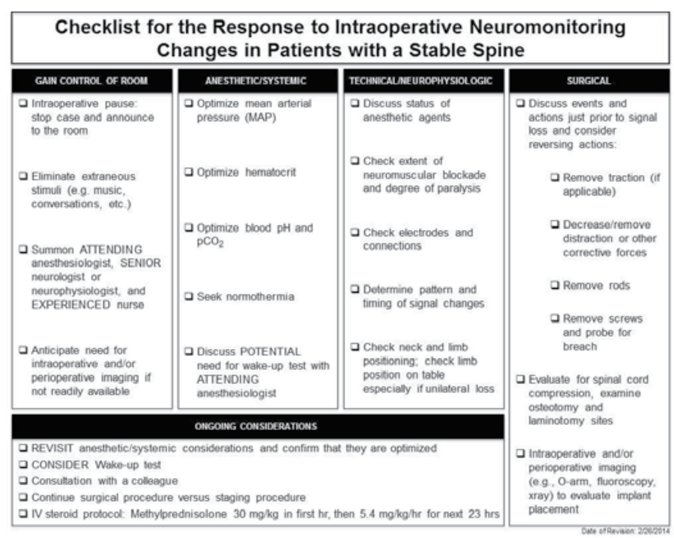
- How can we improve and streamline responses?
- Incorporate a solid structure and communication to practice

Delphi and Nominal Group Technique



IONM Optimal Practices Guideline

- Somatosensory Evoked Potentials (SSEP) and Transcranial Motor Evoked Potentials (TcMEPS) should be used in all spine deformity cases.
- "Significant warning criteria" in spine deformity surgery is constituted by a 50% degradation in SSEP signal amplitude from baseline, or a sustained decrease in TcMEP signal amplitude
- If persistent signal degradation occurs, Wake-Up Tests should not be ruled out


Checklist for the Response to Intraoperative Neuromonitoring Changes in Patients with a Stable Spine

GAIN CONTROL OF ROOM	ANESTHETIC/SYSTEMIC	TECHNICAL/NEUROPHYSIOLOGIC	SURGICAL
❑ Intraoperative pause: stop case and announce to the room	❑ Optimize mean arterial pressure (MAP)	❑ Discuss status of anesthetic agents	❑ Discuss events and actions just prior to signal loss and consider reversing actions: ❑ Remove traction (if applicable) ❑ Decrease/remove distraction or other corrective forces ❑ Remove rods ❑ Remove screws and probe for breach
❑ Eliminate extraneous stimuli (e.g. music, conversations, etc.)	❑ Optimize hematocrit	❑ Check extent of neuromuscular blockade and degree of paralysis	
❑ Summon ATTENDING anesthesiologist, SENIOR neurologist or neurophysiologist, and EXPERIENCED nurse	❑ Optimize blood pH and pCO_2	❑ Check electrodes and connections	
❑ Anticipate need for intraoperative and/or perioperative imaging if not readily available	❑ Seek normothermia	❑ Determine pattern and timing of signal changes	❑ Evaluate for spinal cord compression, examine osteotomy and laminotomy sites
	❑ Discuss POTENTIAL need for wake-up test with ATTENDING anesthesiologist	❑ Check neck and limb positioning; check limb position on table especially if unilateral loss	❑ Intraoperative and/or perioperative imaging (e.g., O-arm, fluoroscopy, xray) to evaluate implant placement

ONGOING CONSIDERATIONS
❑ REVISIT anesthetic/systemic considerations and confirm that they are optimized
❑ CONSIDER Wake-up test
❑ Consultation with a colleague
❑ Continue surgical procedure versus staging procedure
❑ IV steroid protocol: Methylprednisolone 30 mg/kg in first hr, then 5.4 mg/kg/hr for next 23 hrs

Date of Revision: 2/26/2014

Research, Quality, Evidence and Impact

- At the intersection of research and quality, we must turn data into practice

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Navigation and Robotics is Worth the Cost and Improves Performance

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Navigation and Robotics
- CT based with 3D reconstructions
- Repeatable process with Drill, Tap, Wire, Screw
- System *holds* in position
- Reproducible trajectory; more systematic
- *Segmentation vs Alignment*

Advantages
- **Less radiation**
  - Surgical Team vs MISS with Fluoroscopic Assist
  - Patient requires preop or intraop CT scan (similar to navigation)
- **Less exposure**
  - If employed in MISS or MAST Setting
- **Accuracy = Big Question**
  - Freehand?
  - Navigation?
  - Fluoro Assist?
- **Based on Segmentation vs Navigation (alignment)**

Advantages: Clinical Benefits
- Improved accuracy of screw placement —> Reduces complications and surgical revisions
- Reduces use of intra-op fluoro —> Reduces intraoperative exposure
- Pre-op planning in 3D software —> Improved predictability
  Customized approach
  Shorter OR time

Validated in 20+ peer reviewed studies:
- 99% screw placement accuracy
- 5-fold reduction in surgical complication
- 7-fold reduction in surgical revisions
- 60% Reduction in fluoroscopy exposure
- Quicker operating time regardless of # levels

What Does this Cost?
1. To the Patient – disability, time off work, emotional, less productive
2. To the Surgeon – Stress, burnout, doing less instrumented cases
3. To the Hospital – less cases, less inpatient stays, malpractice
4. To the Payor – additional procedures
5. To the malpractice carrier/coverer
6. To overall healthcare GDP

Workflow Changes

Freehand or Navigation
1. Exposure
2. Facetectomies
3. Decompression(s)
4. PCOs
5. Screws (benefit open canal)
6. TLIFs
7. Correction

Robotic Assistance
1. Exposure
2. Wires/Tap +/- Screws
3. Facetectomies
4. Decompressions
5. PCOs
6. TLIFs
7. Correction

Economics

"Cost"
- Capital investment
- Leasing
- Consumables
- Cannulated screw cost
- OR time
- Learning curve

Benefits
Accuracy
Re-operation rate?
Patient outcomes?
Patient volume??
Surgeon Stress
Placing more screws
Planning software
OR Time

Robotic vs Freehand
Robotic Group
Fewer pedicle breach (5.4% vs 1.5%)
Lower radiation exposure (33s vs 0.9s per screw)
Shorter procedure time (1.98h vs 1.23h)

Navigation/Robotics Increases Cost and Worsens Performance

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Background:

- Image-Guided Spinal Surgery?
- "Navigation" vs. "Robotics"
- Specific technologies & How they work
- Using Navigation & Robotics
- The Pros and Cons
- The Evidence!

Pros "for the misinformed"
- Improved Screw Accuracy
- Decreased Radiation to Surgical Team
- Improved Operative Time (after initial learning curve), which may never happen!
- Execution of Templated Plan (Robots)
- Reduced Surgeon Fatigue / Manual Error (Robots)
- Enable surgeons to do more…
  - Less invasive surgery
  - More complex surgery (Revision/Deformity) *Really*?
  - Single position Lateral – OLIF/LLIF
  - More precise screw diameters/lengths
  - Confirm level (e.g., thoracic pathology)
  - "See the Danger" – vertebral a., aorta, nerve root, tumor
- Cost Savings from Reduced Reoperation / Malpractice
- Marketing: "Yeah Baby, Yeah!"
- "Better Sleep at Night" for the robot or for the developers of the technology?

Cons:
- Systematic Errors causing Catastrophic Failures
- High Initial Capital Investment
- Longer operative time
- Higher radiation to the patient (Who cares, right?) the patient does
- Becoming Dependent "another forn of addiction"
  - What happens if it isn't available?
    - System down, Outreach setting,
    - Other surgeons using it…
  - Not Necessary if you know what you're doing
  - Changes the workflow, too many people in the room; increased SSI?
  - Additional incision
  - False Assurance
  - Need a regular team of operative staff
  - "Out-of-date" equipment, even more cost
  - No facetectomies, no Pontes. God forbid the segments might move slightly (big trouble)

The Evidence:

1- Worldwide survey on the use of navigation in spine surgery: Hartl, R., et al. World Neurosurg, 2013
  - A 12-item questionnaire to 3348 AOSpine. Response rate: 20%
  - <u>Only 11% of spine surgeons use Navigation routinely</u>
  - High-volume procedure surgeons, neurological surgeons, with a busy minimal invasive surgery practice are more likely to use computer-assisted technology.

2- Accuracy of Robot-Assisted Placement of Lumbar and Sacral Pedicle Screws. A prospective Randomized Comparison to Conventional Freehand Screw Implantation: Florian et al, Spine 2012
  - Conventional FH pedicle screw placement in the lumbar and sacral spine was more accurate 93 Vs 85%
  - Radiation exposure was not reduced by robot assistance.

3- Radiation exposure in spine surgery using image-guided system based on intraoperative cone-beam CT: Analysis of 107 consecutive cases. Costa et al. J Neurosurg Spine. 2016
  - 107 cases of O-arm guided surgery
  - Patient received avg **5.15 mSv** (1.5-7.6mSv)
  - Scan operator received avg **0.005 microSv**
  - Other members of team received **0**

4- Operative Time:
Spinal Robotics: current application and future perspectives. Roser et al. Neurosurgery 2013
  - Substantial more preop and intraoperative time with navigation and robotic assisted

5- Functional outcome of computer-assisted spinal screw placement: a systematic review and meta-analysis of 23 studies including 5,992 pedicle screws. Verma et al. Eur Spine J. 2010
  - Navigation **does not show** significant benefit in reducing neurological complications and there was insufficient data in the literature to infer a conclusion in terms of fusion rate, pain relief and health outcome scores.

6- Economics of image guidance and navigation in spine surgery. AL-Khouja et al. Surg Neurol Int 2015.
  - 13 studies included
  - Average cost $17,650 to $39,643
  - There is currently insufficient data to support cost-effectiveness of Nav/robotics assisted pedicle screws placement.

Conclusion:

1- Free hand technique is still gold standard

2- Navigation/robotics cost more, slow you done and take your focus away from what really matter

3- If you have too many misplaced screws or must use fluoro to get the screw in the pedicle, may be you should either consider quitting or changing career. But if you're like me and you haven't saved enough to retire then you may have to get yourself a robot.

4- My robots will continue to Mow the lawn and Vacuum my living room!

Two Surgeon Teams Improve Performance Parameters

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1. Introduction
   a. Why 2 surgeons should be considered for major spinal deformity surgery
      a. Safety for the patient
      b. Stress reduction for the surgeon
      c. Improves resident/fellow education
   b. Why a single surgeon approach should be challenged
      a. Financially incentivized to work alone
2. The pro's of 2 surgeons
   a. SAFETY
      a. Seattle Spine
         1. Complication 52% → 16%
         2. Return to OR 12.5% → 0.8%
         3. Wound Infection 7.5% → 1.6%
         4. DVT 10%→3.2%
         5. UTI 32.5 → 9.7
      b. Ames et al
         1. 7.6 → 5 hours in OR time
         2. 5..3→ 2 Liters of blood loss
         3. 8.9 → 7.8 days in hospital
         4. 24 → 9 major complications
         5. Return to OR in one month 21.4% → 8.3%
   b. Stress reduction
      a. Recent emphasis on the well being of surgeons
      b. Stress reduction is important for sustaining the longevity of our career
      c. Trouble shooting problems allows for efficient decision making in real time
   c. Improves Educational Experience
      a. Many say the dual surgeons diminishes educational opportunities
      b. 2 surgeons allow for a higher level of responsibility
      c. Allows for surgeons to spend more time talking about the case as there is shared responsibility
3. Why Single Surgeon is not ideal
   a. Everything listed above
   b. Financial dis-incentive to have 2 surgeons in the room
   c. Cases take longer with significant downside
4. Conclusion: It is in the best interest of the patient and surgeon to have 2 surgeons in every complex spine procedure

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Two Surgeon Teams (Can) Dilute the Training Experience

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Complex spine surgery, including many types of spinal deformity surgery, carries substantial risk for the patient. Additionally, complex spine surgery places significant mental and physical work demands on the surgeon. Two surgeon teams are gaining popularity as a solution.[1]

Training the next generation of spine surgeons is complex and difficult as well. Attending surgeons must expertly balance the duty of patient care with the duty of resident and fellow education. There is increasing academic interest in optimizing the educational experience and outcomes, especially among spine surgery fellowships.[2-6]

Spine surgery training programs have a multitude of idiosyncrasies, especially when considered from an international perspective. It is unlikely that "one size fits all." Sharing experiences and ideas from well-established and successful training programs can help optimize outcomes for both patients and surgeons-in-training.

Questions to consider when making a plan for a specific surgery:

Can two attending surgeons work well together? Do they have specific expertise?

When are there "too many cooks in the kitchen?"

When is the resident/fellow/PA/APRN competent to be the "second" surgeon?

What educational experience does the fellow/resident need from this case?

What are acceptable times and EBL for each stage of the procedure?

Preoperative Assessment – update H&P, mark site, counsel patient and family
Anesthesia Induction - confirming Antibiotics, TXA, TIVA, etc…

Patient Positioning – GW tongs? Halo? Mayfield?
Surgical Time Out – skin prep, draping
Exposure – BP management
Placement of Instrumentation – free hand vs. fluoro vs. navigation vs. robotics

Decompression/Osteotomy – epidural scar? durotomy management/repair?

Deformity Correction/Rod Placement

Responding to Neuro-monitoring Changes/Alerts – running the checklist

Decortication and Bone Grafting

Closure

Recovery Room/Postoperative Rounding

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Half-Day Course Program & Handouts
Growth and Scoliosis

Room: 517CD

Course Chairs:

Peter F. Sturm, MD & G. Ying Li

Faculty:

Ron El-Hawary, MD; Sumeet Garg, MD; Judson W. Karlen, MD; Jwalant S. Mehta, FRCS, MS(Orth), D(Orth), MCh(Orth); Peter O. Newton, MD; Colin Nnadi, FRCS(Orth); Stefan Parent, MD, PhD; William A. Phillips, MD; Brandon A. Ramo, MD; Amer F. Samdani, MD; James O. Sanders, MD; Masood Shafafy, FRCS(Orth); Per D. Trobisch, MD; Dominick A. Tuason, MD

HDCA: GROWTH AND SCOLIOSIS

Room: 517CD
Chairs/Moderators: Peter F. Sturm, MD & G. Ying Li, MD

14:35-14:40 **Growth Indicators**
James O. Sanders, MD

14:40-14:45 **How Growth Modulation Allows for Curve Correction**
Peter O. Newton, MD

14:45-14:50 **Long Term Results of Fusion: EOS**
Dominick A. Tuason, MD

14:50-14:55 **Long Term Results of Fusion: AIS**
William A. Phillips, MD

14:55-15:05 **Discussion**

15:05-15:09 **Paper #55 Morphological Analysis of 112 Resected Hemivertebrae from a Developmental Perspective**
Tianhua Rong, MD; Jianxiong Shen, MD; Ningyi Jia, MD; Zheng Li, MD; Chong Chen, MD; Youxi Lin, MD; Haining Tan, MD; Yang Jiao, MBBS

15:09-15:13 **Paper #56 Benefits of Best Practice Guidelines in Spine Fusion: Comparable Correction with Higher Density and Fewer Complications**
Pedro M. Fernandes, MD; Joaquim Soares do Brito, MD; Isabel Flores, PhD; Jacinto Manuel Monteiro, PhD

15:13-15:19 **Discussion**

15:19-15:24 **Functional Outcomes: Pulmonary**
Jwalant S. Mehta, FRCS, MS(Orth), D(Orth), MCh(Orth)

15:24-15:29 **Functional Outcomes: Psychological**
Colin Nnadi, FRCS(Orth)

15:29-15:34 **Available Techniques**
Brandon A. Ramo, MD

15:34-15:44 **Discussion**

15:44-15:48 **Paper #57 Rib Cage Deformity and Pulmonary Function After Surgery in Adolescent Idiopathic Scoliosis**
Raphael Pietton, MD; Houssam Bouloussa, MD, MS; Tristan Langlais, MD; Romain Laurent, MD; Wafa Skalli, PhD; Claudio Vergari, PhD; Raphael Vialle, MD, PhD

15:48-15:52 **Paper #58 A 10-year Study for Lung Function in Patients with Severe Rigid Spinal Deformities (SRSDs) Treated by Posterior Vertebral Column Resection (PVCR)**
Jingming Xie, MD; Ni Bi, MD; Yingsong Wang, MD; Qiuan Lu, MD; Ying Zhang, MD; Zhiyue Shi, MD; Quan Li, MD; Zhi Zhao, MD, PhD; Tao Li, MD

15:52-15:56 **Paper #59 Thoracoscopic Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Mid-term Results of 24 Patients**
Tuna Pehlivanoglu, MD; Ender Ofluoglu, MD; Ismail Oltulu, MD; Ender Sarioglu, MD; Guray Altun, MD; Mehmet Aydogan, MD

15:56-16:00 **Paper #60 Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS: An Eight Year Experience**
John T. Braun, MD; Daniel P. Croitoru, MD

16:00-16:12 **Discussion**

16:12-16:17 **When is the Optimal Time to Intervene: Clinical**
Amer F. Samdani, MD

16:17-16:22 **When is the Optimal Time to Intervene: Basic Science**
Stefan Parent, MD, PhD

16:22-16:27 **Best Practice Guidelines**
Judson W. Karlen, MD

16:27-16:32 **Avoiding Complications**
Masood Shafafy, FRCS(Orth)

16:32-16:42 **Discussion**

16:42-16:46 **Paper #61 Long Term Follow up of Patients with Infantile Idiopathic Scoliosis: Is Rib Vertebral Angle Difference a Reliable Indicator of Progression?**
Adam Lloyd, MBBS, MS; Morgan E. B. Jones, MBBS, FRCS; Jwalant S. Mehta, FRCS, MS (Orth); D (Orth); MCh (Orth); Adrian C. Gardner, MBBS, FRCS; Jonathan Spilsbury; David S. Marks, FRCS; Matthew P. Newton Ede, FRCS

16:46-16:50 **Paper #62 Current Use in Growth-friendly Implants for Early Onset Scoliosis: A Ten-year Update**
Walter Klyce, BA; Stuart L. Mitchell, MD; Jeff Pawelek, BS; David L. Skaggs, MD, MMM; James O. Sanders, MD; Suken A. Shah, MD; Richard E. McCarthy, MD; Scott John Luhmann, MD; Peter F. Sturm, MD, MBA; John (Jack) M. Flynn, MD; John T. Smith, MD; Michael G. Vitale, MD, MPH; Behrooz A. Akbarnia, MD; Paul D. Sponseller, MD, MBA; Children's Spine Study Group; Growing Spine Study Group

16:50-16:54 **Paper #63 Magnetically-controlled Growing Rod Patients Have Similar HRQOL Scores Compared to Traditional Growing Rod Patients After Two Years of Treatment**
David L. Skaggs, MD, MMM; Behrooz A. Akbarnia, MD; Jeff Pawelek, BS; Hiroko Matsumoto, PhDc; Tricia St. Hilaire, MPH; Peter F. Sturm, MD, MBA; Francisco Javier Sanchez Perez-Grueso, MD; Scott John Luhmann, MD; Paul D. Sponseller, MD, MBA; John T. Smith, MD; Klane K. White, MD, MS; Michael G. Vitale, MD, MPH; Children's Spine Study Group; Growing Spine Study Group

16:54-17:03 **Discussion**

17:03-17:13 **Case 1**
Ron El-Hawary, MD

17:13-17:23 **Case 2**
Sumeet Garg, MD

17:23-17:33 **Case 3**
Per D. Trobisch, MD

17:33-17:35 **Closing Remarks**
Peter F. Sturm, MD

Half-Day Course Handouts

Growth Indicators and Spine Growth

James O. Sanders, MD
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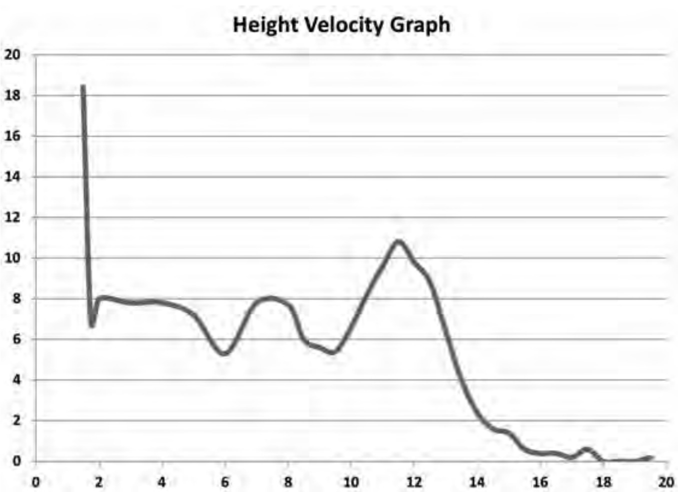
Human growth is unique among animals with a prolonged immature phase followed by rapid growth and skeletal maturity. Safe delivery of an infant with the human brain's large size requires the mother's pelvis to obtain sufficient size at maturity for safe passage. Children are born within a very restricted size which accommodates this maternal pelvic infant head matching. Following birth, children's growth has three major phases.

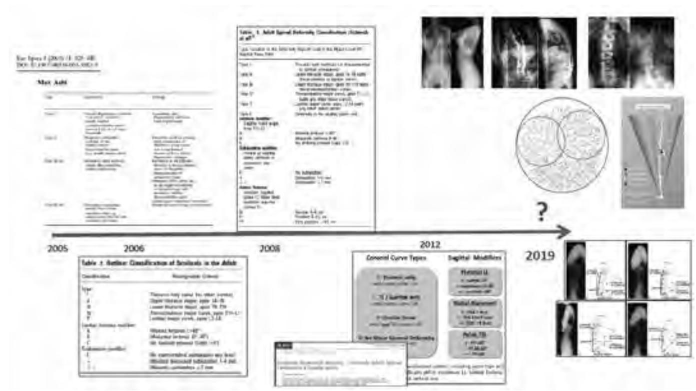


Growth is very rapid during the initial year of life, and then gradually slows until reaching a steady velocity of about 5cm/year at age four. This low, constant rate continues until puberty with the exception of with a small mid-childhood growth spurt around age eight. During the relatively long childhood growth phase, children tend to remain at a constant height percentile compared to their age and sex matched peers, a characteristic described as "canalization". While children tend to remain in a constant percentile relative to same sex peers during the childhood phase, they cross percentiles by entering the adolescent growth spurt at differing times. The change in percentiles as a child ages can be very impressive as some children are growing rapidly at one time while their peers are not. In children with similar environments, normal pubertal timing can vary as much as four years[1, 2]. The adolescent growth spurt typically begins around age 10 for girls, age 12 for boys and spans about four years, beginning about two years before and extending two years beyond the growth peak. The timing of the adolescent growth spurt is not uniform, and boys undergo their growth spurt about two years later than girls.

The Growth Spurt and the Peak Height Velocity:

The maximum growth rate is called the peak height velocity (PHV), and, for musculoskeletal growth, it appears to be the most important maturity marker, likely because it reflects the behavior of physeal endochondral growth. The PHV and its timing are under tight genetic and lesser environmental control[3]. Most studies show peak velocities in girls of about 8cm/yr with a standard deviation of 1cm/yr, and in boys of about 9cm/yr with a slightly larger standard deviation[4-10], and standard reference curves have been developed[9, 11, 12]. Chronological timing of the PHV has been called both the age at peak height velocity (APHV) and the peak growth age (PGA). For simplicity, we will use the term PGA to indicate the timing of the peak height velocity. Tanner first proposed[13] and Buckler first standardized growth by comparing it to the PGA. In this method, PGA - 1yr and PGA +1yr representing one year before and after the PGA respectively[9, 12]. The growth rate peaks about two years later and then slows to cessation after another two years. The two standard deviation range for North American girls' growth peak is 9.7 to 13.3 years[11].

Sanders, et al[14] recently assessed childhood growth and found marked similarity between healthy children of both sexes when their percent of final height is compared to timing relative to their PGA. They identified the coincidence of the PHV timing and completion of 90% final height attainment in both boys and girls. The timing of the 90% adult height's very close correlation with PHV and it more reproducible identification make this timing a useful maturity indicator termed the $PGA_{90\%}$ [see figure].



When the children's heights are normalized to final height and standardized on timing both before and afterwards, the growth patterns of both boys and girls are identical beginning at about 85% of final height which represents the beginning of the adolescent growth spurt. Growth is completed 3.5 years after their PHV. The final 15% of growth is proportionally the same for all children whether boys or girls when standardized relative to the $PGA_{90\%}$. The rate of growth prior to the growth spurt determines the height entering the spurt, which then determines final height.

Maturity Determination:

Maturity is a multidimensional continuum typically determined by chronological age, secondary sexual characteristic staging, growth patterns, or skeletal maturity. Chronological age is reasonable for young children during their initial early rapid growth and in children during their longer steady growth phase when children usually follow a growth percentile. However, because of the variation in growth spurt timing for each sex, chronological age is an inadequate musculoskeletal maturity determination around the adolescent growth spurt.

Secondary Sexual Characteristics

Tanner divided secondary sexual characteristic development into clinically useful stages for breasts and pubic hair development in girl and the scrotum and pubic hair in boys[15-17].

As children mature, their skeletons mature in relatively orderly sequences culminating with maturity and physeal closure. Skeletal maturity scales are based upon radiographic changes associated with this maturation. All these scales were developed similarly by identifying predictable radiographic changes which can be reliably detected and distinguished. There has been very little direct comparison of the maturity scales with each other or with the ultimate measure of growth remaining. In musculoskeletal care, several scales have become prominent because of their specific associations with maturity including spinal deformity prognosis, leg length prediction, and pediatric hip disorders.

The pubertal or Tanner stages are highly though not exactly correlated with the growth spurt and the PHV[10, 18, 19]. Girls' rapid breast development tends to coincide with the acceleration of growth[9]. Girls typically reach their PHV between stages 2 and 3 for breast development and stages 2 to 3 for pubic hair development while boys reach theirs between stages 3 and 5 for testicular and pubic hair growth. Most North American orthopaedists are uncomfortable evaluating patients' secondary sex characteristics in the context of a musculoskeletal examination, and patient self-assessment is unlikely to provide accurate information[20, 21] making secondary sexual characteristic determination problematic in practice. Other secondary characteristics not included in Tanner's staging but helpful in identifying advancing maturity include sweat gland maturation, menarche, voice change, axillary hair, and course facial hair.

Menarche is a readily identifiable maturity indicator associated with beginning the cyclic estrogen-progesterone production in females. We have found menarche follows a normal distribution occurring 0.57 years after the PGA with a standard deviation of 0.57 years. While menarche is usually a reliable sign that growth velocity is decreasing[9, 10], the early menstrual periods are often irregular, and menarche's timing relative to the PGA is much too variable for accurate assessments.

Direct Height Measurements:

The most definitive determination of PHV timing is by measuring height velocity at sequential visits. Accurate height measurement is an exacting task and not often properly done outside of studies. Ideally, height should be measured at the same time of day for every visit because of diurnal variation of up to 1.4 cm[22]. The patient should be stretched by applying gentle manual upward pressure on the mastoids while assuring the feet remain flat on the floor. Sitting height has the potential of looking more closely at spinal growth, but we have found it quite difficult to obtain reliable sitting measurements. Obtaining accurate serial height measurements for maturity determination is often impractical. Short-term growth is non-linear and has periods of both rapid and of little activity[23] creating strange velocity calculations, and a single misreported height can make PHV assessment difficult[24]. Adolescents arriving for evaluation and treatment rarely have accurate serial prior height measurements available, and other maturity indicators are needed. Directly monitoring long-bone and spine physeal activity has been challenging because of the diurnal variation in height caused by spinal disc compression and height shrinkage throughout the day. Individual long bones with readily available anthropometrics have been the only skeletal regions where this has been feasible. The recent description of type X collagen fragments[25] may allow more direct determination of physeal activity over short and longer periods.

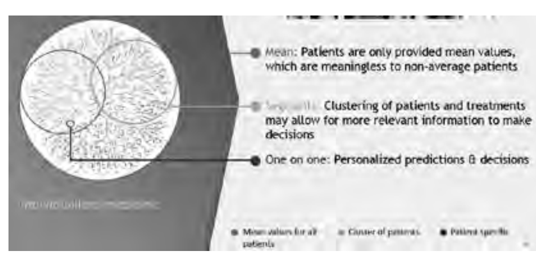
Skeletal Maturity

Skeletal age has been prime maturity measurement for most specialists. Skeletal age is based on bones growing and physis radiographically maturing in orderly, distinguishable sequences. It is useful to consider skeletal age as a developmental stage or maturity level rather than a linear "age". The skeletal radiographic appearance is dependent upon both the overall hormonal maturation state and the inherent genetic control of each particular physis. Any skeletal region with consistent physeal markers is amenable to determining a skeletal age. Just like in linear growth, the physeal appearance is highly dependent upon estrogen levels in both boys and girls.

Important Skeletal Maturity Nuances for Orthopaedists:

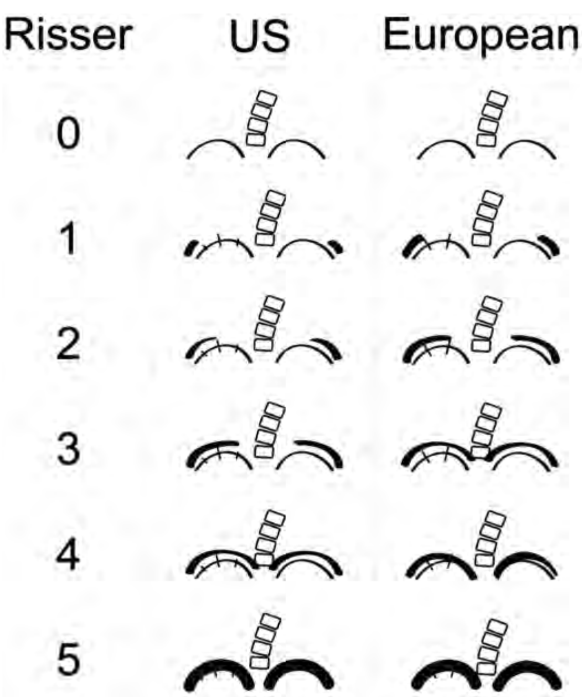
Skeletal ages are derived from healthy children, so their use in children with illness or skeletal dysplasia can be misleading. The most common error in skeletal age determination is malpositioning. In the hand, slight flexion of any digits making interpretation difficult, and rotation can cause the same problem in the elbow.

The Hand: Knowing the various stages of hand's changes is not difficult and is important for accurate maturity determination regardless of which system is used. The various stages of the digits during adolescence are shown in figure **[see figure]** going from uncovered, to covered, to capped, to fusing, to fused.



The ulnar side of the hand (the fourth and fifth digits) is the last to have fully covered epiphyses, the proximal epiphyses cap their respective metaphyses slightly before the distal epiphyses, the distal phalanges close before the proximal and middle phalanges, the digits close before the metacarpals, and the distal radius closes last of all. We have developed a reliable classification system based upon this which corresponds closely to the PHV.

The Risser sign is a commonly used as a maturity indicator in scoliosis based on the radiographic excursion of iliac apophyseal ossification[26-29]. The Risser sign's advantages are its ready appearance on standard AP views of the spine and that it typically proceeds in orderly fashion. However, because of concerns of breast irradiation, most scoliosis films are now PA rather than AP. Unfortunately, because of radiographic parallax, it is much less visible on PA radiographs. If the patient also has a lateral radiograph, then the ossification can sometimes be more clearly seen on the lateral. The Risser sign appears after the PHV[30], does not correlate well with skeletal age and correlates differently in boys than in girls. There are differences between the European and North American Risser signs shown in the figure below.



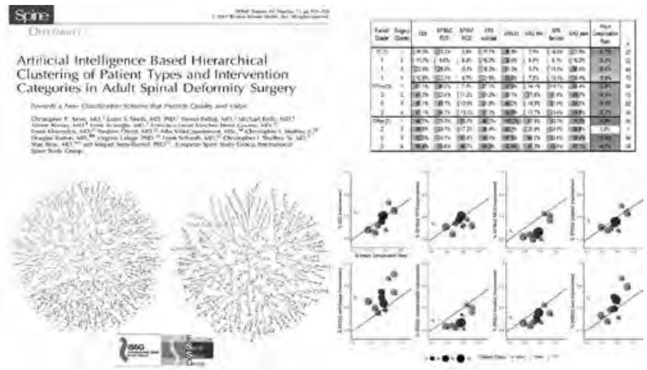
Girls typically have little remaining growth at Risser 4 while boys still have significant growth and may continue to have significant curve progression between Risser 4 and 5. The utility of the Risser sign can be improved by including the pelvis, which has a large number of physeal and apophyseal ossification centers, on the radiographs. However, this utility must be balanced with the increased gonadal irradiation. The triradiate cartilage is currently the most useful of these as it typically fuses before initial iliac apophyseal ossification begins and also correlates closely with the PHV [2, 19, 31, 32].

The elbow has a number of ossification centers visible during the adolescent growth spurt making it useful during puberty[33-37]. DiMeglio and colleagues have looked at the Sauvegrain method during puberty and found it reliable with potential advantages to the Greulich and Pyle with more potential stages during adolescence. Charles, et al[35], have developed a system based on just the olecranon which has reliable stages during adolescence. We [38]compared Sauvegrain scores in both boys and girls and found it highly related to PGA.

Other Skeletal Markers

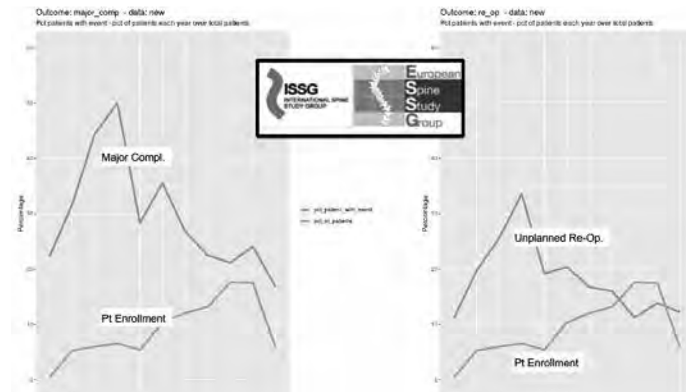
Obviously, there are other potentially useful skeletal sites besides the hand, elbow, and pelvis including the spine with a number of markers particularly ossification of the rib heads and the ring apophysis[39], the cervical spine's appearance[40-42] [43-51], the knee[52-54]the foot [55-57] , and the shoulder which are rarely used for accurate maturity determination. We have developed further simplified methods of maturity staging from the calcaneus, foot, knee, and shoulder which are highly correlated with growth remaining. The shoulder is attractive because it can be seen on scoliosis radiograph if the problems of standard positioning can be addressed.

The adjacent figure shows a comparison of timing of various skeletal maturity assessments which have been described for spinal growth.



Utility of Skeletal Maturity Measures

Although skeletal maturity scales have developed empirically from radiographically distinguishable landmarks, these differences are only useful if they actually correlate with where a child is in their physical growth. From our studies of skeletal maturation and growth, it makes more sense to develop skeletal maturity scales whose distinguishable phases directly reflect growth rather than simply occur sequentially. The coalescence of skeletal maturity as a child enters the growth spurt has been noted by other investigators[58] though the exact timing has not. The hand stages as describe by Sanders, et al[59], are nearly identical between boys and girls at the same stages of the growth spurt and imply that using skeletal maturity appearance itself rather than separate male and female skeletal ages should allow more reliable study of the human growth spurt. **See figure below.**



Type X Collagen Biomarker:

Finally, there is exciting work being done from the Shriners Hospital for Children in Portland who identified a stable biomarker for type X collagen[25]. Growing cartilage has abundant type X collagen at the terminal hypertrophic zone, and its serum levels correlate well with height velocity. It is possible that this biomarker, particularly combined with skeletal maturity measurements.

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How Growth Modulation Allows for Curve Correction

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Anterior Vertebral Body Tethering in Scoliosis

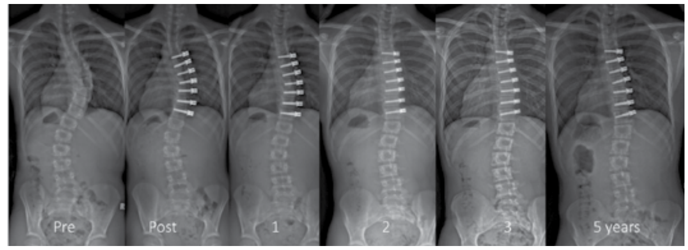
Hueter Volkmann Principle
- Compression across a growth plate limits growth
- Commonly used in limb alignment correction for growing children
- Spine is different – disc within the zone of compression

Animal studies
- Tether changes physeal cartilage zones of proliferation
- Changes in 3D shape of vertebra possible
- Effects of dynamic compression on the disc – physiology and shape

Growth remaining predictions important
- How much time, how much growth remaining per level

Segmental deformity of Scoliosis
- 3D deformity of each vertebra and each disc
- More at the apex
- Bigger discs distally
- Sagittal plane considerations

Clinical Experience
- Powerful tool when growth remains
- Predictability challenges
- Short vs Long term outcomes



Long Term Results of Fusion: EOS

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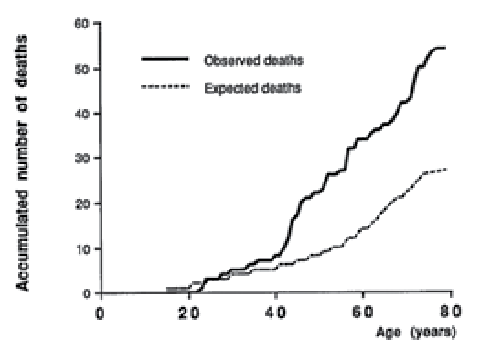
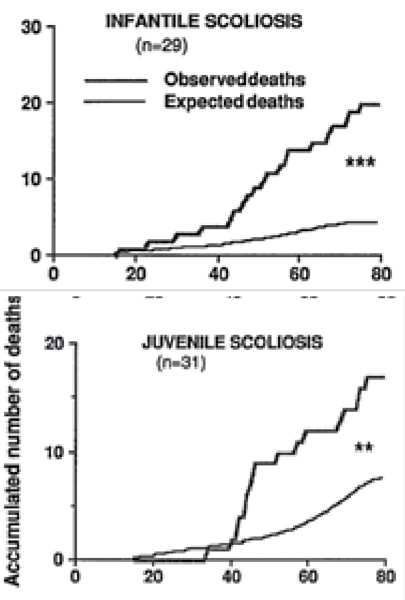
Natural history of untreated scoliosis

- In 1992, Pehrsson reported on a cohort of 115 patients originally studied by Nachemson 24 years earlier.
  - All patients had untreated scoliosis
  - The mean time of follow-up was 56 years
  - **55 of 115 patients had died; expected number of deaths in a group of patients with same age and sex distribution was 27**



- Mortality was increased in severe scoliosis (>70 degrees)

- Mortality was increased in infantile and juvenile scoliosis; not in AIS



- o **Key point:** prognosis is poor in untreated early onset scoliosis, particularly when curves are severe (> 70 degrees)
    - o Increased mortality was largely due to respiratory failure
    - o Increased frequency of hypertension in surviving patients
- o **Conclusion:** Early treatment (fusion) is best in early onset scoliosis

Growth of the spine after birth (Dimeglio JPO B 1992)

- "Age 5 is a turning point between fast, strong spine growth and slow spine growth"
- "Growth deficiency of sitting height after arthrodesis (at age 5) is limited"
    - o **Key point (1992):** "Short, straight spine is better than a long, crooked spine"
        - ▪ Supports early fusion for progressive early onset scoliosis

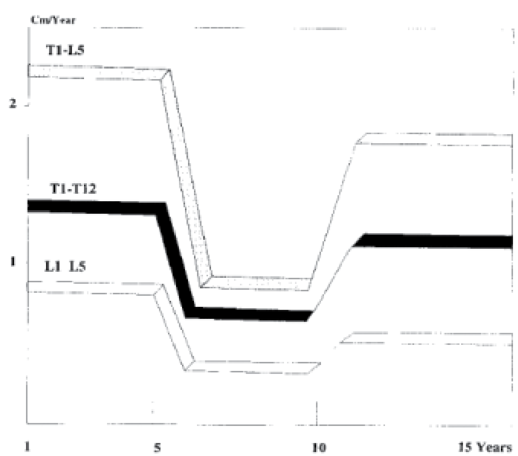
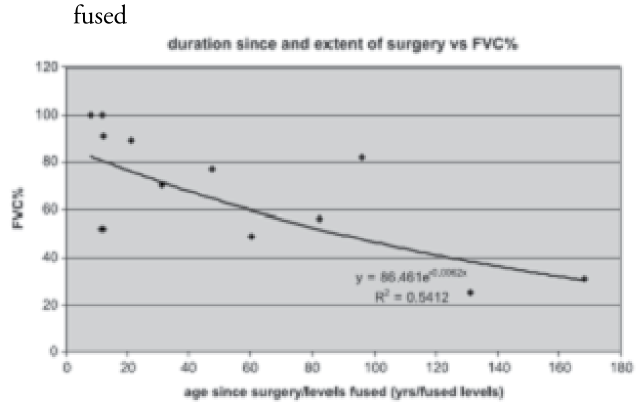


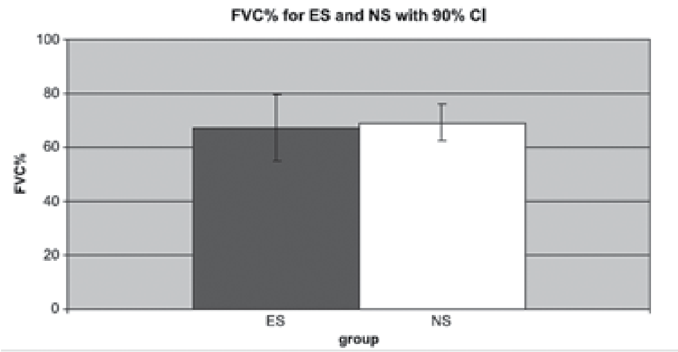
FIG. 7. Growth velocity of T1/L5 segment; thoracic segment T1/T12, and lumbar segment L1/L5.

Intermediate outcome after early fusion for scoliosis

- o In 2003, Goldberg et al. reported on 23 patients with infantile idiopathic scoliosis who were followed to over age 15 years.
    - o Six patients had their scoliosis resolve or were stabilized by nonoperative means at an acceptable Cobb angle
        - ▪ This group had normal cosmesis and pulmonary function (mean FEV1=98.7%, mean FVC=96.6%)
    - o Six patients were managed by casting or bracing and underwent surgery after age 10 (mean age at surgery 12.9 y)
        - ▪ These six had variable cosmesis and acceptable pulmonary function (mean FEV1=79%, mean FVC=68.3%)
    - o 11 patients had progressive deformities that required early surgery at an early age (mean age at surgery 4.1 years). 9 of these had spinal fusion. These children had **recurrence of deformity** (mean Cobb angle at initial surgery was 70 degrees and mean Cobb angle at latest follow up was 80 degrees)
        - ▪ 45% of patients had progression of deformity despite attempted fusion
        - ▪ The 11 patients, on average, showed **diminished respiratory function** (mean FEV1=41%, range 14%–72%, mean FVC=40.8%, range 12%–67%)

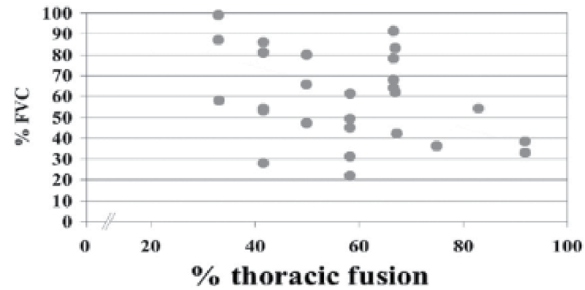
- o In 2004, Emans et al. reported on a series of 13 patients with congenital scoliosis patients fused at an average age of 2.5 years (1-4.5) with an average of 6.9 levels fused
- o **Earlier and more extensive thoracic fusion was associated with diminished pulmonary function**
    - ▪ At an average of 10.8 years' follow-up, the FVC averaged 62% (32% to 94%), with a younger age at fusion being correlated with decreased pulmonary functions and decreased body height.
    - ▪ **Greater number of thoracic levels fused was associated with decreased pulmonary function**
- In 2008, Bowen et al. compared PFTs of 30 patients with congenital scoliosis who had not had any surgery (NS) with those of 13 patients who had early fusion (ES)
    - o Mean age NS = 10.8
    - o Mean age ES = 9.7 (avg. age at surgery 2.9 years)
    - o In ES group there was a trend toward lower FVC% with longer follow-up and greater number of thoracic levels fused





- FVC was decreased in both groups but not significantly different between groups
- Between initial and final follow-up, rate of change of thoracic height and width was decreased in ES vs. NS group

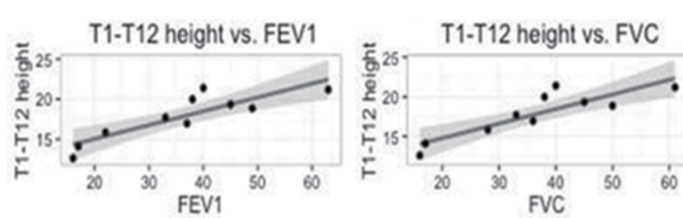
- In 2008, Vitale et al. reported the pulmonary functions on 21 of a series of 62 patients who underwent fusions for congenital scoliosis
  - 12 had a thoracic fusion averaging 7.2 levels at a mean age of 5.3 years at surgery
    - Average follow-up was 6.9 years
  - The FVC for patients who had thoracic fusion at follow-up was 64% of predicted normal
    - This was significantly lower than children with congenital scoliosis who had nonthoracic fusion
    - Data suggests that the patients have developed restrictive lung disease because their thorax could not grow along with the contents of the thoracic cavity
- In 2008, Karol et al. reported on the pulmonary function following early thoracic anterior/posterior fusions in non neuromuscular scoliosis (fusion at less than nine years of age, minimum five year follow-up)
  - Reported on 28 of the 54 eligible patients, of whom 20 had congenital scoliosis
  - Average age at surgery was 3.3 years, with an average of 59% of the thoracic spine fused
    - **39% required revision surgery** due to progression despite initial attempt at fusion
    - At an average age at follow up of 14.6 years (11.3 years follow-up), **the average FVC was 58% of predicted normal**, with two patients requiring respiratory support
      - Clinically significant restrictive lung disease (FVC < 50% predicted normal) was present in 12/28 (43%) of patients
        - All of these patients had 4 or more thoracic segments fused
    - Thoracic height was > 18 cm in 16/28 cases, with an in**verse relationship between the FVC and the extent of thoracic** fusion



- In addition, there was a correlation between the proximal level of the fusion and the decreased FVC
  - Eight of 12 patients with proximal fusion level of T1 or T2 had FVC < 50%
  - 4 of 16 with proximal fusion level of T3 or caudad had FVC < 50%
- **Key point: Spinal fusion at an early age limits the capability of the thoracic spine and cage to grow normally.** Patients who have greater than four thoracic segments fused and a proximal fusion level of T1 or T2 are at highest risk for development of restrictive pulmonary disease. **The pursuit of alternative procedures to treat early spinal deformity is merited**

Long term follow-up after fusion in early onset scoliosis

- In 2017, Bouton et. al. showed that during long-term follow up (minimum 18 years) of the patients in Karol's cohort, **patients had a continued decline in pulmonary function relative to their age as they enter adulthood**, which can be life-threatening
  - Nine of 28 eligible 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 predicted FVC (38.7% vs. 48.7%; p=0.0154) and FEV1 (38.2% vs. 47.8%; p=.0160). There was a positive correlation between thoracic height and both FEV1 and FVC (Corr=0.866, 0.872; p=0.001). The average patient's 6-minute walk test results were 62% of age-matched normals.



- In 2018, Lonstein reported on 11 congenital scoliosis patients who were fused at younger than age 8 and had a long term follow up of 37 years on average. Patients had a low FVC of 53%, one was on permanent oxygen and five complained of dyspnea
  - In this study, like others, there was a tendency to a reduced

FVC with a shorter thoracic spine, but this was not statistically significant in this series.
- There was no correlation between the percentage predicted FVC and the proximal fusion level and no relationship between the SAL and the FVC percentage predicted
- The outcome measures showed little back pain, a high rate of employment, normal range SF-36 scores, and some symptoms of dyspnea at rest and with stairs and problems sleeping

Key points:

- Spinal deformity is not well controlled by early fusion since revision surgery has been required in up to 39% of patients who underwent presumed definitive fusion in early childhood
- Restrictive pulmonary disease, defined as forced vital capacity less than 50% of normal, occurs in 43% to 64% of patients who undergo early fusion surgery with children who have extensive thoracic fusions that involve the proximal thoracic spine at highest risk
- Thoracic growth after early surgery is an average of 50% of that seen in children with scoliosis who do not have early surgery
- Diminished thoracic spinal height correlates with decreased forced vital capacity
- The literature does not support routine definitive fusion of thoracic spinal deformity at an early age in children with scoliosis

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Long Term Results of Fusion: AIS

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Lecture goals

Briefly summarize:

1. Lessons from long term studies
2. Limitations of long term studies
3. Importance of long term studies

1. lessons from long term studies
   a. Most patients do reasonably well with surgery
      i. "one and done" for most (95%) but not all
   b. Big picture- effects of any spinal fusion
      i. Activity
      ii. Pain
      iii. Pregnancy
      iv. Radiation exposure
   c. Limited correlation of x-rays with outcomes
      i. lowest level fused
      ii. residual curves- both fused and unfused
      iii. changes in spine below fusion
   d. "Fine print"
      i. Balance- coronal and sagittal
      ii. Approach- back or front
      iii. Fusion levels- how low should you go?
         1. Should LIV be horizontal?

2. limitations of long term studies
   a. limited numbers, many patients lost to follow-up
   b. images and clinical records inaccessible or lost
   c. varying outcome measures
   d. non-contemporary instrumentation
   e. still only around 30 years

3. importance of long term studies to our patients and our specialty
   a. What convinces us as spine surgeons may not be as convincing to others
   b. Families and we intuitively understand fusion would be nice to avoid
   c. While we can't yet "cure" scoliosis, how well might we manage it without fusion?
   d. "Nothing ruins validates good results like longer follow-up."

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Functional Outcomes: Psychological

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Introduction

The aim of surgical treatment in Early Onset Scoliosis (EOS) apart from controlling curve progression and optimizing growth is to enhance the well-being of the child. This is the ultimate aim of all our treatment strategies in the management of this very challenging and complex condition. These strategies are not just clinical but involve education, fostering relationships and social interactions and in many cases political interventions.

The accepted domains of child well-being are physical, psychological, cognitive, social and economic. Treatment of EOS can negatively impact on any of these domains.

This talk focuses on the psychological impact of surgical treatment in the hospital environment and possible management strategies to minimize negative healthcare experiences for the child.

Positive psychology is a term coined in the 1990's to catalyse a change in psychology from a preoccupation only with repairing the worst things in life to also building the best qualities in life." This approach is very much in tune with how we should approach our EOS patients.

Studies have shown that up to 20% of children admitted into a hospital experience some degree of behavioural and/or emotional disturbance and repeated hospitalization increases the chances of later problems. Pre-operative anxiety, emergence delirium and post-operative behavioural changes are all manifestations of psychological distress in children undergoing surgery. Pre-operative anxiety is most prominent in the anaesthetic induction room. Emergence delirium is frequent and independent of pain levels. Behavioural changes include separation anxiety, tantrums, fear of strangers, eating problems, nightmares, bed-wetting and can last up to a year or more.

Risk factors have been identified which include age <6 years, previous negative experiences in healthcare, type of hospitalisation, post-operative pain, parental anxiety and certain personality traits.

The concern around the psychological impact of EOS treatment is not a radical concept but is gaining more prominence in an era where the focus is increasingly on patient centred care. Much concern has been voiced around the repetitive anaesthesia tendencies that so dominate the treatment of this condition.

The concerns do not just centre around psychology but also the impact of the various aspects of treatment on the physical anatomy which lead to secondary effects on development, cognitive function and behaviour. Studies have commented on the effects of relatively mild exposure to ketamine, midazolam or a combination of these drugs in triggering apoptotic neurodegeneration in the developing mouse brain. The clinical relevance of these studies has been called into doubt however due to contrasting human and rodent physiology. There are also questions around the relatively high doses of anaesthetics and long duration of anaesthetic exposure used to trigger apoptosis in these studies. There are also studies which have looked at the psychosocial effects of repetitive surgeries in children with early-onset scoliosis and found a higher prevalence of abnormal scores in multiple psychosocial domains in the cohorts as compared to national normative data. Aggression, Rule-breaking, and Conduct were positively correlated with total number of surgeries. The authors advocate a need for ongoing screening and mental health care in this high-risk population. Other studies have looked at neurobehavioral functioning of children with EOS after treatment with specific growing rod devices (rib-based growing rod system – RBGS). They concluded that "at risk" children were younger at initial RBGS implantation and had more total surgeries and RBGRS surgeries. A more recent study compared Traditional Growing Rod (TGR) and Magnetically-controlled Growing Rod (MCGR) patients to see if decreased surgical stress really did improve the psychosocial health of Early-onset Scoliosis patients. The authors concluded that there was no difference in psychiatric diagnoses between the groups. MCGR patients scored worse than TGR patients in general functionality domains. TGR patients showed increased functionality and prosocial scores with increased number of procedures. This study however does raise questions about familiarity bias as the length of follow up was significantly different between the groups. Finally, a very large retrospective cohort of more than 10,000 patients from the New York State Medicaid program were analysed for exposure to anesthesia and risk of developmental and behavioral disorders. The conclusions made interesting reading – "The risk of being subsequently diagnosed with developmental and behavioural disorders in children who were enrolled in a state Medicaid program and who had surgery when they were younger than 3 years was 60% greater than that of a similar group of siblings who did not undergo surgery".

In order to mitigate the risk of these problems, preventative strategies in the form of Behavioural Preventative Programmes (BPP) are often advocated. These include pre-operative and post-operative measures to minimize the psychological impact of surgery.. These can involve role play and modelling to mention a few. They are controversial and not always successful. One systematic review found the evidence related to the use of therapeutic play on anxiety and behavior of children undergoing invasive procedures is still questionable. The lack of random sequencing to assign patients to the different groups as well as blinding allocations are cited as factors contributing to this uncertainty.

Despite these uncertainties I would advocate closer working relationships with children's psychologists in the surgical management of EOS. In Oxford where I practice psychology involvement is standard of care for children under 10 years undergoing EOS treatment whilst we use the following criteria for the older adolescent group:

1. Significant anxiety with prospect of surgery
2. Significant distress
3. Patients with emotional and behavioural difficulties
4. Long in-patient stay cases
5. Assistance with decision making

Post-operativel factors which may require input include compliance with physiotherapy or body image issues.

We also use "Hospital passports" which is a small booklet that contains information on the child's preferences and needs in hospital to safely navigate the clinical pathway. This is made readily available to all members of the multidisciplinary team. We have found this very useful.

In summary the surgical management of EOS in addition to controlling spinal deformity and optimising growth seeks to enhance the well-being of children through improvement in quality of life. This relies not just on successful surgery but also on attention to the psychological support which forms a key part of several multi-faceted factors in order to optimise outcomes.

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Available Techniques: Surgical Options for Managing Scoliosis before Fusion

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Brief Outline:

1) **Distraction-Based Systems**
2) **Compression-Based Systems**
3) **Guided Growth Systems**

Distraction-Based Systems

Utilize anchors proximally and distally attached to the spine, ribs, and/or pelvis to apply distracting forces. Original example was the Harrington rod.

- Currently available in use are the vertical expandable titanium rib, magnetically controlled distraction rods, and custom-created implant systems from available components which are FDA-approved for other indications.
- **Pros:**
- Established use with at least 2 implants having FDA approvable for EOS indications.
- Familiarity with anatomy and the systems by most scoliosis surgeons.
- Track record of relative success in publications including growing body of literature in "Growing rod graduates." Can occasionally simultaneously treat chest wall and spine deformities.
- **Cons:**
- Repetitive surgery is guaranteed.
- Complication rates remain extraordinarily high compared to most scoliosis surgery disciplines.
- Currently available magnetically lengthened implants lack 5 year data in the US. Early published reports on magnetically lengthened rods have indicated a reduced number of planned surgical lengthenings compared to traditional growing rods without a reduction in unplanned surgery for complications.
- Adverse effects of local metallosis related to wear and debris of both traditional and magnetically controlled growing rods is

not well understood.

- Cost of currently available magnetically controlled rods may be cost prohibitive in some health care systems
- Once implanted, these systems must be lengthened consistently operatively or non-operatively to prevent becoming a posterior tether.

Compression-Based Systems

- Utilizes a surgical approach which compresses the apex of the deformity in theory allowing growth of the convexity to correct the deformity. Similar concept of the application of Hueter-Volkmann principle with staples and side plate and screws as is utilized in lower limb alignment deformities. Currently, this is generally performed as an anterior-based surgical strategy via thoracotomy or thoracoscopy. Original implants have included a variety of stapling devices to bridge between multiple successive vertebral bodies. Current "in-vogue" strategies have largely shifted to "tethering" while utilizes a flexible cord to be attached to anchors in the anterior vertebral bodies.
- **Pros:**
- Compression-based guided growth provides theoretical advantage of avoiding an intended spinal fusion and presumably may leave more mobility to the treated portion of the spine. This also avoids disruption of the posterior articular facets and paraspinous muscles.
- There is a theoretical promise of a well-timed tethering at the proper Cobb angle and skeletal maturity could lead to full correction of scoliosis at the cessation of growth. This could allow a single surgery rather than repetitive procedures.
- **Cons:**
- theoretical concerns of limiting growth of the convexity of the spine when generally a goal of EOS surgery is to lengthen the spine.
- No currently FDA-approved devices in the United States.
- Published indications for stapling of the spine have had significant overlap with published indications for bracing the immature spine.
- Strategies to operatively treat scoliosis with mechanical implants without spinal fusion have historically had poor track records (Harrington's original article as first example).
- An anterior tether should theoretically create accentuated kyphosis so may not be appropriate for kyphoscoliosis patients.
- There are no long-term studies of tethering available. Unpublished preliminary reports have indicated reoperation rates for tether failure, adding-on, and overcorrection as high as 50%. Good results at 1-2 years have not predicted good results at 5 years and beyond because of the inherent failure mechanism of the utilized device being one of cyclical loading over time.
- The promise of leaving more mobility to the treated portion of the spine has not been corroborated yet and unintended autofusion of the instrumented segments has the potential to negate this benefit.
- The indications for surgery must be better defined relative to both curve severity and patient skeletal maturity

Guided Growth Systems (posterior-based)

- Currently available systems include the use of pedicle screws, hooks and/or wires to create a system which allows attachment to the spine at proximal, middle and distal portions of the spines. Rods can be locked to the central portion (fixed apex construct) and attached via unlocked proximal and distal anchors allowing gliding of the proximal and distal anchors away from the apex. Alternatively, proximal and distal anchors can be attached to overlapping pairs of rods which are then allowed to glide at the central apical aspect of the deformity (Luque trolley and modified Luque trolley concept). Both concepts allow for the implantation of instrumentation at one setting without the need to return for repetitive surgery to lengthen the implants.
- **Pros:**
- Telescoping of the rods on unfixed anchors while attached to fixed anchors allows for growth of the spine without the need for repetitive interventions by the surgeon either in the OR or in clinic. This may allow for single event surgery.
- Newer implant systems are in development (not yet FDA approved for US) which may incorporate polyethylene bands into screws to allow gliding without metal-on-metal friction.
- **Cons:**
- Experience has been primarily at a limited number of centers and success of these implants has not been replicated at centers with less experience in the literature to date.
- Metallosis due to current available implants allowing metal rods to slide through metal screws remains a concern.
- Technique works best when the spinal deformity can be largely corrected at initial implantation so may not be as effective with severe deformity or significant rotation.
- Typically, for a fixed apex construct, 3-5 segments are fused which removes growth potential at those levels.

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When is the Optimal Time to Intervene: Clinical

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1. Introduction
   a. Vertebral body tethering (VBT) is a growth modulation procedure
   b. Current clinical and basic science literature is on patients with growth remaining
   c. Even with growth remaining, VBT is unpredictable

2. Skeletally immature
   a. Triradiate open patients likely to over correct if smaller curve that is very flexible

b. These patients at very high risk for adding on
c. If one is going to intervene, leave residual curve
d. Patient example of overcorrection
   i. Requires release of tether
   ii. Scar tissue can be substantial

3. Skeletally mature
   a. No growth, or insufficient growth, the vertebral bodies will not modulate and tether will likely break
   b. Some surgeons consider double tethers, but difficult to ascertain effect on motion and will tether eventually break again
   c. When option to do selective thoracic fusion, I always only offer to these patients

4. Literature review
   a. Newton JBJS 2018
      i. 17 patients (16/17 triradiate open)
      ii. Reoperation in approximately 50%
   b. Miyanji et al SRS 2018
      i. 32 patients
      ii. Skeletally immature Risser less than 3
      iii. 18% reoperation
   c. Hoershenmeyer et al POSNA 2018
      i. 29 patients
      ii. Mean Risser 1.8
      iii. Four over corrections, 2 progressions
   d. Samdani et al SRS 2019
      i. Prospective/Retrospective FDA IDE study

5. Clinical significance
   a. Motion- we need to look at closely with motion studies
   b. Sagittal profile- perhaps better than PSF but need 3D studies
   c. Disc health- future studies

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When is the Optimal Time to Intervene: Basic Science

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Introduction and Background

Normal vertebral growth is the result of a complex interaction between more than 130 functioning growth plates that work together to allow for 3D growth of the spine, as well as for the development of the thoracic cage and the lungs [1,2]. It is a complex process involving succession of acceleration and deceleration phases. Knowledge of normal growth parameters is mandatory to understand the pathologic modifications induced on a growing spine by an early onset spinal deformity [1,2]. Spinal growth abnormalities result in a significant reduction of thoracic and lung volume [1,2,3,4], which may lead to thoracic insufficiency syndrome [5]. Left untreated, this condition may eventually lead to *cor pulmonale* and death [1,2].

Idiopathic scoliosis is the most common form of scoliosis and affects 2-4% of children and adolescents. As adolescent idiopathic scoliosis (AIS) is a deformity affecting youth (>10 y.o.), juvenile idiopathic scoliosis (JIS) is a subset of scoliosis characterized by early onset at an age below 10 years. The risk of progression of scoliosis is related to both the magnitude of the spinal curvature and to the remaining growth of the child. As a result, JIS patients are at greater risk for developing severe deformities.

The treatment of early onset scoliosis is critical to enhance quality of life, to prevent complications and to permit normal thoracic and lung development. The choice of corrective treatment depends on the severity of the curve. Non-operative treatment by casting and/or braces can be used for patients with progressive JIS greater than 25°. When the curve exceeds 40-50°, surgical treatment is often indicated. For several years, the traditional surgical treatment has been spinal fusion, a definitive procedure in which vertebrae are fused together by arthrodesis. Unfortunately, this treatment was at the expense of any remaining spine growth within the fused regions and, when performed before the end of growth, spinal fusion resulted in a shortened trunk with impaired thoracic development and subsequent pulmonary hypoplasia. More recently, "growth friendly" treatments have been developed that not only prevent further scoliosis progression, but are critical to permit normal spine, thoracic and lung development. These techniques include expandable rods that stabilize the scoliosis, yet allow for continued growth. Another method is Anterior Vertebral Body Growth Modulation (AVBGM) of the spine. This technique works by attachement of a anterior vertebral tether on the convexity of the deformity thereby slowing growth on the convex side, decreasing asymmetrical forces on the growth plate and restoring concave growth and length on the concave side. A thorough knowledge of 3D thoracospinal growth is essential to the understanding of the best timing for these interventions, for determining the extend of required induced growth modulation and operative strategies, as well as for assessing the success of these interventions.

What do we know about normal spine growth?

The vertebrae form from the primitive neural axis during embryological spine formation. The mesoderm will form into paired somites around the notochord (which itself will develop into the nucleus pulposus). The somites will give rise to the sclerotomes with the ventral portion becoming the vertebra and the dorsal portion becoming the neural arch. These will in turn give rise to several ossification centers and also provide ossification centers for the ribs. As the spine grows, ossification occurs, and these ossification centers will eventually fuse. The spine grows more rapidly than the neural elements explaining the position of the cord at birth compared to early gestation. At birth, the cord is usually in its mature position and ends around L1-L2.

Longitudinal bone growth occurs through endochondral ossification and intramembranous bone growth occurs in flat bones such as the skull. Long bones respond to different stresses and stimuli. The Hueter-Volkman law states that bone growth is retarded by increased mechanical compression and is accelerated by reduced loading. Wolf's law states that bone will adapt to loads it experiences (more load increases bone density). Longitudinal bone growth results from endochondral ossification i.e. synthesis of cartilaginous structure with secondary ossification. The physis (growth plate) is the location of this activity and is subject to hormonal variations and loads. Longitudinal bone growth usually stops at the end of adolescence with closure of the physis. Early during formation a fetal hyaline model develops for long bones. Cartilage then starts calcifying giving rise to primary ossification center forms in diaphysis and secondary ossification centers form in epiphysis. Towards the end of growth, ossification of the physis occurs and and bone growth stops

The vertebra does not have a formal growth plate but rather a growing cartilage. This growing cartilage is located at the junction between disk and vertebral body. The ring apophysis will appear during growth and progressively ossify until it unites with the body at the end of growth.

Some studies have attempted to partially fulfill the goal of understanding normal vertebral growth, but it has never been achieved in a detailed, precise and reliable way [6-10]. Using one dimensional coronal plane radiographs, Dimeglio et al. has published sparse data on expected total spine height change during growth but no data at the individual vertebral level or thorax. According to their data, the growth of the thoracic spine is 1.3 cm/year between birth and 5 years of age, 0.7 cm/year between the ages of 5 and 10 years and 1.1 cm/year throughout puberty [1,2]. This one-dimensional data has long been the gold standard for the measurement of spine growth. As current 3D reference spinal dimensions and growth curves for the pediatric spine did not exist, current prescriptions for growth-friendly scoliosis surgeries are made with limited knowledge of the normative growth of the immature spine.

Recently, clinicians have had access to an innovative biplanar imaging technology that utilizes two orthogonal beams of X-rays directed towards a particle detector (Charpak 1992; Nobel prize), intersecting to create two simultaneous linked orthogonal images of an object (in this case, the full length of the spine of a patient), one postero-anterior (PA) and one lateral (LAT). This technique significantly decreases radiation exposure: 8 to 10 times that of conventional X-rays and 800-1000 times that of CT-scan. The digital images can then be imported in a software to create an accurate full-length 3D reconstruction of the spine. This technology allows for low radiation acquisition of cross-sectional and longitudinal data for this comprehensive 3D reference data set of spine growth in normal spines.

In an effort to characterize spine growth in all three dimensions, our research group has developed and validated custom software for precisely measuring the spine throughout multiple dimensions. This includes sagittal spine length (SSL) and 3D true spine length (3D-TSL). A recent multicenter effort has provided the data for longitudinal spine growth to provide reference values for 3D spine dimensions in healthy children and to measure 3D True Spinal Length (3D TSL) and Vertebral body heights as a function of age. This data was then used to estimate centile curves for 3D TSL as a function of age and to calculate growth rate (changes in 3D TSL per month) in the selected age categories.

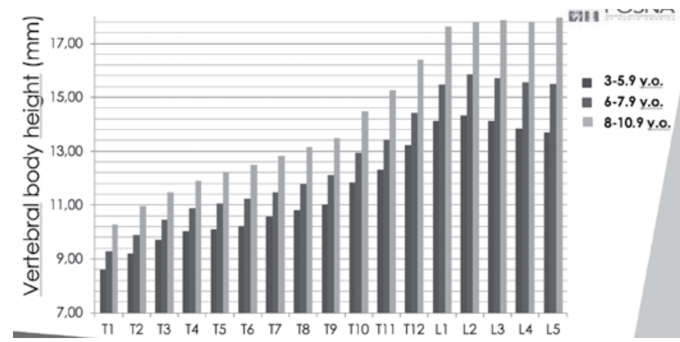

Figure 1 illustrates mean vertebral body heights (mid-vertebra) computed for thoracic and lumbar vertebral levels. Colors identify the selected age groups. Figure 2 presents the centile curves (5th, 10th, 25th, 50th, 75th, 90th, 95th) as a function of age for the 3D True Spine Length (T1-S1). On longitudinal data, mean growth rates were: 3-5.9 yo: 1.16mm ±0.55mm; 6-7.9 yo: 1.15mm ±0.44mm; 8-10.9 yo: 1.29mm ±0.86mm.

Figure 1. Mean vertebral body heights (mm).

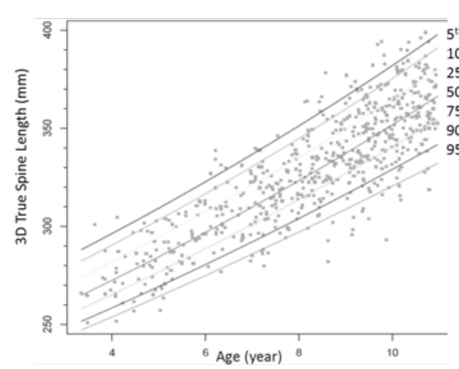

Figure 2. Centile curves for 3D True Spine Length (mm) as a function of age.

When is the best time to intervene

The optimal timing for intervention is based on several factors that are often not under the control of the treating physician. How much growth remains, how much deformity must be corrected, what growth-friendly method is planned will all affect the final outcome.

For these reasons, patient-specific Finite Element Model (FEM) growth modulation planning tools have been developed to better predict the outcome of surgical correction. These models use patient-specific 3D anatomy through 3D reconstruction of the spine and personlaize these models by using patient characteristics such as spine flexibility to personalize the simulations. The surgical procedure is then simulated through the imposition of different boundary conditions simulating each step of the surgical procedure (lateral decubitus, screw and tether installation, application of gravity in the upright position and growth). Depending on the predicted amount of growth, the patient's curve behaviour can predicted over a perior of one, two or three years. D

The surgeon can then be presented with a list of implant configurations that will help determine the optimal procedure (figure 3)

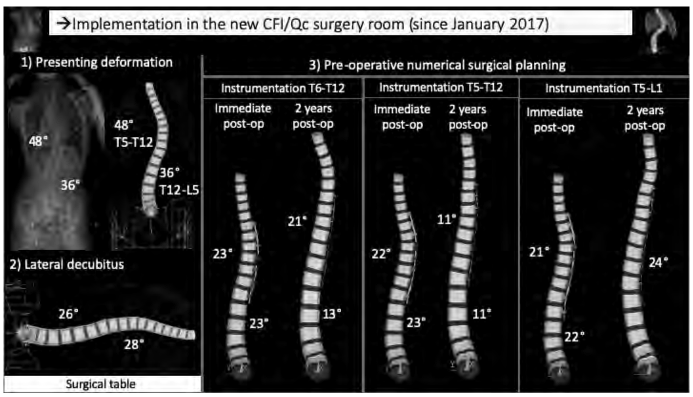

Figure 3: pre-operative planning of growth modulation procedure

In a recent review of the first 54 patients treated with AVBGM using this planning software, 2year post-operative results showed good to excellent correspondence to simulated outcomes. A 32% correction of the actual thoracic Cobb angle was found between the presenting deformation and the intra-operative patient positioning in lateral decubitus (p-value<0.005). The correction was increased to 43% at immediate post-operative correction (p-value<0.005), while an additional 18% correction was measured after 1 year of growth (p-value<0.005) and an additional 5% correction after 2 years of growth (p-value=0.22). The lumbar Cobb angle correction was of 22%, 33%, 49% (p-value<0.05) and 55% (p-value=0.29) respectively for the same time points. The simulated immediate, 1- and 2-year post-operative corrections were predicted within a precision of 4° and 5° as compared to the actual thoracic and lumbar Cobb angles, while the updated simulation reduce this difference to 3° and 4° for all time points. Tables 2 and 3 show a summary of the actual and simulated results for each correction indices.

The actual T4-T12 kyphosis and L1-L5 lordosis angles were both slightly modified by 2° and 4° respectively on average immediately after surgery, and after 1-year and 2-year (p-values≥0.4). The simulated kyphosis and lordosis angles were predicted within 5° for each time point. The actual apical rotation was corrected on average by 6° immediately after surgery (p-value=0.05), while after 1 and 2 years of growth, the correction was of 8° and 9° respectively (p-values≥0.4). Simulated correction in the transverse plane was within 4° of the actual measurements for each time point. Finally, the actual T1-L5 height was of 350 mm immediately after surgery, 366 mm after 1 year of growth and 381 mm after 2 years of growth. Simulated spinal T1-L5 height was within 8 mm of the actual reference measurement at each time point.

Conclusions

Recent data provides valid and reliable reference values for 3D spinal dimensions and growth parameters in healthy children. The obtained detailed and accurate reference values will help physicians better assess their patients' growth potential. It could also be used to predict expected spinal and rib cage dimensions at maturity or changes in pathologic conditions as well as to assess the impact of growth friendly interventions. The best time to intervene varies from patient to patient based on the growth remaining and the severity of the deformity to treat. Over-correction or insufficient correction can be evaluated pre-operatively using a patient-specific FEM planning software. This tool can help the clinician to determine the optimal time to intervene.

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Best Practice Guidelines for Early Onset Scoliosis (EOS)

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1. EOS is defined as scoliosis with onset before 10 years of age

2. Smaller curves with infantile onset (<3yo) are most likely to improve, and can be treated with observation

3. C-EOS has been developed to classify EOS into different subtypes with different prognoses (see below, reproduced from article)
   - ❖ Williams BA, Matsumoto H, McCalla DJ, Akbarnia BA, Blakemore LC, Betz RR,Flynn JM, Johnston CE, McCarthy RE, Roye DP Jr, Skaggs DL, Smith JT, Snyder BD,Sponseller PD, Sturm PF, Thompson GH, Yazici M, Vitale MG.Development and initial validation of the Classification of Early-Onset Scoliosis (C-EOS) *J Bone Joint Surg Am*. 2014;96:1359–1367.

4. Untreated progressive EOS or early spinal fusion (<8yo) can result in restrictive pulmonary failure
   - ❖ Pehrsson K, Larsson S, Oden A,Nachemson A. Long-term follow-up of patients with untreated scoliosis. A study of mortality, causes of death, and symptoms. *Spine*.1992;17(9):1091–1096
   - ❖ Karol LA, Johnston C, Mladenov K, Schochet P, Walters P, Browne RH. Pulmonary function following early thoracic fusion in non-neuromuscular scoliosis. *J Bone Joint Surg Am*. 2008;90(6):1272–1281

5. Elongation derotation flexion (EDF or Mehta) casting is an effective treatment for most children with progressive EOS <5yo
   - ❖ Mehta MH. Growth as a corrective force in the early treatment of progressive infantile scoliosis. *J Bone Joint Surg Br*. 2005;87(9):1237–1247

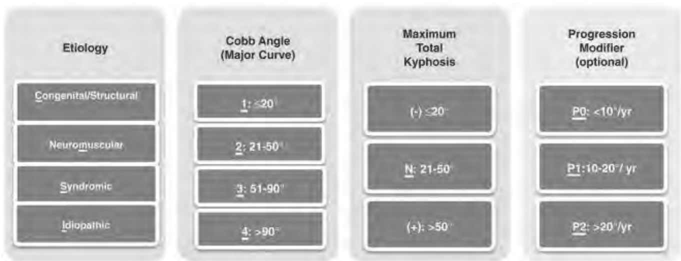
6. Bracing is commonly used. Effectiveness is assumed based on adolescent data, but is likely less than casting. There is not high-quality data specifically in this population
   - ❖ Smith JR, Samdani AF, Pahys J, Ranade A, Asghar J, Cahill P, Betz RR. The role of bracing, casting, and vertical expandable prosthetic titanium rib for the treatment of infantile idiopathic scoliosis: a single-institution experience with 31 consecutive patients. Clinical article. J Neurosurg Spine. 2009 Jul;11(1):3-8

7. Growth-sparing implants are indicated in progressive EOS. These include implants that are distracted directly, magnetically controlled growing rods (MCGR), and guided growth systems.

8. When possible, 2-rod constructs are preferred (lower failure rate). Rod breakage may be more common with 4.5mm rods.
   - ❖ Thakar C, Kieser DC, Mardare M, Haleem S, Fairbank J, Nnadi C. Systematic review of the complications associated with magnetically controlled growing rods for the treatment of early onset scoliosis. Eur Spine J. 2018 Sep;27(9):2062-2071. doi: 10.1007/s00586-018-5590-4. Epub 2018 Apr 19.

9. No clear data or consensus on anchor types (rib vs spine, hook/band vs screw), construct type, or rod type.
   - ❖ Anari J, Cahill, P, Talwar D, Flynn J. Expert consensus for early onset scoliosis surgery 2018. *Spine Deformity* 2018, 6(6) 798

10. Surgical infection prevention measures have been evaluated with a previous survey. 22 statements reached consensus. List below reproduced from article.
    - ❖ Glotzbecker MP, St Hilaire TA, Pawelek JB, Thompson GH, Vitale MG; Children's Spine Study Group; Growing Spine Study Group. Best Practice Guidelines for Surgical Site Infection Prevention With Surgical Treatment of Early Onset Scoliosis. J Pediatr Orthop. 2017 Oct 23.



Avoiding Complications

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Background

Early onset scoliosis remains an enigma with high level of mortality and morbidity if left untreated (1) and significant complications when treated surgically (2),(3),(4).

In Comparison to industry in which Safety and Quality assurance have been ingrained in its fabric for many decades, health systems in general and spinal surgery in particular have been slow to take this message on (5). The reason behind this is several folds.

1- The health monitoring bodies historically, have been based more on the blame and punitive culture rather than creating a learning from mistakes environment thereby making the surgeon less willing to talk about the failures.

2- Historical lack of standardised methods on collecting data on severity and impact of complications (6)

3- Regardless of treatment modality, management of EOS is prolonged and is a continuous fight between nature and intervention and thereby is associated with frequent complications some of which not previously known. (7)

4- Added to that with particular reference to surgery on a growing spine, our knowledge and understating of the condition and the technology to deal with it is evolving at an unprecedented pace. This in itself with time will bring new challenges and complications (8) and new learning curves to be reached and new pitfalls to be realised.

In order to make any attempt to reduce or avoid complications we need to have a clear understanding of the followings

1- Definition of Complication and its related terminology

2- Awareness and ability to identify the complications and in doing so search for the risk factors

Complication in surgical literature has been defined as a "negative out- come", "deviation from the normal postoperative course" (9) or "an undesirable, unintended, and direct result of an operation affecting the patient which would not have occurred had the operation gone as well as could reasonably be hoped" (5)

There has also been attempt to grade complications according to their impact severity from I to V (Dindo & Clavein classification) with Grade V when death of the patient occurs. (9). This classification which was initially purposed in 1992 and finalised in 2004 is more relevant to complications as applied to general surgery and only recently in 2019 attempts have been made to apply it to spinal surgery (10).

With regard to defining complications in paediatric spinal surgery, we face three fundamental problems

1- EOS is a group of conditions each with distinct underlying cause, natural history and different risk and complication profile when surgery is required.

2- The consequences of both natural history and failure of treatment are intermingled, and we do not have a full grasp of where one finishes and the other begins.

3- Our understating about the condition and treatment modalities is evolving so fast that complications sometime cannot be predicted and therefore cannot be planned to be avoided.

Literature Review

In attempt to look at individual complication in specific EOS pathologies, some trends can be established, and particular recommendation can be adopted with reasonable certainty from small sample studies. For example, a recent multicentre study looking at epidemiology of Deep Surgical Site Infection (DSSI) in non-idiopathic EOS showed a variation in the type and sensitivity of the organisms in different groups. A factor which needs to be considered in the choice of prophylactic antibiotics (11). The same study also postulate a cumulative risk of DSSI of 1.95% per procedure for lengthening which again needs to be considered when choosing type of surgery for this group of children. Another recent case-control study in patients undergoing Vrib-based distraction as described by Campbell concluded that timing of administration of Prophylactic antibiotic can influence the risk of DSSI (12). Conclusion can therefore be drawn that the closer the administration to the incision the lower the risk of DSSI. It is also known that two attending surgeons operating simultaneously in children with cerebral palsy reduces the complication rate and improves outcome (13), or certain pre-operative variables such as history of pneumonia or gastrostomy tube are associated with higher post-operative complications (14). Review of historical literature in the past has also shown that pre-operative surgical and medical planning would optimise care and reduce complications(15). Established single institution Multidisciplinary care pathway in small scale has shown to reduce complications in high risk patients (16). However firm conclusions and solid recommendations can only be drawn in large scale national or international multicentre studies.

A retrospective review of the US Pediatric National Surgical Quality Improvement Program (NSQIP) database to determine the short-term mortality, complication, reoperation, and readmission rates revealed DSSI and Pulmonary complications toped the specific and general complications respectively (17). Although the study group included spinal surgery for any pathology, risk factors identified were pulmonary comorbidities, gastric/intestinal disease, CNS conditions, developmental delay, seizure disorder, cerebral palsy, neuromuscular disorder, nutritional support, blood transfusion. (17). This was the first large scale study to confirm trends already known on the smaller scale previous studies.

In 2018, a cross-sectional database study (18), looked at 4073 patients who had undergone adult deformity surgery to see if Machine learning models such as artificial neural network (ANNs) can identify risk factors for complications and found this outperformed ASA scoring and logistic regression in predicting individual complications except for venous thromboembolism (VTE). There is a need for similar study to be emulated in paediatric spine surgery.

Variability in outcome and cost is a well-known fact in surgery for EOS amongst different centres. A review of expert opinion of a group of SRS leading spinal surgeons concluded that standardization of patient care pathway from preoperative to intraoperative and post-operative care will improves outcome. (19) The authors purpose the pathway to start with a pre-operative multidisciplinary approach to identify hidden problems in order to optimise patients' condition. Appropriate surgical plan which is carried out by a cohesive team of highly trained and experienced individuals with well-defined roles and clear guidelines for each eventuality during surgery. Furthermore, they advocate that surgery is planned and performed by fellowship trained surgeons who are mentored during early years of independent practice with dual surgeons operating advocated for more complex procedures. Rigorous outcome and data collection locally, nationally and even internationally to identify trends and risk factors early can help to share experience. It is only in this way that problems can be identified early and complications to be avoided.

Combining the current available literature with clinical experience in order to reduce and avoid complications in surgery for EOS, the following stratified measures can be purposed.

1- Pre-operative
- A. Establish the underlying diagnosis (MDT)*
- B. Establish the need for surgical intervention (MDT)*
- C. Medical pre-operative planning (MDT)* Address and optimise pre-existing conditions, Nutrition, Respiratory, Cardiac, Renal etc
- D. Surgical pre-operative planning (MDT)* Adequate Imaging, Type of surgery, Approach, Instrumentation, Surgical team, support team, Appropriate Consent, Base line neuromonitoring
- E. Anaesthetic pre-operative planning (MDT)* Anaesthetic team, support team, Intubation, Tubes, Equipments, Positioning, Blood loss, Neuromonitoring eventuality, Post op pain, Post op care,

2- Intraoperative
- A. Surgical Team; Adequate training, Fellowship, Mentoring, Two consultants?
- B. Support Teams; Theatre, Anaesthetic, neuromonitoring, radiology, Industry
- C. Appropriate and adequate teams briefing of the surgical plan, setting appropriate stop moments
- D. Appropriate Prophylaxis for Infection, VTE, excessive bleeding, hypothermia
- E. Specific and appropriate guidelines/ protocol for specific stop moments.eg Excessive blood loss, Neuromonitoring alerts etc
- F. Appropriate equipments /implants set out from pre-operative planning

3- Post-Operative (Early)
- A. Appropriate immediate post op care Pathway (PICU, PHDU)
- B. Appropriate Guidelines/ Protocol/ pathway for **
  - I. Post-op pain
  - II. Nutrition
  - III. Bowel care
  - IV. Drain and wound care
  - V. Prophylaxis for Infection and VTE
  - VI. Required imaging
  - VII. Discharge
  - VIII. Short term Follow up and beyond

4- Post-Operative (Late)
- A. Protocol/ Guideline/Pathway on Subsequent Care**
  - I. Clinics: Frequency, assessments parameters,? Role
  - II. Imaging: Frequency, Modality, Type, ?Assessor
  - III. Further Planned Procedures, ? distractions
  - IV. When A and B not right
  - V. Unplanned Procedures
- B. Robust and rigorous Local data collection
  - I. Regular & systematic Audits for risks and efficiency***
  - II. Regular, Open and honest Mortality & Morbidity meetings
  - III. Structured Governance structure
    - To follow and enforce recommendations
    - To arrange team retraining
    - To revisit guidelines/ protocol
    - To scan the Horizon for unexpected complications locally and beyond
  - IV. Structured Data entry in recognised Registries ***

Conclusion:

In summary, as for any other surgical intervention we can strive but can never make the surgery for EOS completely risk free. However, by putting measures in place we can avoid or reduce complications.

1- Since younger age at initiation of intervention is associated with higher risk of complications (20), surgery needs to be delayed as long as it is safely possible.

2- We should continue to Identify trends and risk factors in individual and cohort of patients by developing mathematical models based on large scale date basis

3- Surgical and medical planning through MDTs can help to predict problems in advance so that measures can be taken to reduce their risks and impact.

4- By establishing Standardised patient pathways, care in this group of patients can be streamlined thereby deviations from the expected course can be identified and addressed.

* Multidisciplinary Teams (MDT) can have different members depending on the aim and agenda for discussion and again depending on that MDT can be in the form of several separate ones

each addressing specific issue or a super MDT encompassing all stakeholders in the care pathway discussing all the issues at once. MDTs in whatever form, requires a dedicated Co-ordinator who can bring all the decisions and plans under one umbrella and facilitates communication between different teams and oversees all the plans.

**This role can be assigned to a dedicated and fully trained Nurse practitioner. In our institution we have a dedicated Scoliosis Nurse practitioner who has this role as well as the MDT co-ordinator role.

*** This can be overseen by a clinical Governance lead supported by a governance facilitator. Compliance with data collection, audits, M&M and entry in registries are currently being considered as part of financial incentive in the form tariff up lifts and or reduction in indemnity premium in some countries. In the UK even financial penalties are being considered for non-compliance with data entry in the British Spine registry.

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Half-Day Course Program & Handouts
Adult Spinal Deformity: Case Based Debate

Room: 517A

Course Chairs:

Eric O. Klineberg, MD & Ferran Pellisé, MD, PhD

Faculty:

Christopher P. Ames, MD; Saumyajit Basu, MS(orth), DNB(orth), FRCSEd; Marinus de Kleuver, MD, PhD; Munish C. Gupta, MD; Virginie LaFage, PhD; Jean-Charles Le Heuc, MD, PhD; Lawrence G. Lenke, MD; Eric O. Klineberg, MD; Ferran Pellisé, MD, PhD; Christopher I. Shaffrey, MD; Justin S. Smith, MD; Juan S. Uribe, MD;Kota Watanabe, MD, PhD; Caglar Yilgor, MD

HDCB: ADULT SPINAL DEFORMITY: CASE BASED DEBATES
ROOM: 517A

Chairs/Moderators: Eric O. Klineberg, MD & Ferran Pellisé, MD, PhD

14:35-14:40 **Case Introduction for Alignment Goals and Proximal Junctional Kyphosis**
Ferran Pellisé, MD, PhD

14:40-14:45 **Adult Alignment Targets Provide Improved Outcomes and Decreased Complications (Schwab-ISSG)**
Virginie Lafage, PhD

14:45-14:50 **Alignment Targets Need to Include Age, Location of Lordosis to Decrease Complications (GAP-ESSG"Caglar Yilgor, MD**

14:50-14:55 **Alignment Parameters in India**
Saumyajit Basu, MS(orth), DNB(orth), FRCSEd

14:55-15:05 **Case Conclusion and Discussion**
Ferran Pellisé, MD, PhD

15:05-15:10 **Case Introduction for Predictive Analytics and Avoiding Complications**
Eric O. Klineberg, MD

15:10-15:15 **Predictive Analytics are the Future and Can Help Surgeons Avoid Complications**
Christopher P. Ames, MD

15:15-15:20 **Let's be Cautious with Predictive Analytics**
Marinus de Kleuver, MD, PhD

15:20-15:25 **Are Current Western Predictive Models Applicable in Asia?**
Kota Watanabe, MD, PhD

15:25-15:35 **Case Conclusion and Discussion**
Eric O. Klineberg, MD

15:35-15:39 **Paper #64 Benefits of Medical Optimization Before Thoracolumbar Three-column Osteotomies: An Analysis of 618 Patients**
Andre M. Samuel, MD; Noor M. Maza, BS; Avani S. Vaishnav, MBBS; Francis C. Lovecchio, MD; Yahya A. Othman; Steven J. Mcanany, MD; Sravisht Iyer, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

15:39-15:43 **Paper #65 The 5-factor Modified Fragility Index (MFI-5) is Predictive of 30-day Postoperative Complications and Readmission in Patients with Adult Spinal Deformity (ASD)**
Neil V. Shah, MD, MS; George A. Beyer, MS; David J. Kim, BS; Neil Patel, BS, BA; Douglas A. Hollern, MD; Saad Tarabichi, BS; Daniel E. Suarez, ; Dan Monessa, BS; Suriya Baskar, BA; Peter L. Zhou, MD; Ahmed M. Eldib, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD; Bassel G. Diebo, MD

15:43-15:47 **Paper #66 Surgical Risk Stratification Based on Preoperative Risk Factors in Adult Spinal Deformity**
Mitsuru Yagi, MD, PhD; Takehiro Michikawa, MD, PhD; Naobumi Hosogane, MD, PhD; Nobuyuki Fujita, MD, PhD; Eijiro Okada, MD, PhD; Satoshi Suzuki, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD; Takashi Asazuma, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD Kota Watanabe, MD, PhD

15:47-15:51 **Paper #67 Predictive Risk Calculators for Unplanned Readmissions and Reoperations Following Adult Spinal Deformity (ASD) Surgery**
Ferran Pellisé, MD, PhD; Miquel Serra-Burriel, PhD; Justin S. Smith, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Michael P. Kelly, MD, MS; Alba Vila-Casademunt, MS; Francisco Javier Sanchez Perez-Grueso, MD; Shay Bess, MD; Jeffrey L. Gum, MD; Douglas C. Burton, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Virginie Lafage, PhD; Ibrahim Obeid, MD, MS; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Ahmet Alanay, MD; Christopher P. Ames, MD;International Spine Study Group; European Spine Study Group

15:51-16:10 Discussion

16:10-16:15 **Case Introduction for Correction Options for Adult Deformity**
Ferran Pellisé, MD, PhD

16:15-16:20 **Anterior/Posterior Yields Superior Correction and Outcomes**
Munish C. Gupta, MD

16:20-16:25 **Posterior Only Correction is Effective in Achieving Alignment Goals**
Lawrence G. Lenke, MD

16:25-16:30 **MIS is the Only Option for Achieving Superior Outcomes**
Juan S. Uribe, MD

16:30-16:40 **Case Conclusion and Discussion**
Ferran Pellisé, MD, PhD

16:40-16:45 **Case Introduction for Cervical Deformity: Does Alignment Matter**
Eric O. Klineberg, MD

16:45-16:50 **Cervical Alignment is as Important as Thoracolumbar Alignment**
Justin S. Smith, MD, PhD

16:50-16:55 **Cervical Alignment is Less Critical, and Here is Why**
Jean-Charles Le Huec, MD, PhD

16:55-17:00 **Cervical Deformity, Approach Considerations**
Christopher I. Shaffrey, MD

17:00-17:10 **Case Conclusion and Discussion**
Eric O. Klineberg, MD

17:10-17:14 **Paper #68 Increasing Cost Efficiency in Adult Spinal Deformity Surgery: Identifying Predictors of Lower Total Costs**
Peter G. Passias, MD; Avery Brown, BS; Renaud Lafage, MS; Virginie Lafage, PhD;Christopher P. Ames, MD; Douglas C. Burton, MD; Jeffrey L. Gum, MD; Robert A. Hart, MD; Richard Hostin, MD; Khaled M. Kebaish, MD, FRCS(C); Brian J. Neuman, MD; Shay Bess, MD; Breton G. Line, BS; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Eric O. Klineberg, MD; International Spine Study Group

17:14-17:18 **Paper #69 Predicting ASD Surgeries That Exceed Medicare Allowable Payment Thresholds: A Comparison of Hospital Costs to What the Government Will Actually Pay**
Jeffrey L. Gum, MD; Miquel Serra-Burriel, PhD; Breton G. Line, BS; Themistocles S. Protopsaltis, MD; Alex Soroceanu, MD, FRCS(C), MPH; Richard Hostin, MD; Peter G. Passias, MD; Michael P. Kelly, MD, MS; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Eric O. Klineberg, MD; Han Jo Kim, MD; Andrew B. Harris, BS; Khaled M. Kebaish, MD, FRCS(C); Frank J. Schwab, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group

17:18-17:22 **Paper #70 How Much Correction is Possible? Minimally Invasive Multilevel Lateral Lumbar Interbody Fusion Combined with Posterior Column Osteotomy using Stiff Rod (6.35 mm Cobalt Chrome) in Adult Spinal Deformity Surgery as Compared with Pedicle Subtraction Osteotomy**
Jung-Hee Lee, MD, PhD; Ki-Young Lee, MD; Won-Ju Shin, MD; Dong-Gune Chang, MD, PhD; Sang Kyu Im, MD; Seong Jin Cho, MD

17:22-17:35 Discussion

Half-Day Course Handouts

Adult Alignment Targets Provide Improved Outcomes and Decreased Complications (Schwab-ISSG)

Virginie Lafage, PhD
Frank Schwab MD
Hospital for Special Surgery
New York, New York, USA

Context

Classification of adult spinal deformity and associated alignment targets aim to provide guidelines for patients' evaluation. Ideally, these guidelines should lead to improved clinical outcomes while mitigating the risk of complications. While several approaches have been described in the literature, it is important to understand their genesis instead of systematically opposing them (a classic human behavior). This short presentation aims to describe the reasoning behind the SRS-Schwab classification and how it helps in providing improved outcomes.

A brief overview of the SRS-Schwab Classification

The SRS-Schwab classification was designed almost 10 years ago and published in 2012 by the SRS Adult Deformity committee [1]. While it may be perceived as a pure radiographic classification, the parameters were chosen based on their correlation with clinical disability measured with the ODI. As such, it is indeed a clinical classification more than a simple description of the radiographic alignment. The reasoning for such approach was that surgical treatment should first aim at addressing the patients' disability instead of realigning the spine to a set of normative values. Following its initial publication, numerous studies have demonstrated its reliability [2,3]which was conducted from February 2009 to January 2012. Long-cassette standing posterior-anterior and lateral radiographs of the spine and the pelvis were obtained from patients with ASD in the fist-on-clavicle position. All 102 cases were classified according to the new SRS-Schwab classification by 4 observers.

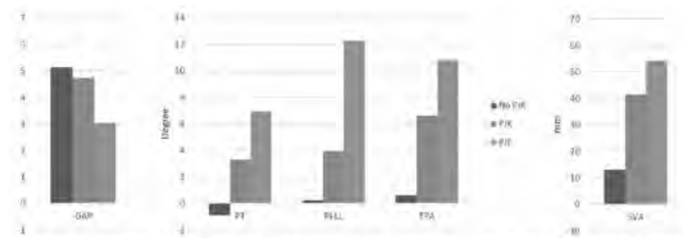
Evolution of the Schwab-ISSG approach

Despite defining quantitative targets for sagittal alignment, the SRS-Schwab classification failed to investigate the potential relevance of incorporating the age of the patients. In light of the known increase of disability with age in the general population, Lafage R and the ISSG[7] redefined the alignment thresholds and demonstrated that alignment targets for surgical realignment should take into account the patient's age … with younger patients requiring a more rigorous alignment than older patients.

Clinical Relevance

In an area of patient-specific evaluation, the clinical relevance of the age-adjusted approach has been extensively investigated by the ISSG. More specifically it has been demonstrated that:

1. **Under correction** of sagittal deformities based on age-adjusted alignment thresholds leads to **worse health-related** quality of life[8]
2. **Over correction** of sagittal deformities based on age-adjusted alignment thresholds
   a. **Provides no additional** clinical benefit in HRQL[8]
   b. **Increase the risk of junctional failure** (PJK / PJF)[9]



Comparison between no PJK, PJK and PJK-R using virtual alignment. GAP score demonstrated a more proportional score (closer to 0) for PJK-R in regard to PI while age offset demonstrated an over-correction versus patient age

PJK and PJK patients were over-corrected when compared to age-adjusted

Conclusions

While numerous systems exist in the literature, the Schwab-ISSG framework provides a patient-specific approach and permits to mitigate mechanical complications while improving patients outcomes.

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Alignment Targets Need to Include Age, Location of Lordosis to Decrease Complications (GAP-ESSG)

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Compensation & Complications

Compensation is a process in which the change in a given direction is counteracted by another conscious or unconscious change. As a response to positive sagittal malalignment, body progressively recruits compensatory mechanisms in the spine and/or non-spinal segments in an effort to maintain the gravity line and an horizontal gaze.

It was suggested that when a patient is in the need to use compensation after instrumented fusion the distribution of loads on the implants, instrumented vertebrae, adjacent segments and the grafts cannot be normalized. Thus, in order to avoid mechanical complications, goal when performing instrumented fusion is to end up in a position that the patient does not need any compensation whatsoever especially in longer fusions to pelvis when compensation capacity is limited.

Achieving this goal would require a proper preoperative planning and simulation, selection of approach to execute surgery, intraoperative evaluation of surgical results, and postoperative evaluation and prediction. Among these, preoperative planning is the most important one.

Sagittal plane undercorrection and overcorrection have both been reported to be a main cause of mechanical complications. Thus, one can conclude that although the restoration of "normal sagittal alignment" is a critical goal of reconstructive spine surgery, "normal" and "pathologic" alignment remain poorly defined.

Non-ideal correction implies the use of compensatory mechanisms after surgery. It was suggested that the amount of compensatory mechanisms used after instrumented fusion determines the distribution of loads on implants, instrumented vertebrae, adjacent segments, and grafts. PI-adjusted interpretation of the spinopelvic alignment allows the setting of personalized radiographic targets for preoperative planning.

The GAP Score

GAP score comprised PI-adjusted radiographic parameters of Relative Pelvic Version (Measured minus Ideal Sacral Slope), Relative Lumbar Lordosis (Measured minus Ideal LL), Lordosis Distribution Index (L4-S1 lordosis/L1-S1 lordosisx100), Relative Spinopelvic Alignment (Measured minus Ideal Global Tilt) and age factor. RPV indicates the spatial orientation of the pelvis relative to the ideal sacral slope as defined by the magnitude of the pelvic incidence. RLL indicates the amount of lordosis relative to the ideal lordosis as defined by the magnitude of the pelvic incidence. LDI defines the amount of lower arc lordosis in proportion to the total lordosis. RSA indicates the amount of malalignment relative to the ideal global tilt as defined by the magnitude of the pelvic incidence.

GAP score of 0-2 is proportioned, while 3-6 is moderately disproportioned and ≥7 is severely disproportioned. GAP score quantifies spinopelvic shape and alignment on the basis of a given person's respective realignment needs for every PI size. Thus, GAP score individualizes of the sagittal plane analysis with an all-inclusive single score that offers a "one-size-fits-all" solution for diverse clinical scenarios with different levels of compensation and different magnitudes of pelvic incidence.

Setting surgical goals in the sagittal plane on the basis of the proportional indices reflected by the GAP Score might allow reaching the goal of GAP score of ≤2 that reflects a proportioned spinopelvic state. Such a state requires minimum usage of compensatory mechanisms and a more appropriate distribution of loads on implants, instrumented vertebrae, adjacent segments, and grafts. As such, preoperative planning with the GAP score might be used as a prevention tool for mechanical complications.

Distribution of Lordosis

Contact force distribution depends on the vertebral plate orientation within the curvature. Therefore, the shape of the lordosis is as important as the magnitude. Lordosis, should be quantified as the amount of lordosis in regards to one's ideal in proportion to PI with RLL, plus the amount of lower arc lordosis in regards to the total lordosis.

The 'amount' of lordosis quantified by a single value is not enough to fully describe a lordotic curve. Through a horizontal line crossing the apex of the curve, lordosis can be reconstructed into two tangent arcs of circle. This allows better understanding the shape of lordosis as upper and lower arc lordosis.

Loss of lumbar lordosis is the driver of the vast majority of sagittal plane deformities. Compensatory mechanisms voluntarily or involuntarily act to maintain the forward gaze. These compensations alter the magnitude of the curves as well as their shape. In the setting of lower lumbar degeneration, more proximal lumbar lordosis may signify more extension in the upper lumbar spine. In such a case, PI-LL can remain relatively unaffected. RLL as well can be relatively unaffected while LDI will be lower displaying that the lower arc lordosis is hypolordotic in proportion the total lordosis denoting the use of the compensatory mechanism 'local hyperextension'.

Age & Alignment Goals

As spinopelvic alignment is known to vary for age, and the fact that the normal and pathologic aging processes of the spinopelvic alignment have been described, attempts have been made to adapt these changes to ASD realignment objectives. Age-adjusted correction was recommended with a tendency to obtain less rigorous correction and to accept slight malalignment in elderly.

Aging is a previously defined risk factor for mechanical failures. Age is a rough, but easy to use, indicator for osteoporosis and age-related changes that occur in musculoskeletal and neural systems. Thus, the GAP Score includes an age factor to attribute 1 point for patients over 60 years of age.

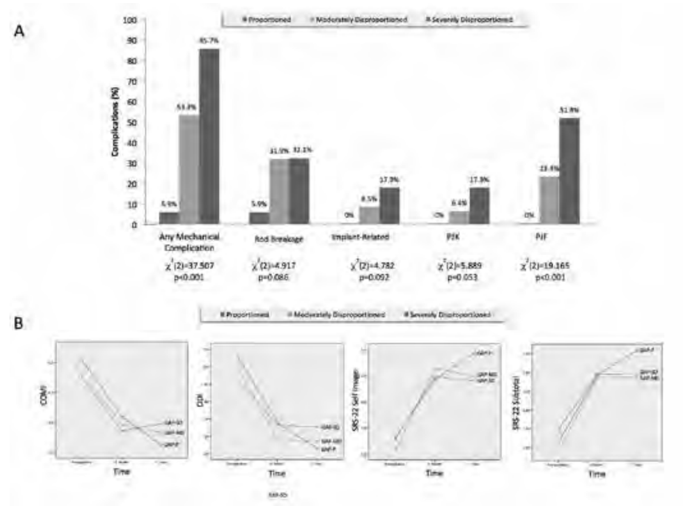
Effects of Restoring Individualized Sagittal Shape and Alignment on Mechanical Complications and Patient-Reported Outcomes in Elderly Patients Fused To Pelvis

This was a retrospective analysis of data collected in the multicenter, consecutive, prospective study of the European Spine Study Group (ESSG), a collaboration of spine surgeons from 6 sites across Europe. Enrollment criteria were an age of ≥18 years and at least 1 of the following: coronal Cobb angle of ≥20°, sagittal vertical axis of ≥5 cm, pelvic tilt of ≥25°, and thoracic kyphosis of ≥60°. For the present study, the specific inclusion criteria were ≥60 years of age, ≥4 levels of posterior instrumented fusion, UIV to be between T8-L1, and LIV to be S1-S2 or ilium, and ≥2 years of follow-up.

Mechanical complications were defined as proximal junctional kyphosis or failure, distal junctional kyphosis or failure, rod breakage, and implant-related complications. PJK was defined as ≥10° increase in kyphosis between UIV and UIV+2 between early postop. and follow-up radiographs. PFJ was defined as fracture of UIV or UIV+1, pullout of instrumentation at the UIV and/or presence of sagittal subluxation. Single or double rod breakages were considered rod breakage. Other radiographic implant-related complications (that were not related to PJF) such as screw loosening, breakage or pullout, or interbody graft, hook or set screw dislodgements were recorded as implant-related complications.

120 patients were included. Of these, 100 were female and 20 were male. Mean age was 69.6±5.7 years. Mean follow-up was 30.8±5.7(24-62) months.

Post-operatively, 17 patients were GAP-P, while 46 and 57 were GAP-MD and GAP-SD, respectively. Mechanical complication rates were 5.9% in GAP-P, 53.2% in GAP-MD and 85.7% in GAP–SD groups. Details for each type of mechanical complications are given in the figure below.



In an homogeneous group of elderly patients who were fused from lower thoracic to sacroiliac spine mechanical complication rates were lower when sagittal plane was restored to the personalized ideal.

It is further interesting to note that regardless of the postoperative alignment, elderly patients undergoing spinal fusion surgery reported improvement in their PROMs. However, this was only sustainable in the first year in patients that personalized sagittal plane shape and alignment is reached. The fact that the PROMs remained stable or worsened in patients that personalized sagittal alignment goals are not reached, might be related to the complications and revision surgeries these patients are experiencing.

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Alignment Parameters in India

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INTRODUCTION:

Various spinal alignment parameters has been described in the past and commonly used sagittal parameters include cervical lordosis (CL), thoracic kyphosis (TK), thoracolumbar angle (TL), lumbar lordosis (LL), sagittal vertical axis (SVA) and standard spinopelvic parameters like pelvic incidence (PI),pelvic tilt (PT), and sacral slope (SS)[1]. Coronal parameters like central sacral line (CSL), clavicular angle with shoulder height and iliac crest level are being used[2]. Normal variations of these alignment parameters became very important due to significant variations in alignment parameters based on patient specific characters and ethnicity. Hence many authors has studied variation in these parameters with respect to age, sex, size and ethnicity[1 3 4 5 6 7 8]the sagittal balance and spinopelvic parameters were evaluated, including vertical sagittal axis, sacral slope, pelvic tilt and pelvic incidence. Results: The data obtained in this study are according to the values presented in the worldwide literature. None of the radiographic parameters showed any differences between the genders. Comparing the values presented in this study with those of other reports, with different populations, it was observed that: there was no significant difference in any of the pelvic parameters between Brazilian and Korean populations; there was a significant difference in pelvic incidence between Brazilian and European populations in a total sample (p=0.0001 [9 10].

Singh et al has studied normal variation in spinal alignment parameters in Indian population and compared with other ethnic groups. He concluded that (a) There was significant difference in radiographic parameters between males and females and no differences in any of the pelvic parameters between the Indian, Brazilian, and Korean populations, (b) However, there were differences in pelvic incidence between the Indian and European populations both in the total sample and in the male and female groups, (c) There were differences in sacral slope between the Indian and European populations in relation to the total sample and the female group[6].

EXISTING RECOMMENDATIONS FOR ADULT SPINAL DEFORMITY CORRECTION AND IT DISADVANTAGES:

Schwab et al has developed classification systems for adult spinal deformity which is major milestone in the management of adult spinal deformity. Schwab-SDSG adult spinal deformity classification categorizes the deformity according to its location: apical level of the major curve in the coronal plane (Type I to V) or sagittal plane deformity-only (Type K). It also includes 3 sets of modifiers, which were found to correlate with pain and disability i.e.(a) Lordosis measured according to the Cobb technique in the sagittal plane from T12 to S1 (Lordosis modifier), (b) maximal subluxation expressed in mm and measure in both coronal and sagittal plane (Subluxation modifier), and (c) global balance measured as the sagittal plane C7 offset from the posterosuperior corner of S1(-Global balance modifier) [11 12]. Lordosis modifier consists of group A (Marked lordosis >40^0), Group B (Moderate lordosis 0-40^0) and Group C (No lordosis <0^0). Subluxation modifier has 3 groups i.e. 0 (No subluxation), +(Subluxation of 1-6mm) and ++(Subluxation >7mm). Global balance modifier also has 3 groups namely, N (Normal 0-4cm), P (Positive 4-9.5cm) and VP (Very positive >9.5cm). They found that the modifiers of the classification had significant variation in surgical rates as the grade of the modifier increased (i.e., lordosis A to C, subluxation 0 to ++ , sagittal balance N to VP). As lordosis was lost, surgical rates increased significantly (A, 37%, C, 51%, P =0.05). With increasing subluxation the operative rate went from 35%(0) to 52%(P<0.05). Finally, patients with greater sagittal imbalance (VP, rate =58%) were more likely to receive surgical treatment than patients with moderate (P, rate=46%) or neutral (N, rate =39%) sagittal balance (N vs.VP, P =0.002).

The patient group most likely to improve from surgery had the following characteristics:

• Low baseline HRQOL scores (greater disability)

• High baseline classification modifier scores (C, ++ or VP)

• An improvement in lordosis and global balance modifiers through surgery (By use of osteotomies, Fusion to sacrum for significant sagittal imbalance)[11 13].

After these recommendations by pioneers of spinal deformity, many patients underwent surgery for spinal deformity. But due to increasing rates of surgical intervention for adult spinal deformity, problems associated with it like persistent pain, infection, neuro-deficits, pseudoarthrosis, implant related issues, adjacent segment problems, progressive increase in deformity has come in to light[14]. One of the devasting complication of adult spinal deformity correction is proximal junctional kyphosis (PJK) which is still an unresolved issue[15]with a range of causes including wound infection, nonunion and adjacent level pathology. While some of these complications have been amenable to changes in patient selection or surgical technique, Proximal Junctional Kyphosis (PJK. Glattes et al described abnormal PJK by 2 criteria: (1) proximal junction sagittal Cobb angle >10° and (2) proximal junction sagittal Cobb angle at least 10° greater than the preoperative measurement [16]. Incidence of 26% was reported initially [16] but actual incidence is unknown due to non-reported asymptomatic PJKs. Significant number of cases who underwent surgery for adult spinal deformity require revision surgery for PJK[15]with a range of causes including wound infection, nonunion and adjacent level pathology. While some of these complications have been amenable to changes in patient selection or surgical technique, Proximal Junctional Kyphosis (PJK.

Schwab sagittal modifiers have been widely accepted as targets for appropriate alignment, but achieving these targets does not always prevent high mechanical complication or revision rates. Schwab did not consider pelvic incidence, pelvic anteversion, distribution of lordosis and negative malalignment. Hence Yilgor et al developed Global alignment and proportion score (GAP Score) based on pelvic-incidence-based proportional parameters to better predict mechanical complications[17]. Parameters of GAP score were relative pelvic version (the measured minus the ideal sacral slope), relative lumbar lordosis (the measured minus the ideal lumbar lordosis), lordosis distribution index (the L4-S1 lordosis divided by the L1-S1 lordosis multiplied by 100), relative spinopelvic alignment (the measured minus the ideal global tilt), and an age factor. The GAP score was calculated by adding the scores of above parameters and ranged from 0 to 13 points. GAP score of 0 to 2 was categorized as proportioned spinopelvic state, 3 to 6 as moderately disproportioned and ≥ 7 as severely disproportioned. In their study, patients with a proportioned spinopelvic state had a mechanical complication rate of 6% while those with a moderately or severely disproportioned spinopelvic state had rates of 47% and 95%, respectively. Hence, they concluded that GAP score is a new pelvic-incidence-based proportional method of analysing the sagittal plane that predicts mechanical complications in patients undergoing surgery for adult spinal deformity and setting surgical goals according to the GAP score may decrease the prevalence of mechanical complications[17].

PROBLEMS TO BE RESOLVED:

1. Are we overtreating the adult spinal deformity based on existing recommendations?? Many patients with deranged alignment parameters when managed conservatively and followed up over time does fairly well. And many patients whom we operate based on present recommendations develop complications and deteriorate as compared to pre-op. Hence there is need for developing better indications and risk stratifications.
2. Should we develop technologies which is streamlined to targets? Lavage et al in their retrospective review, has studied whether age should be included in assessing sagittal parameters while planning and interpreting operative goals in adult spinal deformity. They demonstrated spinopelvic values increases with age, ranging from PT=10.9 degrees, PI-LL=10.5 degrees, and SVA=4.1mm for patients under 35 years to PT=28.5 degrees, PI-LL=16.7 degrees, and SVA=78.1mm for patients over 75 years. Clinically, older patients had greater compensation, more degenerative loss of lordosis, and were more pitched forward. They concluded that sagittal spino-pelvic alignment varies with age. Thus, operative realignment targets should account for age, with younger patients requiring more rigorous alignment objectives[18]Wolters Kluwer Health, Inc. All rights reserved. Study Design. Retrospective review of prospective, multicenter database. Objective. The aim of the study was to determine age-specific spino-pelvic parameters, to extrapolate age-specific Oswestry Disability Index (ODI.

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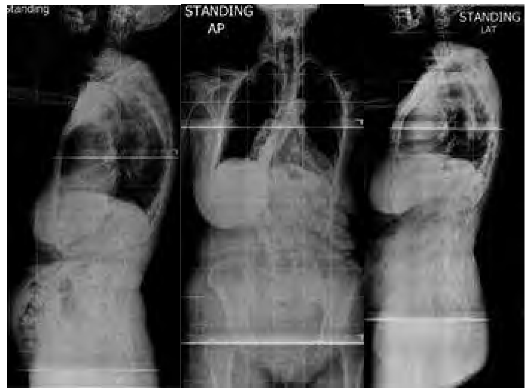
CASE 2: 68 years female came with progressive deformity (a) Pre-operative whole spine standing AP and lateral views showing thoracolumbar scoliosis with cobb angle of 50 degrees. (b) Post-operative whole spine standing AP and lateral views shows good alignment parameters (c) 4 years follow up with well maintained alignment parameters



CASE 2: 68 years female came with progressive deformity (a) Pre-operative whole spine standing AP and lateral views showing thoracolumbar scoliosis with cobb angle of 50 degrees. (b) Post-operative whole spine standing AP and lateral views shows good alignment parameters (c) 4 years follow up with well maintained alignment parameters

Predictive Analytics are the Future

Christopher Ames MD
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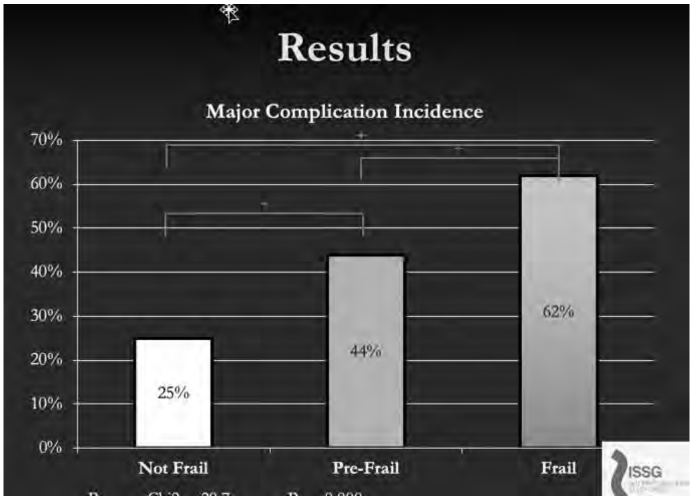
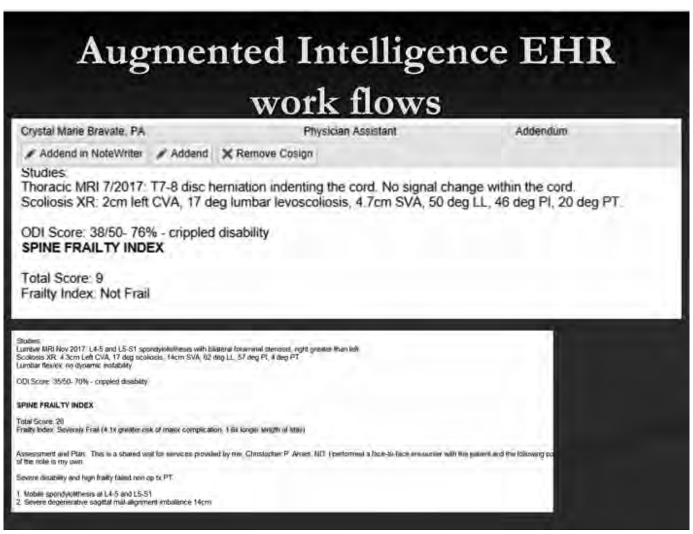
1. Our population is aging and the US healthcare system is running out of money
   a. 80million over 65 by 2050
   b. Medicare out of funds by 2026
   c. Spinal Deformity Surgery > $100 billion annual cost in US

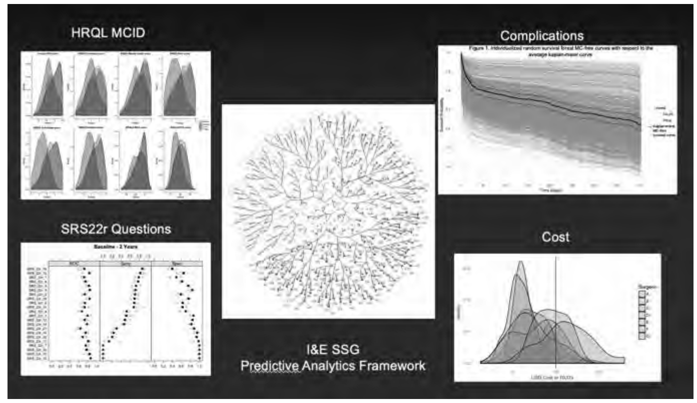
2. Older population is demanding higher levels of function as they age
   a. ASD surgery results in significant disability improvement in many cases
   b. ASD surgery more expensive as patients age
   c. Increased complications with increased frailty
   d. Improved disability improvement with increased age and Frailty



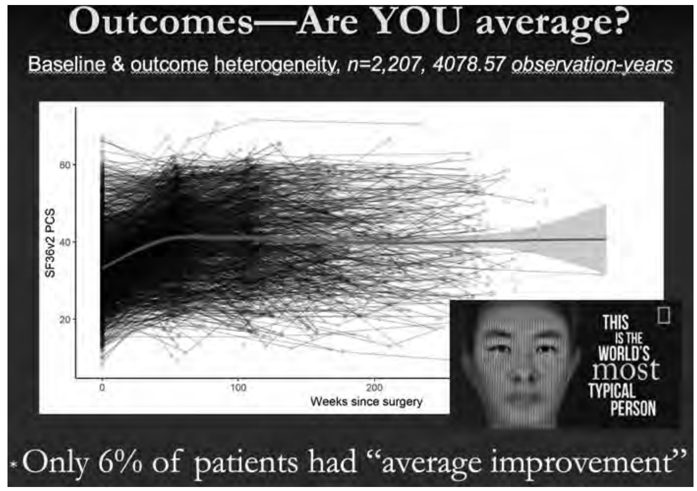
3. Solutions
   a. Collective intelligence – focus on the complication side—ration care to those who will be cheaper and less at risk of major complications
   b. Risk Stratification using datification of the patient and the procedure
      i. Frailty
      ii. Invasivness



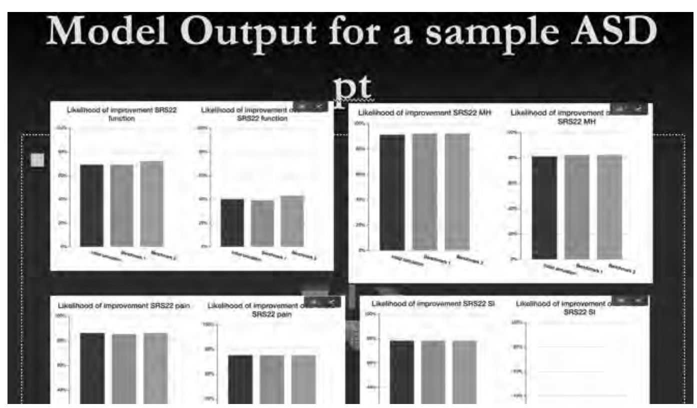
   c. Artificial Intelligence Predictive models that consider both outcomes and complications
      i. ISSG ESSG Models accurately predict major complication, reoperation and readmission prior to surgery



      ii. ISSG ESSG Models predict any improvement and MCID in ODI, SRS, SF 36



   d. Precision Medicine
      i. Unsupervised AI clustering based new ASD classification system based on quality and value
      ii. Surgery for specific goals –ISSG ESSG models predict chance of improvement in each SRS 22 question. e.g. Will my walking improve?



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Development of Validated Computer-based Preoperative Predictive Model for Proximal Junction Failure (PJF) or Clinically Significant PJK With 86% Accuracy Based on 510 ASD Patients With 2-year Follow-up.

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PMID: 27831987

Let's be Cautious with Predictive Analytics

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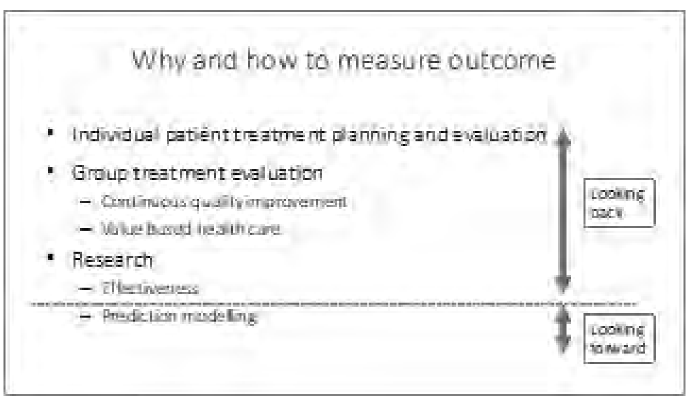
Background:



Looking back:

We can often verify a solution when it occurs, e.g. a complication.

We can explain with hindsight why something occurred.

Looking forward (predictive analytics)

We cannot accurately predict when a complication will occur.

We may be better at predicting what NOT to do, eg: we know that poor sagital alignment increases the risk of PJK, or fusing ASD to L5 increases the risk of distal failure.

We do not know what we should do.

Predictive analytics and artificial intelligence is playing an increasingly important role in our world, and has proven benefit in image / pattern recognition.

Contents lists available at ScienceDirect

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Decision support tools in low back pain

Veerle M.H. Coupé [a,*], Miranda L. van Hooff [b,c], Marinus de Kleuver [c], Ewout W. Steyerberg [d], Raymond W.J.G. Ostelo [a,e]

However….Let's be careful with predictive analytics:

Stephen Hawking:

"The development of full artificial intelligence could spell the end of the human race. Once humans develop artificial intelligence, it will take off on its own and redesign itself at an ever-increasing rate. Humans, who are limited by slow biological evolution, couldn't compete and would be superseded".

Modelling is based on data:

Linear systems vs Complex adaptive system

The human body is a classic complex adaptive system

- There are multiple (endless?) bio-psycho-social influencing factors
  - Age, gender, comorbidities, genetics, social environment, psyche etc
- The patiënt demonstrates multiple adaptive, emergent compensatory solutions,
  - eg how to compensate aging, sagital imbalance, BMI
- Almost all inter-relationships are non linear

Examples in spine care

complicated, not complex.	
Decision making is based on distinct measurable biomedical factors • starting with the X-ray • symptoms play a minor role – Disease severity • Imaging = Curve magnitude – Disease modifiers • Maturity • Gender • BMI • Pre-op pain • Curve type (e.g. Lumbar vs Thoracic	Decision making is based on multiple non-distinct non-measurable bio-psycho-social factors, • endless permutations of symptoms play a major role e.g. neurogenic pain vs back pain • ending with imaging – General health, • incl. psychosocial domains – Comorbidities – Spine specific complaints – Curve description (X-ray and MRI)
Can be solved with reductionism	**Cannot** be solved with reductionism
Can be predicted with relative accuracy	**Cannot** be predicted outcome changes over time

Concerns:

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Machine Learning and Prediction in Medicine — Beyond the Peak of Inflated Expectations

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Department of Medicine, Stanford University, Stanford (J.H.C., S.M.A.), and the Center for Innovation to Implementation (Ci2i), Veteran Affairs Palo Alto Health Care System, Palo Alto (S.M.A.) — both in California

"Issues ranging from patient self-selection to confounding by indication to inconsistent availability of outcome data can result in inadvertent bias, and even racial profiling, in machine predictions. Awareness of such challenges may keep the hype from outpacing the hope for how data analytics can improve medical decision making".

"When our goal is learning how medicine should be practiced in the future, the relevance of clinical data decays with an effective "half-life" of about 4 months"

"Clinical data alone have relatively limited predictive power for hospital readmissions that may have more to do with social determinants of health".

<u>Next steps….</u>

What do we want to predict? Which outcome matters to patients?

<u>STEP 1,</u> always identify outcome that you want to predict,

e.g. when predicting the weather, are you interested in

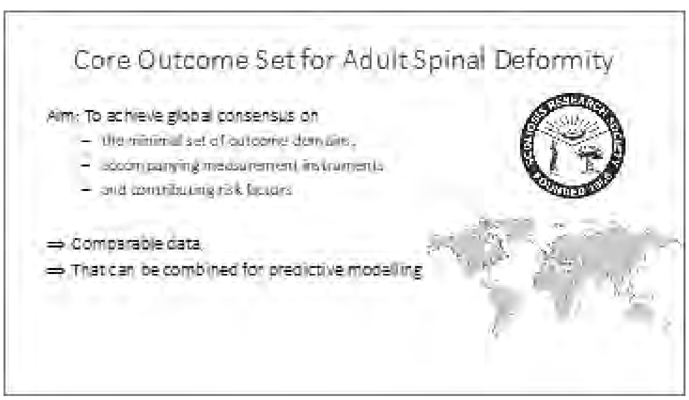
– Rain (do I need to bring an umbrella?) or Temperature (do I need to bring a coat?) or both?

In spine surgery the outcomes are often composite, and in bio-psycho-social domains, e.g. disability, ability to work, social participation, which change over time.

Hippocrates*:*

"It's more important to know what sort of a person has a disease than to know what sort of a disease a person has'

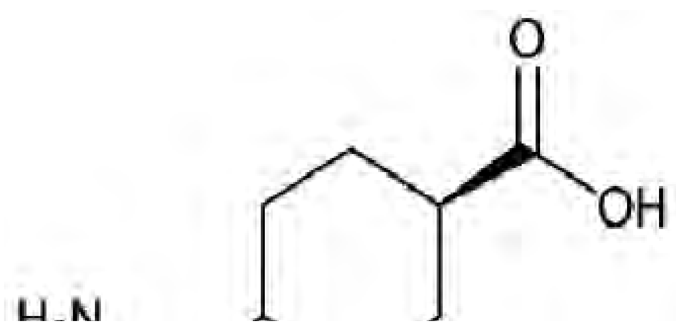
So we need to identify the important metrics/end-points, to build <u>large, reliable, real time</u> data sets.



<u>STEP 2:</u> Collect uniform data, that can be merged.

- Large Volumes of data.
  - Personal medical records, Radiology images, Human genetics, Biometric sensor readings
- Velocity:
  - Data is accumulated in real-time and at a rapid pace
- Variety
  - structured, unstructured and semi-structured
- Veracity:
  - ' data assurance', error-free, credible.

<u>STEP 3</u>. Build a model, based on correlations (≠ cause-effect!)



<u>STEP 4</u>: Test external validity, based on historical data, which may be outdated (e.g. new techniques)

<u>External validity:</u>

Predictive models are often dependent on historical data and depend on the context and the institute, e.g. the experience of the surgical team, or how the hospital has implemented risk reduction strategies such as a 2 surgeon approach for complex spinal deformity surgery.

- The external validity (e.g. generalisability) may therefore be limited, and each hospital may need to customise its own risk calculator.
- Does not take into account the evolution of our field. May harm innovation?
- The models often only predict a small part of the variance.

<u>Conclusion:</u>

- Much of spine pathology can be considered a <u>complex adaptive system</u>,
- We can <u>check</u>/confirm outcome (eg success/failure), and try to learn from that
- – The majority of our outcome assessment is "looking back", with a significant time lag
- We can to some degree predict negative outcome (failure)
- It is very difficult to predict positive outcome (success)
- When predicting outcome, correction for risk factors is needed
- We are only just beginning to look at predicting outcome real time, but
  - <u>Based on historical data</u>.
  - Based on correlations (not causative!)
  - Almost solely biomedical domain,
    - Missing important psycho-social aspects
  - Does not take into account the evolution of our field.
    - May reduce innovation?
- External validity of datasets is a significant limiting factor
  - Does not take into account setting/context.

Are Current Western Predictive Models Applicable in Asia?

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Back ground

Mechanical failure (MF) is the most common and critical complication after corrective surgery for ASD. The reported incidences of MF are 30 - 50%(1-6). In our series, MF developed 40% after corrective surgery. The prediction of the occurrence of MF prior to surgery may be beneficial in deciding the difficulty of the surgery, and in preventing and improving perioperative surgical treatments. Several studies about the prediction of MF in ASD surgery have been reported16,30. Among them, global alignment and proportion (GAP) score is one the well-known predictive score established by Yilgor et al(7). They have reported excellent predictiveness of GAP score for the risk of MF based on the immediate post-operative global alignment and proportion and age.

Evaluation of the efficacy of GAP score in Japanese population

We aimed to validate the efficacy of GAP score in Japanese population. We included the subject with following criteria. Age at least 20 years at the index surgery and had a spinal deformity defined by a Cobb angle ≥ 20°, a C7 sagittal vertical axis (C7SVA) ≥ 5 cm, or pelvic tilt (PT) ≥ 25°, at least 5 fused vertebral levels, segmental instrumentation and fusion from the upper-instrumented vertebra (UIV) to the LIV (lower-instrumented vertebra), and complete 2-year follow-up data. Despite the excellent predictive power of GAP score in the original article, no significant difference was found for GAP score and its subscale between MF and MF-free group in Japanese population. AUC was 0.56 (95%CI= 0.48-0.63).

Establishment of predicting model based on Japanese population

We created predicting model of postoperative MF for ASD surgery (patient demographic and radiographic index and surgical invasiveness for mechanical failure; PRISM) based on the individual's baseline demographic, radiographic, and surgical invasiveness data in Japanese population.

The predicting model consisted of 6 risk variables including 4 variables identified in the multivariate analysis and 2 variables age and level of LIV (pelvis) which were considered clinically important variable. The risk for MF increased exponentially as the PRISM score worsened. The PRISM score also showed excellent accuracy for predicting the incidence of MF in both training and testing samples, with an AUC of 0.81 (95% CI 0.76 - 0.86) in training samples and of 0.86 (95% CI 0.77 - 0.95).

CONCLUSION

Despite the excellent predictive power of GAP score in the western cohort, the effect was not significant in Japanese cohort. Our established risk-stratification scoring established based on Japanese cohort accurately predicted MF following ASD surgery.

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Anterior and Posterior Treatment for Adult Scoliosis

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1. Goals of Adult Deformity Surgery
- Coronal plane balanced correction
  - Fractional Lumbosacral curve
  - Rigid and leads to coronal decompensation
- Sagittal plane correction
  - Nothing worse than a long fused flatback needing a revision surgery
- Achieve fusion
  - Nonunions can be found much later than a year unlike adolescents

2. Osteoporosis
- Disc degeneration and narrowing
  - Difficult to distract the disc space to get a release
- Bone Implant interface is a weak link
  - Fixation Failure
- Osteoporotic Vertebral column failure
  - Pedicle fracture
  - Vertebral body fracture
  - Pelvic fracture

3. When to do an Anterior Release?
- Sagittal plane is kyphotic in the Thoracolumbar or lumbar

spine
- Rigid fractional lumbosacral curve with coronal malalignment
- Need Low lumbar lordosis correction

4. Type of Disc release
– Anterior Lateral approach
  - Thoracolumbar
  - Lumbar
– Lateral LIF
  - Many variations and trade names
- Posterior intradiscal approaches
  - PLIF
  - TLIF

5. Advantages of an anterior approach
- Anterior release makes the correction easier
- Anterior fusion decreases the nonunion rate
- Anterior disc space structural grafts help restore the sagittal plane.

6. Problems with an anterior approach
- Longer operating time
- Morbidity of an additional approach
- Abdominal wall weakness
- Vascular injury
- Deep venous thrombosis

7. Summary
- ALIF is useful in large rigid curves and curves with rigid oblique lumbosacral junction
- Easier to release rigid osteoporotic curves
- When
  – Kyphotic -Thoracolumbar or lumbar spine
  – Rigid fractional lumbosacral curve with coronal malalignment
  – Need Low lumbar lordosis correction
- PSO for rigid curves previously fused

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Posterior Only Correction is Effective in Achieving Alignment Goals

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Post. Only TX. Of Spinal Deformity

- Pedicle Screws – "Stabilizer"
- Posterior Osteotomies – ""Carpentry"
  - PCOs (SPOs/Ponté Osteotomies)
  - PSO
  - VCR
- TLIF'S at Base of Support
- Multimodality SCM – "Safety"
- All Deformities have be Corrected from a Post. Only Approach since 2002!

Posterior Methods of Spinal Realignment

- Positioning
- Facet/Ligament Releases
- TLIF's
- Osteotomies

	Preoperative		Intraoperative	Postoperative
Position	Upright	Supine	Prone	Upright
Increased lordosis group	-25.9°±19.5	-40.0°±19.8*	-43.1°±16.5*	-48.9°±12.4*
Unchanged lordosis group	-54.2°±15.8	-53.8°±15.7	-50.3°±14.8	-55.7°±13.0

Increasing Lumbar Lordosis by 18 Deg by Intraop Positioning!

Increasing Lumbar Lordosis in Adult Spinal Deformity Pts. Due to Intraoperative Prone Positioning. Spine 2009;34(22):2406–12

TLIF Technical Key Points

- Complete Bilateral Facetectomy (PCO)
- Post.-Based Distraction:
  - Midline with Laminar Spreader
  - Contralateral with Temp. Rod
  - Ipsilateral With Screw Distractor
- Thorough Discectomy with Thinning of Ipsilateral Annulus (On Concavity of L-S Curve), and ALL
- Endplate Distraction to "Plane Endplates" to Parallel Surfaces and Further Stretch Annulus
- Cage Placement Anterior and Central
- Posterior Compression on L-S Convexity with Pedicle Screws +/- Distraction on L-S Concavity if needed for Coronal Realignment

Decision on Who Needs Osteotomies? Preop X-Ray/Clinical Assessment

<u>Spinal Flexibility</u>

- Upright
- Supine
- Push-Prone
- Side-Bending
- Traction
- Hyperextension Bolster (kyphosis)
- Hyperflexion Bolster (lordosis)

Flexible(A)

vs.

Stiff(B)

vs.

Stuck/Fused(C)

Silva, Lenke et al JNS Spine 2011

How Best To Assess Flexibility????

- Supine Side Bending X-rays – Gold Standard?
- Traction Films
- Push-Prone Films
- Hyperextension Films (Kyphosis)
- Hyperflexion Films (Lordosis)
- **Supine Ap & Lat X-Rays**-most Reproducible!- can obtain from Scout Sagittal CT/MRI films

Menu of Spinal Osteotomies 3 Types

- **PCO** – Posterior Column Osteotomy
- **PSO** – Pedicle Subtraction Osteotomy
- **VCR** – Vertebral Column Resection

Selecting the Type of Osteotomy(Ies)

- Type of Deformity – Scoliosis/Kyphosis/Lordosis
- Magnitude – Cobb measures
- Stiffness – Determined preop & intraop
- Angularity- Deformity Angular Ratio (DAR)
- SCSCS- Spinal Cord Shape Classification System
- Global Coronal & Sagittal Imbalance
- Bone Density – Proxy for PS purchase
- Surgeon Experience/Comfort level
- Minimization/Avoidance of complications

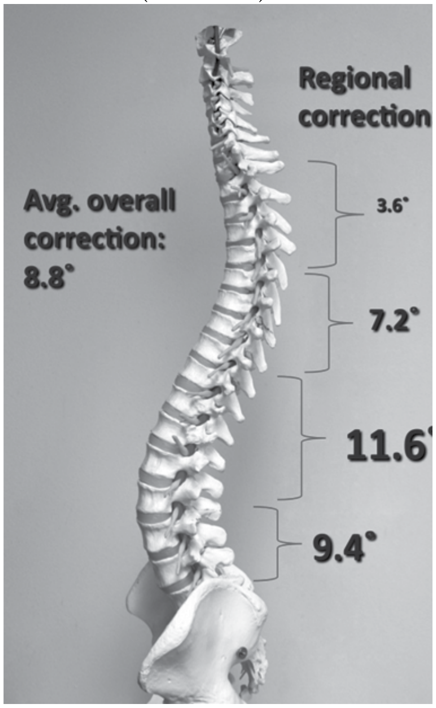
Sagittal Correction

- Not all PCOs are created equal!
- Overall mean 8.8° ± 7.2°

- Correction affected by age
  - 10.2° ± 7.8° per level for patients <21 years vs. 7.7° ± 6.3° for ≥21 (P<0.0001)
  - Correction affected by Region of Spine (P<0.0001), as shown

Conclusions

- All Spinal Deformities can be Realigned from a Posterior Only Approach (since 2002)
- Realignment begins with Proper Pt. Positioning
- TLIF's can Restore both Coronal and Sagittal Segmental Alignment, mainly used at Distal end
- Various Spinal Osteotomies (Carpentry) are utilized based on the Magnitude of Deformity, Flexibility, Angularity (DAR) and Operative Goals.
- PCO's are the Workhorse Osteotomy for the vast Majority of Pts.
- 3-CO'S (PSO/VCR): Fixed and/or Angular Deformities!



Minimally Invasive Surgery for Spinal Deformity

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MIS Introduction

With the aging population, there is a rising prevalence of degenerative spinal deformity and the need of surgical care for such patients. Surgical treatment options for adult spinal deformity (ASD) are often fraught with high complication rates. Minimally invasive surgery (MIS) has for the past decade been adopted to treat ASD in the effort to reduce access-related morbidity as well as perioperative complications. The benefits of MIS approach in general and recent development of MIS techniques to avoid long-term complications like pseudoarthrosis or proximal junctional kyphosis. MIS deformity correction includes anterior, lateral, and posterior techniques that can be tailored to each patient while capturing the strength of each respective technique. Previous limitations of obtaining sagittal correction have been overcome with anterior column realignment (ACR) and the mini-open pedicle subtraction osteotomy.

Correction of global alignment and restoration of radiographic pelvic parameters has been correlated with improved outcomes and improved health-related quality-of-life (1,2). MIS techniques with mini-open pedicle subtraction osteotomy (PSO) and anterior column realignment (ACR) with hyperlordotic interbodies allow for substantial changes in segmental lordosis and global sagittal balance (3-6). The goals of surgical intervention for ASD are decompression to alleviate back and radicular pain with durable restoration of sagittal and coronal balance (7). New and evolving MISS techniques can be applied to ASD correction and have the ability to achieve goals of surgical intervention.

Indications

The most common presenting symptoms of ASD include disabling axial back pain, neurogenic claudication and/or lower extremity radicular complaints. Findings that relate to central stenosis can include spondylolisthesis and/or lateral listhesis. The concavity side can cause foraminal stenosis contributing to radicular complaints whereas the convexity can lead to nerve stretch and irritation. Correlating the patient's symptoms to radiographic findings is key.

Risk factors associated with curve progression include a Cobb angle greater than 30 degrees, lateral listhesis of greater than 6mm, asymmetric disc space above or below the apical vertebra, and a deep-seated L5 vertebra relative to the intercrestal line (8,9). Indications for surgical intervention include new or progressive neurologic deficit, radicular pain and/or back pain that has been recalcitrant to conservative measures. Failure of conservative measures with multimodal pain management and physical therapy must be exhausted prior to surgical consideration.

Surgical Planning

Minimally invasive surgical correction of ASD requires adequate planning. MIS techniques can be offered to patients via foraminotomy or laminectomy (10). Decompression may serve as an appealing, less invasive alternative for patients with more leg than back pain who are reluctant to undergo extensive thoracolumbar correction for ASD. Consideration of focal decompression alone can be considered in elderly patients with or without high-risk comorbid conditions and primary complaints of radicular pain. Patient counseling should include possible progression of scoliosis, deformity, or stenosis.

Short segment fusion has been offered as an alternative to long segment fixation and correction of ASD (11,12). Long construct instrumentation and, as needed, decompression are the definitive surgical options for ASD. Surgical planning should include correction of lumbar lordosis, sagittal and coronal balance while calculating interbody size/lordosis, and instrumented levels that generally extend from the lower thoracic levels to the pelvis. Minimally invasive techniques include anterior lumbar interbody fusion (ALIF), transforaminal lateral interbody fusion (TLIF), lateral lumbar interbody fusion LLIF, anterior column realignment (ACR), mini-open pedicle subtraction osteotomy (PSO), and percutaneous pedicle screw placement.

As a matter of preference, the transpsoas LLIF is used as access for interbody placement levels including the thoracolumbar junction down to the L4-5 level. The lateral transpsoas approach is advantageous in that it does not disturb facets or the posterior or anterior ligamentous structures. Advantages include the ability to execute this approach without the need for an access surgeon, placement of large interbody grafts that allow for restoration of disc height and lordosis. LLIF interbodies bear a large footprint for fusion as well as central and foraminal indirect decompression of the neural elements (13-18). Contraindications to LLIF include the L5/S1 disc space, high grade spondylolisthesis, previous retroperitoneal surgery that may have caused scarring, vascular anomalies overlying the lateral/anterolateral vertebral body, significant osteophyte and/or ossification of the disc space.

Transforaminal lumbar interbody fusion is entertained when anatomic restrictions to the disc space inhibited by anatomic restrictions. Advantages to minimally invasive TLIF techniques include minimal to no nerve root retraction, ability to perform facetectomies, direct decompression, use of expandable cages, and the ability to perform interbody fusion in the same prone position as pedicle screw placement (19).

ALIF is used at the lumbosacral junction to provide a larger footprint as to minimize subsidence, promote fusion and increase lumbosacral segmental lordosis. Additionally, ALIF allows for decompression of bilateral foramina at the index level, resection of the anterior longitudinal ligament, wide discectomies, and if performed at the L4/5 level there is less mobilization of the psoas and thereby the lumbar plexus (20-22). This may not be feasible pending vascular anatomy, retroperitoneal structures, retroperitoneal scarring, or elevated sacral slope limiting access and graft placement at the L5/S1 level. Additionally, an ALIF can be done in the lateral position allowing for a single-position LLIF and ALIF combination.

In cases with severe kyphotic deformity in need of additional lumbar lordosis, an ACR can be indicated (6). A minimally invasive LLIF with ACR can be performed in lieu of a PSO and achieve 20–30 degrees of sagittal correction with less morbidity than traditional open techniques (5). An ACR supplemented with additional posterior osteotomies can significantly increase segmental lordosis by 72.7% when compared to ACR alone, as described by Turner et al. (23). While ACR is a powerful tool for the minimally invasive surgeon in need of significant sagittal correction, although opportunities may be limited by patient anatomy (i.e., vascular structures or ankylosed levels).

Open osteotomies incur increased risk and morbidity when compared to minimally invasive techniques (24,25). Elevated peri-operative morbidity of open techniques have promoted a mini-open approach for osteotomies (3,4,26). The mini-open PSO in addition to the powerful sagittal correction for ASD. Although long-term studies are needed this technique can be considered maximal sagittal correction when combined with ACR (4).

There are many techniques for thoracolumbar percutaneous pedicle screw placement. Bi-planar fluoroscopic guidance for pedicle screw placement has been described with 2.7% violation of the medial wall with a zero percent complication risk (neurologic or otherwise) (27). Intra-operative navigation has become more commonly used technology for minimally invasive spine surgeons. Variations of CT based navigation techniques have been shown to reduce operative time, reduce radiation exposure while improving accuracy compared to traditional fluoroscopic techniques (28-31).

Robotic Guidance

Recent developments in robotic technology have facilitated robotic guidance systems that enable percutaneous placement of pedicle screws. In multilevel constructs, robotic guidance systems deliver pedicle screw accuracy similar to open and fluoroscopic techniques (32-34).

Conclusion

Combinations of interbody placement (LLIF, TLIF, ALIF) can be used to obtain the desired sagittal correction. MIS techniques are beneficial for ASD correction and must be tailored on patient-to-patient basis.

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Cervical Alignment is as Important as Thoracolumbar Alignment

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Cervical alignment and deformity:

- The cervical region is the most flexible portion of the spine.
- Cervical deformity is complex and spans a range of conditions.
- Cervical deformity/malalignment can produce significant impact (e.g., disability, pain, neurological deficits)
- Literature on cervical alignment and deformity is limited with regard to definition assessment, optimal treatment, outcomes, etc.[1]

Importance of thoracolumbar alignment:

- Thoracolumbar alignment and deformity have been studied extensively over the past 2-3 decades resulting in marked improvement in understanding of the impact of TL malalignment

- Glassman et al was among the first to draw our attention to the important of positive sagittal alignment in adult deformity patients, showing that even mildly positive Cy-S1 sagittal vertical axis had negative impact on health-related quality of life.[2]
- Schwab et al demonstrated the value of radiographic parameters (both thoracolumbar and pelvic) in adult deformity patients.[3,4]
- How could cervical alignment be as important as thoracolumbar alignment?

Health impact of adult cervical deformity:

- Cervical malalignment/deformity can have profound impact on health-related quality of life
- Smith et al assessed baseline EQ-5D scores for 115 adult cervical deformity patients presenting for surgical management.[5] Compared scores with age- and gender-matched normative population and with other chronic disease states.
  - ► Adult cervical deformity patients had baseline EQ-5D index values that were significantly below the bottom 25th percentile for generational norms.
  - ► All subdomains of the EQ-5D were significantly impacted in adult cervical deformity patients (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression)
  - ► Mean EQ-5D index for adult cervical deformity patients was comparable to the bottom 25th percentile for blindness/low vision, emphysema, renal failure, and stroke, and were significantly below the bottom 25th percentile for chronic ischemic heart disease, malignant breast cancer, and malignant prostate cancer.

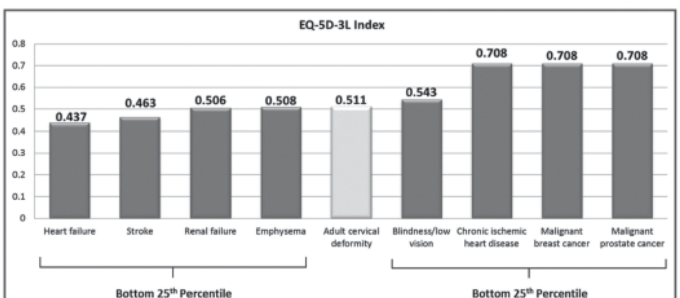


FIGURE 3. Graphical comparison of the mean EQ-5D index for the 115 adult cervical deformity patients in this study with the mean index values for the bottom 25th percentile of patients with a variety of disease states in a US population.

Examples of why cervical alignment is highly impactful:

- C2-C7 SVA significantly correlates with disability (Neck Disability Index; NDI)
  - ► Tang et al assessed the impact of C2-C7 SVA on health-related quality of life following posterior cervical fusion surgery;[6] found significant linear correlation between NDI and C2-C7 SVA; correlation even stronger than was found by Glassman et al between C7-S1 SVA and Oswestry Disability Index.[2]

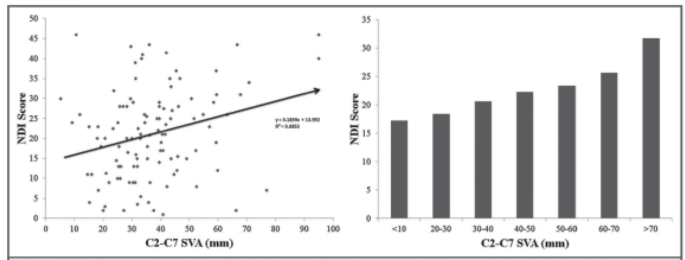
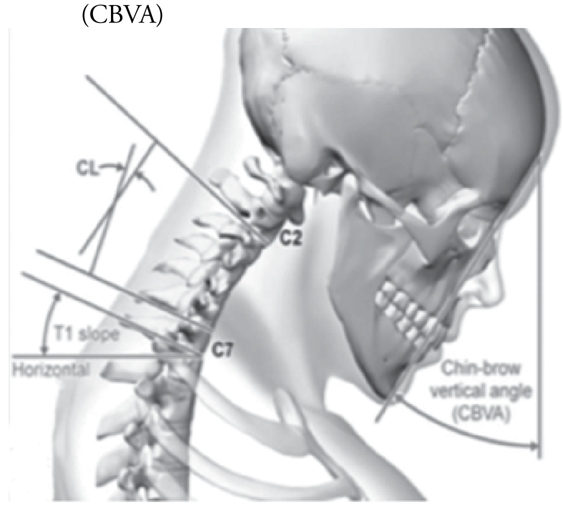


FIGURE 2. Positive correlation observed between C2-C7 SVA and NDI scores. Left, regression results superimposed on raw data. Right, bar graph of mean data. SVA, sagittal vertical axis; NDI, neck disability index.

- Cervical alignment is the final determinant of horizontal gaze
  - ► Horizontal gaze is a fundamental human function that allows interaction with others and the environment; commonly measured based on the chin-brow vertical angle (CBVA)



  - ► Suk et al assessed significance of CBVA in correction of kyphotic deformities in 34 patients treated with a pedicle subtraction osteotomy.[7] They assessed horizontal gaze function based on the Modified Arthritis Impact Measurement Scale. If the CBVA was under-corrected to a limited degree, patients seemed to tolerate this much better than if the CBVA was over-corrected. Patients with over-corrected CBVA ("bird watcher's position) had significantly worse horizontal gaze scores, especially for the ability to safely go down stairs. Suggested that goal CBVA should be between -10º and +10º.
  - ► Lafage et al evaluated natural head posture in the setting of sagittal spinal deformity and determined thresholds for CBVA that correspond to a low to moderate level of disability (between -4.8º and +17.7º).[8]

- Cervical kyphosis can produce and exacerbate cervical myelopathy
  - ► Most common etiology for cervical myelopathy is multi-level spondylosis. Less attention given to cervical kyphosis as a source of myelopathy.
  - ► Chavanne et al demonstrated increased spinal cord intramedullary pressure with progressive degrees of cervical kyphotic deformity in a cadaveric study.[9]
  - ► Smith et al assessed 56 patients with cervical spondylotic myelopathy presenting for surgical treatment.[10] They found a

significant correlation between C2-C7 SVA and the severity of myelopathy based on the mJOA score.

- Yuan et al retrospectively reviewed 212 cervical spondylotic myelopathy patients. They assessed the preoperative cervical sagittal alignment parameters and their impact on myelopathy.[11] The mJOA score was found to significantly correlate with C2-C7 SVA and with the T1 slope. Age combined with C2-C7 SVA was found to be very sensitive for predicting the mJOA score.

- Cervical malalignment can impact the ability to swallow and breath
  - Ota et al assessed the relationship between cervical alignment and oropharyngeal space in 40 asymptomatic volunteers.[12] They found an "extremely strong" correlation between the change in the occiput to C2 angle (O-C2) and the percentage change in the narrowest oropharyngeal airway space. They noted that for each 10º decrease in the O-C2 angle, there was a 37% reduction in the narrowest oropharyngeal space.
  - Kaneyama et al assessed the relationship among cervical alignment, oropharyngeal space, and the incidence of dysphagia after occipitothoracic fusion in 32 patients.[13] They found a strong relationship between pharyngeal tilt angle and the diameter of the oropharyngeal airway space and the incidence of dysphagia. Their findings suggest that dysphagia after occipitothoracic fusion may be caused by narrowing of the oropharyngeal space due to compression from an anteriorly protruded mid-cervical spine.

- Conclusions:
  - Both thoracolumbar and cervical alignment are important.
  - Although not as well understood, the impact of cervical alignment goes far beyond simply the ability to stand up straight or walk.
  - Cervical alignment is finely tuned to enable several very fundamental human functions than can be severely impacted by malalignment.

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Cervical Alignment is Less Critical, and Here is Why

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Cervical spine is part of the spine with the most mobility in the sagittal plane. It is important for surgeons to have reliable, simple and reproducible parameters to analyse the cervical spine.

Material and method : This study is a systematic review and a critique of current parameters to help improve the study of cervical spinal balance. 138 articles were found by the electronic search. After complete evaluation 20 articles were selected. Then we propose our daily practice of sagittal balance management for cervical spine and how different it is from thoraco-lumbar analysis

Results: C2_C7 lordosis, C2-C7 SVA, T1slope or C7 slope and T1 slope/cervical lordosis mismatch are the most commonly used parameters. Very few gobal balance analysis of the cervical spine have been described. The TIA described by Janusz (thoracic inlet angle) was finnally reported as not pertinent in an other study. The Spino-cranial Angle (SCA) described by Le Huec and the CIA (cranial inclination angle) described by Faundez A seems better parameters to predict the risk of PJK. These parameters are highly correlated with the C7 slope and the cervical lordosis. Other studies reported parameters that are more global balance analysis including the cervical spine which seems important like the ODHA (odontoid-hip axis) reported by Amabile C and the cranial SVA described by Lenke L. According to Faundez A the most important anatomical point to avoid PJK at upper instrumented vertebra (UIV) in long thoraco lumbar fusion is to consider the lever arm of the segment of the body localized on top of UIV with evaluation of the distance of the theoretical gravity line that normally falls through the femoral head. The lever arm of the above mention segment of the body is more important than the alignment. The first 5 thoracic vertebra should be considered as the "sacrum" of the cervical spine + the head and therefore the inclination of this segment and the value of the C7 slope are crucial.

Discussion: The most important parameters to analyse the cervical sagittal balance according to the literature available today for good clinical outcomes are the following: C7 or T1 slope, average value 20°, must not be higher than 40°. cSVA must be less than 40mm (mean value 20mm). SCA (spine cranial angle) and CIA must stay in a norm (83°+/- 9° and 75° +/- 5 respectively). Future studies should focused on those parameters to analyse and compare pre and post op data and to correlate the results with the quality of life improvement.

In summary: **Cervical Alignment is Less Critical than cervical – head complex positioning on top of C7-T1 considered as a basement. New angles like CIA have a predictive value for the risk of PJK and must be included in the planning of the surgery.**

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Cervical Deformity, Approach Considerations

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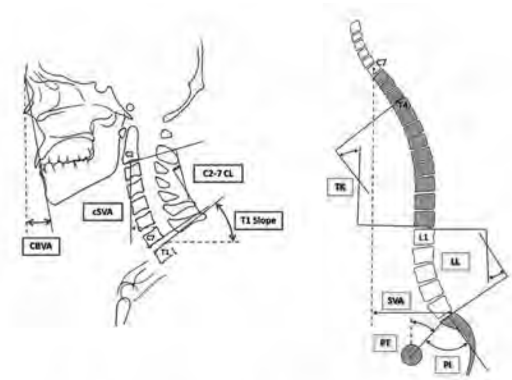
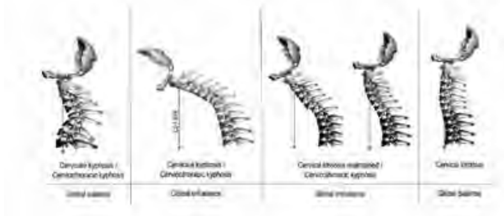
General Approach Considerations

The "best" approach for the surgical correction of cervical deformity takes into consideration a number of factors. There can be more than one surgical plan or approach that can be successfully employed to correct the deformity. Factors to consider include:

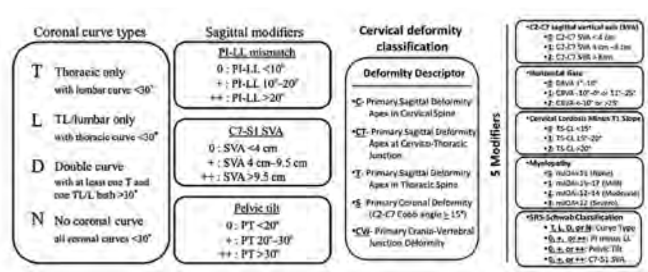
- The magnitude of deformity
- The location of the deformity via thorough radiographic assessment including global balance1
- The flexibility (or lack of flexibility) of the deformity including presence of pseudarthrosis
- The presence or absence of prior spinal instrumentation
- The severity of neural compression (central and foraminal)
- The integrity of the anterior and posterior columns
- The quality of the bone
- The history and outcomes of prior surgical procedures
- Complications related to prior procedures such as vocal cord paralysis or vertebral artery injury
- The classification of the deformity





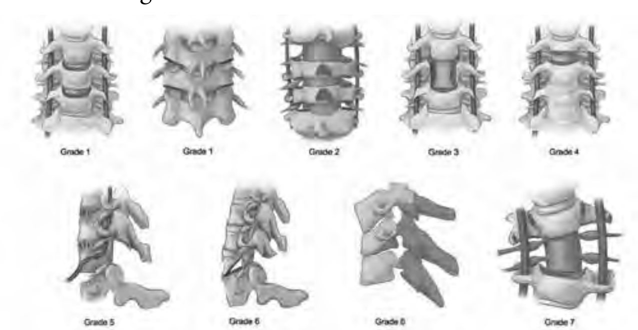
Classification of Spinal Deformity

Using a standardized classification of spinal deformity provides a framework for systematically analyzing the spinal deformity. This analysis is critical for identifying the appropriate surgical approach. A recent deformity classification provides a framework to better assess cervical deformity[2]. These studies emphasizes the importance of assessment of the entire spine as a part of the assessment needed to determine the appropriate surgical approach[1,2].



Release Techniques for Correction of Cervical Deformity

An article was published where the objective was to establish a universal nomenclature for cervical spine osteotomies to provide a common language among spine surgeons. The soft tissue release and osteotomy grading was hierarchical with the author's belief that as the soft tissue release/osteotomy grade increased the surgical complexity and complications performing the procedure would track with the grade[3].



It was recently determined that patients with 3CO treatment of

Pre-Meeting & Half-Day Course Handouts

rigid cervical deformity showed a significantly different correction of C2–C7 SVA with an average 27 mm compared to patients without 3CO showing a change of C2–7 SVA of average 7 mm however complications were not insignificant for these major surgical procedures1.

Invasiveness of Different Surgical Approaches

Consensus from experienced spine and neurosurgeons selected weightings for each variable that went into the invasiveness index developed for cervical deformity (CD) surgery that incorporated CD-specific parameters[4]. 85 patients with CD were analyzed and binary logistic regression predicted high operative time (>338 minutes), estimated blood loss (EBL) (>600 cc), or length of stay (LOS; >5 days) based on the median values of operative time, EBL and LOS. Multivariable regression modeling was utilized to construct a final model incorporating the strongest combination of factors to predict operative time, LOS, and EBL. Binary logistic regression predicted high operative time (>338 minutes), estimated blood loss (EBL) (>600 cc), or length of stay (LOS; >5 days) based on the median values of operative time, EBL and LOS. Multivariable regression modeling was utilized to construct a final model incorporating the strongest combination of factors to predict operative time, LOS, and EBL.

Surgical Factors	*Points Assigned*
ACDF	2 points per level
Corpectomy	4 points per level
Levels Fused	1 point per level
Implants	1 point per implant
Posterior Decompression	2 points per level
Smith-Peterson Osteotomy	3 points per level
Three-Column Osteotomy	8 points per level
Fusion to upper cervical spine	2 points
Revision Status	3 points
Radiographic Factors	
Absolute change in cSVA	0.5 point per 1mm change
Absolute change in TS-CL	0.5 point per 1° change
Absolute change in Thoracic Kyphosis	0.5 point per 1° change
Absolute change in SVA	0.5 point per 1mm change

Consideration of the parameters associated with higher levels of invasiveness should be taken into consideration when more than one surgical approach would be potentially acceptable for correction of deformity.

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Case Discussion Abstracts

The Scoliosis Research Society gratefully acknowledges NuVasive for their support of the Annual Meeting Announcement Board, Beverage Break, Charging Stations, Directional Signage, E-Poster Kiosks, E-Poster USBs, Newsletter, Printing Stations, Ribbon Display, and Welcome Reception.

SRS
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Case Discussion Abstracts

1A. Screw vs Aorta: A Vertebral Body Tether Case Report Illustrating Approach to Diagnose and Treat Periaortic Screws

Michael S. Warren, MD; Lawrence L. Haber, MD; Michael A. Nammour, MD; Taylor A. Smith, MD; Heather Taillac, MD; Vincent R. Adolph, MD

Summary
Screw vs Aorta: A Vertebral Body Tether Case Report Illustrating Approach to Diagnose and Treat Periaortic Screws

Hypothesis
A multi-disciplinary team is the best way to approach periaortic screws. With propper planning, stent placement can be reserved for definite injuries.

Design
This is for the case presentation session and is used to demonstrate a pragmatic algorithm to treat periaortic screws.

Introduction
15-year-old female had a VBT placed T6-L1 with an open right approach 18 months prior at an outside hospital (OSH). Her curve corrected from 55 to 10 degrees after 18 months. 8 weeks post-operatively, due to a pleural effusion, CT scan found screws that were long by a concerning amount. The T9 screw was abutting the aorta. Intravascular ultrasound (IVUS) showed significant aortic indentation. Utilizing pediatric and vascular surgery, we a developed a reproducible surgical plan. Major concerns were positioning to allow access to the contralateral chest, endovascular stenting, open vs thoracoscopic approach, whether to revise or just remove the tether.

Methods
A right femoral arterial line was placed by vascular surgery to allow for immediate vascular access. The patient was positioned in a left lateral decubitus with the right groin and arterial access line prepped into the surgical field. The initial approach was thoracoscopic. We converted to an open approach due to significant adhesions.. All equipment for stent deployment was available in the room. The vascular surgeon and all necessary aortic stents and endovascular equipment were in the room during screw removal. The T6-T9 screws were removed/revised. The cord was re-implanted from T6-T12. There was no evidence of bleeding from the aorta. Though prepared for intraoperative angiogram and potential stent placement, neither was needed.

Results
We suggest a multidisciplinary approach to screw removal with femoral arterial line placement by vascular surgery prior to incision. IVUS is useful to evaluate impingement. Vascular surgery and equipment for stent placement should be immediately available.

Conclusion
We recommend against prophylactic aortic stents. With careful planning and preparedness, these devices can be reserved for definite aortic injury. Use of a multidisciplinary team is critical

Take Home Message
With femoral arterial line placement by vascular surgery prior to incision and equipment for stent placement immediately available, prophylactic aortic stents can be safely reserved for definite aortic injuries.

Intra-vascular Ultrasound

CT Scan T9

CT Scan and Intra-Vascular Ultrasound of T9 Screw Impinging Aorta

1B. A Case Series on Pectoralis Major Muscle Flap for Esophageal Perforation after Revision ACDF

Michael A. Nammour, MD; Heather Taillac, MD; Michael S. Warren, MD; Bhumit R. Desai, BS; Paul C. Celestre, MD, Lawrence L. Haber, MD

Summary
This case series examines three patients who underwent multilevel ACDF at outside hospitals complicated by severe osteomyelitis and diskitis associated with esophageal perforation. In coordination with the otolaryngology service, all three patients underwent corpectomy with revision ACDF with a pectoralis major muscle flap (PMMF) for soft tissue coverage. All flaps were successfully

incorporated for coverage of the esophageal defect. We suggest that pectoralis major muscle flap is a promising option for esophageal injuries following ACDF.

Hypothesis
N/A

Design
Case Series

Introduction
Esophageal perforation (EP) after anterior cervical discectomy and fusion (ACDF) is a rare but serious complication with an incidence of approximately 1%. Poor blood supply, contamination by esophageal contents, scar tissue and implanted hardware provide a poor environment for wound healing and contribute to a high rate of recurrence with primary closure. Pectoralis major muscle flap (PMMF) is associated with decreased rates of recurrence and earlier time to oral feeding as the flap provides a highly vascular tissue to strengthen the closure, promote wound healing and improve antibiotic delivery.

Methods
This case series discusses three patients who underwent multilevel ACDF at outside hospitals prior to treatment at our facility. On presentation, all three were found to have EP with severe diskitis and osteomyelitis. In coordination with the otolaryngology service, all three patients underwent corpectomy with revision ACDF with PMMF for soft tissue coverage.

Results
All patients had full incorporation of the PMMF. One patient tolerated a soft diet within 3 weeks and a regular diet at 10 weeks post-op. This patient underwent posterior spinal fusion (PSF) four months after revision ACDF due to poor bone quality. The second patient tolerated a soft diet at 7 weeks post-op and a regular diet at 10 weeks post-op. At 18 months this patient required irrigation and debridement of a deep abscess; however, the PMMF was intact without evidence of EP. The third patient had a history of a laryngectomy complicated by a tracheoesophageal fistula with prior cervical radiation and B-cell lymphoma. This patient required PSF for kyphotic collapse one month after his revision ACDF and flap coverage. Due to the prior fistula this patient was unable to tolerate a diet.

Conclusion
EP has a reported mortality rate up to 18%, and there is a paucity of orthopaedic literature on the subject despite a 1% incidence following ACDF. We suggest that PMMF for esophageal injuries following ACDF is a promising option as it provides a robust blood supply capable of covering large tissue defects.

Take Home Message
Pectoralis major muscle flap is a promising option for esophageal injuries following ACDF.

1C. Intraoperative Anaphylaxis from Intraosseous Gelatin Administration Leading to Surgery Abandonment in AIS Patients

Vishal Sarwahi, MD; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Melanie A. Smith, cPNP; Terry D. Amaral, MD

Summary
17 year old female with 24.4 BMI underwent posterior spinal fusion for AIS. Intraoperatively, patient developed anaphylactic reaction. Surgery was aborted.

Hypothesis
Undocumented gelatin allergies can lead to anaphylactic reactions intraoperatively, complicating outcomes.

Design
Case Study

Introduction
AIS patient with 58° thoracic and 74° lumbar curve underwent posterior spinal fusion from T3-L3. Preoperative pulmonary and cardiology testing was negative. Allergy history consisted of food dye only, no iodine allergy.

Methods
Patient was induced and intraspinal duramorph was administered by anesthesiologists at 8:16 AM. Incision began at 9:39. Screw tracts were made on the left side starting from L3 to T5 using freehand anatomic technique and less than 1 cc per screw hole of Surgiflo™ was injected to prevent bony bleed. This was completed by 10:20 and screws were not placed. There were no pedicle tract breaches. At 10:22, there was a sudden drop in blood pressure to MAP 45 (baseline MAP was 80) and oxygen drop of 61%. Signals remained at baseline. Patient was turned supine and anesthesia code was initiated. After an hour, it was decided to continue with the surgery. The patient was repositioned and the wound was re-opened. However, there was decreased amplitude of the right abductor hallucis with some latency on MEP. MAP > 80 mmHg. Patient was given 8 mg Decadron and 1 mg/kg of lidocaine. Signals did not improve. Due to concerns about the unknown cause of hemodynamic instability and nuanced (not significant) signal changes likely due to hypotension, surgery was abandoned

Results
Precipitous drop in MAP and oxygenation suggested anaphylaxis. MAT confirmed this, with an elevated serum tryptase of 15.8 ng/mL (<11 ng/mL). Discussion with the family revealed that patient was also allergic to gummy bears and gel-coated capsules, suggesting a gelatin allergy. Based on the surgical log, the obvious cause was Surgiflo™ use. Second surgery was completed POD 3 without duramorph or Surgiflo™. Signals remained at baseline and procedure and discharge was uneventful.

Conclusion
Due to frequent gelatin-thrombin mix use in hemostatic matrixes, gelatin allergies should be considered in preoperative questionnaires as well as diagnostic testing.

Take Home Message
Gel-foam, Surgiflo, Floseal are gelatin products which are frequently utilized for hemostasis during spinal surgery. Gelatin allergies should be considered to avoid negative intraoperative events.

Preoperative posteroanterior (A) and lateral (B) with postoperative posteroanterior (C) and lateral (D) x-rays.

1D. Don't Underestimate the Hazard of Thoracolumbar Kyphosis in Skeletal Dysplasia

William Giles Stuart Mackenzie, MD; Anthony Dinardo, DC; Rameez Qudsi, MD, MPH; Colleen Ditro, RN, BSN, DNP,CPNP; Suken A. Shah, MD; William G. Mackenzie, MD, FRCS(C)

Summary
Thoracolumbar kyphosis is a common finding in children with skeletal dysplasia and can be associated with catastrophic outcomes after anesthesia. With positioning under anesthesia, dynamic changes at the level of kyphosis can result in spinal cord injury. This case presentation highlights the vigilance needed in the multidisciplinary management of syndromic patients with thoracolumbar kyphosis.

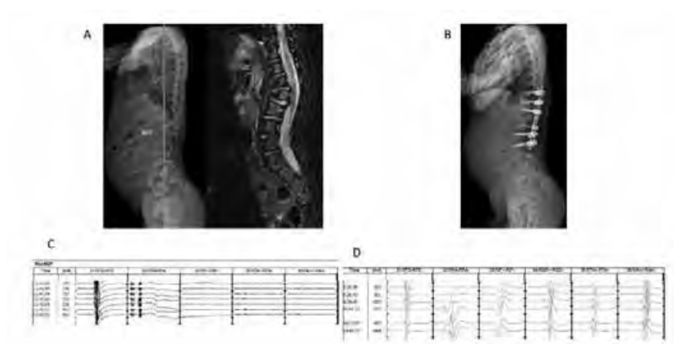
Design
Case report

Introduction
Thoracolumbar kyphosis is associated with several forms of skeletal dysplasia, and can be treated nonoperatively in patients without progressive deformity and no signs of spinal cord compression. Asymptomatic patients with thoracolumbar kyphosis remain at increased risk of spinal cord injury when under anesthesia.

Results
A 5 year-old boy with Mucopolysaccharidosis type VI, thoracolumbar kyphosis of 40 degrees and hip dysplasia required bilateral hip reconstruction. He had no neurologic symptoms and underwent pre-operative spine x-rays and MRI without instability or cord compression. As per our protocol for skeletal dysplasia patients with thoracolumbar kyphosis, multimodality neuromonitoring (SSEPs and MEPs) was performed on the day of surgery. After induction and supine positioning, MEPs of both lower extremities were undetectable despite intact SSEPs, with normal SSEPs and MEPs in the upper extremities. The patient was rolled to the lateral decubitus position and was fully intact on wake-up test. The procedure was aborted and MRI did not demonstrate any acute change to the spinal cord. After review, it was determined the patient had sustained an anterior cord syndrome likely due to distraction of the spinal cord at the apex of his deformity, resulting in transient ischemia. The patient subsequently had full motor strength on exam and was able to ambulate. Decompression of the spine was attempted two weeks later, although lower extremity MEPs remained highly attenuated, and the procedure was delayed two months. On return to the operating room, the patient was found to have fully monitorable MEPs and SSEPs and underwent an uneventful L1-3 laminectomy with posterior instrumentation and fusion T10-L4. Once he was decompressed and stabilized, this boy had bilateral hip reconstruction with neuromonitoring, and remains ambulatory with full neurologic function 24 months after injury.

Conclusion
Skeletal dysplasia patients with thoracolumbar kyphosis are at risk for spinal cord injury during anesthesia. Neuromonitoring can detect spinal cord dysfunction early and help prevent irreversible harm in this complicated patient population.

Take Home Message
Skeletal dysplasia patients with thoracolumbar kyphosis require neuromonitoring while under anesthesia, and our colleagues should be aware of this potentially devastating complication, even when performing non-spine procedures.



Preoperative imaging B) Postoperative X-ray C) Neuromonitoring MEPs at time of injury D) Neuromonitoring MEPs at time of spine decompression

2A. The Management of Scoliosis Following an Infantile Hemipelvectomy for Ewings Sarcoma

Otis C. Shirley, MD; Robert Rowan, FRACS

Summary
Scoliosis is a recognised sequela following hemipelvectomy. This rare pediatric case illustrates the complexities in surgical decision making.

Design
Case Study

Introduction

The patient, a 15 year old female had a thoracolumbar scoliosis following a hemipelvectomy for Ewings Sarcoma at age 22 months. She mobilised with a prosthesis and used a wheelchair for longer distances. She developed a progressive thoracolumbar scoliosis, and extreme pelvic obliquity with uncovering and subluxation of her hip. The hip abductors were defunctioned by the relative hip adduction and there was concern that the hip may dislocate.

Methods

Surgical goals where to prevent further deterioration, to improve spinal alignment, to preserve hip function, and patient mobility. Discussion points include a. Could surgery on the spine preserve hip function? b. What is the ideal alignment in the presence of a hemipelvectomy? c. How could the desired alignment be achieved?

Results

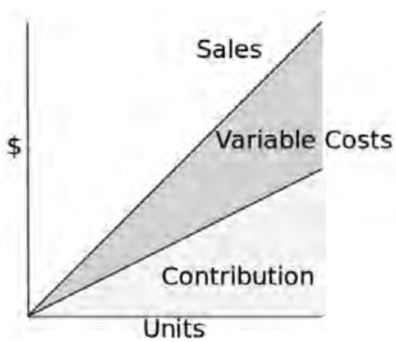
A Spino-Pelvic fusion was undertaken. The patient gained 9cm in height, and had significant improvement in hip centre- edge angle. She remains independently mobile and is attending University. Conclusion This rare case of paediatric thoracolumbar scoliosis following an infantile hemipelvectomy demonstrates the complexities in surgical decision making in this situation. The results of surgical treatment are discussed.

Conclusion

This rare case of paediatric thoracolumbar scoliosis following an infantile hemipelvectomy demonstrates the complexities in surgical decision making in this situation. The results of surgical treatment are discussed.

Take Home Message

Spinopelvic fusion for thoracolumbar scoliosis following a hemipelvectomy can be achieved with excellent radiographic and functional results



Preoperative X-ray

2B. En Bloc Spondylectomy of Primary Chondrosarcoma Arising within a Previous Spinal Fusion: A Case Report and Discussion

Floreana N. Kebaish, MD; Andrew B. Harris, BS; Khaled M. Kebaish, MD, FRCS(C)

Summary

We present the case of a patient who presented with persistent back pain following multiple lumbar spinal fusions. Radiographs and MRI showed a suspicious lesion within the previous fusion. A biopsy confirmed the diagnosis of primary chondrosarcoma. The patient underwent successful en-bloc spondylectomy of L4, containing the tumor, from within the fusion. This highlights the importance of following sound diagnostic methods while evaluating patients labelled as having failed multiple back surgeries.

Hypothesis

Rare diagnoses can easily be missed when focusing on the more common diagnoses such as chronic low back pain following multiple spinal fusions.

Design

Case report.

Introduction

The patient is a 63 year-old female who underwent lumbar spinal fusion in 2005, extension to L3 in 2015, then anterior-posterior fusion at L5-S1 in 2016 for persistent low back pain. There was a lesion noted at L4 prior to her most recent fusion which was not evaluated further at the time. Upon referral to our facility, diagnostic workup including CT, MRI, and surgical biopsy confirmed a diagnosis of chondrosarcoma involving the vertebral body of L4, within a solid fusion mass the extended from L3 to sacrum. We believe this is the first reported case of a chondrosarcoma resection arising within a previous spinal arthrodesis.

Methods

A chart review has been conducted on this single patient regarding history, clinical presentation, surgical procedure and postoperative outcome.

Results

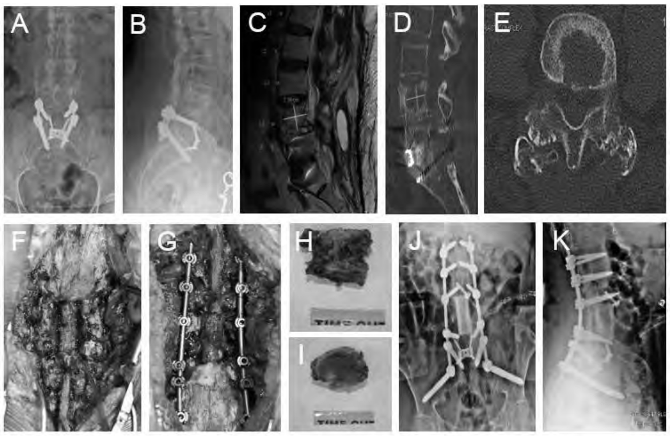
En-bloc spondylectomy of L4 was performed as a 3-stage procedure through a posterior-anterior-posterior approach. First: the spine was exposed through a posterior approach, neural structures were isolated and preserved, posterior elements were resected with a segment of the fusion mass at L4, and posterior cuts through the discs proximal and distal were made. Posterolateral dissection was also done. Second: through a right retro-peritoneal approach, the L4 vertebral body was isolated from surrounding structures. Anterior cuts were made, freeing the vertebral body, which was then removed without violating the tumor. Reconstruction was done using a femoral allograft. Third: posterior instrumentation and compression around the graft was finalized. EBL was 1500 ml and the patient had neurological function postoperatively.

Conclusion

Primary spinal chondrosarcoma is a rare diagnosis and surgical treatment is the only potentially curative option. This rare malignancy arising within a prior fusion may have led to the delayed diagnosis and added to the complexity. This patient was treated successfully with en-bloc spondylectomy, while preserving neurologic function.

Take Home Message

Primary malignancy arising within a spinal arthrodesis is very rare, and the diagnosis may be delayed or even missed. En bloc spondylectomy is the only potentially curative treatment.



2C. Supplementary Thoracoscopic Anterior Rib Strut Grafting Following Posterior Spinal Fusion and Instrumentation for Dystrophic Kyphoscoliosis in Neurofibromatosis

William Z. Morris, MD; Karl E. Rathjen, MD; Daniel J. Sucato, MD, MS

Summary

A 12-year-old female with pronounced dystrophic kyphoscoliosis secondary to neurofibromatosis was successfully treated with staged posterior cervicothoracic instrumented fusion and supplementary video-assisted throacoscopic anterior structural autologous rib strut graft placement.

Hypothesis

Supplementary anterior rib strut grafting may be a useful augment to posterior fixation in cases of stiff, severe kyphotic deformity in neurofibromatosis

Design

Case Report

Introduction

Dystrophic kyphoscoliosis (KS) secondary to neurofibromatosis (NF) presents a challenge for treatment as the kyphotic deformity is severe and posterior element erosion compromises fixation options. Three column osteotomies are increasingly used to treat such severe deformity. Although use of thoracoscopy has decreased, the combination of a thoracoscopically-assisted structural strut graft and posterior instrumented fusion and instrumentation (PSFI) is an effective and safe alternative to manage challenging KS from NF.

Methods

A chart review was performed to evaluate the patient's clinical course surrounding her staged anterior and posterior cervicothoracic instrumented fusion.

Results

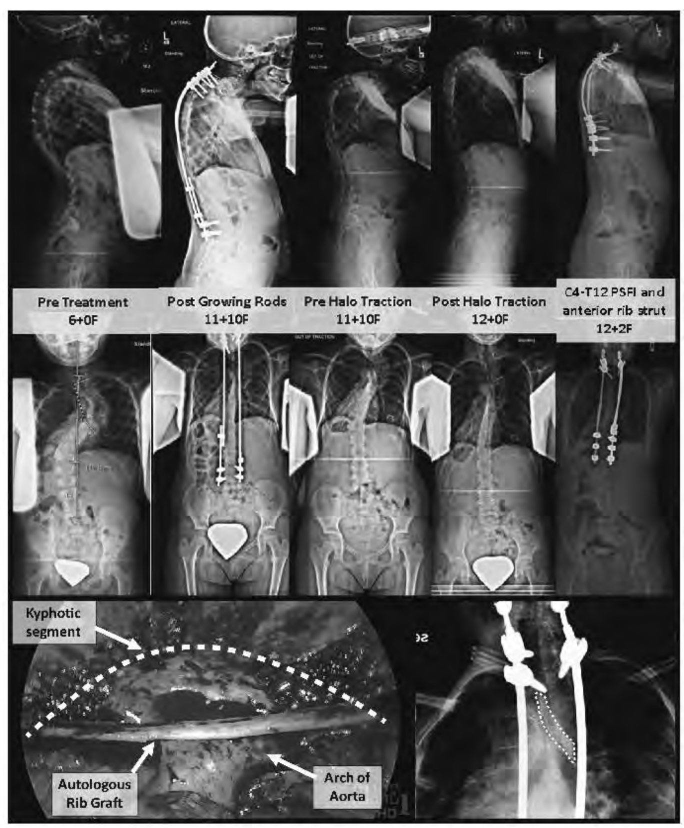
A 12-year-old female with dystrophic KS secondary to NF had been preliminarily treated at age 6 with traditional growing rods. She underwent successive lengthenings over 5 years until her implants were removed at age 11 and she was placed in 8 weeks of halo gravity traction (HGT) in anticipation of final fusion (Figure 1, top). Given the stiffness of the short kyphotic segment during HGT and the erosion of the apical posterior elements seen on advanced imaging, the surgeon and family elected to proceed with staged PSFI with delayed anterior rib strut grafting. The patient underwent PSFI with extension from C4-T12. She was placed in a halo vest for two months prior to the second stage video-assisted thoracoscopic autologous rib anterior strut grafting between T2 and T9 (Figure 1, bottom). The patient tolerated the procedure well and awoke without any neurologic deficits. She was discharged home on postoperative day 3 without any perioperative complications.

Conclusion

Dystrophic KS represents a challenging deformity for surgical management. However, supplementary thoracoscopically-assisted anterior rib strut grafting provides the opportunity for structural support complementary to PSFI without the inherent risks of three column osteotomies.

Take Home Message

Thoracoscopically-assisted anterior rib strut grafting provides valuable supplementary structural support to PSFI in dystrophic KS.



Top: Timeline of treatment of dystrophic kyphoscoliosis from left to right; Bottom: Thoracoscopic view (left) and radiographic appearance (right, dashed line) of autologous rib strut graft placement between T2 and T9.

2D. Facilitation of Transcranial Motor-evoked Potentials in Spinal Muscular Atrophy with Intrathecal Nusinersen: A Case Report

Suken A. Shah, MD; William Giles Stuart Mackenzie, MD; Scott S. Furstenau, BS, CNIM; Alier J. Franco, PhD; William G. Mackenzie, MD, FRCS(C)

Summary

Patients with spinal muscle atrophy (SMA) commonly develop early onset spinal deformity and require operative intervention. Intraoperative neurologic monitoring is challenging due to progressive motor neuron loss. Intrathecal infusion of nusinersen was shown in this patient with SMA1 to have a significant facilitation effect of transcranial motor-evoked potentials after infusion compared to instrumentation lengthening episodes before infusion. This is the first report of this finding.

Hypothesis

Intrathecal infusion of nusinersen will have no effect on the ability to perform TcMEP on patients with SMA

Design

Case report

Introduction

Spinal muscle atrophy is a progressive, neuromuscular condition caused by a defect of the survival motor neuron (SMN) 1 gene, resulting in a deficiency of the survival motor neuron (SMN) protein and motor neuron loss; these patients have a high prevalence of early onset spinal deformity. Intrathecal nusinersen, a medication indicated for SMA, known to increase production of SMN by upregulated transcription of the SMN2 gene, has shown, in pivotal clinical trials, maintenance of function in late onset and improvement of motor milestones in infantile onset SMA.

Results

A 6 year-old boy with SMA1 previously treated with bracing presented with progressive neuromuscular scoliosis and needed growth friendly surgery for early onset spinal deformity. Typical of children with this disorder, neurogenic and transcranial motor-evoked potentials (TcMEP) are of poor quality, progressively decline over time and eventually become non-monitorable. However, the somatosensory pathways are preserved. He underwent insertion of vertical expandable titanium rib to pelvis devices with excellent correction of his coronal and sagittal plane deformity. He underwent 10 lengthening/revision episodes over seven years with multimodality monitoring recorded at every episode. Progressive decline of TcMEP signal quality was seen over time. However, he recently received intrathecal infusion of nusinersen and significant improvement of his signal quality (TcMEP amplitude) was seen when monitoring his last two lengthening episodes (see Graph). This was directly and temporally related to the lengthenings after infusions.

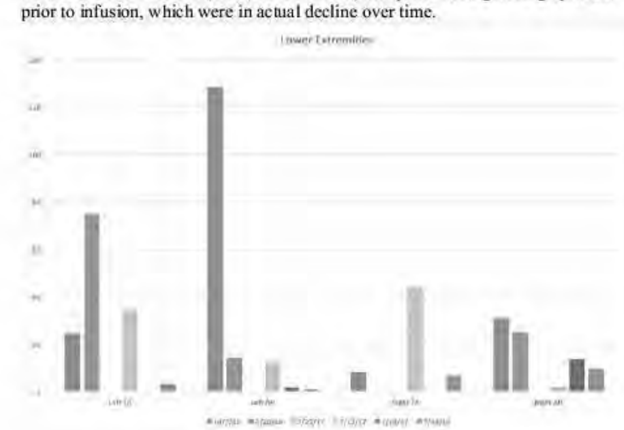
Conclusion

Intrathecal infusion of nusinersen was shown in this patient with SMA1 to have a significant facilitation effect of transcranial motor-evoked potentials after infusion compared to instrumentation lengthening episodes before infusion. This is the first report of this finding and prompted us to commence a multicenter study of TcMEP after infusion of nusinersen in SMA patients.

Take Home Message

Nusinersen may have promising effects with regard to neurologic monitoring, an indicator of health of spinal motor neurons, known to undergo atrophy and apoptosis in the natural history of SMA.

Figure: TcMEP amplitudes show significant improvement in bilateral TA and AH after nusinersen infusion (1/18, 5/18 and 9/18) compared to lengthening episodes prior to infusion, which were in actual decline over time.



3A. The Utility of Virtual Reality in Surgical Planning for Fixed Cervical Deformity: A Case Illustration

Joshua Hanna, MD; Jonathan Riffle, DO; Caleb Stewart, BS; Edna Gouveia, MD; James Kalyvas, MD

Summary

We present a case in which the use of Immersive Virtual Reality (IVR) aided in enhanced visualization and preoperative planning in a patient with fixed cervical deformity. The patient presented with complex anatomy including tortuous carotid vasculature and previous cervical fusion with iatrogenic unilateral vertebral artery injury. IVR was used as an adjunct to reduce stages in a multi-stage surgery and protect vital neurovascular structures while still achieving the major goals of surgery.

Hypothesis

Virtual reality improves planning for corrective spine surgery

Design

Case Report

Introduction

Surgical reduction of fixed cervical deformity is technically challenging and requires high risk maneuvers in the setting of aberrant anatomy. Careful pre-operative planning necessitates extensive review of multi-modal imaging and complex visuo-spatial processing. Immersive Virtual Reality (IVR) holds significant promise as a preoperative tool.

Methods

A 60 year-old female with Neurofibromatosis Type 1 presented with debilitating neck pain, radiculomyelopathy, and severe fixed cervical kyphoscoliosis. History included C2 neurofibroma resection with right vertebral artery sacrifice and C2-3 ACDF. Utilizing conventional imaging, a three-stage cervical procedure was considered, including posterior decompression and release, anterior cervical fusion, and occiput to T2 fusion. IVR imaging was rendered from cervical CTA to inform osseous and vascular anatomic relationships that altered the surgical plan. Tortuous bilateral carotids and vertebral artery anatomy was better appreciated, elucidating the risks of anterior approach. The need for intraoperative CTA navigation during posterior release also became more clear. The surgical plan was addended to a two-stage procedure: 1. C3-7 posterior column osteotomies with C2-T2 fixation under navigation to protect the lone vertebral artery with interim cervical traction; and 2. occiput to T2 rodding. The patient's post-operative course was uncomplicated with significant improvements in posture, gait, and pain at 6 month follow-up.

Results

IVR is an emerging technology in spine surgery planning with significant utility in complex cases such as this fixed cervical deformity. Here, the use of IVR eliminated one surgical stage, underscored the need for intraoperative CTA navigation, and enhanced our understanding of complex anatomy in order to protect vital anomalous vasculature during posterior decompression.

Conclusion

Preoperative planning with IVR allows better appreciation for patient-specific anatomy, improves spatial understanding of pathology, and reduces the inherent risks of cervical spinal deformity surgery.

Take Home Message

The use of Immersive Virtual Reality in pre-operative planning for fixed cervical deformity aids in protecting vital neurovascular structures and improving patient outcomes.

3B. Treatment of Congenital Spinal Deformity under the Guidance of Mixed Reality Navigation: A Case Report

Baoguo Mi, PhD; Dingjun Hao, MD, PhD; Lequn Shan, MD, PhD

Summary

The current report was the first to perform orthopedic surgery in a patient with congenital spinal deformity under the guidance of mixed reality navigation. We successfully developed both multi-segment Ponte osteotomy and thoracoplasty with mixed reality for the patient and predicted the postoperative correction effect by the guidance of mixed reality technology. Mixed reality technology makes congenital spinal deformity orthopedics more precise and effective.

Hypothesis

We assume that mixed reality technology makes congenital spinal deformity orthopedics more precise and effective.

Design

A case report

Introduction

Mixed Reality technology is a new digital holographic imaging technology after virtual reality technology and augmented reality technology. Although Mixed reality environments for medical applications have been explored and developed over the past three decades in an effort to enhance the clinician's view of anatomy and facilitate the performance of minimally invasive procedures. However, few mixed reality environments have been successfully used in orthopedic surgery, especially for orthopaedic osteotomy of congenital spinal deformity.

Methods

A 15-year-old woman visited her physician complaining of neck and back deformity for the previous 10 years, and diagnosed as congenital spinal deformity. After completing the preoperative examination, we developed both multi-segment Ponte osteotomy and thoracoplasty with mixed reality for the patient and predicted the postoperative correction effect by the guidance of mixed reality technology.

Results

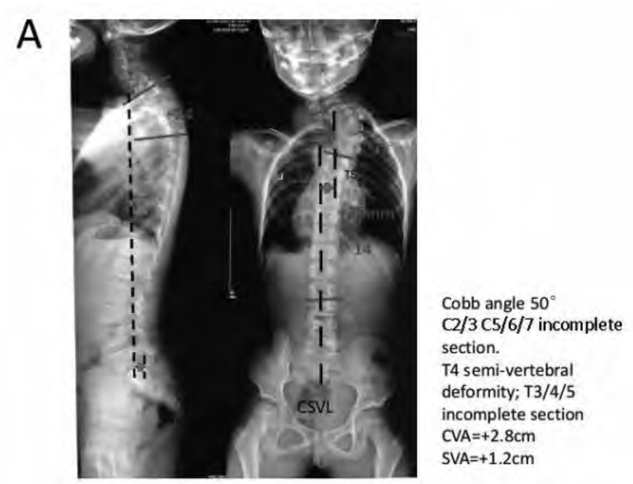
The surgery went successfully. Before and 3 days after surgery, the VAS scores of neck and shoulder were 5 and 2, the kyphosis Cobb angles were 50° and 8°, the scoliosis Cobb angles were 24° and8°. She can walk normally while wearing a brace 3 days later and without any discomfort.

Conclusion

Mixed reality is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. At present, the research on mixed reality technology in spinal orthopedics mainly involves concept, principle research and cadaveric experimental research. There was no literature reported that congenital spinal deformity orthopedic surgery was performed under the guidance of mixed reality navigation using an optical see-through head mounted display. It is the world's first. Our literature reports mixed reality technology successfully applied to spinal deformity orthopedic surgery for the first time. Mixed reality technology makes congenital spinal deformity orthopedics more precise and effective.

Take Home Message

The literature reports mixed reality technology successfully applied to spinal deformity orthopedic surgery for the first time. Mixed reality technology makes congenital spinal deformity orthopedics more precise and effective.



A-B: Preoperative X-ray and CT examination, C-D: Preoperative and intraoperative osteotomy design, E: Preoperative and postoperative general photo comparison, F: Postoperative X-ray examination.

3C. Concomitant Congenital Cervicothoracic/Upper Thoracic Deformity Associated with Sprengel Deformity and Klippel-Feil Syndrome: A Rare Condition

Huseyin Ozturk, MD; Yunus Emre Akman, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

Summary
3 patients with congenital cervicothoracic/upper thoracic scoliosis deformity associated with Sprengel deformity and Klippel-Feil syndrome were treated safely and effectively at the same surgical session.

Design
Case report

Introduction
Congenital cervicothoracic/upper thoracic anomalies are rare deformities and may present in conjunction with other conditions or syndromes. The aim of this study is to adress the surgical treatment of congenital cervicothoracic/upper thoracic scoliosis deformity associated with Sprengel deformity and Klippel-Feil syndrome (KFS).

Methods
3 female pts (6-10 yrs) who had upper thoracic scoliosis, Sprengel deformity and Klippel-Feil syndrome were included. All pts presented with shoulder imbalance and asymmetry with restricted shoulder ROM (limited abduction). Radiological examination revealed cervical instability and congenital fused cervical vertebrae due to KFS. Preop and f/up x-rays were compared in terms of Cobb angles, shoulder height difference, sagittal spinal parameters. Preop and f/up shoulder ROM were also compared. Surgical treatment included anterior cervical discectomy and fusion followed by clavicle osteotomy (morselization). Following clavicle osteotomy patient was positioned to prone and modified Woodward procedure was performed to mobilize and descend the scapula. Posterior instrumentation and three-column osteotomy were performed for correction of the spinal deformity following Woodward procedure at the same session.

Results
Mean f/up was 8.7 yrs(4-12). Preop cobb angle 43.3°(35-49) corrected to 9.3°(8-14). Shoulder height difference improved from 25mm to 4mm. Abduction of shoulder improved from 95° to 150° at f/up. There was no implant failure, PJK, pseudoarthrosis or neurological deficit. The Cavendish cosmetic grade of scapula improved in all patients. Solid fusion was achieved in both cervical discectomy and three column osteotomy site.

Conclusion
Concomitant congenital cervicothoracic/upper thoracic deformity associated with Sprengel deformity and KFS are rare and challenging conditions. Cervical instability, scapula deformity and congenital spinal deformity can be treated safely and effectively at the same surgical session. Clavicle morselization is essential prior to scapula descending in order to prevent brachial plexus palsy

Take Home Message
Congenital cervicothoracic/upper thoracic scoliosis deformity associated with Sprengel deformity and Klippel-Feil syndrome can be treated safely and effectively at the same surgical session.

Preop, posop x-rays and preop, postop clinical pictures.

3D. Missed Cervical Myelopathy: An Unusual Presentation of Erbs Palsy in a Child with C5 Hemivertabrae with Complete Subluxation of C4 on C6

Michael S. Warren, MD; Michael A. Nammour, MD; Heather Taillac, MD; Bhumit R. Desai, BS; Paul C. Celestre, MD

Summary
A case report demonstrating an unusual presentation of “Erb’s Palsy” (EP) in child with C5 Hemivertabrae with complete subluxation of C4 on C6.

Design
Case Report

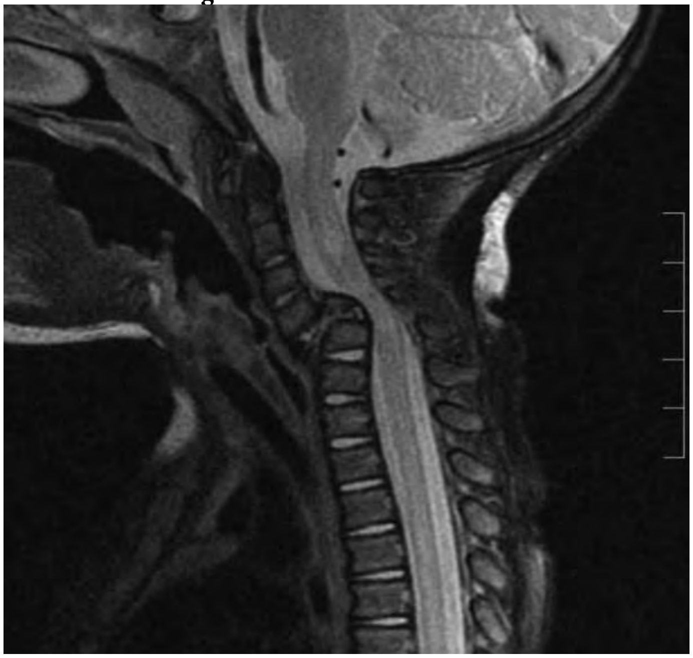
Introduction
Obstetric brachial plexopathy such as EP is reported in 0.1-0.5 percent of natural born children. Injury to the C5 and C6 nerve roots after traction injury at birth result in the affected arm being held in the position of adduction, internal rotation at the shoulder with elbow extension and forearm pronation. This well described as a “waiters tip” (WT) position. Although commonly treated with observation and physical therapy surgical management may be considered.

Methods
Our patient is an 18 month old female that presented for evaluation of bilateral lower extremity weakness and increased tone. After difficult delivery her right upper extremity displayed WT positioning and was diagnosed with EP at 1 month of age. Brachial plexus exploration at 10 months of age at outside facility was unremarkable. On examination the patient exhibited classic WT posturing of her right upper extremity with spasticity of bilateral lower extremities. Decision was made to send the patient for cervical spine and brain MRI.

Results
During cervical spine MRI the patient was noted to have C5 hemivertbrae with complete anterolisthesis of C4 on C6 vertebrae with severe cord compression and myelomalacia. A CT scan demonstrated that C5 was a hemivertabrae suggesting this was congenital in nature. The patient was placed in cervical collar with plan for elective correction. After 1 year of observation to allow for growth she did regain some strength of her LUE but was still unable to ambulate. The patient underwent halo application for pre-operative cervical traction with subsequent excision of C5 hemivertabrae, C6 corpectomy and anterior spinal fusion C4-C7. She is now 2 years post-operative with improving right hand function and stable neurologic exam.

Conclusion
We present a case of missed cervical myelopathy where early cervical spine imaging may have prevented further neurologic deterioration. We suggest early imaging of the cervical spine in patients with physical exam concerning for EP.

Take Home Message



MRI cervical spine

Notes

Podium Presentation Abstracts

The Scoliosis Research Society gratefully acknowledges OrthoPediatrics for their Educational Grant support of the Annual Meeting and support of the Annual Meeting Welcome Reception

SRS
Scoliosis Research Society

Podium Presentation Abstracts

1. The Benefits of Sparing Lumbar Motion Segments in Spinal Fusion for Adolescent Idiopathic Scoliosis are Evident at 10 Years Postoperatively

<u>Masayuki Ohashi, MD, PhD</u>; Tracey P. Bastrom, MA; Michelle Claire Marks, MS, PT; Carrie E. Bartley, MA; Peter O. Newton, MD; Harms Study Group

Summary
The benefits of sparing lumbar motion segments in surgical correction for major thoracic adolescent idiopathic scoliosis (AIS) on spinal mobility and health-related quality of life (HRQOL) were prospectively analyzed 10 years postop. Thoracic fusion with the lowest instrumented vertebra (LIV) of L1 or above resulted in a lower % reduction of spinal mobility than thoracic fusions extending more distally into the lumbar spine at 10 years post-operatively. Patients with a reduction in motion of ≥40% had significantly worse SRS-22 scores.

Hypothesis
Retaining spinal mobility by sparing lumbar motion segments results in better SRS-22 scores 10 years postop.

Design
A prospective multicenter study

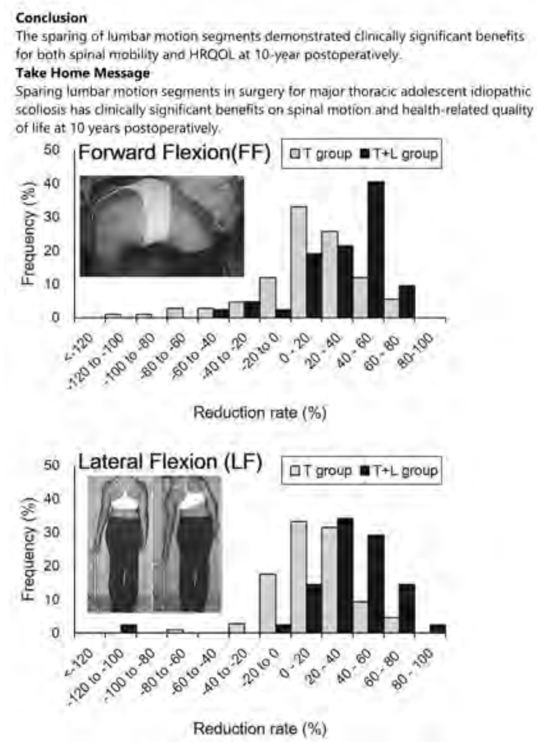
Introduction
Although surgical correction for major thoracic AIS focuses on sparing lumbar motion segments as well as stabilizing the curves, the long-term benefits on spinal mobility and HRQOL remain unclear.

Methods
A prospective multicenter registry was reviewed and patients with major thoracic AIS (Lenke types 1-4) and availability of both pre- and 10-year postoperative mobility data were included. Spinal fusions ending at L1 or above were defined as thoracic fusions (T), and those ending at L2 or below as thoracic and lumber fusions (T+L). Spinal mobility was evaluated with a measuring tape. The excursions between the starting and ending positions were measured using the distance from the spinous processes of C7 to S1 for forward flexion (FF), and the distance from the tip of the middle finger to the floor for lateral flexion (LF). Substantial reduction of spinal mobility was defined as a reduction rate (a ratio of postoperative change divided by preoperative mobility) of ≥40%. Motion data were correlated with LIV levels and group comparisons were performed.

Results
We identified 151 patients (average age, 25.1 years; T group, n=109; T+L, n=42). LIV level demonstrated significant correlations with mobility (rho=0.21-0.37, p≤0.01), all of which decreased with a more distal LIV. The mean reduction rate (FF: 14.7% vs. 32.9%, LF: 18.6% vs. 37.2%, p<0.01) and the incidence of substantial reduction of spinal mobility (FF: 17.4% vs. 50%, LF: 14.8% vs. 51.2%; p<0.001) were significantly lower in the T group than in the T+L group (Figure). Patients with substantial reduction in LF had lower SRS-22 scores for pain (mean difference, 0.35), function (0.22), satisfaction (0.41), and total (0.25) scores than those with <40% reduction at 10-year follow-up (p<0.05).

Conclusion
The sparing of lumbar motion segments demonstrated clinically significant benefits for both spinal mobility and HRQOL at 10-year postoperatively.

Take Home Message
Sparing lumbar motion segments in surgery for major thoracic adolescent idiopathic scoliosis has clinically significant benefits on spinal motion and health-related quality of life at 10 years postoperatively.



2. Residual Curve and Truncal Shift Impact Patient Satisfaction after Surgery for AIS

Majd Marrache, MD; Paul D. Sponseller, MD, MBA; Baron S. Lonner, MD; Aaron J. Buckland, MBBS, FRACS; Michael P. Kelly, MD, MS; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD; <u>Amit Jain, MD</u>; Harms Study Group

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper
The Russell A. Hibbs Awards are presented to both the best clinical and basic research papers presented at the Annual Meeting. The nominated abstracts, selected by the Program Committee, are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

Summary

Prior AIS literature has demonstrated that patient satisfaction correlated weakly with individual SRS-22r domains and did not correlate with specific radiographic parameters. We hypothesized that residual deformity may be associated with worse satisfaction. Analyzing the results of 1,229 Lenke 1 and Lenke 2 patients, we found that at the 2-year follow-up, 60% patients reported complete satisfaction (defined as score of 5). Radiographic factors associated with incomplete satisfaction/dissatisfaction were: residual trunk shift and residual major curve.

Hypothesis

We hypothesize that in patients with adolescent idiopathic scoliosis (AIS), residual deformity may be associated with worse satisfaction.

Design

Retrospective analysis of a prospective AIS registry

Introduction

Little is known regarding the implications of residual deformity on patient satisfaction in surgically corrected AIS patients. Prior studies have shown no association between individual SRS 22r domains and postoperative radiographic parameters.

Methods

1,229 Lenke 1 and 2 AIS patients with available radiographic data and SRS scores at the 2-year follow-up were included. A score of 5 on the SRS-22r satisfaction domain at 2- years was considered "complete satisfaction," and anything below a score of 5 was considered "incomplete satisfaction/dissatisfaction." Radiographic parameters that were 2 standard deviations below the mean were deemed to have a "residual deformity" (Table 1). Univariate and binary logistic analyses were performed to assess the association of residual deformity with patient satisfaction.

Results

At the 2-year follow-up, 689 (60%) patients reported complete satisfaction, while 455 (40%) reported incomplete satisfaction/dissatisfaction. Radiographic factors associated with incomplete satisfaction/dissatisfaction were: residual trunk shift (OR 3.32, p=0.001) and residual major curve (OR 1.7, p=0.036). Patients with residual trunk shift and major curve also had worse SRS-22r self-image domain scores at the 2-year follow-up. Residual differences in shoulder height (p=0.534), T1 tilt angle (p=0.062), Apex to CSVL distance (p=0.969), and % correction of the major curve (p=0.102) did not reach statistical significance for predicting incomplete satisfaction/dissatisfaction.

Conclusion

Residual Curve (>34°) and Truncal Shift (>2.2 cm) impact patient satisfaction after Surgery for AIS. These factors ought to be taken into account during surgical planning.

Take Home Message

Residual trunk shift (>2.2 cm) and major coronal curve (>34°) are associated with incomplete satisfaction/dissatisfaction at the 2-year follow-up in AIS patients with Lenke 1 and 2 curve

		% Patients Reporting Complete Satisfaction	P value
Coronal Curve	Control	648 (61%)	0.028*
	2 SD away from mean (≥34°)	41 (49%)	
Trunk Shift	Control	528 (63%)	<0.001*
	2 SD away from mean (≥2.2 cm)	13 (34%)	
T1 Tilt Angle	Control	672 (61%)	0.062
	2 SD away from mean (≥13°)	17 (44%)	
Apex to CSVL	Control	666 (60%)	0.969
	2 SD away from mean (≥ 4cm)	23 (61%)	
Shoulder Height	Control	500 (62%)	0.626
	2 SD away from mean (≥ 2.6)	28 (67%)	
Percent Correction	Control	670 (60%)	0.486
	2 SD away from mean (≤37%)	19 (54%)	

Table: Percent of patients reporting complete satisfaction.

3. Greater Residual Thoracic Curve at 10 years after Surgery in Primary Thoracic Adolescent Idiopathic Scoliosis is Associated with Below Normal SRS-22 Pain Scores

Tracey P. Bastrom, MA; Masayuki Ohashi, MD, PhD; Carrie E. Bartley, MA; Michelle Claire Marks, MS, PT; Burt Yaszay, MD; Peter O. Newton, MD; Harms Study Group

Summary

Ten years post-operatively, patients with primary thoracic AIS and a pain score below the average of normal controls had greater residual scoliosis deformity on multiple measures. The residual primary thoracic curve magnitude at 10 years was the strongest predictor of a pain score below normal, with a curve >26° found to be associated with a 4-fold increased rate of pain.

Hypothesis

Patients with below normal Scoliosis Research Society (SRS)-22 pain scores at 10 years after surgery for primary thoracic adolescent idiopathic scoliosis (AIS) have different characteristics than those with normal pain scores.

Design

Review of prospectively collected multi-center study data.

Introduction

Understanding what characteristics are associated with pain at 10 years after surgery will help improve outcomes.

Methods

A query of patients who underwent surgical correction of major thoracic AIS between 1997 and 2007 and had 10 year follow-up SRS-22 scores was obtained. Pain scores at 10 years were classified

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

as below normal (<2 standard deviations below average score for controls of similar age/sex from published literature) or within/above the control range. Demographic, 10 year radiographic, 10 year trunk shape, and surgical variables were evaluated as potential predictors of pain scores below normal at 10 years (indicating increased pain).

Results

173 patients with an average of 10.5 ± 0.8 years (range 9.4-14) follow-up were included. Average age at surgery was 14 ± 2 years and average age at follow-up was 25 ± 2. No surgical characteristics evaluated (approach, upper/lower instrumented vertebra, selective thoracic fusion, instrumentation size) were significant ($p>0.05$); however, differences in age, radiographic measures, and rate of revision surgery were noted (Figure). Classification and regression tree (CART) analysis identified 10 year thoracic curve magnitude as the only significant predictor of pain. When the thoracic curve magnitude was ≤26° at 10 years there was a 7% rate of lower than normal pain scores compared to a 27.5% rate when the curve was >26° (OR=4.8, $p<0.05$). The $\varphi=0.27$, approaching an effect of medium magnitude (0.30).

Conclusion

Ten years post-operatively, patients with abnormal pain scores had increased deformity on multiple measures. Primary thoracic curve magnitude at 10 years was the strongest predictor of abnormal pain scores, with curves >26° found to be associated with a 4-fold increased rate of pain.

Take Home Message

These results suggest that there is an association between self-reported pain and residual scoliotic deformity in thoracic major AIS at 10 years post-operative.

	Pain Score		
	Below Normal	Within Normal Limits	p
Age at follow-up	26 ± 3	25 ± 2	0.016
Thoracic Curve	26 ± 9	21 ± 8	0.006
Thoracic Curve % Correction	49 ± 16	58 ± 16	0.016
Lumbar Curve	19 ± 12	15 ± 9	0.049
Coronal C7 to CSVL	0.13 ± 1	-0.45 ± 1	0.036
Thoracic Apical Translation to CSVL	2.4 ± 1	1.2 ± 1	0.001
EIV Angulation	9 ± 8	6 ± 6	0.037
EIV Translation	0.8 ± 1	0.1 ± 1	0.041
Lumbar Prominence	3.5 ± 4	2.1 ± 2	0.015
Revision Surgery	21%	5%	0.011

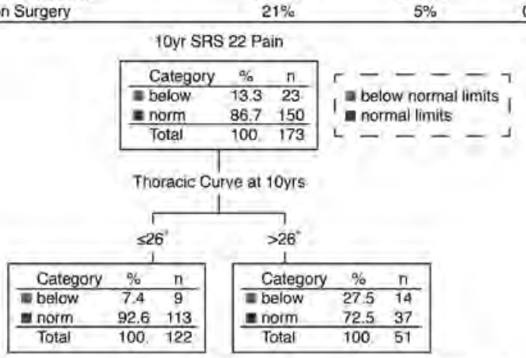


Figure: Table of significant univariate findings and tree diagram of CART results

4. Thoracoscopic Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Minimum 2 Years Results of Patients Reaching Skeletal Maturity

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Summary

This study reports a single European center experience on 14 thoracoscopic vertebral body tethering (VBT) patients with ≥2 years' f-up for patients that reached skeletal maturity (Sanders 7). Surgical correction is followed by growth-dependent correction attained during follow-up. Spontaneous corrections in the non-operated upper thoracic and lumbar levels were also noted. VBT improved pulmonary function test results. Overall pulmonary and mechanical complications rates were 14% each.

Hypothesis

VBT is safe and effective

Design

Retrospective analysis of prospectively collected data

Introduction

Growth modulation with VBT has been reported to be safe and effective. This is the first report with ≥2 years' f-up, in which all patients reached skeletal maturity.

Methods

Data were collected preoperatively, before discharge, and at each follow-up. Demographic, perioperative, clinical, radiographic data and complications were recorded. Respiratory function tests were done at preop and 1 year postop. Surgical and total f-up correction percentages were calculated. Descriptive statistics are given.

Results

14 Lenke 1 pts (14F, 12.3±0.9 yrs) with a mean f-up of 28.9 (24-54) months were included. Preoperatively, all but 2 pts were premenarchal (median Sanders: 3 (2-5), median Risser: 0 (0-3)). The mean preop main thoracic (MT) curve was 45.4° (36-59°). Mean preop upper thoracic (UT) and lumbar (L) curves were 27.5°(14-44°) and 32.3° (22-42°), respectively. A mean of 7.3 (7-9) levels were tethered (UIV: T5/T6, LIV: T11/T12/L1). Mean surgical time was 233±71min. Mean EBL was 55±41ml. Mean initial correction rates were 34%, 54% and 49% for UT, MT and L curves, respectively. Following initial gain in height, patients grew 6.4cm (2- 16) on average, where 7mm (-5 to 15) was between UIV-LIV. This growth was reflected into spontaneous f-up correction. Last f-up correction rates were 44%, 78% and 83% for UT, MT and L curves, respectively. Preop mean hump of 12° was reduced to 5.4° at final f-up. No significant changes were noted in kyphosis and lordosis. Mean forced vital capacity increased from 2350 to

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2858ml at 1 yr (range of change, 20-1220ml). All patients reached skeletal maturity. Pulmonary complications (14%) were 1 atelectasis that resolved with physical therapy, and 1 pulmonary effusion that required readmission (7%). Mechanical complications were 2 overcorrection (14%) one of which was accompanied by LIV screw loosening. No tether breakages were observed.

Conclusion

VBT enabled spontaneous correction while allowing growth. All overcorrections were observed in Sanders 2 patients. VBT resulted in improved pulmonary functions.

Take Home Message

VBT is safe and effective in children with remaining growth potential. Sanders 3-5 patients possess a lesser risk of mechanical complications.

5. Impact of Prematurity on Immediate Postoperative Outcomes Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

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Summary

Premature patients are reported to increased risk for cardiopulmonary complications when undergoing general anesthesia. However, little is known about the impact of prematurity on surgical outcomes in the AIS population. Utilizing the ACS NSQIP-Pediatric database, we propensity score-matched for age, sex, and number of levels fused and compared AIS patients with and without prematurity at birth (<37 weeks) following posterior spinal fusion (PSF) for 30-day outcomes. Prematurity was a significant predictor for 30-day deep/organ space infections, all infections, and readmissions.

Hypothesis

AIS pts who were premature at birth would experience increased 30-day adverse outcomes following PSF.

Design

Retrospective cohort

Introduction

Premature pts are reported to increased risk for cardiopulmonary complics when undergoing general anesthesia. We sought to elucidate the impact of prematurity on 30-day surgical outcomes following PSF for AIS.

Methods

Utilizing the ACS NSQIP-Pediatric database, all AIS pts (ICD9 737.30) undergoing PSF (CPT 22800-4) were identified (2012-16). Pts were grouped into premature at birth (<37wks) or non-premature cohorts & 1:1 propensity score-matched for age, sex and # levels fused. Pt demographics, hospital-related parameters, & 30-day postop outcomes (complics, readmissions & revisions) were compared. Multivariate logistic regression was used to identify independent predictors of outcomes (covariates: prematurity, sex, race, age & indiv comorbidities).

Results

Included: 958 pts (n=479 each). Age, sex & race were comparable between cohorts. Premature pts had higher BL cognitive impairment (37.2 v 11.7%), cerebral palsy (22.6 v 4.0%), esophago-gastrointestinal disease (16.5 v 8.4%) & asthma (12.5 v 6.3%), all p≤0.001 (Table). Overall & individual complics, including superficial & deep infections, as well as revisions (4.4 v 2.5%) were comparable. However, premature pts had higher readmission rates (11.6 v 2.7%, p<0.01). Regression revealed that prematurity at birth predicted 30-day readmission (OR=3.0, 95%CI, 1.1-8.3) as well as deep space/organ infection (OR=4.4, 95%CI, 1.2-15.5) & overall infection (OR=2.3, 95%CI, 1.1-4.8) following PSF (p≤0.035), but not superficial infections, overall complics & revisions. Baseline cognitive impairment among AIS pts predicted 30-day postop complics (OR=4.3, 95%CI, 1.9-9.7) & revisions (OR=4.6, 95%CI, 1.6-13.3) following PSF (both p≤0.006).

Conclusion

Prematurity increased 30-day risk of readmission, deep wound infections & overall infections following PSF for AIS. The prognostic implications of these results may assist preop optimization & postop risk mitigation, as well as guide pt counseling regarding short-term postop course following PSF for premature AIS pts.

Take Home Message

Prematurity at birth significantly predicted 30-day readmissions as well as deep & overall infections in AIS pts undergoing PSF, providing spine surgeons with important data to improve preoperative risk-stratification.

Baseline Comorbidity	Premature	Non-Premature	p-value
Cognitive Impairment/Developmental Delay	37.16%	11.69%	<0.001
Neuromuscular Disorder	29.44%	25.26%	0.147
Cerebral Palsy	22.55%	3.97%	<0.001
History of Asthma	12.53%	6.26%	0.001
Structural CNS Abnormality	20.25%	7.31%	<0.001
Esophago-Gastrointestinal Disease	16.49%	8.35%	<0.001
Seizure Disorder	15.45%	3.80%	<0.001
Bronchopulmonary Dysplasia/Chronic Lung Disease	7.93%	2.71%	<0.001
Structural Airway Abnormalities	7.72%	5.13%	0.152
Previous Cardiac Surgery	6.89%	1.88%	<0.001
Hematologic Disorder	2.30%	1.46%	0.541
Past or Current Cancer	0.84%	1.04%	0.738

Table. Comparison of the baseline comorbidities between AIS patients with and without prematurity at birth prior to posterior

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spinal fusion. Abbreviations: CNS – central nervous system.

6. Do Patients with Anterior Vertebral Body Growth Modulation Have a Better Quality of Life than Patients with a Posterior Spinal Fusion?

Marjolaine Roy-Beaudry, MSc; Julie Joncas, RN; Isabelle Turgeon, BS; Abdulmajeed Alzakri, MD, MS; Stefan Parent, MD, PhD

Summary

Preoperative and 2-year postoperative clinical and radiological data of Anterior Vertebral Body Growth Modulation (AVBGM) were evaluated and compared with patients undergoing posterior spinal fusion (PSF) for Idiopathic Scoliosis (IS). Patients with AVGBM have better post-operative HRQoL when compared to patients having undergone PSF. the self-image domain reached MCID for both groups. AVBGM produces significantly better HRQoL for general health, social functioning and role-emotional when compared to PSF patients.

Hypothesis

Patients with IS undergoing surgical correction with AVBGM have a better quality of life 2-year post-op compared to patients undergoing PSF.

Design

Prospective comparative study

Introduction

AVBGM aims to gradually correct scoliosis, using the patient's growth, while preserving spine motion. The objective was to compare patients with IS undergoing surgical correction with AVGBM for clinical and radiological outcome with a matched cohort of patients with PSF.

Methods

We reviewed the clinical, perioperative and radiological prospectively collected data of the first 53 patients who received AVBGM at our institution. Each AVBGM patient was matched to a PSF patient based PreOp Cobb Angle, sex and Lenke class. Quality of life questionnaires (SRS-22 and SF-12) were collected. Preop and 2-year post-op data were compared and analyzed. Paired t-test of specific parameters and questionnaires scores were calculated on 49 patients with AVBGM that reached 2-year follow-up.

Results

Patients were paired with pre-op Cobb Angle (PSF 53.5°±8.2°, AVBGM 49.6°±8.7), Lenke type and sex. AVBGM cohort is younger (12.4±1.2 vs.13.9±2.4). Two-year post-op %correction showed similar rates for AVBGM vs. PSF (69% vs. 73.1%; p=0.342). Pre-op SRS-22 analysis (see table) demonstrated that AVBGM patients have less pain (p=0.03), a better self-image (p=0.005) and a better total score (p=0.019) compared to PSF patients. Pre-op SF-12 analysis demonstrated that AVBGM patients have better social functioning (p=0.023) compared to PSF patients. Post-op SRS-22 analysis demonstrated a trend that AVBGM patients score better in all domains(NS). Post-op SF-12 analysis demonstrated that AVBGM patients have better general health (p=0.025), social functioning (p=0.041) and role-emotional (p=0.05) compared to PSF patients. AVBGM and PSF patients reached the MCID for the self-image domain.

Conclusion

Although patients in the PSF group had slightly larger pre-operative curves, AVBGM patients show a better quality of life 2 years after the surgery while obtaining similar surgical correction rates. Their HRQoL are better before the surgery and this trend persists after surgery.

Take Home Message

When compared to a matched cohort of patients undergoing PSF, AVBGM patients demonstrated significant improvements in the general health, social functioning and role-emotional domains with similar surgical results.

Table. Descriptive Statistics on Individual Domain Scores

	Pre-Operative			Post-Operative		
	PSF	AVBGM		PSF	AVBGM	
SRS-30 Pain domain	3.8 ± 0.7	4.1 ± 0.6	p=0.03	4.3 ± 0.8	4.4 ± 0.5	
SRS-30 Mental Health	3.9 ± 0.6	4.1 ± 0.6		4.1 ± 0.8	4.3 ± 0.6	
SRS-30 Self-Image	3.2 ± 0.6	3.6 ± 0.7	p=0.005	4.1 ± 0.7	4.3 ± 0.6	
SRS-30 Activity	4.1 ± 0.5	4.2 ± 0.4		4.3 ± 0.4	4.4 ± 0.3	
SRS-30 Total Score	3.8 ± 0.5	4.0 ± 0.4	p=0.019	4.2 ± 0.6	4.4 ± 0.4	
SF-12 Physical functioning	74.0 ± 29.2	80.7 ± 23.2		82.9 ± 40.6	87.9 ± 26.0	
SF-12 Role-physical	75.3 ± 27.0	83.1 ± 22.6		84.3 ± 19.5	92.1 ± 11.0	
SF-12 Bodily Pain	60.9 ± 31.3	64.6 ± 24.1		79.3 ± 19.6	70.0 ± 24.1	
SF-12 General Health	78.3 ± 17.6	77.3 ± 24.0		75.7 ± 28.8	86.5 ± 14.4	p=0.025
SF-12 Vitality	69.8 ± 21.2	72.9 ± 22.4		73.6 ± 21.8	80.0 ± 19.0	
SF-12 Social Functioning	78.7 ± 27.3	89.6 ± 18.5	p=0.023	81.6 ± 24.9	92.7 ± 13.1	p=0.041
SF-12 Mental Health	66.2 ± 18.0	71.1 ± 18.8		68.9 ± 22.2	77.1 ± 18.6	
SF-12 Role-Emotional	82.6 ± 24.3	87.0 ± 20.1		85.0 ± 22.7	93.6 ± 11.9	p=0.05

p : paired TTest

7. What Are Parents Willing to Accept? A Prospective Study of Risk Tolerance for AIS Surgery

Baron S. Lonner, MD; Amit Jain, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Michael P. Kelly, MD, MS; Andrea Castillo, BS; Majd Marrache, MD; Christopher P. Ames, MD; Suken A. Shah, MD

Summary

Surgical treatment of Adolescent Idiopathic Scoliosis (AIS) involves healthy individuals without severe pain or disability. Parents are responsible for consent to surgery on behalf of their children, a burden that often causes trepidation and concern.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Therefore, explanation of operative risk is a critical component of the informed consent process and parent decision-making. In this evaluation of parental risk aversion toward surgery (RA), we found RA decreased as more detailed information was made available to parents of adolescents undergoing spinal fusion.

Hypothesis
Parent willingness to proceed with surgery for their child will improve as more information regarding the risk profile of each complication is provided.

Design
Level 1, Prospective multi-center study.

Introduction
Surgical treatment of AIS involves healthy individuals without severe pain or disability. Parents are responsible for surgical consent on behalf of their children, a burden which causes trepidation and concern. Therefore, explanation of operative risk is a critical component of informed consent and parent decision-making. We set out to quantify parental risk aversion (RA).

Methods
RA questionnaires were administered preoperatively to parents of 60 AIS patients undergoing spinal fusion (SF). RA is the likelihood of a parent to consent to their child's SF (1- least likely, 10- most) with increasing allotments of data about potential complications at each stage (S1-complication named, S2-explained, S3-incidence given, S4-all information). A statistically significant mean difference in answers from each stage was assessed using paired sample t-test or Wilcoxon rank t-test. Normality was assessed by performing Shapiro-Wilk test.

Results
AIS patients (age 14.2 yrs, 83.8% female, major curve 60.1°) were included. Mean scores for each of the stages were 4.5 2.5, 5.0 2.5, 6.5 2.5, 6.7 2.5, respectively. Highest and lowest RA were reported for death and inadequate pain relief, respectively. The greatest increase in likelihood to proceed with surgery was seen after counseling on malposition of implants and on death, 2.4 and 2.3 respectively ($p<0.001$). The lowest increase in likelihood to proceed with surgery was seen after education on infection, 0.4 ($p<0.001$). For all complications, there was an increase in parent willingness to proceed after providing descriptions and occurrence rates, mean increase from S1 to S4 of 1.9 (95% CI, 1.4 – 2.4), $p<0.001$.

Conclusion
RA toward surgery decreased, parent willingness to proceed with surgery for their child improved, as more detailed information was made available regarding potential complications with SF for AIS.

Take Home Message
Providing parents with information regarding risk and complication incidence of surgery for AIS is an important part of the informed consent process and likely to decrease their risk aversion.

8. Impact of Poor Mental Health on Clinical Outcomes in Surgically Treated Adolescents Idiopathic Scoliosis Patients

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Summary
In the adult spine deformity literature, poor mental health has been shown to be associated with worse postoperative outcomes. We hypothesized that in adolescent scoliosis, low SRS-22r mental health scores are largely due to the presence of deformity and the correction of the deformity would potentially improve mental health scores. We found that AIS patients with low mental health at baseline experienced significant improvements with surgery, and most of these patients achieved MCID for the SRS-22r at the 2-year follow-up.

Hypothesis
We hypothesize that in AIS, low SRS-22r mental health scores are largely due to the presence of deformity and the correction of the deformity would potentially improve mental health scores.

Design
Retrospective review of prospective AIS registry

Introduction
Prior literature in patients with adult spine deformity has found that poor mental health at baseline is associated with worse post-operative outcomes.

Methods
1532 (1261 girls, 271 boys) with available baseline and 2-years follow-up SRS-22r scores were included. Patients with baseline mental health domain scores who were 1 standard deviation below the mean (<3.3) were classified as "Low Mental Health" score (LMH) group, and patients who were 1 standard deviation above the mean (> 4.7) were classified as "High Mental Health" score (HMH) group. The remaining patients were classified as "Intermediate Mental Health" score (IMH). A minimal clinically important difference (MCID) of 0.6 was used for SRS-22r for analysis.

Results
There were 247 patients in the LMH group, 1015 in the MMH group, and 270 in the HMH group. Compared to baseline, all 3 groups demonstrated significant improvements in the overall SRS-22r scores at the 2-year follow-up: 0.8 ± 0.5 in the LMH group,

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0.5 ± 0.4 in the IMH group, and 0.29 ± 0.35 in the HMH group (P<0.001 each). Further, at the 2-year follow-up, 72% of patients in the LMH group, 40% of patients in the IMH group, and 17% of patients in the HMH group reached MCID for SRS-22r. At the 2-year follow-up, there was no significant difference in the final SRS-22r score of the 3 groups.

Conclusion
In a segment of the AIS population, alterations in normal body image may results in low mental health at baseline. These patients can experience significant benefit with surgery, and majority of these patients achieve MCID for the SRS-22r at the 2-year follow-up.

Take Home Message
AIS patients with poor mental health at baseline can experience significant improvements with surgery, and the majority of these patients achieve gains above MCID for the SRS-22r at 2-years.

9. The Ultimate Patient Reported Outcome Tool: Patient Generated Index in Adolescent Idiopathic Scoliosis

Baron S. Lonner, MD; Andrea Castillo, BS; Amit Jain, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Michael P. Kelly, MD, MS; Christopher P. Ames, MD; Majd Marrache, MD; Suken A. Shah, MD

Summary
Patient-specific outcomes assessment is lacking in the evaluation of the Adolescent Idiopathic Scoliosis (AIS) patient. The Patient Generated Index (PGI) has been developed to address this deficiency. Forty-five AIS patients and their parents reported different concerns and decision regret regarding surgical treatment. The PGI provides unique insight into patient and parental views toward the disease and its treatment.

Hypothesis
AIS patients and their parents will have distinct perspectives regarding the impact of AIS on patients' lives.

Design
Level 1, Prospective multi-center study.

Introduction
Current outcomes assessment tools for AIS fail to fully assess patient-specific impact of disease and fail to distinguish between the perspectives of the patients and their parents. PGI has been used in other disease states, including adult spinal deformity, to assess individual experiences. The purpose of this study is to assess PGI in operative AIS patients and their parents.

Methods
45 AIS patient and parent pairs completed the PGI questionnaire comprised of 3 stages (S1, S2, S3) and Decision Regret (DR). S1 asks for five areas of the patient's life most affected by AIS, S2 focuses on the magnitude of effect, S3 identifies the desire to improve affected areas and DR if the surgery did not improve the specific area. S1 free responses were organized into 14 domains. All stage scores were compared and analyzed between both groups using paired t-test.

Results
Age at surgery was 14.3 yrs, 84.4% F, average cobb 61°. The three most common patient-reported concerns prior to surgery were (in descending order): Sports, General Function, and General Fitness. In contrast, the three most common parent-reported concerns were (in descending order): General Function, Sports, and Self-Esteem. Patients reported Self-Esteem and parents reported Physical Appearance as the domain most affected by AIS (S2). Patients reported Pain and Self-Esteem and parents reported Uncertainty of Future Health and Self Esteem as main operative aspirations (S3). Decision regret was highest for Uncertainty of Future Health in patients and Sleep in parents (Figure 1).

Conclusion
AIS patients and their parents reported different concerns and decision regret regarding surgical treatment. The PGI provides unique insight into patient and parental views toward the disease and treatment.

Take Home Message
The PGI is a patient-specific outcomes instrument that provides insight into the impact of AIS on the patient as well as patient and parental treatment aspirations.

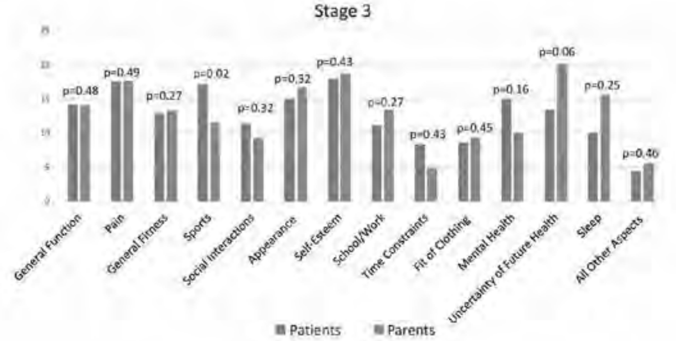

Figure 1: Stage 3 Results

10. Shoulda Gone to L4: Risk Factors for Poor Outcome Following L3 LIV Selection in Adolescent Idiopathic Scoliosis (AIS)

Scott M. LaValva, BA; Jason Brett Anari, MD; John (Jack) M. Flynn, MD; Harms Study Group

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Summary

In surgical planning for AIS, L3 is chosen over L4 whenever possible to maximize motion segments below the LIV. Data from a large multicenter registry reflect this strong preference: of 1038 cases with an L3 or L4 LIV and 2 year follow-up, 62% (646/1038) are L3. Here we present the 5-year outcomes following fusion to L3 and report several pre-operative factors which make patients high-risk for coronal imbalance or revision surgery.

Hypothesis

There are specific pre-operative factors that increase a patient's risk for poor outcome following fusion to L3.

Design

Retrospective Case-Control

Introduction

Fusion to an L3 LIV is common, though the rate of failure and its risk factors have not been described. Our aim was to identify a cohort of patients with poor outcomes and determine factors that make an L3 LIV high-risk.

Methods

In this analysis of prospectively-collected multicenter data of AIS patients who underwent PSF to an L3 LIV, we identified patients with a "poor outcome": (1) out of balance (OOB) in the coronal plane (> 2cm) at 5 years and/or (2) required revision surgery. Radiographs were reviewed to identify those patients whose poor result could be specifically attributed to an L3 LIV (coronal malalignment, end-instrumented- vertebra (EIV) disc wedging, adding on, L4 rotation). Patients without a poor outcome at 5 years served as controls. Pre-operative patient and radiographic factors were compared between cases and controls to identify risk factors for poor outcome.

Results

Of 222 patients (79% females; 14.7+/-2.1 years at surgery) who underwent PSF to L3 with 5 years of follow-up, 11 (4.9%) were judged to have a poor outcome (7 OOB, 4 revisions) attributable to selecting L3 as the LIV. There were statistically significant differences on univariate analysis between cases and controls with respect to several pre-operative factors, including BMI (24.5 in cases vs. 20.1 in controls; p=0.01), lumbar curve (56 vs. 45 deg; p<0.01), TL/L apical vertebral translation (AVT) (6.2 vs. 4.1cm; p<0.01), EIV angulation (30 vs. 22 deg; p<0.01), EIV translation (4.3 vs. 2.9cm; p<0.01), thoracic rib hump (7 vs. 12 deg; p=0.02), and lumbar rib hump (16 vs. 10 deg; p<0.01). Multiple logistic regression showed that pre-operative BMI, TL/L AVT, EIV angulation, EIV translation, and lumbar rib hump were independent predictors of poor outcome. EIV angulation > 25 deg was associated with a 17 times greater risk of poor outcome.

Conclusion

4.9% of patients with an L3 LIV had a poor result attributable to LIV selection. There are several pre-operative predictors of poor outcome following fusion to L3.

Take Home Message

An L3 LIV is usually successful unless EIV angulation >25, EIV translation >4cm, TL/L AVT >6cm, or the lumbar curve is big (>55), stiff (bend >35), and rotated (>10).

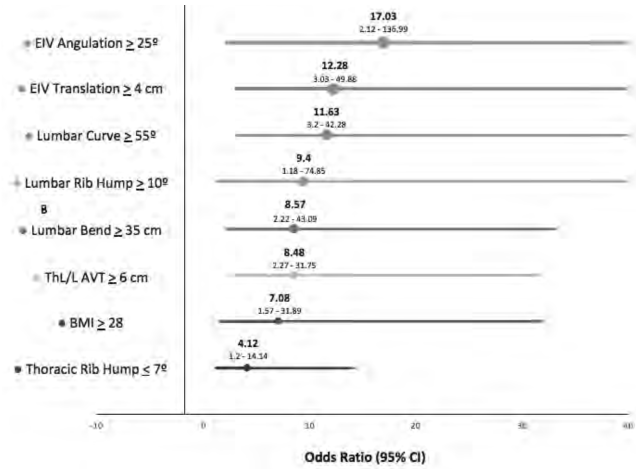

Figure 1. Odds ratios for poor outcome following PSF to an L3 LIV based on several independent pre-operative risk factors.

11. Does a Leveled Lowest Instrumented Vertebra (LIV) Lead to Better Outcomes at 5 Years Following PSF When Ending at L3 vs. L4?

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Summary

Extension of fusion distally to L4 remains a difficult decision due to less-than ideal outcomes reported in the literature. Our study shows that leveling the LIV results in better SRS-22 pain domain scores improvement while fusion extent to L4 seems to favor the self-image domain. When fusing to L3, improvement in self-image was associated with leveling of the LIV <5°. Fusion to L4 does not always produce poor outcomes at 5 years post-op.

Hypothesis

Leveling the LIV to <5° will result in a difference in outcome for patients fused to L4 vs. L3 at 5 years post-op.

Design

Retrospective case-control analysis of prospectively collected data.

Introduction

Fusion distally to include L4 has been shown to generate less than

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

ideal results with long-term disk degeneration under the fusion. Thus, the decision to include L4 remains difficult. There may be unrecognized benefits of extending the fusion distally to include L4. The objective of this project was to determine if leveling the LIV independent of the level fused played a role in midterm outcomes (5 years post-op).

Methods
All patients of all curve types with a fusion either to L3 or L4 with pre-op and 5-year post-operative visits were included. Chi-square and CART analysis were performed to determine if leveling the distal fusion level to a tilt <5° would result in an improvement meeting minimally clinically important difference (MCID) for both the SRS-22 pain and self-image domains.

Results
We identified 380 patients. When looking at pain (MCID ≥ 0.20) and self-image (MCID ≥ 0.98), leveling of the LIV showed greater rate of improvement for both (Table). CART showed that for Pain, leveling the LIV was more impactful than extent of fusion with a 63% rate of improvement compared to 44% when not leveled. When LIV tilt was <5°, patients with a fusion to L4 did not improve as much (41%) as patients fused to L3 (46%). For self-image, extent of fusion was of primary impact; L4 vs L3 (68% vs. 56% improvement respectively). When stopping at L3, leveling the LIV resulted in 61% vs. only 52% improvement when not leveling the LIV.

Conclusion
Surgeons often try to avoid extending the fusion down to L4 based on the risk of disk degeneration under the fusion. In our cohort, overall leveling the LIV <5° resulted in greater improvements in SRS-22 pain and self-image scores. Different interactions between LIV and LIV tilt existed based on SRS domains. Leveling the LIV was of primary importance for an improved MCID pain score, regardless of fusion extent. Whereas for self-image, LIV extent (longer fusion) was more impactful on an improvement in score.

Take Home Message
The decision to include L4 in the fusion does not always result in poor outcomes. When L3 cannot be levelled, careful consideration should be given to include L4.

	Percent MCID improvement	
LIV tilt/LIV	Pain	Self-Image
Level L3	61%	61%
Level L4	70%	82%
Not level L3	46%	52%
Not level L4	41%	62%
p	**0.007**	**0.015**

12. Pregnancy Outcomes and C-Section Rates in Operative vs. Nonoperative AIS Patients at Mean 30-year Follow-up

Lauren Swany, BS; A. Noelle Larson, MD; Suken A. Shah, MD; Pawel Grabala, MD; Todd Milbrandt, MD, MS; Michael J. Yaszemski, MD, PhD

Summary
Birth rates were similar to US population in adolescent idiopathic scoliosis (AIS) patients at a mean 30-year follow-up. However, increased rates of C-section were observed in patients fused in childhood to L3 or below when compared to patients with fusion above L3 or those treated with bracing or observation.

Hypothesis
Patients treated with fusion surgery to L3 or below would have a higher incidence of C-section compared to patients treated nonoperatively or with a shorter fusion.

Design
Retrospective review of long-term follow-up cohort of AIS patients.

Introduction
Although the impact of scoliosis on future pregnancy and child delivery is a common question for patients and parents, there is limited data regarding pregnancy outcomes following childhood treatment of AIS.

Methods
Between 1975-1992, 337 patients (281 females) underwent treatment for AIS with bracing, surgery, or observation. Of those, 54 female patients had data regarding obstetrical history available in the medical record. Mean age at latest follow-up was 46 years (CI 43, 47). Mean time to follow-up since childhood treatment was 32 years (CI 30, 34). In childhood, 28 had nonoperative treatment (16 patients braced, 12 were observed), and 26 had fusion surgery. During the follow-up period, 2 nonoperative patients and 1 operative patient had fusion surgery in adulthood, but after childbearing years.

Results
Nonoperative patients had a mean of 2.4 pregnancies (range, 0-5) and 2.1 live births (range, 0-4). Patients who underwent childhood fusion for AIS had a mean of 2 pregnancies (range, 0-7) and 1.5 live births (range, 0-5). For reference, expected number of births per woman's lifetime in the US is 1.8, and C-section rate in our region is 27.4%. 82% of nonoperative patients were able to deliver vaginally on at least one occasion compared to 76% of operative patients (p=0.68). For surgical patients fused to L3 or lower, 63% required at least one C-section, compared to 19% of patients fused to L2 or higher, or 26% of patients who did not have surgery (p=0.032). There was no difference in rate of C-sec-

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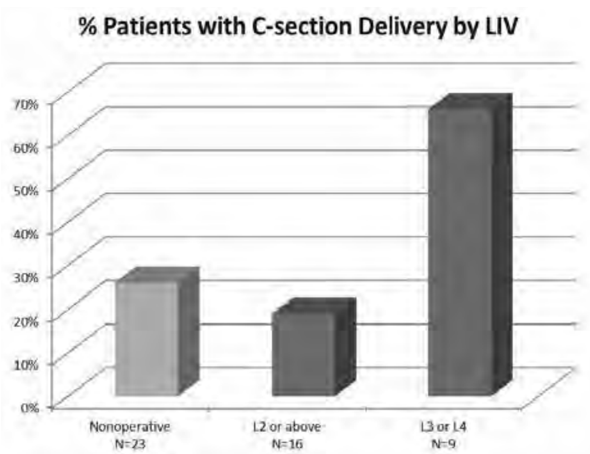
tion between patients fused above L2 compared to nonoperative patients (p=0.59).

Conclusion
In this long-term AIS cohort, fusion below L3 was associated with an increased incidence of C-section, with a 2 fold increase over regional rates. Additional study of the effects of fusion surgery on pregnancy outcomes is warranted.

Take Home Message

At mean 30-year follow-up, patients with LIV at L3 or L4 were at a higher risk for C-section compared to those fused above L3 and those treated nonoperatively.



13. The 'Touched Vertebra' Method and Trunk Shift in Patients with Lenke Type I in AIS: A Prospective Randomized Study

Giedrius Bernotavicius, MD, PhD; Kestutis Saniukas, MD, PhD; Rimantas Zagorskis, MD; Vykintas Sabaliauskas, MD

Summary
When the risk factors are assessed, the Lenke I type curve fixation distal level can be done above the "touched vertebra" and thus save more vertebrae. In the case of coronal imbalance of a patient, possibility of distal adding on and progression of the non-fused curve of the lumbar spine, fixation should end at the level of the "touched vertebra"

Hypothesis
Fixation of the spine in Lenke I AIS should end at the "touched vertebra".

Design
Prospective study

Introduction
Selection of instrumentation levels in adolescent idiopathic scoliosis (AIS) surgery remains one of the most heatedly discussed subjects of the past 20-30 years. Therefore, it is crucial for spinal surgery practice to define better criteria for the selection of appropriate levels to achieve a balanced spine. The purpose of this prospective randomized study was to identify risk factors for Trunk Shift after surgery according fixation level selecting „touched vertebra" method.

Methods
The clinical study was carried in single institution from 2014-2017. The study subjects were randomly assigned into three groups according to the type of lumbar spine fixation method on the concept of the "touched vertebra". Randomization was carried out by applying the envelope technique with the sequence of digits 1, 2 and 3. Risk factors identification for Trunk Shift were evaluated before surgery and 2 years post op.

Results
Subgroup I – patients with Trunk Shift ≥ 20 mm after 2 years (18 patients). Subgroup II – patients with Trunk Shift < 20 mm after 2 years (55 patients). In the final stage, we entered the logistic regression "stepwise" model of all significant parameters and fixation levels according "touched vertebra" method, aiming to find the strongest correlation between the risk factors and Trunk Shift progression. We identified 4 factors for Trunk Shift after surgery: C7-CSVL distance before surgery, the OR for progression is 0.8 , p = 0.02, correction of lumbar curve OR is 0.9, p= 0.003, correction of thoracic curve OR 1.1, p =0.01 and fixation level above LTV , the OR 3.3, p=0.04. Total area under ROC curve of this logistic regression model is 0.89.(x2=33.7, p =0.006, Nagelkerke R^2 = 0.5). Fixation level at LIV-1 group in distal adding-on subgroup had statistically larger Trunk Shift after 2 years f/u, p=0.02.

Conclusion
When the risk factors are assessed, fixation to LTV could be perform in AIS Lenke I type curve and thus prevent Trunk Shift progression after surgery.

Take Home Message
Curve fixation at "touched vertebra" distally is an effective method to avoid distal adding-on and Trunk Shift progression in Lenke I AIS .

14. Thoraco-lumbar Junction Alignment is Critical for Surgical Planning in Lenke Type 1A Curve Pattern: Analysis Using Segmental 3-D Measurements

Stephen G. George, MD; Subaraman Ramchandran, MD; Harry L. Shufflebarger, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Harms Study Group

Summary
The influence of 3-Dimensional sagittal thoraco-lumbar alignment

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in decision making for types 1AR and 1AL is unknown. In a series of 75 patients with type 1A curves, the thoraco-lumbar alignment was significantly different in subtypes 1AR and 1AL curves with respect to coronal Cobb, sagittal Cobb and apical rotation. Distal adding on was observed in 35% of patients when the lowest instrumented vertebra was not inclusive of the entire TL junction (LIV< L2).

Hypothesis
Three dimensional alignment of thoraco-lumbar junction is different for the two subtypes of Lenke 1A curves

Design
Retrospective multi-centric

Introduction
Risk factors for distal adding on in Lenke 1A curve patterns have been previously reported, which include choice of LIV, skeletal immaturity and coronally balanced curve. The influence of Thoraco-lumbar (TL) alignment in decision making for level selection in these curve patterns is unknown.

Methods
A prospectively collected multicenter database was queried for AIS patients with type 1 curves with 2 year follow up. 3-D models were reconstructed using 2-D stero-radiographs using summation of segmental measurements in the plane of the deformity. Lenke curve types 1AR and 1AL were compared for alignment at baseline and 2-year follow up. Distal adding on (defined as change in disc angulation > 5deg below the LIV from the first erect to 2-year radiographs) was assessed in 1AR curves stratified based on distal fusion levels with respect to TL junction.

Results
75 patients were included (33 1AL and 42 1AR). Types 1AR and 1AL curves differed significantly at baseline with respect to C7-CSVL, AVT- CSVL and EIV translation (p< 0.05 all) with 1AR being more coronally balanced. 3-D analysis of TL junction revealed significantly less lordosis in 1AR compared to 1AL curves (-4.5 vs. -8.7deg, p=0.03), increased apical rotation (5.9 vs. -0.5deg, p< 0.001) and increased TL coronal Cobb (32.5 vs. 29deg, p=0.001). Distal adding on was observed in 12 of 34 patients (35%) who underwent fusions that didn't include TL region in type 1AR curves, despite the LIV being the lowest substantially touched vertebra in 7 of these cases. However, none of the 8 patients with fusions that included the TL region had distal adding on.

Conclusion
3-Dimensional sagittal alignment is different in the two distinct Lenke 1A curve patterns. The TL junction of Lenke 1AR curves appear to have relatively increased coronal curve magnitude, less lordosis and greater apical rotation. Patients with 1AR curves where the fusion does not include the entire TL junction have an increased risk of adding on at 2 years.

Take Home Message
Thoracic curve subtypes 1AR and 1AL differ with respect to the sagittal thoraco-lumbar alignment when analysed using 3-Dimensional measurements. This should be taken in consideration to decide fusion levels.

Comparison of 3-Dimensional parameters between types 1AR and 1AL curves

3-D TL junction parameters	Type 1AL	Type 1AR	P value
Thoracic kyphosis (T1-T12)	29.6 ± 12.1	24.9 ± 16.9	0.19
Thoraco-lumbar kyphosis (T10-L2)	-8.75 ± 8.1	-4.5 ± 8.5	**0.03**
Lumbar lordosis	50.4 ± 9.9	47 ± 12	0.2
Upper thoracic Cobb	21.7 ± 6.7	22.4 ± 7.8	0.72
Main thoracic Cobb	47.7 ± 11.4	50.8 ± 7.7	0.18
Thoraco-lumbar Cobb	24.9 ± 10.1	32.5 ± 8.4	**0.001**
Apical rotation of main thoracic curve	-17.1 ± 7.7	-12.1 ± 9.1	**0.016**
Apical rotation of thoracolumbar curve	-0.5 ± 6.4	5.9 ± 6	**0.005**

P values in bold represent significant difference

Relationship between distal adding on and fusion levels in type 1 AR curves at 2-year post-operative interval.

Distal adding on at 2-year post-op	Fusion which involved the entire TL region (LIV=L2 and/or below)		Patients with Type 1 AR curves
	Yes	No	
Yes	0	12	12
No	8	22	30
	8	34	42

15. How to Select the Lowest Instrumented Vertebra in Lenke Type 5 Adolescent Idiopathic Scoliosis Patients?

Qianyu Zhuang, MD; *Jianguo Zhang, MD; Wang Shengru, MD*

Summary
This retrospective study of prospective collected database of 138 consecutive Lenke 5 AIS patients indicates our criteria to select lowest instrumented vertebra (LIV) is able to obtain satisfying correction of scoliosis and trunk shift, while save 1.25±0.67 mobile segments compare to using stable vertebrae.

Hypothesis
The LIV selection criteria which we had established based on our clinical experiences and the review of previous literatures, could obtain satisfying correction, while save mobile segments.

Design
A retrospective study of prospective collected database.

Introduction
The criteria for the LIV selection in Lenke 5 AIS varies widely across centers around the world.

Methods
A total of 138 consecutive patients with Lenke 5 curves who were treated with selective lumbar fusion were retrospectively analyzed, with minimum 2-year follow-up. Our LIV selection criteria were as follows: 1) the most cephalad vertebrae touched by central

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sacrum vertical line; 2) Nash-moe rotation being equal or less than grade I on the standing AP radiograph; 3) Two-thirds of the vertebral body being within the Harrington stable zone on the concave bending film; 4) not at the apex of kyphosis. Trunk shift, lowest instrumented vertebrae tilting (LIVT), LIV distal disc angulation (LIVA) were evaluated before and after surgery and at the final follow-up. Operative data, peri-operative complications and SRS-22 questionnaires were also collected.

Results
The mean follow-up period was 36.8 months. The scoliosis was corrected from 41.35°±6.37° before surgery to 6.57°±2.80° at the final follow up. The TS was 1.97±1.23cm before surgery and 0.95±0.59cm at the final follow up. The LIVT was corrected from 21.06°±6.63° before surgery to 4.87°±2.34°at the final follow up, with the correction rate of 76.8%. The LIVA was 4.62°±3.63° before surgery and 5.23°±2.36° at the final follow up. Compared to fusion to the stable vertebra, our LIV saved 1.25±0.67 mobile segments.

Conclusion
The present study indicates that our criteria is able to obtain satisfying correction of scoliosis and trunk shift, while save 1.25±0.67 mobile segments compare to using stable vertebrae as LIV, and thus provide important guidance for preoperative decision-making.

Take Home Message
Our LIV selection criteria is able to obtain satisfying correction of scoliosis and trunk shift, while save 1.25±0.67 mobile segments compare to using stable vertebrae as LIV.

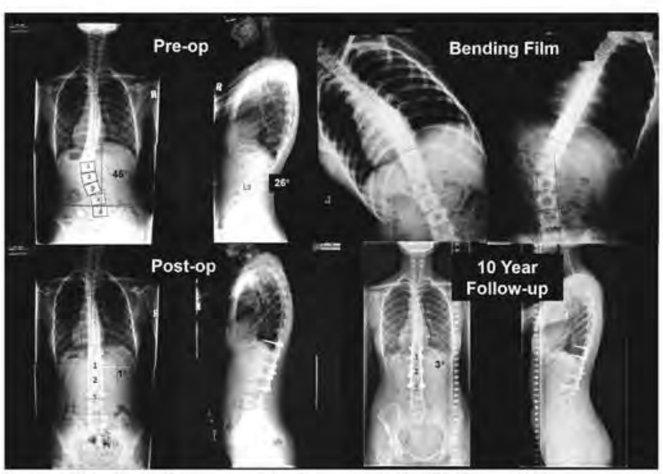

Figure 1: A Lenke 5 AIS case treated using our criteria with 10-year follow-up

16. Reliable Skeletal Maturity Assessment without Added Radiographs: External Validation of the Proximal Humerus Ossification System and Relevant Learning Methodology

<u>Theodor Di Pauli von Treuheim, BS</u>; Don Li, MS; Christopher Mikhail, MD; Daniel Cataldo, DO; Daniel R. Cooperman, MD; Brian G. Smith, MD; Baron S. Lonner, MD

Summary
Accurate assessment of skeletal maturity in the pediatric scoliosis patient is imperative for informing treatment recommendations and assessing outcomes. The Proximal Humerus Ossification System (PHOS) is a novel skeletal maturity staging system proposed to mitigate shortcomings of current standards including radiation exposure, cost, and pubescent staging sensitivity. This is the first study that validates the PHOS at a medical institution independent from the original developers. PHOS reliably predicts remaining growth and is easily learned by novice users of the system.

Hypothesis
We hypothesize excellent inter and intra-observer reproducibility with simplicity in learning and applying the PHOS.

Design
Four individuals from different levels of training reviewed and scored radiographs from the original study on two separate occasions. Scores were compared to the original study.

Introduction
The PHOS is a novel proximal humeral physeal staging system, which has been reported to accurately stage skeletal development leading up to and following peak growth age (PGA) without the need for an image beyond the standard spine x-ray. In order for wide adoption of this new system, it must be reliable beyond those who have developed it, while also being easily taught to trainees with scoring repeatability.

Methods
100 x-rays were reviewed by a medical student, PGY-2, spine fellow, and attending with no prior experience with this system on two separate occasions, a minimum of one week apart. The PHOS learning protocol was systematically controlled for with a five-slide PowerPoint module. Inter and intra-observer reliability of the PHOS was determined by ICC. Means (+/- SD) were determined from pooled data of all observers.

Results
Average intra-observer reliability ICC between scoring sessions was 0.95 (0.93, 0.92, 0.97, 0.96 for the medical student, PGY-2, fellow, and attending, respectively), while average inter-observer ICC was 0.94. On average, radiographs classified as stage 1 had 32% (+/-7.6) growth remaining (GR), stage 2 18% (+/-6.5) GR. Stage

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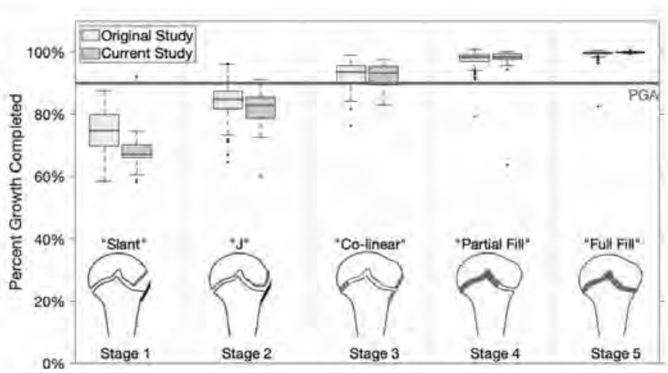
3 immediately followed PGA with 8% (+/-4.3) GR. Stage 4 and 5 had 3% (+/-7.3) and <1% (+/-0.2) GR, respectively. Compared to the study by the PHOS developers, there were 88% exact matches, 10% of the scores differed by 1 stage, and only 2% differed by 2 stages.

Conclusion
The PHOS generates reproducible results beyond the developers' use and reliably assesses skeletal maturity and remaining growth. The system can be adopted into practice with minimal training, because there are only a few, unique osteologic markers; furthermore, it can be retrospectively applied to radiographic assessments that lack a hand x-ray for Sanders staging.

Take Home Message
Measuring skeletal maturity using PHOS is now validated independently from the originating investigators and can easily be taught to individuals of varying training levels without prior experience with the system.



Current PHOS staging scores map similarly to the results published by the system developers, quantified as growth completed (current vs. final standing height). Learning was enhanced by associating stage feature names with key osteologic markers (red).

17. Idiopathic Scoliosis Cobb Angle Prediction from Clinical Measures: A Geometrical Study of a 7591 Subjects Cohort

Francesco Negrini, MD; Sabrina Donzelli, MD; Giulia Angela Antonella Rebagliati, MD; Francesca Di Felice, MD; Fabio Zaina, MD; Stefano Negrini, MD

Summary
We studied 5550 consecutive radiographed Idiopathic Scoliosis with ATR≥5° and 2041 radiographed uncontrolled youngsters with ATR<5°. Curves below 10°-20° were 10-44% for 5° ATR, and 5-31% for 7° ATR, respectively. A 7° threshold would miss 10% of patients >20° and 2% >30°; in the uncontrolled group these rates were 20% and 4%. Hump Height model performed better than ATR: when above 10 mm sensitivity was 75%, specificity 65% and area under the ROC curve 0.70.

Hypothesis
Combining the complementary measures of the prominence given by the Angle of Trunk Rotation (ATR - degrees) and the hump height (HH - mm) can predict expected Cobb degrees and consequently guide the radiographic prescription.

Design
Cross-sectional evaluation of 7591 consecutive first consultations of a tertiary level clinic specialized on spinal deformities.

Introduction
ATR and HH are complementary measures of the same Idiopathic Scoliosis (IS) prominence. The usual 7° ATR threshold for screening could lead to underdiagnose in a specialized conservative setting.

Methods
Inclusion criteria: age 4-18, IS, first consultation, x-rays within 3 months, no previous bracing. Study Group: 5550 consecutive patients with prescribed x-ray for ATR≥5° (22.8% males; age 12.7±2.5; 23.9±13.2°). Uncontrolled Group: 2041 pupils with ATR<5° who already had a radiograph. Subgroups: sex, curve location and age. We checked correlation between °Cobb and ATR, HH, their sum and the geometrical measures of the triangle identified by HH and ATR (hypotenuse inclination). We ran forward/backward stepwise regressions, and adjusted for the covariates age, familiarity, BMI, sex, menarche, aesthetics. A histogram, quantile plot and Akaike Index Criterion (AIC) were used to verify the models. The ROC curve was used for the best cut off to predict °Cobb.

Results
Curves below 10°-20° were 10-44% for 5° ATR, and 5-31% for 7° ATR, respectively. Using 7° instead of 5° would lead to miss 574 patients >20° and 135 >30°. In the <5° group we found 20% >20° and 4% >30°. We developed models for ATR, HH, SUM, and area since they correlated with ° Cobb (0.61-0.67; r2 0.38-0.45). They all performed well, with HH the best. The covariates didn't change the crude coefficient (Table). When HH is above 10, it is 0.17 more likely to find a curve exceeding 20 Cobb degrees (CI95% OR 0.17-0.18). The area under the ROC curve was 0.70, with 75% sensitivity, 65% specificity, 61% positive and 78% negative predictive values.

Conclusion
In a tertiary level institute, a 5° ATR threshold is better than 7° to identify conservative patients. ATR, HH and Sum are good predictors of the expected Cobb angle at X-rays.

Take Home Message
In a specialised setting using 7° instead of 5° ATR for radiograph

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prescriptions lead to miss 10% patients >20° and 2.5% >30°. Hump Height allows better prediction (cut-off 10 mm).

Cobb prediction		Crude coef. (95% CI)	p value
ATR		0.17(0.17-0.18)	<0.001
	Adjusted	0.17(0.17-0.18)	<0.001
	Age (years)	0.07(0.04-0.11)	<0.001
	BMI	-0.11(-0.14—0.09)	<0.001
	Asimmetry	0.36(0.16-0.56)	<0.001
HH		0.33 (0.32-0.34)	<0.001
	Adjusted	0.33 (0.32-0.34)	<0.001
	Age(years)	0.22(0.16-0.28)	<0.001
	BMI	-0.16(-0.20—0.11)	<0.001
	Sex	-0.45(-0.78—0.13)	0.007
SUM		0.50(0.48-0.51)	<0.001
	Adjusted	0.51(0.49-0.52)	<0.001
	Age(years)	0.30(0.21-0.38)	<0.001
	BMI	-0.28(-0.35—0.21)	<0.001
	Sex	-0.51(-1.00—0.03)	0.039
Area		17.36(16.77-17.95)	<0.001
	Adjusted	17.60(16.92-18.29)	<0.001
	Age(years)	14.53(16.93-18.08)	<0.001
	BMI	-6.60(-9.47—3.73)	<0.001
	Sex	-38.65(-58.75—18.55)	<0.001
	Asimmetry	-21.57(-43.11—0.03)	0.05

Models developed and effect on the covariates. ATR: angle of trunk rotation; HH: Hump Height; SUM: sum of HH and ATR; area: area of the triangle described by ATR and HH

18. Dynamic Spinal Posture Changes 2 Years After Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Patients

<u>Sebastien Pesenti, MD, PhD</u>; Solène Prost, MD; Guillaume Authier; Elke Viehweger, MD, PhD; Benjamin Blondel, MD, PhD; Jean-Luc Jouve, MD

Summary
Changes in spine biomechanics were assessed using gait analysis in 24 AIS patients with a 2-year minimum follow-up. Posterior spinal fusion allowed for restoration of a normal gait pattern, especially in the transverse plane.

Hypothesis
Spinal deformity correction affects dynamic posture in adolescent idiopathic scoliosis (AIS) patients

Design
Prospective study

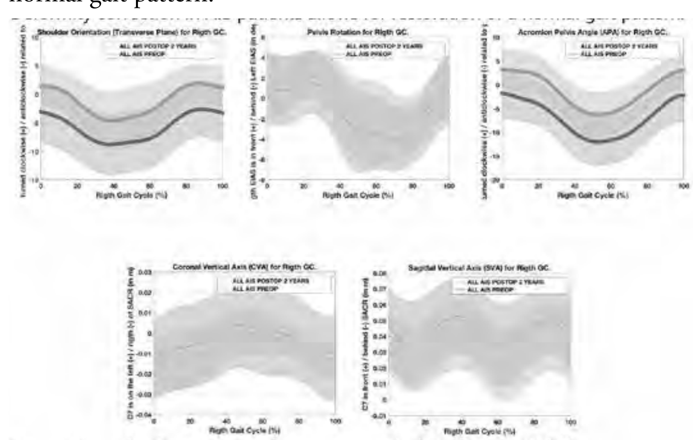
Introduction
AIS is known to alter postural control. However, the effect of spinal deformity correction on dynamic posture remains unclear. Using gait analysis, it is possible to determine changes in spine kinematics induced by spinal deformity correction.

Methods
24 consecutive AIS patients planned for surgical correction were prospectively enrolled in this study. The day before surgery and at 2-year follow-up, AP and lateral x-rays and gait analysis were performed. Dynamic parameters evaluated were: shoulders line orientation, pelvis orientation, acromion-pelvis angle (APA), coronal and sagittal vertical axis (CVA, SVA).

Results
Average follow-up was 31 months and mean age at surgery was 16 yo. Main Cobb angle improved from 53° to 23° at last follow-up (p<0.01). At 2-year follow-up, there was an improvement of shoulders line orientation (-6° vs -2°, p<0.01), pelvic orientation (-1.5° vs 0°, p=0.04) and APA (-7° vs -2°, p<0.01). Global spinal balance remained unchanged between preoperative and 2Y assessment. UIV and LIV position did not influence spinal biomechanics.

Conclusion
This is the largest series of gait analysis in AIS patients at 2-year follow-up. Our results show that posterior spinal fusion allows for restoration of normal gait pattern, especially in the transversal plane. Interestingly, UIV and LIV did not influence dynamic spinal balance, but larger series are warranted in order to shed light on this particular point.

Take Home Message
Deformity correction in AIS patients allows for restoration of a normal gait pattern.



Comparison of gait parameters from preoperatively to 31-month follow-up. Shoulders line and pelvic orientation became more symmetric. There was no change in coronal or sagittal spinal balance. Bold points indicate significant difference <0.01

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

19. The Importance of Lumbar Curve Flexibility in the Prediction of Spontaneous Lumbar Curve Correction for Selective Thoracic Fusion in Lenke Type 1-2-3-4 C Curves

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Summary
Flexibility greater than 70% in preop bending x-rays is strongly correlated with a successful spontaneous lumbar curve correction (SLCC) after selective thoracic fusion (STF) for AIS Lenke type 1-2-3-4 curves with C lumbar modifier. Lumbar apical vertebral rotation (AVR) equal to or under grade 2 at preop x-rays is helpful for prediction of successful SLCC.

Hypothesis
Flexibility of the lumbar curve is an important preop determinant in the decision making for STF in Lenke 1-2-3-4C curves with respect to SLCC

Design
Retrospective analysis of a prospectively collected data

Introduction
The aim of the study was to retrospectively review the clinical, radiographic and postop outcomes of the lumbar modifier C curves (Lenke 1-2-3-4) with STF and to find out the cut-off value of preop lumbar flexibility, apical vertebral translation(AVT) and apical lumbar rotation(AVR); which may predict more than 50% SLCC at minimum 5 yrs f/up

Methods
55 AIS pts(54f,1m) with posterior STF having Lenke 1-2-3-4C curves, mean age 14(11-17), and min 5 yrs f/up(5-23) were included.Group A included pts who had more than 50% SLCC without adding on or decompensation at f/up.Group B included pts with less than 50% SLCC.Two groups were compared in terms of lumbar flexibility, AVT and AVR from preop to f/up x-ray to understand the cut-off value of those parameters for more than 50% SLCC.Receiver Operating Characteristic (ROC) test used for statistics.SRS22 compared to determine the HRoQL

Results
Thoracic curve correction rate was 75% and lumbar curve correction was 59% at the f/up.Group A included 35 pts in early postop and 10 of the lumbar curves improved by the time and the total number of Group A increased to 45(82%) at the f/up.Three pts(5%) showed decompensation at early postop and 2 of them became compensated at f/up.ROC analyses showed 69% flexibility is the cut-off value for SLCC(p<0,01).Preop mean AVTs were similar;25.8mm and 27.1mm for both groups.Preop mean AVRs were mildly different; for Group A=1,9 and for Group B=2,4.No revisions were performed.One pt underwent debridement due to early infection.HRQoL scores improved similarly in both groups from preop to f/u

Conclusion
In Lenke 1-2-3-4C curves when the flexibility in the preop bending x-ray is more than 70% (p<0.01) and AVR is equal or less than 2 grades, STF provides satisfactory clinical and radiological SLCC at min. 5 yrs f/up.This flexibility rate can be helpful in the decision making for successful STF in Lenke 1-2-3-4C curves

Take Home Message
When preop lumbar curve flexibility is more than 70% it is a strong decision making determinant to achieve and maintain SLCC with selective thoracic fusion in Lenke 1-2-3-4 C curves

20. Does Postoperative Thoracic Hypokyphosis Affect Cervical Disc Degeneration at 10 Years Postoperatively? A Comparison to Controls

Ayato Nohara, MD; Ryoji Tauchi, MD; Toshiki Saito, MD; Tetsuya Ohara, MD; Kazuki Kawakami, B.Kin; Noriaki Kawakami, MD

Summary
We evaluated the effect of residual thoracic hypokyphosis on the cervical and lumbar spine in patients with adolescent idiopathic scoliosis (AIS) who have undergone corrective fusion of thoracic curvature at 10 years postoperatively. Previous studies have warranted increased rates of disc degeneration (DD) at longer follow-up periods in patient who have had postoperative hypokyphosis due to reduced cervical lordosis(CL).

Hypothesis
Patients with thoracic hypokyphosis can affect sagittal parameters and DD in longer follow-up periods.

Design
Retrospective cohort study

Introduction
Postoperative hypokyphosis after corrective surgeries in patients with AIS have been postulated to affect sagittal alignment, pulmonary function, and cause pain in the neck and low back in longer follow-up periods. The purpose of this study is to evaluate the effect of thoracic hypokyphosis on cervical and thoracic DD.

Methods
86 female patients with AIS who have undergone corrective surgery using PS for thoracic curves with available cervical and lumbar MRIs at 10yrs postop were participants of this study. These patients were further separated into those with TK be-

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low 15° (H-group; 43 pts), and 20-40° (N-group; 25 pts). We compared each of these group with an age-matched controlled group(C-group) without scoliosis or any other surgery for the spinal disorders.

Results

Comparing the H-group and N-group, no significant difference was seen in age (p=0.067), number of fused vertebrae (p=0.086), pre- & postoperative thoracic main curve (p=0.084/0.178), pre- & postoperative lumbar curve (p=0.634/0.645), cervical and lumbar lordosis (p=0.169□p=0.071), and pelvic incidence (p=0.228). On the other hand, significant differences were seen in preop upper thoracic curve (p=0.025), preop thoracic kyphosis(TK) (p<0.0001), postop CL (p=0.03), and number of mobile segments proximal to fused area (p=0.012). At 10yrs postop, significance was seen in the preop CL (P<0.0001) and TK (p<0.0001). No significant differences were found with respect to the number of lumbar DD and, at least 1 DD was found in each patient in 35% of the H-group, 36% in the N-group, and 35% in the C-group. On the other hand, cervical DD was found in at least 1 disc per patient in 77% of the H-group, 64% in the N-group, and 65% in the C-group, with a trend greater in the H-group. DD occurred more frequently at C4/5 and

Conclusion

Inadequate correction of TK in AIS patients disrupts appropriate development of lordosis in the cervical spine, and in the long-term, increases the likelihood of DD than in non-scoliotic individuals.

Take Home Message

Corrective surgeries for AIS should focus not only in the scoliosis, but also in correcting the thoracic hypokyphosis to reduce potential cervical DD in the future.

	H-Group	N-Group	C-Group
C2/3	19% (8/43)	12% (3/25)	6% (2/35)
C3/4	33% (14/43)	32% (8/25)	31% (11/35)
C4/5	42% (18/43)	28% (7/25)	11% (4/35)
C5/6	60% (26/43)	52% (13/25)	45% (16/35)
C6/7	19% (8/43)	24% (6/25)	20% (7/35)
Total (Patients)	77% (33/43)	64% (16/25)	65% (24/35)
Total (Discs)	34% (74/215)	29% (37/125)	22% (40/185)

21. Flexibility of Thoracic Curve and Three-dimensional Thoracic Kyphosis can Predict Pulmonary Function in Nonoperatively Treated Adult Patients with Adolescent Idiopathic Scoliosis

Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Naoto Endo, MD, PhD

Summary

We aimed to analyze the relationship between pulmonary function and radiographic parameters of spinal deformity in nonoperatively treated adult patients with adolescent idiopathic scoliosis (AIS). Thoracic curve magnitude, flexibility, apical vertebral rotation and translation, and 3-dimensional (3-D) thoracic kyphosis (TK) demonstrated significant correlations with pulmonary function, while 2-D TK did not. Of these parameters, flexibility and 3-D TK were independent predictors of percent-predicted forced vital capacity (%FVC) and expiratory volume in 1 s (%FEV1.0) (R^2=0.36 and 0.34, respectively).

Hypothesis

Radiographic parameters would be associated with pulmonary function.

Design

Long-term follow-up study

Introduction

Although several radiographic predictors for pulmonary function in adolescent patients have been reported, those in adult patients remain unclear.

Methods

Of 319 patients treated nonoperatively for AIS, 90 returned to the survey (average age, 40 years). Full-length posteroanterior and lateral radiographs of the spine were obtained with the patient standing, and side-bending radiographs were taken in the supine position. Standard 2-D radiographic measurements were performed. 3-D TK reported by Newton et al [J Bone Joint Surg Am 2015] was calculated from 2-D radiographic data using a validated formula [Spine Deform 2017]: 3-D TK (°)=18.1+0.81×(2-D TK)+0.54×(Thoracic Cobb angle). 3-D TK was defined as the sum of segmental kyphosis between T5 and T12, which eliminates the overestimation of TK in 2-D measurements due to rotational deformity. Correlation analysis, followed by a stepwise multiple linear regression analysis, was performed.

Results

The average Cobb angle of the thoracic curve at the time of survey was 49.4°±14.6° with flexibility of 37.5%±18.2%. Thoracic curve magnitude, flexibility, apical vertebral rotation and translation, and 3-D TK were significantly correlated with %FVC and %FEV1.0, while 2-D TK was not correlated with pulmonary function (Table and Figure). Stepwise multiple regression analysis showed that curve flexibility and 3-D TK were significant, independent predictors of %FVC (R^2=0.36) and %FEV1.0 (R^2=0.34), curve flexibility having a greater impact (standardized coefficient >0.45) than 3-D TK (<0.32).

Conclusion

Our results indicate that maintaining flexibility of the thoracic curve may have benefits for nonoperatively treated patients with

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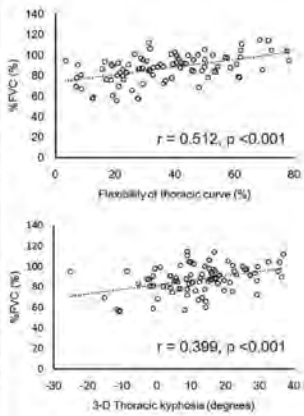
AIS to prevent future pulmonary impairment. Moreover, 3-D TK is another independent predictor of pulmonary function, which suggests that segmental sagittal alignment is a new component of deformity correction to focus on.

Take Home Message

Flexibility of the thoracic curve and 3-D TK, the sum of segmental kyphosis, can predict pulmonary function in nonoperatively treated adults with AIS.

	%FVC		%FEV1.0	
	r/rs	P	r/rs	P
Thoracic curve				
Cobb angle	-0.48	<0.001	-0.44	<0.001
Flexibility	0.51	<0.001	0.51	<0.001
Apex	-0.09	0.38	-0.00	0.98
AVT	-0.33	0.002	-0.31	0.003
AVR	-0.37	<0.001	-0.29	0.006
No. of involved vertebra	0.10	0.35	-0.05	0.63
Lumbar curve Cobb angle	0.04	0.69	0.04	0.68
2-D TK	0.09	0.39	0.08	0.44
3-D TK	0.40	<0.001	0.37	<0.001
TLK	0.09	0.40	0.09	0.41
LL	0.06	0.55	0.02	0.86

Pearson's correlation coefficient (r) or Spearman's rank correlation coefficient (rs).



22. Do You Really Want to Know? How Contaminated is the Wound Before Closure in Pediatric Spinal Surgery

Lara L. Cohen, BS, MPH; Richard M. Schwend, MD; John (Jack) M. Flynn, MD; Daniel J. Hedequist, MD; Michael T. Hresko, MD; Lawrence I. Karlin, MD; John B. Emans, MD; Brian D. Snyder, MD, PhD; Patricia E. Miller, MS; Michael P. Glotzbecker, MD

Summary

The risk of surgical site infection is between 1 and 4.3% in idiopathic populations and up to 24% in patients with neuromuscular disease. Nearly one-quarter of pediatric posterior spinal fusion (PSF) tissue cultures are positive, with a higher rate in neuromuscular patients. This study evaluated the feasibility of a larger, complete RCT studying the efficacy of surgical site irrigation with povidone-iodine (PVP-I) compared to sterile saline (SS) to reduce the bacterial contamination rate prior to closure in children undergoing PSF.

Hypothesis

A complete RCT is feasible with more subjects.

Design

Pilot RCT

Introduction

PVP-I has been shown to reduce the infection rate in adult patients after PSF. The standard protocol for irrigation prior to wound closure uses SS. The purpose of this study was to evaluate the feasibility of a complete RCT studying the efficacy of surgical site irrigation with PVP-I compared to SS to reduce the rate of bacterial contamination prior to closure in children undergoing PSF.

Methods

One-hundred seventy-five subjects were enrolled in a multi-center, single-blind, pilot RCT to evaluate implementation of PVP-I irrigation compared to SS prior to wound closure in subjects 3-18 years old undergoing elective PSF of at least six levels for spinal deformity. We recruited patients at low (LR) and high (HR) risk for infection 3:1, respectively. Prior to wound closure, an aerobic swab or tissue culture of the wound was collected. Nonviable tissues were debrided and the wound was soaked with 0.35% PVP-I or SS for three minutes. The wound was then irrigated with 2 L saline and a second sample was collected.

Results

Of the enrolled subjects, 153 completed the protocol, consisting of 77 subjects allocated to PVP-I (18 HR, 59 LR) and 76 allocated to SS (19 HR, 57 LR). Positive cultures were found in 18% (14/77) of PVP-I samples (2 HR, 12 LR) and in 17% (13/76) of SS samples (3 HR, 10 LR) pre-irrigation and in 16% (12/77) of PVP-I samples (5 HR, 7 LR) and in 18% (14/76) of SS samples (4 HR, 10 LR) post-irrigation. Propionibacterium acnes was the most common bacteria in 81% of all positive cultures (88% pre-irrigation, 74% post-irrigation). 8% HR (3/37) subjects (1 PVP-I, 2 SS) experienced infection at 30 days postoperative that continued at 90 days postoperative. There were no infections detected in the LR subgroup.

Conclusion

Positive cultures were similar across treatment groups and infection risk groups pre- and post-irrigation. The type of irrigation did little to change the wound contamination rate compared to the pre-irrigation contamination rate. The bacterial contamination of wounds prior to closure remains high regardless of irrigation type. This does not translate to infection risk.

Take Home Message

Further research is necessary to determine to what extent bacterial wound contamination causes wound infection in pediatric spine fusion surgery patients. A complete RCT would require many more patients.

Pre- and post-irrigation culture comparison by risk and irrigation groups.

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23. Can We Reduce the Infection Rates Associated with High Implant Density in Deformity Surgeries?

Aakash Agarwal, PhD; Boren Lin, PhD; Hossein Elgafy, MD, FRCS, FRCS(C); Hossein Elgafy, MD, FRCS, FRCS(C); Vijay K. Goel, PhD; Anand K. Agarwal, MD; Chris Karas, MD; Steven R. Garfin, MD; Jeffrey C. Wang, MD; Neel Anand, MD

Summary
A multi-center study was performed to assess the degree of intraoperative microbial contamination of pedicle screws, and if use of an impermeable guard could mitigate it. All pedicle screws were carrying bacterial bioburden, whereas intraoperative shielding of pedicle screws using a guard mitigated such occurrences.

Hypothesis
Handling and exposure of implants in the "sterile" field contaminates the implants, which then gets implanted deep in the bone.

Design
Prospective multi-center study with an appropriate control group

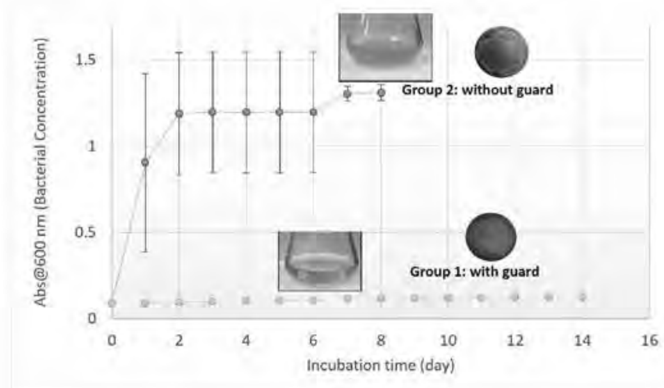
Introduction
Post-operative infections in deformity surgeries occur at the higher end of 10-20%, and despite vancomycin application immediately before closure, it is theoretically impossible to irrigate the screw-bone interface post-implantation. Consequently, any contamination of pedicle screw before implantation is permanent, and has the potential to cause deep-bone infection, or hardware loosening due to encapsulation of biofilm between the bone and the screw.

Methods
Two groups of sterile prepackaged pedicle screws, one with an intraoperative guard and the other without such a guard, each consisting of 26 samples distributed over 23 independent timepoints (spinal fusion surgeries) and 4 independent hospitals, were loaded onto the insertion device by the scrub tech and left on the sterile table. 20 minutes later, the lead surgeon who had just finished preparing the surgical site, touches the pedicle screw. Then instead of implantation it was transferred to a sterile container using fresh clean gloves for bacterial analysis.

Results
Spectrophotometry results detected saturated levels of turbidity within 24-48 hours in samples from group 2. The samples from group 1 showed no turbidity for the entire duration of the incubation period (14 days). Every plate, from each sample of group 2 had visible CFU growth within 24 hours past streaking. The total CFUs ranged from 105-107 per sample. The colonies continued to grow until confluency was reached. No CFU growth occurred in plates extracted from group 1 for the duration of the incubation period (7 days).

Conclusion
Standard pedicle screw handling techniques leads to contamination of pedicle screws and thereby the screw-bone interface. This can be avoided by using a sterile intraoperative guard, which can come preinstalled inside the individually packaged sterile screws, thereby shielding the pedicle screws intraoperatively until implantation.

Take Home Message
The study proves that it is necessary to shield sterile implants intraoperative (inside "sterile" field), otherwise they become "unsterile".



Quantitative spectroscopy data showing saturated levels of growth within 24-48 hours in group 2, versus no growth for 14 days in group 1.

24. Promising but Imperfect: The Effectiveness of Quality Programs for Surgical Site Infections in Pediatric Spinal Surgery Diminishes Over Time

Michael G. Vitale, MD, MPH; Bradley Hammoor, MS; Hiroko Matsumoto, PhDc; Gerard F. Marciano, BS; Lucas K. Dziesinski, BS; David Price Roye, MD; Benjamin D. Roye, MD, MPH

Summary
This study examines the effect of programs implemented to prevent surgical site infection (SSI). Patients aged 0-21 that underwent spine surgery between 2006 and 2018 were included. Time-series data demonstrated the impact of these programs to decrease SSI incidence from 4.4% to 2.9%. However, an observed decrease in SSI incidence immediately following program implementation was followed by resurgence suggesting that program lessons may be forgotten or adherence may decline after a certain period of time.

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Hypothesis
Programs aimed at SSI reduction decrease SSI incidence in patients undergoing spine surgery.

Design
Retrospective cohort study

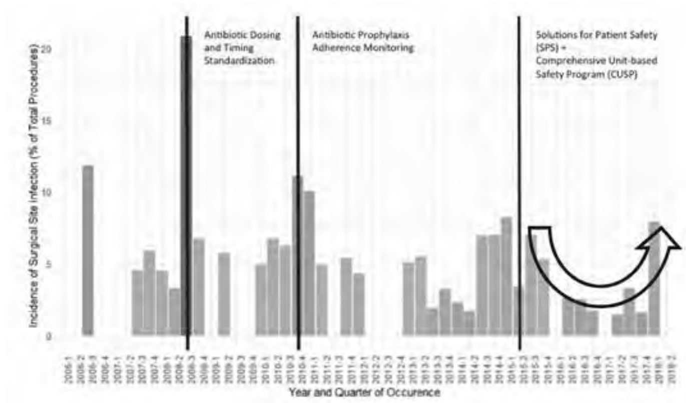
Introduction
Surgical site infections (SSI) are a risk after spine deformity surgery. In response to increased SSI incidence at our institution, a multi-disciplinary anti-infection effort was instituted. Two major programs were adopted to decrease SSI: the Comprehensive Unit Based Safety Program (CUSP), a structured approach to address OR inefficiency; and the Solutions for Patient Safety (SPS), which created perioperative protocols and mandated appropriate antibiotic timing and dosing.

Methods
Patients aged 0-21 who underwent spine instrumentation and fusion (SIF), lengthening, revision, or definitive fusion between 2006-2018 for treatment of scoliosis were included. CDC definitions of deep and superficial SSIs were used to record infections (within 90 and 30 days of procedure, respectively). Procedures were categorized as pre-program implementation, prior to June 2015, and post-program implementation, after June 2015 when SPS and CUSP were in effect.

Results
1200 patients undergoing 2082 procedures were examined. SSI incidence decreased from 4.4% to 2.9% after June 2015. Comparing procedures performed before June 2015 to those after, SSI incidence was reduced in congenital (3.6%; 1.0%), neuromuscular (7.8%; 7.2%), and syndromic (4.1%; 2.2%) cases. There was no difference in idiopathic (1.2%; 1.2%). Decreases in incidence are observed after program implementation, however, incidence increases as time from implementation grows (Figure 1). In subgroup analysis, neuromuscular casese decreased in the post-implementation period, but the pattern is still observed.

Conclusion
Time-series data demonstrate that the initial effectiveness of SPS and CUSP diminishes. SSI reemergence after iterative efforts in the past decade further exhibit the reduced effectiveness these programs have over time suggesting the need for strategies to ensure adherence and effectiveness.

Take Home Message
Quality progams are effective in reducing SSI incidence in pediatric spinal surgery but the effectiveness diminishes over time.



SSI incidence after pediatric spine procedures. Vertical black lines mark anti-infective program implementation

25. Is it Growth or Natural History? Increasing Spinal Deformity after Sanders Stage 7 in Females with AIS

Olivia Grothaus, BA; Domingo Molina IV, MD; Cale Jacobs, PhD; Vishwas R. Talwalkar, MD; Henry J. Iwinski, MD; Ryan D. Muchow, MD

Summary
This study examines progression of female AIS patients at 2 year follow up after Sanders Stage 7. The results indicate significant progression, 50.6% of the cohort progressing ≥5° and 12.4% progressing beyond 50° or undergoing surgery. A threshold curve of 39.5° at SS7 was identified as high risk of progressing to this degree. Curves of this size should have continued follow up. The average rate of progression was 2.25° per year compared to accepted natural history of <1° per year.

Hypothesis
We hypothesize a subset of patients continue to progress at a greater rate than natural history after SS7.

Design
Retrospective cohort study. Level of evidence III.

Introduction
Accurate prognosis and treatment decisions in AIS demand a reliable radiographic marker of growth cessation. Sanders Stage 7 (SS7) is a useful marker of spine growth cessation in females and proposed as a bracing endpoint. The purpose of this study was to determine the amount of curve progression in females with AIS after achieving SS7.

Methods
This retrospective review included female patients with AIS treated at a single institution from May 2008-May 2018. Patients required a hand radiograph demonstrating SS7 and concurrent

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spine radiograph measuring <50º, plus a 2-year follow up spine radiograph. Progression was defined as an increase of the main curve ≥5º. Comparison between groups was analyzed with independent t-tests and chi square or Fisher Exact tests as appropriate. Binary logistic regressions were used to construct a model predictive of progressing beyond 50º or undergoing surgery.

Results

89 patients met inclusion criteria, average main curve magnitude 32.5º (SD 9.2) at SS7 and 37.7º (SD 11.0) at 2-year follow-up. 50.6% progressed ≥5º and 19.1% progressed at least 10º. 70 patients had curves <40º at SS7 and 22 (31.4%) progressed to >40º at 2 years. 11 (12.4%) patients progressed to >50º or had surgery at 2-year follow-up. ROC curve analysis identified a threshold curve of 39.5º at SS7 associated with progression to >50º or surgery (AUC=0.94, p<0.001, sensitivity=100%, specificity=87%). Patients with initial curves >40º did have additional height gained (2.1cm, SD 1.5), but this was not different than those <40º (p>0.05). No other variables had statistically significant association with those that progressed (p>0.05). The average rate of progression was 2.25º per year, compared to the accepted <1º per year reported in natural history.

Conclusion

A curve >40º at SS7 is at high risk for progressing to a curve measuring >50º or requiring surgery. Those with curves below this threshold still have potential to make clinically significant progression after skeletal maturity.

Take Home Message

Follow up beyond SS7 is essential for curves >40º. Reaching SS7 with a curve <50º may not be an endpoint for treatment as unpredictable clinically significant growth may remain.

26. Untreated Adolescent Idiopathic Scoliosis in Adulthood: How Often Do These Patients Require Surgery?

Jace Erwin, BS; Brandon B. Carlson, MD, MPH; Joshua Bunch, MD; Robert Sean Jackson, MD; Marc Asher, MD; Douglas C. Burton, MD

Summary

AIS in adulthood is seldom a disabling condition that requires surgery. A retrospective study looking at ODI and its correlations was performed to better understand the natural history of AIS. ODI increased with increasing age, BMI, and curve size. Despite curve sizes deemed "surgical" in the adolescent population, few (14%) adults seeking evaluation for their deformity went on to surgery. Pediatric deformity surgeons can use this information when counseling skeletally mature AIS patients and their families regarding surgery.

Hypothesis

We predict that increasing ODI scores will correlate with age, curve size, and curve location.

Design

Retrospective study

Introduction

Weinstein and Ponsetti have previously shown that despite some increased pain, adults with previously unoperated AIS typically lead normal functioning lives. Our purpose is to analyze ODI scores in unoperated adults with AIS to better understand the natural history of AIS in adulthood and to see its correlation with progression to surgery.

Methods

All unoperated adult (≥20 years of age) AIS patients who presented to a tertiary deformity clinic from 2008-2018 were reviewed. Demographics, curve size [thoracic (T) and thoracolumbar (TL)], comorbidities, ODI, and SRS-22r were recorded for each patient. ODI scores ≥20 and ≥30 were analyzed across 3 age groups: 20-39 (G1), 40-59 (G2), and 60+ (G3). Multivariate linear regression was performed analyzing ODI as the dependent variable against all other variables.

Results

249 consecutive AIS patients were seen by one author over the 10-year study period. 214 patients had an ODI score and are the subject of this study. ODI scores had positive correlations with increasing age, BMI, and curve size (p<.001). 17/249 patients went on to have adult deformity surgery. Patients with ODI ≥20 and ≥30 were as follows: G1 (47/108, 17/108); G2 (36/60, 20/60); G3 (37/46, 25/46). When comparing cobb major (T vs. TL), the mean cobb size was no different between T and TL curves (47.7o, p=.988), however, the mean ODI score was significantly different (T=20.07; TL= 25.02, p=.018). Increased ODI correlated with increasing T (Pearson r= .235, p=0.028) and TL curve (Pearson r= .236, p=0.005). Among patients with T ≥50 degrees and/or TL ≥40 only 16/115 (14%) patients underwent surgery.

Conclusion

ODI increased with increasing age, BMI, and curve size. Despite "surgical size" curves, few (14%) patients seeking evaluation for their deformity went on to surgery. Pediatric deformity surgeons can use this information when counseling skeletally mature AIS patients and their families regarding the need for surgery.

Take Home Message

14% of adult patients with surgical size AIS curves elected to have surgery. Pediatric surgeons can use this information in counseling adolescent patients.

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Table 1: Demographic & Outcome Data

	Age 20-39 (n=108)	Age 40-59 (n=60)	Age 60+ (n=46)	p
Demographic				
Sex				
F	102	60	48	
M	28	6	5	
Race				
White	110	61	51	
Black	8	3	1	
Hisp.	4	1	1	
Other	8	2	0	
BMI	25.46	25.45	25.54	
ODI Outcomes				
Raw ODI Score				
<20	61 (47%)	24 (36%)	9 (17%)	<.001
≥20	47 (36%)	36 (55%)	37 (70%)	
≥30	17 (13%)	20 (30%)	25 (47%)	
Avg. ODI Score	18.34	24.43	32.15	<.001

	Thoracic (T)	Thoracolumbar (TL)	p
Radiography			
Cobb Major (#)	88	126	
Avg. Cobb Size	47.74°	47.7°	.988
Avg. ODI Score	20.07	25.02	.018
Age	34	46	<.001

*% values under Raw ODI Score do not add up to 100% because two categories are overlapping. Consider the % independent of one another.

27. Risk of Progression of Larger AIS Curves After Maturity: What Should We Be Telling Our Patients?

<u>Kevin M. Neal, MD</u>; Gary M. Kiebzak, PhD

Summary

This retrospective cohort study analyzed the risk of AIS progression in girls with curves 30° to 45° after skeletal maturity (Risser 4-5). Follow-up averaged 24 months. The risk of progression of 10° or more was 20% for 30° curves, 28% for 35° curves, 46% for 40° curves, and 35% for 45° curves. The risk of progression to 50° or more was 8% for 30° curves, 14% for 35° curves, 46% for 40° curves, and 60% for 45° curves.

Hypothesis

Curves measuring 30° to 45° in mature girls with AIS may progress.

Design

Retrospective cohort

Introduction

The natural history of AIS is variable. Fusion is elective, since larger curves do not decrease life spans or limit activity. After maturity, patients with larger curves may progress, but the size at which progression is inevitable is unknown. 50° has been a threshold above which surgery is recommended, and below which observation is advised, but the risk of progression for 30° to 45° curves after maturity is not well-known. This study seeks to define that risk.

Methods

We searched our Non-Operative AIS Database for patients with curves 30° or more at maturity (Risser 4 or 5), and follow up (FU) to document progression. Progression of 10° or more was considered significant. Non-progressive curves with <12 months FU were excluded. 30°, 35°, 40°, and 45° curves were analyzed for 10° progression and any progression to 50° using chi-squared tests and Fischer's exact tests. T-tests were used to detect differences in ages, Risser stages, Sanders Scores (SMS), months post-menarche, and brace use. Differences between groups were compared using ANOVA.

Results

100 patients were included with average FU 24 months. Averages at skeletal maturity were 14.25 (years), 4.12 (Risser), 6.84 (SMS), and 19 (months post-menarche). Progression 10° or more for each stating point was 20% (30°), 28% (35°) (P=0.0045), 46% (40°) (P<0.0001), and 35% (45°) (P<0.0008). Progression to 50° or more for each starting point was 8% (30°), 14% (35°), 46% (40°) (P<0.0001), and 60% (45°) (P<0.0001). At 30°, months post-menarche averaged 3 in progressive curves versus 22 in non-progressive curves (P=0.0025). There were no other significant differences between progressive and non-progressive groups, including brace use after maturity (p=0.078).

Conclusion

Curves that measure 30° to 45° at maturity can progress. Patients should be counseled regarding this risk so they can make informed decisions about treatment choices. The decision to proceed with surgery should be based on patients' concerns about their spines and their risk of future progression, rather than on any specific curve size threshold.

Take Home Message

When girls with AIS have curves from 30° to 45° at skeletal maturity, there is still substantial risk of progression 10° or more, and ultimately to 50°.

Curve Size at Skeletal Maturity	30°	35°	40°	45°
Progression 10° or More	20% (P=0.051)	27.6% (P=0.0045)	46.2% (P<0.0001)	[illegible]
Progression to 50° or More	8% (P=0.490)	13.8% (P=0.110)	46.2% (P<0.0001)	[illegible]
P values are the rate of progression compared to no progression using Fischer's exact test with P<0.050 considered significant				

Rates of progression of various sized curves in skeletally mature girls with AIS.

28. Outcome of Multilevel Spinal Deformity Surgery in Patients Over 60 Years of Age: A Multicenter International Prospective Study

<u>Stephen J. Lewis, MD, FRCS(C)</u>; Sigurd H. Berven, MD; Yukihiro Matsuyama, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Christopher I. Shaffrey, MD; Benny T. Dahl, MD, PhD, DMSci; Marinus de Kleuver, MD, PhD; Maarten Spruit, MD, PhD; Ferran Pellisé, MD, PhD; Kenneth MC Cheung, MD; Ahmet Alanay, MD; David W. Polly Jr., MD; Jonathan N. Sembrano, MD; Yong Qiu, MD

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Summary
To determine the utility of multi-level spinal deformity surgery in patients over 60 years, a prospective multi-centre international study was undertaken. Patients undergoing fusions of greater than 5 levels were followed at 10 weeks, 1 and 2 years and completed the SRS-22r, Oswestry disability index, NRS leg and back, and EQ5-D. Significant improvements were seen in all outcome measures at 1 and 2 year follow-up. Carefully selected healthy patients greater than 60 years can benefit from spinal deformity surgery.

Hypothesis
Patients over 60 years of age will benefit from spinal deformity surgery

Design
Prospective multi-centre international case series

Introduction
With the known risks and possible complications, counselling elderly patients on the utility of multilevel spinal fusion procedures can be difficult. Significant variation in procedures, comorbidities, and pathologies further complicates the matter.

Methods
A multicenter international prospective study of patients over 60 years of age, undergoing primary fusions of 5 or more levels for spinal deformity were reviewed. The decision to operate and the procedure performed was made at the discretion of the treating surgeon. A central organization oversaw the study to ensure each centre complied with the study protocols and collected the data at the appropriate time intervals. Multiple outcome measures were utilized and collected at 10 weeks (± 6 weeks), 1 year (±2 months) and 2 years (±2 months) follow-up. Mixed effect models were applied to evaluate the outcome scores over time.

Results
219 of the 255 patients enrolled from 12 centers met the criteria for inclusion in the study. There were 176 females and 43 males with a mean age of 67.5 (range 60-83 years). 210 patients completed the 10 week, 188 completed the 1 year, and 179 completed the 2 year follow-up visits. Significant improvements were seen in the SRS-22r total score and subdomains of function, pain, self-image, and satisfaction, EQ-5D, Oswestry Disability Index, and numeric rating back and leg scales at 1 and 2 year follow-ups. Some improvement was seen at 10 week follow up with maximal improvement at 1 year that was maintained at 2 years follow-up. No difference in outcome scores was noted between age groups when comparing patients between the ages of 60-64, 65-69, 70-74, and those greater than 75 years of age.

Conclusion
Despite the magnitude of the procedures, significant improvements in patient reported outcome was observed in 4 different outcome measures at 1 and 2 year follow-up. Carefully selected healthy patients greater than 60 years old can benefit from multi-level spinal deformity surgery.

Take Home Message
Patients over the age of 60 years undergoing multi-level spinal fusion for spinal deformity showed significant improvements in patient reported outcome scores at 1 year and 2 years follow-up.

	Pre-op	10 weeks	1 Year	2 Year
SRS-22r Total	2.8	3.2	3.7*	3.7*
SRS-22r Function	2.7	2.7	3.4*	3.5*
SRS-22r Pain	2.7	2.9	3.7*	3.7*
SRS-22r Self Image	2.3	3.5*	3.7*	3.6*
SRS-22r Mental Health	3.1	3.4	3.8*	3.8*
SRS-22r Satisfaction	3.1	4.1*	4.0*	4.1*
EQ-5D VAS	55.7	65.8*	72.8*	70.0*
EQ-5D Index	0.53	0.65*	0.75*	0.74*
Oswestry Disability Index	46.3	41.2*	28.2*	26.4*
Numerical Rating Scale Back	6.1	3.5*	2.8*	2.7*
Numerical Rating Scale Leg	4.3	2.4*	2.1*	2.3*

*= P<0.05

Patient reported outcome scores

29. Patient Factors Affect Outcomes in Operative Treatment of Adult Symptomatic Lumbar Scoliosis (ASLS)

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Summary
As-treated analyses from a multi-center study of observational and randomized cohorts of patients with adult symptomatic lumbar scoliosis (ASLS) found greater baseline disability (ODI>36, SRS-SS<3), and leg pain (>=7) had greater improvements in ODI and SRS-SS 2 years after surgery. Higher BMI(> 25kg/m^2), larger PI-LL mismatch(>-11), and smaller coronal Cobb(<50 degrees) had greater improvements after surgery. No factors were associated with outcomes after nonoperative care. These data may assist patients and physicians with decision making in the care of ASLS

Hypothesis
Patient factors will affect treatment outcomes in ASLS.

Design
Combined analysis of randomized and observational cohorts

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Introduction

Results from as-treated analyses of randomized (RCT) and observational (OBS) cohorts found improvements in health-related quality of life (HRQOL) following surgery for ASLS. Knowledge of patient factors associated with improvement, and lack thereof, is essential to informed decision making for patients and providers.

Methods

ASLS Patients were enrolled in a dual-arm RCT and OBS study comparing operative (OP) and nonoperative (NON) treatment. Standard demographic and radiographic data were collected. Primary outcome measures were SRS-22 Subscore (SS) and Oswestry Disability Index (ODI). Groups were combined into a single as-treated cohort. Potential modifiers were prespecified: education, income, smoking, deformity magnitude, and the baseline SS and ODI. Regression tree analysis (CART) identified other potential modifiers. Potential cutoffs were determined by CART or with clinical relevance. Generalized linear models estimated change in PRO at 2yr followup. P-values for heterogeneity were calculated.

Results

286 Patients were enrolled; 256 (90%) completed exact 2yr followup. OP had superior outcomes across all subgroups versus NON, with the exception of those without pelvic incidence-lumbar lordosis (PI-LL) mismatch. Heavier (BMI > 25kg/m^2) patients, those with smaller coronal plane deformities (< 50 degrees), and larger PI-LL (>-11) experienced greater mean improvements in ODI and SS in the surgical cohort. No differences were observed for mental health, education, income, nor smoking. Worse baseline PRO (ODI >36, SRS-SS <3) and worse baseline leg pain (Numerical rating >=7) had greater improvements with surgery. No modifiers were associated with better improvement with NON. (Table 1)

Conclusion

Patients with worse baseline ODI, SRS-SS, and leg pain had greater 2yr improvement after surgery. Higher BMI, larger PI-LL mismatch, and small coronal plane deformities also had greater ODI/SRS-SS improvements in the surgical cohort. No category was associated with greater nonoperative improvement.

Take Home Message

Patients with greater disability complaints had greater improvement with surgery, but not with nonoperative care. Some commonly held "negative" predictors, e.g. education and mental health, did not affect surgical outcomes.

	ODI Score			SRS Subscore		
	Mean Change at 2 years (SE)		Difference in average change (95% CI)	Mean Change at 2 years (SE)		Difference in average change (95% CI)
	Nonoperative	Operative		Nonoperative	Operative	
Baseline MCS						
<44, N=80	-2.0 (2.9)	-15.6 (2.1)	-13.7 (-20.9, -6.5)	0.22 (0.11)	0.77 (0.08)	0.55 (0.29, 0.81)
44+, N=206	-2.6 (1.2)	-16.1 (1.1)	-13.4 (-16.8, -10.1)	0.13 (0.05)	0.74 (0.05)	0.62 (0.48, 0.75)
P-value*	0.835	0.862	0.953	0.404	0.721	0.666
Education						
Bachelor's degree or higher, N=151	-3.0 (1.6)	-17.4 (1.3)	-14.4 (-18.6, -10.3)	0.19 (0.06)	0.77 (0.05)	0.57 (0.41, 0.74)
Less than bachelor's degree, N=135	-1.2 (1.9)	-14.4 (1.6)	-13.3 (-18.2, -8.4)	0.10 (0.07)	0.74 (0.06)	0.64 (0.45, 0.83)
P-value*	0.449	0.149	0.721	0.336	0.750	0.616
Income						
$75,000 or higher, N=137	-1.7 (1.7)	-14.6 (1.5)	-12.8 (-17.4, -8.3)	0.23 (0.07)	0.72 (0.06)	0.49 (0.32, 0.67)
Less than $75,000, N=108	-1.9 (1.9)	-20.4 (1.8)	-18.5 (-23.8, -13.2)	0.08 (0.07)	0.84 (0.07)	0.75 (0.55, 0.95)
P-value*	0.939	0.012	0.112	0.132	0.192	0.052
Smoking						
Yes, N=104	-1.9 (3.6)	-12.2 (3.0)	-10.4 (-20.0, -0.8)	0.11 (0.14)	0.55 (0.12)	0.44 (0.06, 0.81)
No, N=182	-2.8 (1.3)	-16.1 (1.1)	-13.3 (-16.7, -10.0)	0.17 (0.05)	0.77 (0.04)	0.60 (0.47, 0.73)
P-value*	0.815	0.231	0.565	0.688	0.077	0.412
BMI						
<25, N=158	-3.9 (1.5)	-12.5 (1.5)	-8.6 (-12.9, -4.3)	0.21 (0.06)	0.65 (0.06)	0.45 (0.28, 0.62)
25+, N=128	-0.6 (1.9)	-18.1 (1.4)	-17.4 (-22.1, -12.8)	0.08 (0.07)	0.82 (0.06)	0.74 (0.56, 0.92)
P-value*	0.176	0.006	0.006	0.173	0.041	0.021
Lumbar Cobb angle						
≤50 degrees, N=140	-2.7 (1.5)	-19.0 (1.5)	-16.4 (-20.7, -12.0)	0.10 (0.06)	0.87 (0.06)	0.77 (0.61, 0.94)
>50 degrees, N=145	-0.7 (1.9)	-14.1 (1.4)	-13.4 (-18.2, -8.7)	0.20 (0.07)	0.69 (0.05)	0.49 (0.31, 0.67)
P-value*	0.425	0.018	0.372	0.284	0.020	0.024
PI LL Mismatch						
≤-11, N=29	-1.3 (2.6)	-5.2 (3.5)	-3.9 (-12.8, 5.1)	0.29 (0.12)	0.38 (0.16)	0.09 (-0.32, 0.50)
>-11, N=257	-2.5 (1.3)	-16.7 (1.1)	-14.3 (-17.6, -10.9)	0.14 (0.05)	0.77 (0.04)	0.64 (0.51, 0.77)
P-value*	0.682	0.002	0.033	0.228	0.018	0.012
Coronal balance (absolute value)						
≤15 mm, N=128	-2.3 (1.7)	-15.6 (1.7)	-13.3 (-18.1, -8.6)	0.19 (0.06)	0.75 (0.06)	0.57 (0.39, 0.74)
>15 mm, N=156	-2.5 (1.8)	-15.9 (1.4)	-13.4 (-17.8, -9.0)	0.13 (0.07)	0.75 (0.05)	0.62 (0.44, 0.79)
P-value*	0.922	0.889	0.986	0.558	0.980	0.680
Baseline ODI						

Table. Within and Between Group Comparisons of Patient-Level Modifiers

30. Mechanical Complications Following 3-Column Osteotomy Surgery: A Competing Risk Analysis in 193 Consecutive Adult Spinal Deformity Patients

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Summary

In a consecutive cohort of 193 patients undergoing 3-Column Osteotomies (3COs), cumulative incidence of two-year revision surgery due to mechanical failure was estimated to 34%. Correction of >30° in Lumbar Lordosis (LL) increased odds of revision.

Hypothesis

In a consecutive cohort of 193 patients undergoing 3-Column Osteotomies (3COs), cumulative incidence of two-year revision surgery due to mechanical failure was estimated to 34%. Correction of >30° in Lumbar Lordosis (LL) increased odds of revision.

Design

Retrospective.

Introduction

3COs allow major surgical correction of Adult Spinal Deformity (ASD); although, the risk of mechanical complications remains considerable. Previous reports have been based on smaller cohorts or multicenter databases. None have utilized Competing Risk (CR) analysis.

Methods

All ASD patients undergoing 3CO (pedicle subtraction osteotomy (PSO) or vertebral column resection (VCR)) surgery from 2010-2015 were retrospectively included. A CR-model was used to esti-

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

mate rates of revision surgery due to mechanical failure. Covariates were assessed for prediction of failure and reported as odds ratios (OR) with 95% confidence intervals (CI).

Results

A total of 193 patients were included with two-year follow-up available for 88% (median [IQR]: 33 [24-49] months). Mechanical failure occurred in 120 cases (62%), the most frequent being rod breakage affecting 86 patients (45%). Cumulative incidence of revision surgery due to mechanical failure was estimated to 34% at two-years and 56% at five-years. Multivariate proportional odds model with death as competing risk showed higher odds of revision with increasing age (OR: 1.03 per year increase; CI: 1.00-1.07) and surgical increase in LL >30° (OR: 2.70; CI: 1.31-5.58). Type of 3CO (PSO or VCR), history of previous surgery, number of instrumented vertebra, and postoperative SRS-Schwab modifiers and Global Alignment and Proportion score did not increase odds of revision.

Conclusion

In a consecutive single-center cohort of ASD patients undergoing 3CO surgery, the incidence of revision surgery due to mechanical failure was estimated to 34% two-years postoperatively. Increasing age and surgical correction of LL >30° were associated with elevated odds of revision.

Take Home Message

In 3CO surgery, major correction of LL can lead to mechanical failure.

31. Artificial Intelligence-based Adult Spinal Deformity Risk-benefit Classification: Hierarchical Clustering of 1245 Patients and Surgeries with Machine-based Learning and Simplified Decision Trees

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Summary

Unsupervised hierarchical clustering successfully classified patient deformity type and surgical interventions according to outcomes improvement and major complication (MC) incidence in adult spinal deformity (ASD).The clustering was back-walked to provide a decision tree based ASD classification. These decision trees preserve accurate clustering while allowing for general use at point of care by simplifying patient and surgery types. Pattern identification can be used to educate patients and surgeons on which treatment patterns yield optimal improvement with lowest risk.

Hypothesis

The combination of AI-based unsupervised learning and expert cluster interpretation will yield a risk-benefit ASD classification which does not require computer access.

Design

Retrospective cohort

Introduction

The Schwab-SRS ASD Classification is based on disability scores and the sagittal plane and is limited by the lack of preoperative information on associated risk or outcome. Unsupervised learning has classified ASD patients and surgeries based on risk and benefit. We aimed to improve the analysis with more than twice the 2-yr follow-up sample size and filter the results by reducing the number of groups to enable point of care clinical application.

Methods

Two prospective cohorts were queried for surgical ASD patients with baseline, 1-yr, and 2-yr SRS-22/SF-36v2 data. Dendrograms were fitted, one with surgical features and one with patient characteristics. Both were built with Ward distances and optimized with the gap method. Normalized 2-yr improvement and major complications (MC) were computed for patient and surgery clusters. Patient clusters and surgery types were filtered to enhance interpretability and back walked to provide a decision tree.

Results

1245 patients were included (mean 55.7 yrs; 77.6% female) in this analysis. The 3 patient types were: Young Coronal (YC, n=200), Old Primary (OPrim, n=527), and Old Revision (ORev, n=516). 5 surgical types were drawn: 3-column osteotomy (PSO /3CO, n=254), interbody fusion (IBF with [n=296] or without decompression [n=216]), single PCO [n=258], and multiple PCO [n=219]. The figure shows normalized improvement in outcomes and cumulative incidence of MC based on patient type and surgical plan.

Conclusion

Unsupervised hierarchical clustering can identify data patterns that may guide preoperative decision making by predicting outcomes and MC. In addition to creating a novel AI-based preop risk-benefit ASD classification, pattern identification may facilitate treatment optimization by educating surgeons on which treatment patterns yield optimal improvement with lowest risk.

Take Home Message

AI-based unsupervised clustering has provided a risk-benefit ASD classification for clinical point-of-care application to aid in patient counseling and treatment planning aimed to achieve optimal improvement with lowest risk.

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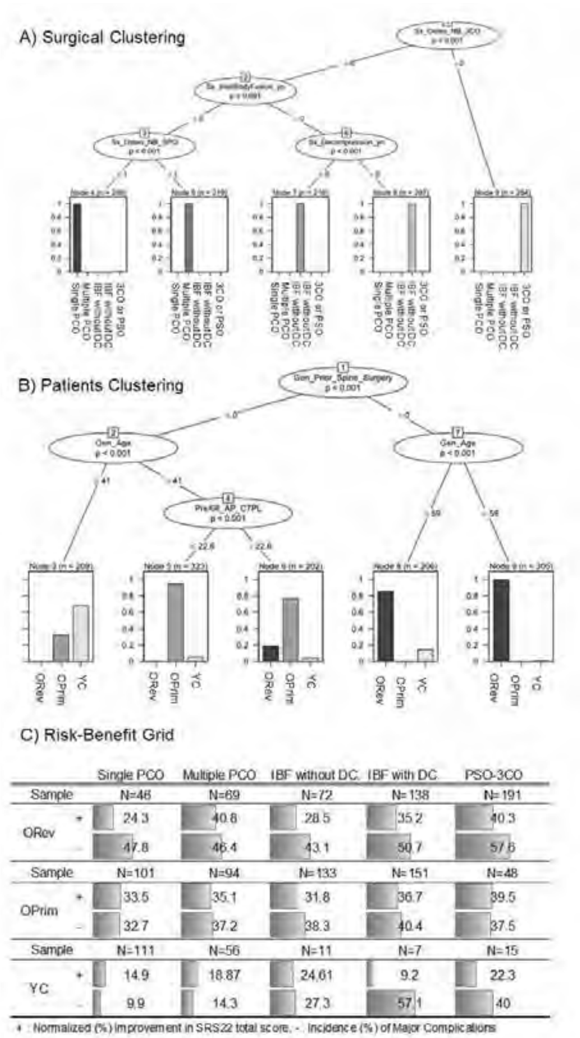

Figure 1. ASD surgical treatment classification with expected benefit and risk

32. Decision Analysis in Quest of the Ideal Treatment in Adult Spinal Deformity Revisited

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Summary

To analyze the utilities and improvement rates provided by surgery (S) and non-surgical (NS) treatment modalities in adult spinal deformity (ASD), a decision analysis model was performed. The results of this multicenter study suggest that S has a lesser disease burden and a lesser chance of deterioration, but equal chances for improvement when compared with NS patients at the end of 2-year follow-up.

Hypothesis

The utilization of longer follow-up period and database specific minimal clinically important difference (MCID) values on health related quality of life parameters might have an impact on overall patients' outcomes, hence the treatment decision.

Design

A retrospective review of prospectively collected multicenter ASD database.

Introduction

Identification of the best treatment modality in ASD provides a challenge. Surgery (S) has been shown to yield better results compared to non-surgical methods (NS) by several studies using fixed MCID values for improvement or deterioration. Recent studies however, suggest that MCID values may vary significantly by the treatment modality.

Methods

A total of 1452 patients (F: 1216, M: 236; S: 746, NS: 706) with a follow-up period of 2 years were analyzed. S group was further subcategorized into; no complication (N, n=1259), minor complications (Min, n=103) and major complications (Maj, n=90) groups to analyze the effect of complications on treatment results. MCID values for ODI were calculated by latent class analysis specific to ASD and its treatment (Overall: 14.31, S: 14.96, NS: 2.48), then the patient outcomes were categorized as improved (I), unchanged (U) and deteriorated (D). Utilities, as measures of the disease were calculated for each population (range: 0-worst- to 1-no burden-) and treatment modality based on VAS mapping. Finally, these data were incorporated into decision trees.

Results

At the end of the 2nd year, 38.3% of S patients were I, 39.2% U, and 22.5% D whereas these values were 39.4%, 10.5%, 50.1%, respectively, for NS patients. S group were sensitive to complications with improvement rates of 40.1%, 39.3% and 33.3% and deterioration rates of 19.2%, 22.5% and 29.4% for N, Min and Maj, respectively. For utilities; S provided a higher value (0.583) than NS (0.549); hence, less burden (Figure 1). Utilities in S were sensitive to the presence of treatment complications, being 0.634, 0.564 and 0.497 in N, Min and Maj, respectively.

Conclusion

S has a less disease burden and a less chance of deterioration than NS, but equal chances for improvement at the end of the 2nd year. The effect of complications are clearly delineated.

Take Home Message

Surgery appears to be a better modality in the absence of any

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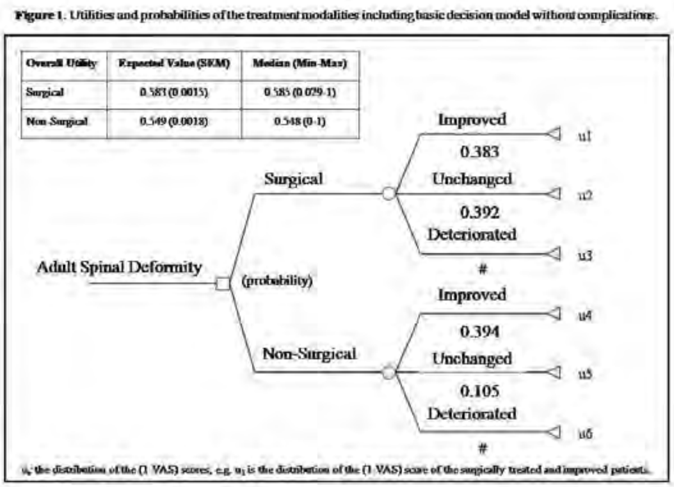
complications, future efforts need to be directed for decreasing the complication rates of surgical treatment in ASD.



Utilities and probabilities of the treatment modalities including basic decision model without complications

33. Development and Expanded Validation of an Individualized Preoperative Predictive Risk Calculator for Major Complications Following Adult Spinal Deformity Surgery: A Step Forward to Improve Shared Decision Making in a Value-driven Economy

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Summary

Data from 1612 adult spinal deformity (ASD) patients operated before July-2016 (57 surgeons, 24 sites, 5 countries) were used to build major complications (MC) risk calculating models. Accurate preoperative risk stratification of surgically eligible ASD patients is possible at the point of care and in real-time. Patient-related factors, >1/3 of which are modifiable, account for 55% of the model weight.

Hypothesis

Preoperative predictive models (PM) can accurately estimate likelihood of MCs associated with ASD surgery.

Design

Combined multi-national registry analysis.

Introduction

Given the complexity of risk factors associated with MCs in ASD, a disease-specific prediction tool is needed. Current models are immature, rely on regression modeling, and do not account for complex variable interactions.

Methods

Surgical ASD patients with >2y follow-up were identified from 2 multi-center, multinational registries. Demographic, radiographic, operative, baseline PROMs (ODI, SRS22, SF36) and complications data were analyzed. Event free survival (Cumulative Incidence) curves for MCs were modeled. Two MC PMs, preop and immediately postop (included surgical data and represented the pre-discharge state), were created using random survival forest with 80/20 train/test sets. New expanded external validation was done using patients operated after July 2016.

Results

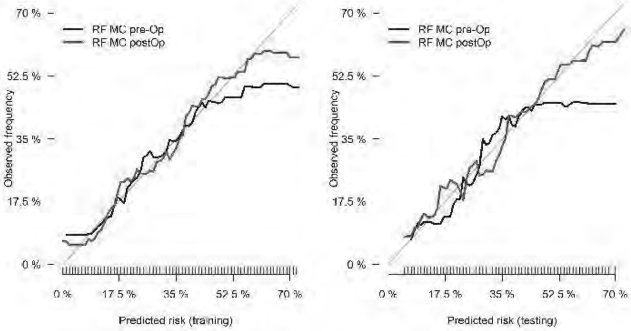
1612 ASD patients (76.6% women, 56.7 mean age, 10.4 levels fused, 55.1% pelvic fixation, 20.6% 3CO) operated by 57 surgeons with 2,047.9 observation-years were analyzed. Kaplan-Meier estimates found that 12.1% of patients had at least one MC by 10 days, 21.5% by 90d and 36% by 2y. Individual cumulative risk estimates for MC at 2y ranged from 3.9%-74.1%. C-statistic value (71.7%;95%CI [68-75%]) indicated successful model fit. Surgical invasiveness (LIV-pelvic fixation, length of fusion, prior surgery) (20% PM weight), age (11% PMW), sagittal deformity (24% PMW), patient frailty (walking and lifting capacity) (19% PMW) and blood loss (23% PMW) most strongly predict MC.

Conclusion

Prediction modeling offers accurate preoperative and pre-discharge risk stratification of surgical ASD patients. The Major Complications-ASD Predictive Models may assist providers and patients in understanding risk and therefore in choosing the most appropriate plan according to preferences and risk-tolerance. This is a first-step toward individualized care in ASD and may improve outcomes via expectation management.

Take Home Message

Machine learning using data from two of the largest ASD-databases allows accurate prediction of major complications following surgery and preoperative risk stratification in real time, at the point of care.



34. The 5-item Modified Frailty Index is Predictive of Severe Adverse Event in Patients Undergoing Surgery for Adult Spinal Deformity

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Summary

Retrospective review of prospectively enrolled 285 consecutive patients data from multi-center ASD database revealed that the mFI-5 and the mFI-11 were equally effective predictors in the development of severe adverse effect (SAE) in ASD surgery (weighted Kappa: 0.87). The mFI-5 is a straightforward assessment tool that correlates with development of SAE after ASD surgery (frail; relative risk for SAE: 2.2[95%CI:1.3-3.7]). It can be used to help surgeons predict severe adverse events and facilitate informed discussions with their patients.

Hypothesis

Utilization of the simple 5-item modified frailty index (mFI-5) would be a valid method in predicting postoperative severe adverse event (SAE) in adult spinal deformity (ASD) surgery.

Design

A retrospective review of 285 consecutive ASD surgery (mean 55±19yr, 91% female, 2y f/u) from multicenter ASD database.

Introduction

Several recent studies have focused on the associations between frailty and surgical complications. However, the predictive power and usefulness of mFI-5 have not been proven in past literatures. The goal of our study was to compare mFI-5 to the conventional 11-item modified frailty index (mFI-11) in terms of value and predictive ability for SAE.

Methods

SAE was defined as follows: Clavien-Dindo grade >3, required reoperation, motor deficit at discharge and new motor deficit in 2y. Spearman's rho was used to assess correlation between the mFI-5 and mFI-11. mFI-5 and mFI-11 were categorized as below (robust; mFI-5, -11= 0, prefrail; mFI-5 =1 or -11< 0.27, frail: mFI-5> 2 or -11> 0.27). Univariate and multivariate Poisson regression analyses were conducted to analyze the relative risk [RR] for mFI-5 and mFI-11 as a predictor of SAE in ASD surgery. Age, gender, and baseline sagittal alignment [Schwab-SRS classification C7SVA, PI-LL, and PT subcategories] were used to adjust the baseline valiance of the patients.

Results

Of the 285 patients, 63 (22%) patients developed SAE at 2y. Frailty was associated with increased total complications, perioperative complications, mechanical complications, and SAEs (Table). As mFI-5 increased from 0 to ≥2, the rate of SAE increased nearly 4-fold from 17% to 63% (P < 0.01) and the RR was 2.2 (95%CI:1.3-3.7). Weighted Kappa ratio between the mFI-5 and mFI-11 was 0.87 indicating excellent concordance across ASD surgery. Adjusted and unadjusted models showed similar c-statistics for mFI-5 and mFI-11, and strong predictive ability for SAE in ASD surgery.

Conclusion

The mFI-5 and the mFI-11 are equally effective predictors in the development of SAE in ASD surgery. The mFI-5 can be used to help surgeons predict severe adverse events and facilitate informed discussions with their patients.

Take Home Message

mFI-5 is a valid method in predicting SAE in ASD surgery and can provide an effective and robust risk assessment tool to appropriately counsel patients and aid in preoperative optimization.

	Frailty (mFI-5)	Complication (%)	RR	95% CI	p value	Frailty (mFI-11)	Complication (%)	RR	95% CI	p value
Total complications	Robust	32	Reference			Robust	31	Reference		
	Prefrail	57	1.3	1.0-1.9	0.09	Prefrail	55	1.4	1.0-1.9	0.06
	Frail	74	1.7	1.2-2.3	<0.01	Frail	85	2.2	1.6-2.9	<0.01
			p for trend< 0.01					p for trend< 0.01		
Periop complications										
	Robust	21	Reference			Robust	21	Reference		
	Prefrail	45	1.8	1.1-2.9	0.03	Prefrail	40	1.5	0.9-2.5	0.08
	Frail	55	2.0	1.2-3.5	0.01	Frail	75	3.1	1.9-4.0	<0.01
			p for trend< 0.01					p for trend< 0.01		
Mechanical complications										
	Robust	22	Reference			Robust	20	Reference		
	Prefrail	43	1.1	0.7-1.8	0.58	Prefrail	42	1.3	0.8-2.0	0.29
	Frail	67	1.7	1.2-2.6	<0.01	Frail	82	2.5	1.7-3.7	<0.01
			p for trend= 0.02					p for trend= 0.02		
SAEs										
	Robust	17	Reference			Robust	17	Reference		
	Prefrail	45	1.7	1.0-2.9	0.06	Prefrail	42	1.6	1.0-2.7	0.07
	Frail	63	2.2	1.3-3.7	<0.01	Frail	75	2.8	1.7-4.7	<0.01
			p for trend<0.01					p for trend= 0.01		

Adjusted risk analysis for total, perioperative, mechanical complication, and severe adverse effect in the robust, prefrail, and frail groups stratified by mFI-5 and -11

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

35. Prognostic Nutritional Index Less than 50 Indicate High Possibility of Medical Complications After Adult Spinal Deformity Surgery

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Summary
Many complications are highly likely to occur in malnutrition status. Prognostic nutritional index (PNI) is used recently when evaluating nutritional condition. The postoperative medical complication were investigated according to PNI score among 270 patients with adult spinal deformity surgery. Medical complication rates are significantly higher in patients with PNI less than 50. Especially, serious complications such as death may occur when PNI is too low.

Hypothesis
Prognostic nutritional index (PNI) should be useful for predicting postoperative medical complications after adult spinal deformity (ASD) surgery.

Design
Retrospective study among patients with adult spinal deformity surgery aged over 40

Introduction
It is reported that many complications are highly likely to occur in malnutrition status. PNI is often used recently when evaluating this nutritional condition. PNI can be conveniently calculated by albumin and lymphocyte count of blood sampling test. Recently, we reported that postoperative delirium after ASD surgery occurred at high rates in cases with PNI less than 50. The purpose of this study was to identify postoperative outcome including medical complications (except for surgical complications, i.e. proximal junctional kyphosis, rod breakage etc.) according to the nutritional state before surgery.

Methods
A total of 270 patients aged over 40 who underwent ASD surgery in our hospital were divided into PNI<50 group (group L) or PNI≥50 (group H). Medical complications were defined as those within 30 days after the surgery. However, surgical site infection and death was evaluated up to 2 years after the surgery.

Results
Group L and group H were 117 and 153 patients, respectively. The mean age of both groups was 69 years old. There was significant difference in BMI (group L: group H=22:24, P=0.000), PNI score (46:55, P=0.000), and medical complications (48 patients [41%]:33 patients [22%], P=0.000). Especially, 4 patients in group L died within 2 years after the surgery (3.4%, mean PNI=42.8). Multiple logistic regression analysis suggested that significant risk factors for postoperative medical complications were male (P=0.008, odds ratio [OR]=2.5, 95% confidence interval [CI]=1.27-4.85) and PNI<50 (P=0.003, OR=2.3, 95% CI=1.33-3.94).

Conclusion
Medical complication rates are significantly higher in patients with PNI less than 50 and males. Especially, serious complications such as death may occur when PNI is too low. In malnourished patients scheduled for adult spinal deformity surgery, improvement of preoperative nutritional status is important to avoid medical complications.

Take Home Message
In malnourished patients scheduled for adult spinal deformity surgery, improvement of preoperative nutritional status is important to avoid serious medical complications such as death.

36. Assessing the Five-year Baseline Prevalence of Metabolic Bone Diseases in the Adult Spinal Deformity Surgical Patient Population: A Call to Own the Bone

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Summary
Metabolic bone diseases (MBDs) are commonly encountered in older populations, especially those with adult spinal deformity (ASD). As varying etiologies of MBD are associated with different complications, we sought to determine which MBDs were the most common in ASD pts. The New York Statewide Planning and Research Cooperative System (SPARCS) database was utilized to gather data. Osteoporosis was the most prevalent MBD in ASD and the prevalence of all MBDs increased with patient age.

Hypothesis
We hypothesized that osteoporosis would be the most prevalent MBD in the ASD population and that overall prevalence of MBDs would increase as patients became older.

Design
Retrospective cohort

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Introduction

With an aging population and the substantial mortality associated with MBD, it is crucial to track the outcomes of MBD. ASD is one such outcome. At certain age points, ASD approaches 65% prevalence, but specific etiologies of MBD-related ASD are not well documented. We sought to detail the most common etiologies across demographic subgroups.

Methods

SPARCS was queried to identify all ASD patients between 2009 and 2013. Pts were compared by age (<45yo, 45-64yo, and >64yo), sex, and race. Pt MBD diagnoses were recorded for each subgroup, including: osteoporosis (OP), vitamin D deficiency (VDD), postsurgical hypothyroidism (PHT), glucocorticoid deficiency (GD), nontoxic uninodular goiter (NUG), and sickle cell trait (SCT). Prevalence was then calculated.

Results

12,530 patients were identified. The most prevalent conditions for ASD pts overall were: (1) OP 8.1% (2) VDD 2.1% (3) PHT 1.0% (4) GD 0.6% (5) NUG 0.5%. These were also the top 5 for the 45-64yo and >64yo groups. The most common in the <45yo group were VDD 1.0%, SCT 0.8%, and OP 0.6%. The OP rate in each age range significantly differed from the other two (0.6vs6.3vs17.5%; $p<0.05$). Although VDD was the top MBD in <45yo, the <45yo rate was significantly less than the other two age groups' VDD rates (1.0vs2.7vs2.9%; both $p<0.05$). Females experienced greater rates of all the 5 most common MBDs compared to males (OP 12.1vs2.6%; VDD 2.6vs1.6%; PHT 1.5vs0.3%; GD 0.7vs0.4%; NUG 0.7vs0.3%), all $p\leq0.013$. OP was the most common MBD across all races (W 9.6%, B 3.1%, H 5.0%, O 6.4%). White pts had significantly higher OP rate than Black, Hispanic, or Other pts, $p<0.05$.

Conclusion

Our study provides exact data on MBD etiologies across various demographic subgroups of ASD pts, and illustrates that across all subgroups except pts <45yo, OP is the most common etiology. These trends also underline the rising rates of vitamin D deficiency in the Northern hemisphere.

Take Home Message

OP is the most prevalent MBD in ASD patients. Prevalence of MBDs increased significantly as patients got older, especially in female patients.

Age (Years)	<45	45-64	>65	p-value
Osteoporosis	0.6%[a]	6.3%[b]	17.5%[c]	<0.001
Vitamin D Deficiency	1.0%[a]	2.7%[b]	2.9%[b]	<0.001
Postoperative hypothyroidism	0.1%[a]	0.9%[b]	[illegible]	<0.001
Glucocorticoid deficiency	0.1%[a]	0.7%[b]	0.9%[b]	<0.001
Non-toxic uninodular goiter	[illegible]	0.6%[b]	0.8%[b]	<0.001
Sickle cell trait	0.8%[a]	0.1%[b]	0.0%[b]	<0.001

Sex	Male	Female	p-value
Osteoporosis	2.6%	12.10%	<0.001
Vitamin D Deficiency	1.60%	2.60%	<0.001
Postoperative hypothyroidism	0.30%	1.50%	<0.001
Glucocorticoid deficiency	0.40%	0.70%	0.013
Non-toxic uninodular goiter	0.30%	0.70%	0.002
Sickle cell trait	0.10%	0.40%	<0.001

Race	White	Black	Hispanic	p-value
Osteoporosis	9.6%[a]	3.1%[b]	5.0%[c]	<0.001
Vitamin D Deficiency	2.4%[a]	2.4%[a]	1.1%[b]	0.012
Postoperative hypothyroidism	1.1%	0.8%[b]	[illegible]	0.018
Glucocorticoid deficiency	0.7%[a]	0.2%[b]	0.5%[b]	0.232
Non-toxic uninodular goiter	0.6%[a]	0.3%[b]	0.5%[b]	0.503

Prevalence of the most common metabolic bone diseases in adult spinal deformity patient population undergoing surgery across different subgroups of age (<45yrs, 45-64yrs, >65), sex, and race groups

37. Lateral Lumbar Interbody Fusion for Adult Spinal Deformity: Is it Superior to the Conventional Posterior Spinal Fusion for Correcting Sagittal Imbalance?

Hyeong Joo Lee, MD; Chang Ju Hwang, MD, PhD; Dong-Ho Lee, MD, PhD; Choon Sung Lee, MD, PhD; Jae Hwan Cho, MD, PhD; Jae Woo Park, MD

Summary

Lateral lumbar interbody fusion (LLIF) combined with posterior spinal fusion (PSF) is superior to conventional PSF for sagittal plane correction when long-level fusion is necessary in lumbar degenerative disease, including adult spinal deformity (ASD).

Hypothesis

LLIF combined with PSF may be superior to conventional PSF for correcting sagittal imbalance when long-level fusion is necessary for ASD.

Design

Retrospective observational study

Introduction

LLIF has been commonly used for treating degenerative lumbar disease; it is often necessary to have long-level fusion to correct deformity. However, it has been reported that the correction force for sagittal alignment is limited. Few reports have compared the change of sagittal profile after LLIF with that after conventional PSF. We analyzed the change in the sagittal profile after LLIF combined with PSF and compared it with that after conventional PSF for ASD.

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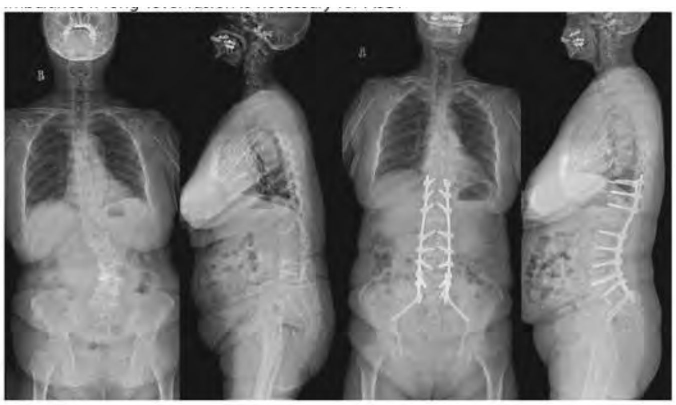
Methods
We examined patients with degenerative lumbar disease, including ASD using the following criteria: regional or global sagittal imbalance, >4 levels of fusion, and a minimum of two years follow-up. Thirty-five patients who underwent LLIF combined with PSF (LLIF group) were compared with 34 patients who underwent PSF (conventional group). Radiological outcomes included global sagittal parameter and pelvic parameters, and the clinical outcomes preoperative and three months postoperative, two-year postoperative examination, and last follow-up, which were assessed.

Results
No significant difference in the correction of coronal deformity was seen; however, increase of lumbar lordosis in the LLIF group was significantly higher postoperatively (41.29° vs 16.38°, P<0.001) and at the last follow-up (35.51° vs 13.03°, P<0.001). Decrease of sagittal vertical axis, pelvic tilt and T1-pelvic angle were also higher in the LLIF group, and increase of thoracic kyphosis was significantly higher in the LLIF group postoperatively and at the last follow-up compared with those measures in the conventional group. Clinical outcomes improved postoperatively; there was no significant difference between the groups in the occurrence of major complications. PJK occurrence was higher in the LLIF group, although the difference was not significant.

Conclusion
LLIF has advantages over conventional PSF in the correction of sagittal imbalance, including restoration of lumbar lordosis

Take Home Message
LLIF combined with PSF is superior to conventional PSF in correcting sagittal imbalance if long-level fusion is necessary for ASD.



38. Clinical Implications of Lateral Access to the Concavity Side for Adult Spinal Deformity

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Summary
The laterality of access to a coronal curve from the convexity or concavity affords similar outcomes with previously described increased morbidity when accessing the coronal curve from the concave side. This review illustrates that access from the concavity can be done safely and offers unique advantages compared to approaching from the convex side.

Hypothesis
A concavity approach to the coronal curve can be done with limited morbidity.

Design
Retrospective chart review

Introduction
Minimally invasive spine surgery (MIS) techniques, particularly lateral lumbar interbody fusion (LLIF) have become increasingly popular for adult spinal deformity (ASD) correction. Much discussion has been had regarding theoretical and clinical advantages to addressing coronal curvature from the convex versus concave side of the curve. This study evaluates the clinical outcomes of addressing ASD with circumferential MIS (cMIS) techniques while accessing the lumbar coronal curvature from the concave side.

Methods
A multi-institution, retrospective chart and radiographic review was performed for all ASD cases with at least 10 degrees curvature as defined by the Scoliosis Research Society (SRS) who underwent cMIS correction. Data harvested included the convexity versus concavity access to the coronal curve, durable or sensory femoral nerve injury lasting greater than six weeks, vascular injury, visceral injury, any additional major complication with at least two-year follow up.

Results
A total of 126 of 152 cases of ASD treated with cMIS correction and lateral access to the concave side were identified. In the concavity group 1 motor (0.8%) and 4 sensory (3.2%) deficits remained after six weeks post-operative and no vascular, visceral or catastrophic intra-operative injuries were encountered.

Conclusion
It has been reported that lateral access to the convexity has similar clinical and radiographic outcomes with less complications when compared to concavity access. Magnetic resonance imaging studies have shown an anterior displacement of the lumbar nerves travers-

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

ing the psoas on the concave side when compared to the convex side. Contrary to these findings, this review highlights the safety and limited morbidity of accessing the coronal curve from the concave side. Advantages to approaching the lumbar spine from the concave side include utilizing one incision to access multiple levels, breaking the operative table to assist with curvature correction, easier access to the L4-5 disc space, and often avoids the need to access/traverse the thoracic cavity.

Take Home Message
LLIF for ASD from the concave side is safe and offers advantages compared to access from the convex side.

39. Does Interbody Fusion Protect Against Rod Failure in the Lower Lumbar Spine after Long Fusions to the Sacrum: A Comparative Analysis of Adult Spinal Deformity Patients

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Summary
Rod failures in the lumbar spine after long fusions to the sacrum for ASD correction remain high despite the use of BMP and sacropelvic fixation. We compared the rate of RF in 256 ASD pts who underwent long spinal fusion using BMP and sacropelvic fixation with and without Interbody fusion in the lower lumbar spine. The addition of interbody fusion was not associated with a statistically significant difference in RF, 21% in IF group vs 17% in NIF pts.

Hypothesis
Interbody fusion in the lower lumbar spine in long PSF to the sacrum with the use of sacropelvic fixation and BMP is not associated with decrease in rod failure rate

Design
Retrospective cohort study

Introduction
The question whether Interbody fusion is needed with the combination of sacropelvic fixation and use of BMP after long PSF to the sacrum in ASD remains unanswered.

Methods
Single center database with 526 ASD pts was reviewed, only primary surgeries were included. Pts were dichotomized into interbody fusion (IF) group and no-interbody fusion (NIF) group. Interbody fusions were performed in the lower lumbar spine L3-S1 most commonly at L5-S1. The primary outcome of interest was the rod failure rates from L3-S1. All patients had a minimum two-year follow-up.

Results
256 pts underwent long PSF for correction of ASD, 141 pts had interbody fusion (IF group) at any level L3-S1 with mean f/u of 59 ±29 mos and 115 pts had no interbody fusion(NIF group) with 50±22 mos mean f/u. At baseline, there were no significant differences between both groups in gender (p=0.97), BMI (p=0.62), smoking status (p=0.40), diabetes(p=0.34) or osteopenia p=0.73. The median number of levels fused in the IF group was 10(7-15) compared with 8 levels (7-15) in the NIF group. BMP and sacropelvic fixation (233 iliac screws and 23 pts had S2AI screws) was used in all pts. Pre-op sagittal plane deformity was not different between both groups. At last follow-up, there was no statistically significant difference in rate of Rod failure between IF n=29(21%) vs NIF n=17(15%) p=0.23. IF group had 19(13%) unilateral RF, 10(7%)bilateral. NIF group 12(10%) uni- and 5(4%) bilateral RF. The location of RF was different between groups, L3-4 was most common location in IF group 6.5% followed by L5-S1 in 6.1%. Interbody fusion was performed at L4-5 and L5-S1 in majority of pts that failed at L3-4. In NIF group L5-S1 was most common location in 6.4% followed by L4-L5 in 2.7%

Conclusion
IBF does not protect against rod failure in the lower lumbar spine in ASD pts with long PSF and may encourage failure at L3-4, the level above the IBF

Take Home Message
IBF does not protect against rod failure in the lower lumbar spine in ASD pts with long PSF and may encourage failure at L3-4, the level above the IBF

Podium Presentation Abstracts

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Characteristic	Interbody Fusion Cohort(n=141)	No Interbody Fusion Cohort(n=115)	p-Value
Length of Follow-up(Months)	59.50±29.20	49.99±22.40	0.01
Rod Fracture (n,%)	29(21)	17(15)	0.23
Unilateral Rod fracture(n,%)	19(13)	12(10)	0.46
Bilateral Rod fracture(n,%)	10(7)	5(4)	0.34
2-years Radiographic Parameters			
Mean C7 SVA (mm)	2.78±3.80	2.44±3.85	0.48
Mean Pelvic Incidence(°)	54.88±12.21	53.30±14.43	0.35
Mean Sacral Slope (°)	32.15±8.82	32.21±10.25	0.96
Mean Lumbar Lordosis (°)	46.89±12.17	46.34±13.50	0.74
Mean Pelvic Incidence–Lumbar Lordosis (°)	8.11±12.15	6.96±15.74	0.53
Thoracic Kyphosis (°)	36.90±12.08	36.23±12.97	0.67
Thoracolumbar Kyphosis (°)	**8.24±12.05**	**12.45±10.16**	**0.01**
Coronal Cobb Angle	25.53±14.36	26.45±15.55	0.63

Location of Rod Fracture	Rod failure uni-and bilateral in both groups	Interbody Fusion Cohort(n=141)	No Interbody Fusion Cohort(n=115)	p-Value
L3(%)	2.5	0.32	0.45	0.65
L3-L4 (%)	31.25	6.51	2.28	0.08
L4-L5(%)	12.50	1.30	2.73	0.10
L5-S1(%)	41.25	6.18	6.39	0.17
S1-Ilium (%)	12.50	2.28	1.36	0.83

Table showing Rod Fracture rate and Laterality in both groups and most common location and 2-year radiographic parameters

40. Combined Anterior-posterior vs All-posterior Approaches for Adult Spinal Deformity Correction: A Matched Control Study

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Summary

Anterior approach is increasingly being used for Adult Spinal Deformity (ASD) Surgery. This is the first study directly comparing surgical outcomes between Combined Anterior-Posterior (CA) approaches and All Posterior (PO) approach in a matched ASD population. Despite an added morbidity, CA does seem to decrease complication rate, offer better immediate deformity correction and improve long term functional outcomes starting 2 years after surgery. Benefit is maintained at 3 years.

Hypothesis

CA Approaches provide powerful segmental sagittal correction potential and increase the surface area available for fusion in ASD surgery, both of which would improve overall outcome when compared to PO approaches

Design

Retrospective Matched-Control cohort analysis

Introduction

Anterior approaches are gaining popularity for ASD surgeries especially with the introduction of hyperlordotic cages and improvement in MIS techniques. There are no direct comparative studies to all posterior approaches to justify their added morbidity

Methods

Retrospective Matched-Control cohort analysis with substitution using a multicenter prospectively collected ASD data of patients with >2-yr FU. Matching criteria include: Age, American Society of Anesthesiologists Score, Lumbar Cobb angle, Sagittal deformity (Global Tilt) and ODI. Patients with missing data were excluded (Flowchart)

Results

1022 ASD patient were available for analysis. Out of the 29 CA patients who met inclusion criteria only 22 could be matched to 2 controls each (1:2 Ratio). Preoperative non-matched demographical, clinical, surgical and radiological parameters were comparable between both groups, validating matching criteria. CA group had longer surgeries (548 mns vs 283; p<0.001) with more blood loss (2850ml Vs 1471; p<0.001) and needed longer ICU stays (74 hrs Vs 27; p<0.001). Despite the added morbidity, they had comparable complication rates but with significantly less readmissions (9.1% vs 38.1%) and reoperations (18.2% vs 43.2%). CA group achieved a more individualised and harmonious deformity correction as measured by Global Tilt and GAP score parameters. Both groups however achieved similar final radiological corrections and functional results were comparable up to two years after surgery. At the 2-year control, CA patients reported better outcomes as measured by COMI and SRS scores. This trend was maintained in the CA group reaching 3-years

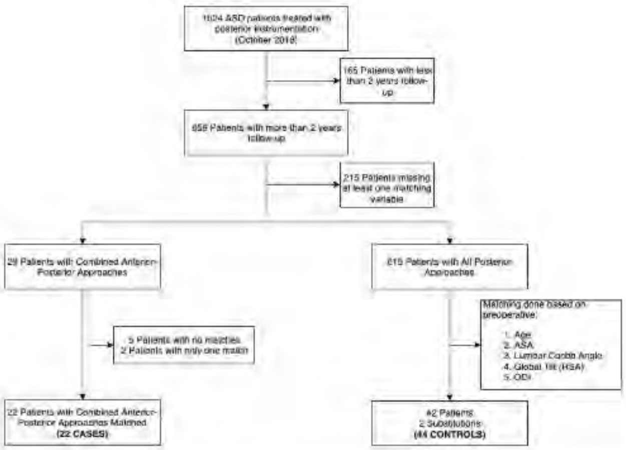
Conclusion

Despite an increased initial surgical aggression, CA seems to achieve a more harmonious correction, need less revisions and have improved long-term functional outcomes starting two years after index surgery when compared to PO for ASD

Take Home Message

Combined approaches offer a superior sagittal deformity control, decreased revision rates and improved long term functional outcomes when compared to all-posterior approaches for ASD deformity correction.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper



Preoperative Variables					
	Cases (n=22)		Controls (n=44)		
	Mean / %	St. Dev.	Mean / %	St. Dev.	P-Value
Demographical Variables					
Gender (Fenale)	72,73%		81,82%		0,524
*Age	58,57	13,01	57,78	15,77	0,841
*ASA Classification	18,18%		18,18%		1,000
	68,18%		68,18%		
	13,64%		13,64%		
BMI	25,56	3,69	25,30	3,74	0,791
Diabetes	9,09%		2,27%		0,256
Liver disease	0,00%		0,00%		1.000
Nervous System Disorder	13,64%		11,36%		0,538
Osteoporosis / Osteopenia	9,09%		18,18%		0,476
Renal disease	4,55%		6,82%		0,593
Smoker	13,60%		22,70%		0,339
Prior Spine Surgery	54,55%		59,09%		0,795
Radiological - Preoperative					
*Lumbar Cobb	12,02	14,67	11,09	12,50	0,790
Major Cobb	38,88	26,33	38,95	23,66	0,992
Coronal Balance	6,14	56,66	-12,52	36,50	0,113
Sagittal Balance	69,05	81,82	66,57	58,41	0,888
Lumbar Lordosis	-34,21	22,60	-36,25	20,60	0,716
PI	56,22	12,69	55,84	12,69	0,909
PT	26,81	10,96	26,17	11,90	0,834
SS	29,41	12,30	30,29	8,93	0,743
*Global Tilt	35,89	17,35	33,50	19,07	0,623
PI-LL	22,01	22,85	19,60	24,52	0,701
HRQoL - Preoperative					
Back Pain VAS	7,36	2,65	7,48	2,30	0,858
Leg Pain VAS	5,18	3,57	4,68	3,75	0,605
COMI Back - Score	7,49	1,82	7,52	1,74	0,958
*ODI - Score (%)	47,00	18,57	45,45	17,23	0,739
SRS22 - Function	2,80	0,62	2,79	0,65	0,928
SRS22 - Pain	2,14	1,02	2,20	0,82	0,814
SRS22 -SI	2,18	0,76	2,14	0,62	0,831
SRS22 - MH	3,11	0,92	3,07	0,79	0,874
SRS22 - Satisfaction	3,09	1,20	3,20	1,04	0,796
SRS22 - SRS Subtotal	2,57	0,57	2,56	0,55	0,913
SRS22 - SRS Total score	2,60	0,57	2,58	0,55	0,888
SF36 - PCS	33,04	7,86	33,09	7,24	0,982

41. Adult Spinal Deformity Patients Who Undergo Staged Surgery Within 3-months Have Equivalent Timeline to Functional Recovery as Those with Non-staged Surgery

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Summary

Patients with Adult Spinal Deformity (ASD) undergoing non-staged surgery have equivalent chances of achieving clinically important improvement in functional health-related quality of life in a similar period of time compared to patients who have staged procedures within three months. When deciding to stage ASD surgery, this information should be utilized in the shared decision making process.

Hypothesis

Adult Spinal Deformity (ASD) patients who undergo staged surgery have equivalent timeline to functional recovery compared to patients who have non-staged surgery.

Design

Retrospective review of a single-center database.

Introduction

A potential limitation of staging surgery in ASD patients is delayed functional recovery; however, this finding has not been well demonstrated.

Methods

A prospectively collected database was used to identify patients with ASD (>5 levels fused) and fusion to the pelvis. Patients' functional status was assessed using the Scoliosis Research Society (SRS-22r) Activity domain. Minimal Clinically Important Difference (MCID) was defined as 0.4-point improvement in SRS-22r Activity. Patients were excluded with staged procedure greater than 3 months after the index procedure, or who had less than 2-year follow-up and did not meet MCID. Using a cox proportional hazard model, we controlled for primary vs. revision surgery, number of levels fused, age, gender and baseline functional scores. Our study was powered to detect a relative hazard ratio (HR) of 0.53, $\beta = 0.20$.

Results

87 ASD patients (>5 levels fused) were included. Mean age of patients was 61 ± 11 years, 78% females, SVA of 10.7 ± 9.5cm. Mean levels fused were 8.8 (range 6-18). 38 (46%) of patients had a second-stage surgery, while 44 (54%) had nonstaged surgery. Mean preoperative SRS-22r Activity was 2.8 ± 0.6. Staged and non-staged groups had similar gender, age, baseline SRS-22r Activity, (p>0.05). Patients with a staged surgery did not have

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decreased likelihood of reaching SRS-22r Activity MCID at compared to patients without a staged surgery (HR 0.74, 95% CI: 0.41 – 1.36). Median time to reaching SRS-22r Activity MCID was 191 days in patients with a staged procedure and 181 days in patients with unstaged surgery, p=0.75.

Conclusion

ASD patients undergoing staged surgery within three months achieve clinically important functional improvement with the same frequency and time interval as patients without staged surgery.

Take Home Message

ASD patients undergoing non-staged surgery do not have decreased changes of achieving clinically important functional improvement in the same time interval compared to patients having staged procedures within three months.

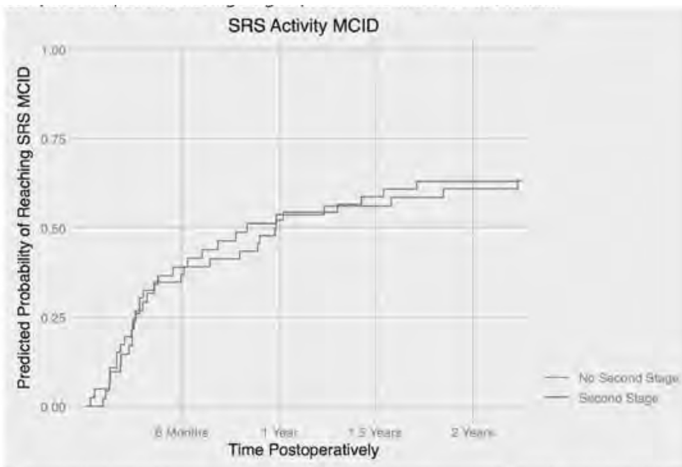

Figure 1. Kaplan Meier curve demonstrating predicted probability of reaching MCID in SRS-22r Activity among Adult Spinal Deformity patients throughout the 2-year follow-up period, stratified by patients who had staged vs. unstaged procedures.

42. Multiple Rod Construct and PSO: A Survival Analysis with Minimum 2 Year Follow-up

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Summary

High Rod failures rates following Pedicle Subtraction Osteotomy (PSO) have been previously reported. To reduce this incidence, multiple rod constructs have been used across the PSO site. This study reports significant differences in rod failures in 4 different constructs strategies. However, a decrease in survival rate for multiple rod strategy was seen with longer follow-up highlighting the importance of achieving a fusion.

Hypothesis

Constructs utilizing multiple rods prevent early rod failure following pedicle subtraction osteotomies (PSO)

Design

Multi-center, prospective observational analysis

Introduction

Early rod failures are common following PSO. Multiple rods may be utilized to mitigate rod failure, however the ideal rod configuration remains unknown and nomenclature for rod configuration is needed.

Methods

All pts. undergoing a PSO in a prospective database of operative adult spinal deformity (ASD) patients (scoliosis>20°, SVA >5cm, or thoracic kyphosis >60°) with min 2 yr f/u were included. The number and the rod configurations around the PSO were classified as either Accessory (A) or Satellite (S) (Fig). Rate of instrumentation failure and a Kaplan Meier survival analysis was used to investigate differences in failure.

Results

102/120 eligible pts. treated with a PSO had sufficient data (mean age 62yo, 72% F Mean f/u was 36mo.±13). Pre-op data showed a large deformity (PI-LL: 36.7°±17.6; TPA: 35.5°±11.9) with severe disability (ODI: 48.4±17.5; PCS: 29.1±8.9). Common PSO levels were L3 (49.0%) and L4 (21.6%). Mean EBL was 3.1L±1.9 with a mean OP Time of 473min±157. Pts. had a significant change in sagittal alignment (PI-LL: 33.8°±13.6; TPA: 17.7°±8.6; SVA: 10.6cm±6.1 all p <0.001). 4 major types of construct were found: 2 main rods (2R: 43.1%), 3 rods, main 2, accessory 1 (2R+1A: 18.6%), 4 rods, main 2, accessory 2 (2R+2A: 11.8%), 4 rods, main 2, satellite 2 (2R+2S: 12.8%). Overall rate of rod failure was 25.5% (N=26) with a significant difference between 2 rods vs multiple rods (35.3% vs 8.4% p = 0.023) and across the 4 types of construct (2R: 40.9% 2R+1A: 15.8% 2R+2A: 0% 2R+2S: 15.4% p = 0.010). Survival analysis demonstrated a significant difference between the 4 types of construct (Log Rank: p = 0.010) with higher survival rate for multiple rod constructs. At longer f/u (> 1500 days), 2R and 2R+1A converge to a similar survival rate.

Conclusion

Multiple rods can significantly reduce early rod failure. Different type of constructs demonstrated different survival rates. Multiple rods constructs can also fail with longer follow up highlighting the importance of achieving a fusion.

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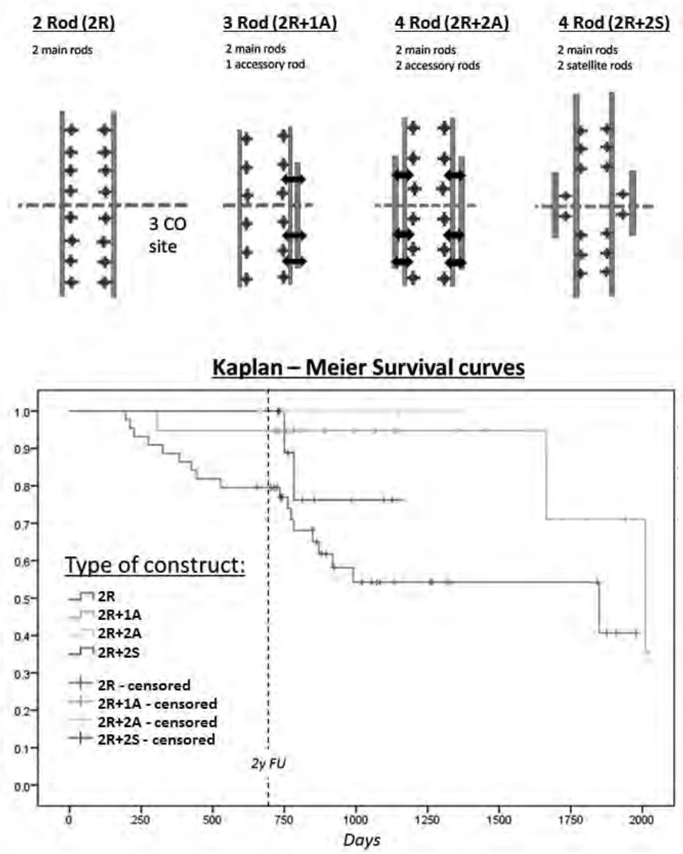
Take Home Message

Multiple rod constructs reduce early rod breakage at PSO site, however long term follow-up demonstrated convergent survival rates for all constructs indicative of the importance of achieving spinal fusion.



43. The Risks, Reasons, and Costs for 30- and 90-day Readmissions After Adolescent Idiopathic Scoliosis Surgery

Nathan J. Lee, MD; Jalen D. Dansby, BS; James D. Lin, MD, MS; Alex Ha, MD; Paul J. Park, MD; Meghan Cerpa, BS, MPH; Eric Leung, BA; Ronald A. Lehman Jr., MD; Lawrence G. Lenke, MD

Summary

While adolescent idiopathic scoliosis (AIS) surgery is generally associated with a low rate of complications, unplanned readmissions do occur. The Nationwide Readmission Database (NRD) was used to study readmission rates after AIS surgery. Risk factors for readmissions included LOS>5 days, obesity, neurologic disorders, and chronic use of anticoagulants. The top reasons for readmissions were wound infection and implant complications respectively. The mean costs associated with the first admission, 30-, and 90-day readmissions are $189,433, $73,529, and $54,130.

Hypothesis

Both 30- and 90- day readmissions are associated with potentially modifiable risk factors.

Design

Case-control study

Introduction

With the continued evolution of bundled payment plans, there has been a greater focus within orthopedic surgery on quality metrics up to 90 days of care. Although CMS does not currently penalize hospitals based on their pediatric readmission rates, it is important to understand the drivers for unplanned readmission to improve the quality of care and reduce costs.

Methods

The NRD provides a nationally representative sample of all discharges from US hospitals, and allows follow up across hospitals up to one calendar year. Adolescents (age 10-18) who underwent idiopathic scoliosis surgery from 2012 to 2015 were included. Patients were separated into those with and without readmission for within 30 days or between 31 to 90 days. Demographics, operative conditions, hospital factors, and surgical outcomes were compared using Chi-square and t-tests. Independent predictors for readmissions were identified using step-wise multivariate logistic regression.

Results

30,677 patients underwent AIS surgery from 2012-2015. The average rates for 30- and 90-day readmission are 2.9% and 4.1%, respectively. The mean costs associated with the first admission, 30-, and 90-day readmissions are $189,433, $73,529, and $54,130. Common risk factors for readmissions included LOS>5 days, obesity, neurologic disorders, and chronic use of antiplatelets/anticoagulants. The index-stay complications associated with readmissions were dural tears, SIADH, and SMA syndrome. Hospital factors, discharge disposition, and operative conditions appeared to be less important for readmission risk. The top reasons for 30day and 90day readmissions were wound infection (34.7%) and implant complications (17.3%), respectively. Readmissions requiring a reoperation were significantly higher in those that occurred between 31 to 90 days after the index readmission.

Conclusion

Readmission rates are low for both 30 and 90 day readmissions for AIS surgery patients. Nevertheless, readmissions are costly and appear to be associated with potentially avoidable risk factors.

Take Home Message

90-day readmission rate for AIS surgery is 4.1%. Top reasons for readmission were wound infection and implant complications.

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Independent Risk Factors Index Stay for 30- and 31-90 Day Readmissions for AIS Patients				
30 Day Readmissions, C Statistic = 0.712; H-L = 0.0974				
Effect	**Odds Ratio**	**95% Confidence Limits**		**P Value**
Length of Stay > 5 Days	1.8	1.6	2.2	<0.0001
Anemia Deficiency	2.0	1.6	2.5	<0.0001
Hypothyroidism	3.0	2.0	4.5	<0.0001
Fluid and Electrolyte disorders	1.8	1.5	2.3	<0.0001
Neurologic Disorders	1.9	1.4	2.4	<0.0001
Obese	2.9	2.2	4.0	<0.0001
Chronic use of antiplatelets/antithrombotics/anticoagulants	7.0	3.0	16.4	<0.0001
Intraoperative Dural Tear	2.7	1.6	4.7	0.0003
Index Stay Complication: SIADH	4.7	2.6	8.4	<0.0001
31-90 Day Readmissions, C Statistic = 0.752; H-L = 0.1632				
Effect	**Odds Ratio**	**95% Confidence Limits**		**P Value**
Length of Stay > 5 Days	2.8	2.2	3.6	<0.0001
Neurologic Disorders	2.2	1.6	3.2	<0.0001
Obese	3.6	2.3	5.6	<0.0001
Chronic use of antiplatelets/antithrombotics/anticoagulants	29.3	12.8	66.7	<0.0001
Index Stay Complication: SMA Syndrome	24.7	9.4	65.3	<0.0001

44. Forecasting Spinal Deformity Healthcare Burden and Operative Utilization in the United States from 2015 to 2040: An Epidemiological-based ARIMA Computation Modeling

Piyush Kalakoti, MD; Nathan R. Hendrickson, MD, MS; Joshua M. Eisenberg, MD; Andrew Pugely, MD

Summary

Using an Autoregressive Integrated Moving Average (ARIMA) and seasonal ARIMA computation modeling, the study provides projection forecasting of healthcare burden and economic assessment culminating from spinal deformity disorders in the United States from 2015 to 2040. This is the first study that provides projection-forecasting for various spectrums of spinal deformities and for operative spinal correction.

Hypothesis

Accurately forecasting healthcare burden/resource utilization due to spinal deformities is beneficial for reasonable planning and allocation of resources to meet the rising demands.

Design

Epidemiological-based, Time-Series analysis/Forecasting

Introduction

Prior projection-forecasting of spinal deformity disorders national burden can be beneficial for reasonable planning and allocation of resources to meet rising demands.

Methods

A time-series analysis was performed to forecast healthcare burden from the spinal deformity spectrums in the US between 2015-2040 using an Autoregressive Integrated Moving Average (ARIMA) modeling approach. For projection analysis, epidemiological data from the National Inpatient Sample 2001-2014 was utilized for future predictions. All projections were compared to the baseline 2014 year to assess percentage increase in spine deformity burden, operative utilization, costs, and length of stay (LOS). Diagnostics for forecasting models were assessed prior to model selection.

Results

In 2030 and 2040, hospital admissions from spine deformity spectrum will increase by approximately 75% and 122% from their baseline 2014 crude-admission rates. During the same period, the rate of surgical deformity correction outpaced conservative techniques and likely to witness 87.9% and 143% increase from 2014 rates. Despite inflation-adjustment to 2018 $ value, the cost of care will be expensive by 48% (+$55223 in 2030) and 76% (+$87220 in 2040) compared to 2014 baseline values.

Conclusion

This is the first study that provides projection-forecasting for various spectrums of spinal deformities and for operative spinal correction. The study notes that operative utilization for deformity surgery will outpace conservative strategies, thereby underscoring the need for training subspecialty spine surgeons in deformity correction. From a policymaking perspective, our data could be utilized as an adjunct for deciding the adequate number of orthopedic or neurosurgeons specializing in spine deformity surgery to cater the increasing demand while appropriately allocating resources for optimized care.

Take Home Message

Hospital admissions and surgical utilization rates for deformity surgery is likely to increase and our findings call for preparedness and resource utilization.

45. Cost-effectiveness of Operative vs Nonoperative Treatment of Adult Symptomatic Lumbar Scoliosis: An Intent-to-Treat Analysis with Five Year Follow-up

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Summary

In an intent-to-treat cost-effectiveness study with five year follow-up, neither nonsurgical nor surgical treatment was dominant for adult lumbar scoliosis, as greater QALY gains in the surgery group came at a greater cost.

Hypothesis

Operative treatment for Adult Symptomatic Lumbar Scoliosis (ASLS) is more cost-effective than non-operative treatment.

Design

Secondary analysis using data from the NIH sponsored study on ASLS that included randomized and observational arms.

Introduction

There continues to be uncertainty in the appropriate treatment approach for ASLS. Nonoperative care has not been shown to improve outcomes. Surgical treatment has been shown to improve outcomes, but is costly with high revision rates. The purpose of this study is to perform an intent-to-treat cost-effectiveness study comparing operative versus non-operative care for ASLS at five years after enrollment.

Methods

Patients with at least five-year follow-up data were included. Data collected every three months included use of nonoperative modalities, medications and employment status. Costs for index and revision surgeries and non-operative modalities were determined using Medicare Allowable rates. Medication costs were determined using the RedBook and indirect costs were calculated based on reported employment status and income. Quality Adjusted Life Years (QALY) was determined using the SF6D.

Results

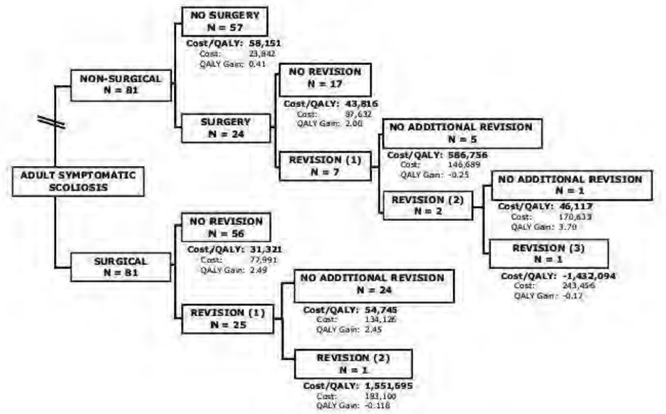
There were 81 of 95 cases in the Operative (Op) and 81 of 95 in the Non-operative (Non-Op) group with complete five-year follow-up data. Not all patients were eligible for five-year follow-up at the time of the analysis. All patients in the Op and 24 (30%) in the NonOp group had surgery by five years. At five years, the cumulative cost for Op was $96,000 with a QALY gain of 2.44 and for Non-Op the cumulative cost was $49,546 with a QALY gain of 0.75 with an ICER of $27,480 per QALY gain.

Conclusion

In an intent-to treat analysis, neither treatment was dominant, as the greater gains in QALY in the surgery group come at a greater cost. The ICER for operative compared to non-operative treatment was above the threshold generally considered cost-effective in the first three years of the study but improved over time and was highly cost-effective at four and five years.

Take Home Message

In an intent-to treat analysis, neither operative nor non-operative treatment was dominant for ASLS, as the greater gains in QALY in the surgery group come at a greater cost.



46. Postoperative Spinal Injection Reduces Length of Stay and Postoperative Narcotic Use Following AIS Fusion Surgery

Daniela Galeano-Garces, MD; Fady Baky, MD; William J. Shaughnessy, MD; Anthony A. Stans, MD; Dawit T. Haile, MD; A. Noelle Larson, MD; Todd Milbrandt, MD, MS

Summary

Spinal injection following fusion surgery for AIS reduced length of stay and total narcotic usage during hospitalization. There were no noted neurologic complications.

Hypothesis

Intrathecal hydromorphone injection performed at the completion of spinal fusion surgery would reduce in-hospital narcotic use and length of stay.

Design

Retrospective comparative study.

Introduction

With the rising cost of healthcare and concerns about postoperative narcotic use, centers are working to reduce length of stay and postoperative narcotic use. We sought to determine the effects of a single shot hydromorphone injection performed by the anesthesiologist or the surgeon at the completion of spinal fusion surgery for in-hospital narcotic use and length of stay.

Methods

For 97 AIS patients, 52 had postoperative spinal injection with hydromorphone at the completion of the case, while the remaining 45 patients had usual care with postoperative IV narcotics. Length of stay, total in-hospital narcotic use, and need for ICU hospitalization was assessed. For LIV below L2, the surgeon placed the injection intraoperatively. Otherwise, the anesthesiologist placed in the injection at the completion of the surgery.

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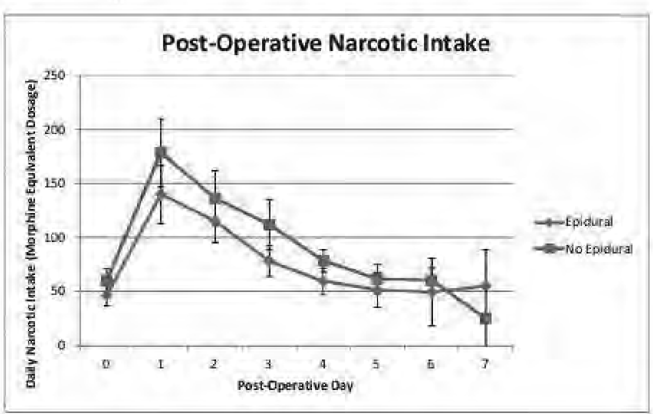
Results
Number of levels fused (11.3 vs. 11.2 vertebrae), blood loss, and ASA score did not differ between the two groups (p>0.05). Mean length of stay was significantly reduced in the intrathecal injection group (4.3 days vs. 5.0 days, p= 0.0048). Mean postoperative oral narcotic use (morphine equivalent dose) was decreased in the intrathecal injection group (mean 102 mg vs. 119 mg, p= 0.048). Postoperative day 1 IV narcotic use was significantly decreased in the intrathecal injection group (8.8 mg vs. 6.2 mg hydromorphone, p=0.04). There were no known neurologic complications or dural leaks associated with the intrathecal injection. Return to eating solid food was significantly faster with 58.3% of the patients in the injection group eating on the first day (POD 1) versus 38.6% in the usual care group (p= 0.01). There were two cases of respiratory depression in the injection group that required a prolonged recovery room stay, but resolved after monitoring.

Conclusion
Length of stay, IV narcotic, and in hospital oral narcotic use was decreased following intrathecal injection at the completion of spine fusion surgery.

Take Home Message
Spinal injection following fusion surgery for AIS reduced length of stay and total narcotic usage during hospitalization. There were no noted neurologic complications.



Daily narcotic use (Morphine Equivalent Dosage) with spinal injection and without in the perioperative time period.

47. Factors Associated with Chronic Opioid Use in Preoperative Opioid Nonusers Following Adult Spinal Deformity Surgery

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Summary
Smoking, higher baseline back pain, worse preoperative functional status scores, and worse mental health scores are associated with chronic opioid use in Adult Spinal Deformity (ASD) patients who were not using opioids regularly preoperatively. New chronic users are also less satisfied with their surgery at 2-years.

Hypothesis
There are demographic and surgical factors associated with increased risk of chronic opioid use following adult spinal deformity (ASD) surgery.

Design
Retrospective review of a multicenter database

Introduction
Retrospective review of a multicenter database

Methods
760 ASD patients (>5 levels fused) were eligible for 2-year follow-up. Of these, 547 (72%) had complete responses to question 11 of the Scoliosis Research Society (SRS-22r) questionnaire, which allowed us to categorize patients into opioid users and non-opioid users preoperatively. 251/547 patients (46%) were not using opioids regularly prior to surgery and included in our analysis. Among nonusers, those reporting opioid use at 1 or 2-year follow-up were classified as CU (chronic user), while patients reporting no opioid use at both 1 and 2 years after surgery were classified as NC (no chronic use). Odds of CU vs. NC were examined in relation to factors of interest, controlling for history of previous substance use disorder and radiographic deformity.

Results
Mean age was 55 ± 17 years, 78% females. Overall, patients were using opioids until 3.2 ± 7.7 months postoperatively. 176 patients (78%) were NC and 51 (22%) CU. Factors associated with significantly increased odds of CU compared with NC included smoking (OR 3.44, 95% CI: 1.06 – 11.11; p=0.039), and each additional point worse on the back pain Numeric Rating Scale (NRS) (OR 1.24, 95% CI: 1.06 – 1.46; p=0.008) SRS-22r Activity domain (OR 1.99, 95% CI: 1.27 – 3.09; p=0.002) and SRS-22r Mental Health domain (OR 1.50, 95% CI: 1.06 – 2.11;

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p=0.022). In addition, CU had worse SRS-22r Satisfaction scores than NC (4.33 ± .93 vs. 3.80 ± 0.17, p=0.001).

Conclusion
The majority of opioid nonusers prior to ASD surgery will not become chronic users following surgery. Factors associated with chronic opioid use in these patients include smoking, higher baseline back pain, worse preoperative functional status, and worse mental health.

Take Home Message
Patients not using opioids preoperatively who smoke, have worse back pain, functional status or mental health are more likely to be chronic opioid users following ASD surgery.

Factor of Interest	Odds Ratio/Coefficient (95% CI)	P-value
Significant		
Smoking	OR 3.44 (1.06, 11.11)	0.039
Baseline SRS Activity	OR 1.99 (1.27, 3.09)	0.002
Baseline SRS Mental	OR 1.50 (1.06, 2.11)	0.022
Baseline NRS Back Pain	OR 1.24 (1.06, 1.46)	0.008
Not Significant		
Gender	OR 1.07 (0.483, 2.355)	0.874
Baseline C7-S1 SVA	Coeff. 0.00 (-0.000, 0.001)	0.282
Prior spine surgery	OR 1.54 (0.748, 3.168)	0.242
Elderly patients	OR 0.63 (0.29, 1.34)	0.229
Number of levels fused	OR 0.01 (-0.001, .025)	0.073
3-Column osteotomy	OR 1.31 (0.542, 0.316)	0.548
Major complication	OR 0.703 (0.379, 1.305)	0.264

48. Preemptive Opioid-sparing Medication Protocol Decreases Pain and Length of Hospital Stay in Children Undergoing Posterior Spinal Instrumented Fusion for Scoliosis

Selina C. Poon, MD; De-An Zhang, MD; Frederick R. Bushnell, MD, MBA; Ronen S. Sever, MD; Robert H. Cho, MD

Summary
Poorly controlled postoperative pain may be associated with delays in ambulation, longer inpatient hospital stays, decreased patient satisfaction, higher hospital cost, and higher opioid use. The purpose of this study is to evaluate the success of a novel, non-opioid, multimodal pain management protocol based on first order pharmacokinetics in the reduction of postoperative pain, length of hospital stay, and opioid consumption in the postoperative period for patients who have undergone posterior spinal instrumentation and fusion (PSIF) for scoliosis.

Hypothesis
Adequate blood concentrations of non-opioid analgesia prior to surgery can decrease the total amount and duration of opioids used postoperatively, while providing optimal pain control.

Design
Retrospective cohort study

Introduction
Multimodal analgesia use has been shown to provide superior analgesia with improved recovery, but has not been described among pediatric patients undergoing spinal surgery. We describe a novel preemptive opioid sparing pediatric pain medication protocol that is started two days prior to surgery with the goal of decreasing postoperative pain, early mobilization and decreasing length of hospital stay.

Methods
We retrospectively reviewed 116 PSIF cases. Fifty-two patients had received standard analgesia while 64 patients received the preemptive protocol consisting of a standardized combination of acetaminophen, celecoxib, and gabapentin 2 days prior to surgery and continued during their inpatient stay. Scheduled oxycodone and intravenous hydromorphone via patient controlled analgesia (PCA) were given to both groups equally during the post-operative hospital stay. We analyzed length of stay, total opioid consumption, and maximum pain scores per day from surgical to discharge date.

Results
Length of hospital stay significantly differed, with means of 3.9 days in the pre-emptive group and 4.5 days in the standard analgesia group (p<.001). Patients in the pre-emptive group recorded significantly lower maximal pain levels than those in the standard analgesia group on post-operative days #1 (4.9 vs. 5.8, p=0.0196), #3 (4.4 vs. 6.1, p=0.0006), and #4 (4.2 vs. 5.4, p=0.0393). Total post-operative morphine equivalents taken did not significantly differ.

Conclusion
This preliminary report demonstrates a significant decrease in maximal pain score and length of stay following PSIF on a cohort of patients receiving a novel pre-emptive opioid-sparing pain medication protocol. Future studies should investigate degree of mobilization and opioid consumption and maximal pain level after discharge from the hospital.

Take Home Message
Implementation of a perioperative nonopioid pain management plan starting two days before surgery may reduce opioid consumption while improving satisfaction among patients undergoing PSIF.

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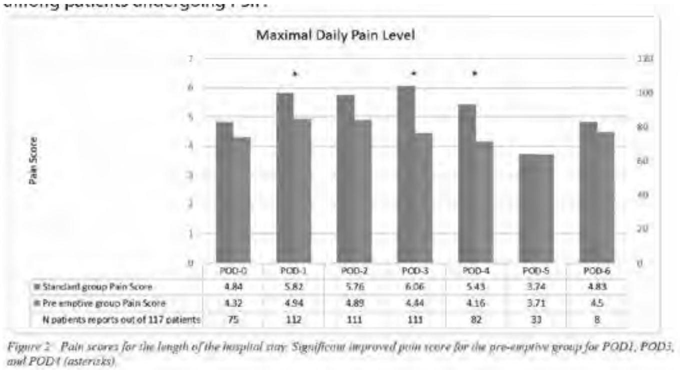

Pain scores for length of hospital stay, with significant improved pain scores for the preemptive group on postoperative days (POD) 1, 3, and 4.

49. Intraoperative Red Blood Cell Salvage in Posterior Spinal Fusions for Idiopathic Scoliosis: Guidelines for Selective Use

Garrett E. Wahl, BS; Scott John Luhmann, MD

Summary

Intraoperative cell salvage (ICS) is commonly used in posterior spinal fusions (PSF) for idiopathic scoliosis (IS). This study analyzed 180 patients undergoing primary PSF for IS and demonstrated ICS provides no benefit for 60% of patients. Several potential factors may guide optimal use of ICS in IS patients undergoing PSF: levels fused >/= 12, major Cobb angle >/= 55°, longer operative cases (>/= 6 hrs), performance of PCOs, and lack of tranexamic acid use.

Hypothesis

There are patient and surgical factors which impact the cost-effectiveness of ICS during primary PSF for IS.

Design

Retrospective case series

Introduction

ICS can be useful in avoiding allogeneic transfusions, however it adds substantial charges ($800 - 1200 US) and requires larger volumes of blood loss in order to provide benefit. This study evaluates the role and effectiveness of ICS in primary PSF surgeries for pediatric IS patients.

Methods

180 primary, consecutive PSF cases for IS patients age 10 – 18 were identified from a single surgeon surgical database. Patterns of estimated blood loss (EBL) and ICS function were analyzed in relation to patient demographics, radiographic measurements, and surgical techniques. ICS was used in all patients in this study.

Results

ICS blood (166.8 ml) was returned in 40.3% of cases, after an average EBL of 528 mL. In 59.7% of cases no blood was returned to the patient, with an average EBL of 288 mL. Overall only 6.4% of the entire cohort received >/= 250 mL via ICS. A positive correlation exists between EBL and vertebral levels fused (p < 0.0002), preoperative Cobb (p = 0.000016), length of anesthesia (p < 0.0001), no tranexamic acid use (p < 0.0001) and with posterior-column osteotomies (PCOs) (p = 0.0077). ICS appears to be more efficacious at/above an inflection point of 12 levels. Preoperative major Cobb of >/= 55° and anesthesia >/= 6 hours demonstrated significant increases in EBL (p = 0.0004) and ICS volume return (p = 0.0386), respectively.

Conclusion

60% of the cohort received no blood from ICS, and only 6.4% received volumes equal to or greater than one unit of allogeneic blood. As cost of ICS is much higher than one allogeneic unit ($1200 vs. $462 US), this study does not support the routine use of ICS in IS when viewed through the lens of cost-effectiveness. Several potential factors may guide optimal use of ICS in IS patients undergoing PSF: levels fused >/= 12, major Cobb angle >/= 55°, longer operative cases (>/= 6 hrs of anesthesia), performance of PCOs, and lack of tranexamic acid use.

Take Home Message

Using ICS in all PSF cases for IS is not an efficient practice. Standard guidelines for ICS use could minimize financial burden without negatively impacting safety or outcomes.

Table 1: Overall ICS trends of clinical significance

	Number of Cases	Percentage (%) of entire cohort	Average Estimated Blood Loss (mL)	Range of Estimated Blood Loss (mL)	Average EBL as % of Total Blood Volume	% of patients receiving postoperative allogeneic transfusions
No blood returned via Cell Saver	102	59.7	288.2	25 - 700	7.96	3.92
Blood returned via Cell Saver (any volume)	69	40.3	528.4	200 - 1800	13.61	5.80
≥ 250 cc returned via Cell Saver	11	6.4	772.7	400 - 1800	17.28	0
< 250 cc returned via Cell Saver	58	33.9	482.1	200 – 1000	10.17	6.89

Table 1: Overall ICS trends of clinical significance

50. Randomized, Controlled Trial of Two Tranexamic Dosing Protocols in Adult Spinal Deformity Surgery

Michael P. Kelly, MD, MS; Mostafa H. El Dafrawy, MD; Lawrence G. Lenke, MD

Summary

We were unable to determine a difference for EBL between H and L dose TXA protocols. However, the study was likely underpowered as the 95% CI suggests a benefit for H with respect to

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EBL. Postoperative transfusions were not different. Importantly, SAE possibly related to TXA were not different between groups, though we did observe one seizure in the H group. Further prospective study, with pharmacologic analysis, is required to determine appropriate TXA use in these patients.

Hypothesis
High dose TXA will result in lower estimated blood loss (EBL) versus low dose TXA in ASD surgeries

Design
Randomized, controlled trial

Introduction
TXA is an anti-fibrinolytic effective in reducing EBL in orthopedic surgery. The appropriate dosing protocol for ASD surgery is not known. The purpose of this study was to evaluate two TXA protocols (Low Dose (L): 10mg/kg bolus, 1mg/kg/hr infusion; High Dose (H): 50mg/kg, 5 mg/kg/hr) in complex ASD surgery.

Methods
Inclusion were ASD reconstructions with minimum 10 fusion levels or planned 3-column osteotomy (3CO) . Standard demographic and surgical data were collected. EBL was calculated by suction canisters minus irrigation plus estimated lost in sponges. EBL was estimated to the nearest 50. Serious adverse events (SAE) TXA were defined a priori as: venothromboembolic event (VTE), cardiac arrhythmia, myocardial infarction, renal dysfunction, and seizure. All serious adverse events were recorded. 52 Patients were enrolled, assuming effect size Cohen's d=0.8, alpha =0.05, with power=0.8. Simple t-tests compared EBL between groups. Packed red cell volume transfused and complications related to TXA were secondary outcomes

Results
62 Patients were enrolled and 52 patients completed the study; 25 randomized to H and 27 to L. Mean age (H: 56.7 +/- 2.9yrs; L: 59.8 +/- 1.8; p = 0.4), mean levels operated (H: 12.9 +/- 0.5 levels, L: 13.3 +/- 0.5, p = 0.6), and length of surgery (H: 456 +/- 125min, L: 497 +/- 93min, p=0.19) were not different. 3CO were not different between groups (H: 9/25 (36%), L: 11/27 (41%). p = 0.7). EBL was not different between groups (H: 1596 +/- 933cc, L: 2046 +/- 1105cc, p=0.12, 95% CI: -1022 – 122cc). Intraoperative transfusion volume (H: 961 +/- 505cc, L: 1105 +/- 808cc, p=0.5) and postoperative transfusion volume (H: 513 +/- 305cc, L: 524 +/- 245cc, p=0.9) were not different. Serious adverse events related to TXA were not different (p=0.7) and occurred in 2 (8%) H and 3 (11%) L. There was one seizure (H), 2 VTE, and 2 arrhythmia.

Conclusion
No differences in EBL, transfusion volume, nor SAE were observed between H and L dose TXA protocols. 95% CI suggests a benefit for high dose.

Take Home Message
No difference in EBL or SAE were observed in an RCT comparing two TXA doses. A larger trial is needed to assess effectiveness and SAE rates.

51. Is Fresh Whole Blood Better than Components in Major Spine Surgery: A Prospective Randomized Study

S. Rajasekaran, PhD; Keerthivasan Panneerselvam, MBBS, MS; Ajoy Prasad Shetty, MS, DNB

Summary
A randomized double blinded study done in 65 patients undergoing major spine surgery to compare fresh whole blood(FWB) with components transfusion in terms of functional and biochemical outcomes. FWB is more physiological and has lesser additives than components. FWB reduced duration of oxygen dependence and ICU stay and induced lesser inflammation as evidenced by lesser incidence of facial puffiness, comparatively better pH and interleukin-6 level. Blood loss during surgery should be replaced with FWB to ensure early recovery

Hypothesis
Fresh whole blood, being physiological, with lesser additives would improve the immediate post-op recovery better than component transfusion

Design
Prospective randomized double blinded study

Introduction
Fresh whole blood transfusion(FWB) has been proved superior to components in oncological and cardiovascular surgery. Major spine surgeries are associated with morbidities and all possible ways to improve the post-operative recovery should be explored. This study aims to compare the effectiveness of FWB and components in improving early post-op period

Methods
Patients undergoing spine surgery with more than 6 levels of fusion, expected blood loss more than 750ml and surgical duration more than 4 hours were randomized. FWB group received fresh whole blood and CG received components. Parameters assessed: pre-operatively demographics and facial measurements to assess puffiness; intra-op fusion level, procedure duration, transfusion volume and blood loss; post-op drain collection, vitals, duration of oxygen support and ICU stay, transfusion volume, facial puffiness and well-being score. Bio-chemical parameters including PT, ABG, calcium, electrolytes, lactate and interleukin-6 were compared

Results
65 patients-(adolescent idiopathic scoliosis(31), early onset

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scoliosis(16), neuromuscular(15) and neurofibromatosis(3)) were included. Pre-operative parameters were comparable. Intra-op blood loss was 926ml(FWB) and 845ml(CG), transfusion was 1.90units(FWB) and 1.61units(CG). FWB significantly superior to CG in duration of oxygen dependence(36.34hours vs 43.29hours), mean pH(7.445 in FWB and 7.397 in CG(p<0.01)) and Interleukin-6(30.63in FWB and 34.48 in CG). Facial puffiness was present in 18 out of 35 CG and only 7/30 in FWB(P<0.01). ICU stay was less in FWB(40.44hours vs 45.53hours). Post-op drain collection was more in FWB(516.84ml vs 406.19ml,p<0.15). Other biochemical parameters were similar

Conclusion

Patient transfused with fresh whole blood achieved better clinical outcome in the immediate post-operative period in terms of decreased oxygen dependence and had lesser inflammatory response

Take Home Message

Fresh whole blood transfusion improves the immediate post-operative recovery in terms of oxygen dependence, ICU stay and inflammatory response and hence it can be utilised in all major spine surgeries

52. New Neurologic Deficit and Recovery Rates in Treatment of Complex Pediatric Spine Deformities Exceeding 100 Degrees or Treated by 3CO

Oheneba Boachie-Adjei, MD; Henry Ofori Duah, RN, MPH; Kwadwo Poku Yankey, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Amer F. Samdani, MD; Peter O. Newton, MD; Suken A. Shah, MD; Mark A. Erickson, MD; Harry Akoto, MD, MB ChB; Brenda A. Sides, MS; Munish C. Gupta, MD; Fox Pediatric Spinal Deformity Study

Summary

A large international multi center study of complex pediatric spine deformity patients with minimum of 100 degrees or treated with 3CO were reviewed for the occurrence of New Neurologic Deficit (NND). A significant proportion – 28/286 (9.3%) developed NND in the immediate post op period. Permanent neurologic deficit remained in 2/23 patients who had the full 2 year follow up. Congenital deformities accounted for 63% of patients who developed NND.

Hypothesis

Complex paediatric spine surgeries are associated with high neurological risk and low recovery rates

Design

Prospective multicenter international observational study

Introduction

The SRS M&M reports identify pediatric patients as having higher rate of NND compared with Adults, and congenital and neuromuscular deformities are associated with higher new neuro risks. Very few studies have had the large numbers of pediatric patients with curves exceeding 100deg to ascertain the NND rates and recovery patterns as it relates to curve type and etiology.

Methods

The FOX pediatric database from 17 international sites was queried for NND as characterized by change in American Spinal Injury Association (ASIA) Lower extremity motor score (LEMS). Recovery rates at specific intervals was recorded and related to the curve type and etiology

Results

286/312 consecutive patients with normal LEMS pre-op were reviewed. There were 160 F vs 125 M; avg age 14.6 (10-20) yrs. NND occurred in 28 pts (9.3%) immediate post op. Cong 18/108 (16.7%); Idiop 8/117 (6.8%); Synd 1/18 (5.6%); Other 1/11 (9.1%):Curve type: Scoli 11/137 (8.03%; KS 9/82 (10.98%); Kyp 8/86 (12.12%). 3 pts were lost to follow-up after discharge; 1 after 3-9mos post op; 1 pt after 1-year f/u (improving). 23 pts had min 2-year f/u. 15 pts had normal LEM at the 3-9-months f/u; 19 pts at 1-year f/u and 21 pts at the 2-year f/u. Only 2 pts (0.69%) had permanent NND at 2-year mark. There were no reoperations for NND.

Conclusion

A significant proportion of patients with complex pediatric spine deformity experience post op decline in LEMS, however significant improvement in LEMS can be expected over time as seen in this study. Congenital etiologies and kyphosis/kyphoscoliosis accounted for 63% of the patients experiencing a decline in LEM.

Take Home Message

Surgeons treating patients with congenital deformities should be aware of high risk of NND. Patients can be reassured of high recovery rates unless there is structural abnormality requiring re-operation.

53. Deformity Angular Ratio is Associated with Intraoperative Neuromonitoring Changes without a VCR: Spinal Deformity is More Influential than Type of Surgery

Ali Siddiqui, BS; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM; Lindsay M. Andras, MD

Summary

Similar to reports by Lewis and Wang et al. of patients undergoing vertebral column resection (VCR), both sagittal DAR (>7) and total DAR (>27) were found to be highly predictive of intraoperative

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neuromonitoring (IONM) loss in patients undergoing posterior spinal fusion(PSF) without VCR. Overall, patients with a high sagittal or total DAR are at increased risk of IONM loss during PSF both with and without VCR.

Hypothesis
We hypothesized that increased DAR would be predictive of IONM loss during pediatric PSF without VCR.

Design
Retrospective case-control study

Introduction
Lewis et al. (2015) and Wang et al. (2016) reported that the deformity angular ratio (DAR), defined as Cobb angle divided by levels of deformity, is predictive of IONM loss during 3 column osteotomies. The purpose of this study is to investigate the effect of DAR on IONM changes during PSF without VCR.

Methods
Retrospective review of patients that had PSF without 3 column osteotomy or VCR for severe spinal deformity between 10/1/08 and 2/1/18. Exclusion criteria were prior instrumentation and lack of IONM. DAR was calculated in the coronal and sagittal planes; total DAR was defined as the sum of coronal DAR and sagittal DAR. IONM signal loss was defined as decrease of greater than 50% in somatosensory evoked potentials or trans-cranial motor evoked potentials.

Results
253 patients met inclusion criteria. Mean age at surgery was 13.7 years. 47/253 (18.6%) patients had IONM loss. 41/253 (16.2%) had signal loss and subsequent intraoperative return to baseline, and 6/253 (2.4%) had signal loss without IONM return to baseline. Intra-operative wake-up test was performed in 7 cases; 3/7 (43%) had a neurological deficit on wake-up test. All neurological deficits resolved at a mean of 41.0 days postop. IONM loss was associated with increased sagittal Cobb angle ($p = 0.003$) and was not associated with coronal Cobb angle ($p = 0.16$). IONM loss was associated with increased sagittal DAR ($p = 0.03$) and total DAR ($p = 0.005$), but not with coronal DAR ($p = 0.06$). Increased risk of IONM loss was seen with sagittal DAR >7 ($p=0.02$) or total DAR >27 ($p = 0.02$). 24/92 (26%) patients with sagittal DAR >7 had intraoperative signal loss compared to 23/161 (14%) with sagittal DAR≤ 7 (OR, 2.1; 95% CI, 1.1-4.0). 7/16 (44%) of patients with total DAR >27 had signal loss compared to 40/237 (17%) patients with total DAR ≤27 (OR, 3.8; 95% CI, 1.3-10.9).

Conclusion
Sagittal DAR and total DAR are predictive of IONM loss during PSF without VCR.

Take Home Message
Patients with sagittal DAR > 7 or total DAR > 27 have a higher risk of IONM loss during pediatric PSF even in the absence of a VCR.

54. Is the Axial Spinal Cord Classification Predictive of Intraoperative Neurologic Alert for Pediatric Scoliosis Patients? A Validation Study

<u>Smitha E. Mathew, MBBS</u>; A. Noelle Larson, MD; William J. Shaughnessy, MD; Anthony A. Stans, MD; Todd Milbrandt, MD, MS

Summary
For 90 pediatric thoracic scoliosis patients with preoperative MRI of the spine, there was a higher rate of neurologic alert for patients with a Type 3 spinal cord (deformation of the cord at the apex of the curve with no intervening CSF) compared to Type 1 spinal cord (circumferential CSF around the cord).

Hypothesis
The axial spinal cord classification as described by Sielatycki et al. would be associated with the rate of intraoperative neuromonitoring alerts for pediatric scoliosis patients undergoing posterior spinal fusion surgery.

Design
Retrospective review.

Introduction
Neurologic deficit is a devastating complication in pediatric spinal deformity surgery. Identification of high risk patients may improve preoperative planning and assist in counseling of patients and families.

Methods
Pediatric scoliosis patients undergoing posterior spinal fusion were retrospectively reviewed at a single tertiary referral center. As MRI is not routinely obtained prior to surgery, only those patients with a preoperative MRI showing high quality axial imaging of the apex of the thoracic deformity were included. MRI was reviewed for spinal cord/CSF architecture as described by Sielatycki et al., SRS 2018 AM, #49. Type 1: circular cord with visible CSF. Type 2: circular cord but no visible CSF at apical concavity. Type 3: cord deformed with no intervening CSF. Intraoperative neuromonitoring records and operative reports were reviewed to determine presence of a neurologic alert.

Results
90 patients met inclusion criteria. Diagnoses included idiopathic scoliosis (74%), followed by congenital (9%), syndromic (7%), neuromuscular/other (10%). Rate of neurologic events was Type 1: 2% (1/41 patients), Type 2: 14% (4/28), Type 3: 52% (11/21, $p<0.0001$). One patient with a Type 3 spinal cord and intraoperative neuromonitoring alert awoke with a significant deficit. There

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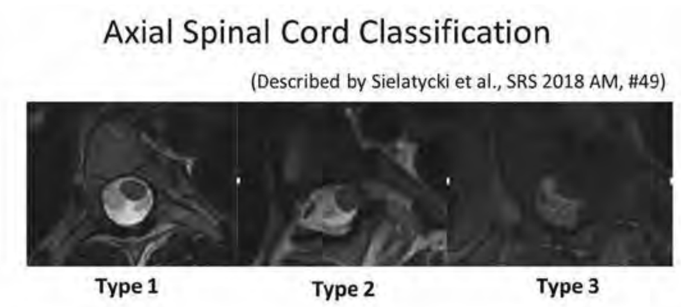
was no difference in gender, diagnosis category, or age at surgery between the three groups.

Conclusion

Although there may be bias in the cohort in that only patients considered to be higher risk have preoperative MRI imaging, the axial spinal cord classification correlated with intraoperative neuromonitoring alerts in pediatric patients with thoracic scoliosis.

Take Home Message

In pediatric scoliosis patients, preoperative imaging of the spinal cord showing spinal cord deformation at the apex is associated with an increased rate of neuromonitoring alerts.



55. Morphological Analysis of 112 Resected Hemivertebrae from a Developmental Perspective

Tianhua Rong, MD; Jianxiong Shen, MD; Ningyi Jia, MD; Zheng Li, MD; Chong Chen, MD; Youxi Lin, MD; Haining Tan, MD; Yang Jiao, MBBS

Summary

This study explored the correlation between morphology of hemivertebra and severity of deformity by reviewing images of 112 isolated hemivertebra (no segmentation failure, normal adjacent vertebra). The transverse width, lateral height and sagittal position of hemivertebra were evaluated. After adjusting by age, the results indicated that hemivertebra with width over central vertical line of lower adjacent vertebra, lateral height ratio over 0.9 and posterolateral position may lead to more severe deformity, and should be intervened more aggressively.

Hypothesis

Certain type of hemivertebra grows faster and causes more severe deformity than others.

Design

Retrospective comparative image study.

Introduction

Unilateral malformation of somite and chondrification center at 4th and 6th week of embryo stage respectively leads to hemivertebra (HV). Various degree of development in the remaining half results in different type of HV. This study explored the correlation between morphology of HV and severity of deformity.

Methods

Patients with isolated HV (no segmentation failure, normal adjacent vertebra) treated by a single surgeon from 2001 to 2017 were enrolled. Coronally, HV was categorized into two types according to whether the width extend across the central vertical line (CVL) of lower adjacent vertebra (LAV) on X-ray. Sagittally, the HV position was divided into lateral and posterolateral group according to whether HV extended ventrally to anterior half of column. Lateral height around HV was measured on convex side. Analysis of covariance was used to adjust the influence of age.

Results

A total of 112 patients met inclusion criteria (mean age 10.0±6.0 years, 63 male and 49 female). All patients underwent HV resection with fusion from 2 to 12 levels. Compensatory curve occurred in 38 (33.9%) patients, and intraspinal anomaly in 24 (21.4%). There were 48 HVs in thoracic region (T2-11), 30 in thoracolumbar (T12-L1), 31 in lumbar (L2-4) and 3 in lumbosacral area. Associated rib was observed in 58 (51.8%) HVs. The cobb angle (CA) of scoliosis and kyphosis was positively correlated with age (r=0.415 and 460, P<0.001, Pearson). Wider HV had larger coronal CA and SVA compared to those within CVL (P=0.047 and 0.014). Though direct comparison showed no difference, after adjusting by age, HV with lateral height ratio (LHR) larger than 0.9 cause larger coronal CA (estimated mean, 50.5±2.0° vs. 46.6±2.6°, P=0.002). On the contrary, after adjustment, sagittal position of HV didn't affect the magnitude of CA (P>0.05). Posterolateral HV was associated with larger AVT than lateral HV (P=0.029).

Conclusion

HV with width over CVL of LAV, LHR over 0.9 and posterolateral position may lead to more severe deformity, and should be intervened more aggressively.

Take Home Message

After taking patient age into consideration, this morphological study indicated that in isolated hemivertebra, larger transverse width, higher convex lateral margin and posterolateral position were related to faster deformity progression.

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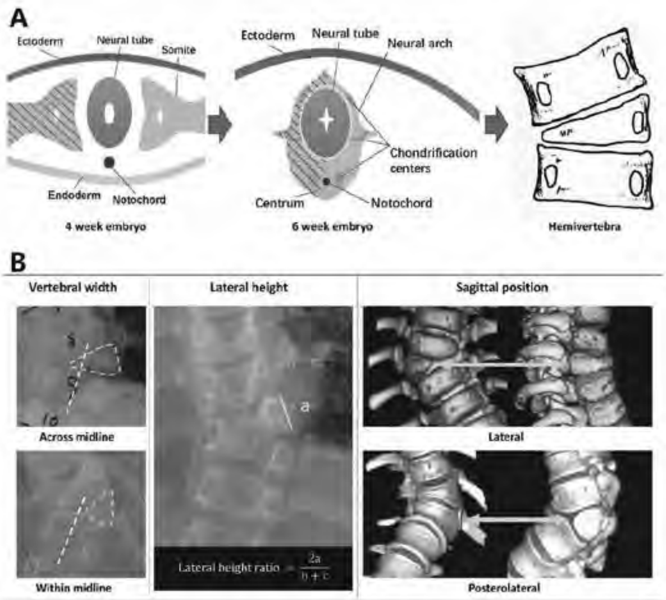


C

Values	Vertebral width			Lateral height ratio			Sagittal position		
	Within n=55	Across n=57	P value (Adjusted)	< 0.9 n=43	≥ 0.9 n=69	P value (Adjusted)	Lateral n=45	Postero-lateral n=67	P value (Adjusted)
Cobb angle (°)									
Scoliosis*	46.5±18.2	53.9±17.9	0.032 (0.047)	50.8±22.2	49.9±15.6	0.810 (0.002)	44.5±12.0	54.1±20.1	0.003 (0.498)
Kyphosis*	30.2±26.9	47.5±30.6	0.002 (0.141)	42.8±36.6	36.6±27.0	0.320 (0.419)	20.1±15.5	51.6±30.8	< 0.001 (0.634)
Balance									
TS (mm)	15.3±11.2	15.2±12.8	0.952	18.2±14.1	13.4±10.2	0.057	14.5±9.1	15.8±13.6	0.572
SVA (mm)	25.2±18.9	35.5±24.3	0.014	30.0±24.2	30.7±21.2	0.881	27.9±21.2	32.1±23.0	0.329
AVT (mm)	34.9±14.9	39.5±17.2	0.133	40.9±17.3	35.0±15.3	0.058	33.2±15.0	40.0±16.6	0.029
Compensatory curve (n & %)	19 (34.5%)	19 (33.3%)	0.892	11 (25.6%)	27 (39.1%)	0.141	14 (31.1%)	24 (35.8%)	0.606
ISA (n & %)	11 (20.0%)	13 (22.8%)	0.717	9 (20.9%)	15 (21.7%)	0.919	12 (26.7%)	12 (17.9%)	0.268

Data are presented as mean± standard deviation or number of patients (percentage). *TS*, trunk shift; *SVA*, sagittal vertical axis; *AVT*, apex vertebral translation; *ISA*, intraspinal anomaly. *Adjusted by age using analysis of covariance.

Figure 1 A, Diagram of hemivertebral development. B, Definition of measurement approaches. C, Summary of results.

56. Benefits of Best Practice Guidelines in Spine Fusion: Comparable Correction with Higher Density and Fewer Complications

Pedro M. Fernandes, MD; Joaquim Soares do Brito, MD; Isabel Flores, PhD; Jacinto Manuel Monteiro, PhD

Summary

Two groups of adolescents were operated upon for idiopathic scoliosis and were compared, based on being exposed or not to a Quality and Safety Program where the use of posterior-based osteotomies, screws and implant densities was also increased. Statistical analysis failed to show relationships between number of implants, postoperative or final deformity correction, or rate of correction loss and SRS-22 global score. Complications though were significantly decreased.

Hypothesis

Clinical outcomes will be affected by Best Practice Guidelines and increased implant density.

Design

Retrospective safety/efficacy comparative analysis

Introduction

There is significant variability in surgeons' instrumentation patterns for adolescent idiopathic scoliosis surgery. Implant density and costs are difficult to correlate with deformity correction, safety, and quality of life measures.

Methods

Two groups of postoperative adolescents were compared based on exposure to best-practice guidelines program (BPGP) introduced to decrease complications. Hybrid and stainless steel constructs were dropped; posterior-based osteotomies, screws, and implant density were increased to 66.8±12.03 vs 57.5±16.7% (p<0.001). Evaluated outcomes were; initial and final correction, rate of correction loss, complications, OR returns, and SRS-22 scores (minimum two-year follow up).

Results

34 patients were operated on before BPGP and 48 after. Samples were comparable other than higher density and longer operative times after BPGP. Initial and final corrections before BPGP were 67.9º±22.9, and 64.6º±23.7; after BPGP, corrections were 70.6º±17.4 and 66.5º±14.9 (n.s). Regression analysis did not show a relation between number of implants and postoperative correction (beta=-0.116, p=0.307), final correction (beta=-0.065,p=0.578) or loss of correction(beta= -0.137, p=0.246). Only with major curve concavity in a model controlled for flexibility was density relevant in initial correction(b=0.293;p=0.038) with significance at 95% not being achieved for final correction despite a similar beta(b=0.263;p=0.069). Complications and OR returns dropped from 25.6% to 4.2%. Despite this, no difference was found in SRS-22(4.30±0.432 vs 4.42±0.39;n.s.). Implant density correlated with less pain in a model controlled for BPGP exposure and major curve flexibility(b=-0.233;P=0.04).

Conclusion

Although counterintuitive, that increasing invasiveness led to fewer complications, we show the value of a BPGP in Spinal fusion. In this sample a 66%(1.32) implant density led to better safety and efficacy relation avoiding a higher cost.

Take Home Message

Best Practice Guidelines in Spinal Fusion relates with fewer complication. 66%(1.32) density presents a good Safety/efficacy ratio avoiding higher costs. High density may favor patients with Pre-operative low SRS-22 pain scores

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Podium Presentation Abstracts

57. Rib Cage Deformity and Pulmonary Function After Surgery in Adolescent Idiopathic Scoliosis

Raphael Pietton, MD; Houssam Bouloussa, MD, MS; Tristan Langlais, MD; Romain Laurent, MD; Wafa Skalli, PhD; Claudio Vergari, PhD; Raphael Vialle, MD, PhD

Summary
Rib cage deformity in adolescent idiopathic scoliosis (AIS) could induce pulmonary restriction. 45 patients with Lenke 1 AIS underwent pulmonary function test (PFT) and biplanar X-rays preoperatively and two years after surgery. Rib cage was reconstructed in 3D to measure rib cage volume (RCV). . RCV was correlated with all PFT parameters. Total lung capacity difference was significantly correlated with RCV change. Rib cage reconstructions from biplanar radiographs could be a low invasive way to approach pulmonary function in AIS.

Hypothesis
Spinal and rib cage reconstructions from biplanar radiographs should be correlated with preoperative and postoperative pulmonary function test (PFT) in adolescent idiopathic scoliosis (AIS).

Design
Prospective cohort.

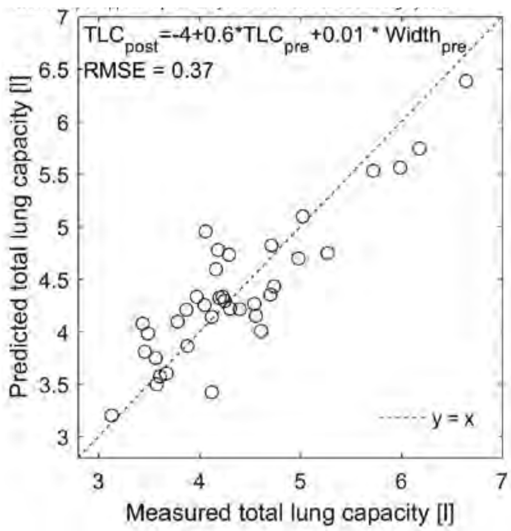
Introduction
Rib cage deformity in AIS could induce pulmonary restriction in severe cases. Few studies established correlations between rib cage volume in severe thoracic AIS and PFT using biplanar radiographs. To our knowledge, no studies have evaluated 3D rib cage changes from biplanar radiographs and pulmonary function after surgery.

Methods
45 patients with Lenke 1 AIS requiring surgical correction were included. All patients underwent PFT and low-dose biplanar X-rays preoperative and two years after surgery. We studied the following parameters: forced vital capacity, slow vital capacity and total lung capacity (TLC). We measured rib cage volume (RCV), maximum rib hump, main thoracic curve Cobb angle (MCCA), maximum width and thickness, T1-T12 and T4-T12 kyphosis. Correlations were analyzed using Spearman's correlation coefficient.

Results
All spinal and thoracic parameters were significantly improved by surgery ($p<0.001$). RCV increased from 4.9 L (±1L) preoperatively to 5.3 L (±0.9 L) ($p<0.0001$) while TLC increased from 4.1 L (±0.9L) preoperatively to 4.3 L (±0.8L) ($p<0.001$) postoperatively. RCV was correlated with all functional parameters before and after surgical correction. RCV improvement was correlated with the correction of the MCCA ($p=0.006$). TLC difference was significantly correlated with RCV change ($p=0.004$). It was possible to predict the postoperative TLC from preoperative CPT and the rib cage width (Figure).

Conclusion
This study describes a promising approach to assess pulmonary function in AIS without PFT. Respiratory parameters can be obtained together with the analysis of the spine and rib cage through a pair of low-dose biplanar X-ray images. This could represent an alternative to PFT, especially in patients where the performance of this type of examination is technically difficult.

Take Home Message
3D spine and rib cage reconstructions from biplanar radiographs could be a low- invasive way to approach pulmonary function before and after surgery in AIS.



Predicted total lung capacity

58. A 10-year Study for Lung Function in Patients with Severe Rigid Spinal Deformities (SRSDs) Treated by Posterior Vertebral Column Resection (PVCR)

Jingming Xie, MD; Ni Bi, MD; Yingsong Wang, MD; Qiuan Lu, MD; Ying Zhang, MD; Zhiyue Shi, MD; Quan Li, MD; Zhi Zhao, MD, PhD; Tao Li, MD

Summary
SRSDs suffered from respiratory dysfunction. Pulmonary function can be improved after spinal deformity correction surgery. This study compared pulmonary function of patients with SRSDs in two different age groups, and analyzed the changed trend of lung function 10 years after PVCR.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Hypothesis
Improvement of pulmonary function would be different in different age patients with SSD.

Design
Retrospective case studies.

Introduction
Spinal deformities can be corrected and pulmonary function be improved after PVCR. Nevertheless, patient ages can affect lung function recovery.

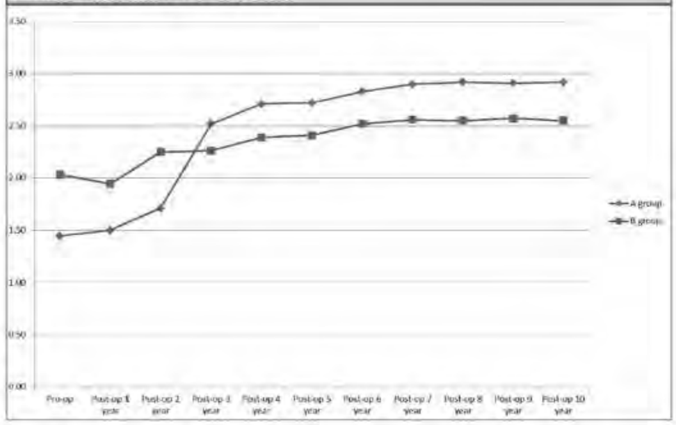
Methods
26 patients with SRSDs and respiratory dysfunction treated by PVCR 10 years ago were enrolled (male 12, female 14).Scoliosis angle >100°, all cases didn't undergo revision surgery and the loss of spinal corrective angle <10°, VC<60%. Patients aged 12-18 were in A group, and those older than 18 were in B group. Deformity angle,pre- and post-operative pulmonary function parameters were recorded .

Results
The improvement happened at 1 year after operation and were apparent better at 2 years. In A group, improvement of pulmonary function peaked at 4 years after surgery and was better than that in B group, without changes at 8 to 10 years. In B group, improvement of pulmonary function peaked at 3 years after surgery but was worse than that in A group, without changes at 6 years. In B group, the lung function drops were found in 2 patients (aged 43 and 46) at 7 years and 9 years after operation, respectively, and without any pulmonary disease.

Conclusion
In this study, improvement of pulmonary function were found at 6 to 8 years after PVCR. The improvements in teenagers peaked at 4 years after surgery, although without changes at 8 to 10 years, and were more obvious than adults for their speed and extent. PVCR should be carried out at 12 to 18 age for better lung function recovery and lower surgical risk. The improvements in adults peaked at 3 years after surgery, perhaps with lower recovery potential or even worse change at 6 years especially for aged patients.

Take Home Message

Fig.1 Comparison of improvement of pulmonary function among group A,B during 10 years after PVCR (FVC)



59. Thoracoscopic Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Mid-term Results of 24 Patients

<u>Tuna Pehlivanoglu, MD</u>; Ender Ofluoglu, MD; Ismail Oltulu, MD; Ender Sarioglu, MD; Guray Altun, MD; Mehmet Aydogan, MD

Summary
Anterior VBT as a growth modulating treatment option by allowing the correction of the scoliotic deformity and restoring the coronal balance without the disruption of sagittal balance is a safe and effective option for the surgical treatment of AIS in skeletally immature patients. VBT also allows the preservation of motion of spinal segments by yielding excellent clinical and radiographic results without major complications.

Hypothesis
Anterior vertebral body tethering could correct the deformity in skeletally immature patients with adolescent idiopathic scoliosis by growth modulation according to Hueter-Volkmann law by inducing compression and distraction on vertebral growth plates

Design
Prospective clinical study

Introduction
Growth friendly surgical options by modulating the spinal growth and preventing the possible complications of fusion are new trends for the management of adolescent idiopathic scoliosis (AIS) in skeletally immature patients.

Methods
24 patients with AIS were included in the study prospectively. All patients were skeletally immature and followed up within a brace for at least 6 weeks. A decision to proceed with surgery was estab-

Podium Presentation Abstracts

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lished after the detection of curve progression within the brace (>40o) with a minimum curve flexibility of 30%.

Results

18 females and 6 males had a mean age of 11.4, mean-follow up period of 2 years. Patients had a mean pre-operative major curve magnitude of 48o and a mean curve flexibility of 48.2%. An average of 8 levels of tethering was performed. Thoracic screws were placed thoracoscopically, while mini-lumbotomy was added in thoracolumbar levels. Tethering cord was advanced transdiaphragmatically and tensioned appropriately. 21 patients underwent unilateral instrumentation, while 3 patients underwent bilateral tethering from the convex side of both double curves. Post-operatively, a mean first erect major curve magnitude of 16o was acquired, while at the last follow-up it was detected as 10o. A TLSO brace was used for six weeks post-operatively to achieve union at the screw bone interface.

Conclusion

Anterior VBT as a growth modulating treatment option by allowing the correction of the scoliotic deformity and restoring the coronal balance without the disruption of sagittal balance is a safe and effective option for the surgical treatment of AIS in skeletally immature patients. VBT also allows the preservation of motion of spinal segments yielding to return sports at the same pre-operative level. It has been shown that anterior VBT was able to yield excellent clinical and radiographic results without causing any major complications.

Take Home Message

Anterior VBT as a growth modulating treatment option is a safe and effective option for the surgical treatment of AIS in skeletally immature patients while preserving motion of spinal segments.

60. Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS: An Eight Year Experience

John T. Braun, MD; Daniel P. Croitoru, MD

Summary

Complications and additional procedures were analyzed in our first 47 patients after AVT for AIS. Complications in the short term included pleural effusion in 2/47 (4.2%) and early tether rupture in 1/47 (2.1%) and in the long term overcorrection/decompensation in 3/30 (10%) and late tether rupture in 4/30 (13.3%). Additional procedures were required for 1/1 early tether rupture, 3/3 overcorrection/decompensations, but only for 1 of 4 late tether ruptures (as these were asymptomatic and well tolerated).

Hypothesis

That the overall complication rate after AVT for AIS would be low but some additional procedures would be necessary.

Design

Retrospective review of consecutive patients (2010-17).

Introduction

Although AVT has been proposed as an alternative to fusion surgery for AIS, the rate of complications and additional procedures is not known. This study analyzed our first 47 patients after AVT for AIS.

Methods

Forty-seven consecutive AIS patients were treated with AVT for T, TL and L curves in the 33-70° range. Endoscopic and mini-open approaches were used. Charts and Xrays were reviewed. Cobb angles were used to compare pre-op, post-op and final curves.

Results

Forty-seven AIS patients (42F/5M) were treated with AVT for 64 curves (31T, 23TL, 10L) averaging 45.7° (33-70) at 14+10 years and skeletal maturity of R=2.9 (0-5). Initial correction from 45.7° to 24.7° was achieved without intra-op complications. Early post-op complications included 2 pleural effusions (both drained) and 1 tether rupture (revised after rupture POD#2). 30 of these 47 patients achieved 3.1 years (2-7years) F/U with 4 late tether ruptures, 2 overcorrections and 1 lumbar decompensation. All late tether ruptures occurred in T12-L3 region at 1-4 years with average 11.2° (10-13°) loss of lumbar curve correction (only 1 required revision). Both overcorrections occurred in very skeletally immature patients at 2 years (both required tether removal with 1 eventual fusion). One lumbar decompensation was treated with fusion. 27 (24F/3M) of the 30 patients had 37 curves (16T, 17TL, 4L) definitively treated with AVT demonstrating correction from 47.9° pre-op to 22.4° post-op to 19.3° final at 3.1 years and skeletal maturity in all but one patient ($p<0.001$).

Conclusion

This analysis of our first 47 patients demonstrated a relatively low rate of complications and additional procedures after AVT for AIS. Though overcorection/decompensation occurred in 3/30 (10%) these were avoided after our first 10 patients. Tether rupture occurred early in 1/47 (2.1%), requiring revision, and late in 4/30 (13.3%), requiring revision in 1 of 4 only. Further study of late tether rupture impact is warranted.

Take Home Message

Complications and additional procedures occurred at a relatively low rate after AVT for AIS with overcorrection/decompensation (10%) and late tether rupture (13.3%) being the most common.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

61. Long Term Follow up of Patients with Infantile Idiopathic Scoliosis: Is Rib Vertebral Angle Difference a Reliable Indicator of Progression?

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Summary
This study retrospectively analysed radiographic measurements obtained during long term follow up of patients with IIS. A RVAD of <20° was a more reliable marker of resolution than a RVAD of >20° as a marker of progression at initial diagnosis and remained an inaccurate marker in predicting outcomes in around 25% of all cases across long term follow up.

Hypothesis
RVAD is not as reliable a marker of IIS progression or resolution than previously published claims.

Design
Retrospective cohort study

Introduction
Despite the landmark description of the rib vertebral angle difference (RVAD) by Mehta in 1972, prediction of progression in infantile idiopathic scoliosis (IIS) remains a significant dilemma, with pressure on surgeons to identify patients at risk of progression and implement early treatment, whilst avoiding over treatment of those with naturally resolving deformities. The aims of this work were to retrospectively analyse patients with IIS and evaluate whether the RVAD reliably differentiated between progressing and resolving deformities over long term serial follow up.

Methods
85 patients were identified from radiographic records that were diagnosed with IIS between 01/04/2008 and 31/03/2018. Each patient's clinical record was studied and each x-ray of the whole spine at every subsequent outpatient review was analysed, totalling 526 individual points of contact for analysis.

Results
Of the 85 patients identified, 38 cases were progressive and 47 were resolving. Mean follow up in all cases was 3.4 years. Of the 38 progressive cases, only 42% had a RVAD over 20° at diagnosis, with only 77.4% showing a RVAD over 20° across the total analysis period. Of the 47 resolving cases, 83.0% had a RVAD less than 20° at diagnosis, with only 72.8% showing a RVAD less than 20° across the total analysis period. The mean RVAD at all time points were significantly different for progressive cases at 36.6° versus 11.6° for resolving cases (p<0.001). There was a moderate positive correlation between Cobb angle and RVAD in progressive cases at 0.49. The correlation between Cobb angle and RVAD in resolving cases was stronger at 0.64.

Conclusion
This study is the first to validate the RVAD as a marker of IIS progression/resolution over long term follow up. In contrast to the original study, RVAD is a less reliable marker of progression/resolution than previously claimed, accurate in around ¾ cases.

Take Home Message
Over 50% of patients with progressive IIS have a RVAD <20° at diagnosis and over 1/4 will progress despite RVAD <20° during the whole course of their condition.

Distributions of RVAD in progressive versus resolving cases of IIS

62. Current Use in Growth-friendly Implants for Early Onset Scoliosis: A Ten-year Update

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Summary
We retrospectively studied 1,339 EOS patients from two international multicenter databases who underwent initial treatment with growth-friendly implants over a ten-year period, assessing both preoperative and postoperative variables. Idiopathic scoliosis was found to have increased as a percentage of C-EOS diagnoses. Age at first surgery increased from 6.1 to 7.7 years, and 87% of patients with definitive treatment underwent final fusion (mean age = 13.4 years). MCGRs comprised >80% of new implants in 2017.

Hypothesis
Age at first surgery and surgical lengthening intervals have increased in the past decade. CP and myelodysplasia have become less common causes of EOS over time.

Design
Retrospective review of two multicenter databases

Introduction
Growth-friendly treatment of EOS has changed substantially with the advent of magnetically controlled growing rods (MCGRs). This study was undertaken to characterize surgical trends in EOS from 2007-2017.

Methods
Two large multicenter EOS databases were queried for all patients undergoing index surgery with growth-friendly implants in a ten-year period. Patients were assessed for construct type, age at first

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surgery, preoperative Cobb angle, C-EOS diagnosis, lengthening interval, and age and type of definitive treatment. Constructs included traditional growing rods (TGRs), MCGRs, vertical expandable prosthetic titanium ribs, and growth-guidance devices (e.g. sliding screws). T-test or ANOVA was used for continuous data, chi-squared or Fisher's test for categorical data. Linear regression was used for chronologic trends.

Results

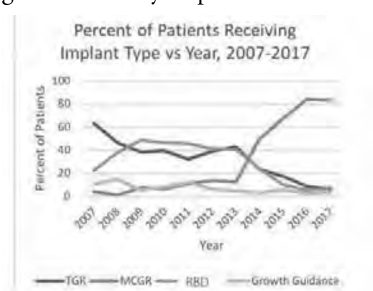
Data were available for 1339 pts; mean lengthening intervals were available for 614, and definitive treatment data for 312. From 2007-2017, age at first surgery steadily increased from 6.1±2.9 yrs to 7.7±2.6 yrs ($R2=0.76$, $p<0.001$). Growth guidance peaked at 16/108 cases (14.8%) in 2008 and never exceeded 10% after 2011. MCGR use had increased to >80% of new implants by 2017. Over the last 2 years of the study growth guidance was used in 6/218 cases (3%) and vertical expandable prosthetic titanium ribs were used in 13/218 (6%). Final fusions were performed in 87% of patients (272/312) who had definitive treatment, with mean age=13.4 yrs. No change was seen in surgical lengthening intervals (range, 6-9 mos). Among all pts, mean preoperative curves did not change (range, 56-71º). Idiopathic cases increased from 12% to 31% ($R2=0.61$, $p=0.005$). No trend was seen for percent CP (range, 5-18%) or myelodysplasia (range, 4-8%).

Conclusion

Surgical treatment of EOS has largely shifted toward MCGR. Mean age at first surgery has increased from 6.1 yrs to 7.7 yrs. Final fusions are performed in 87% of patients at mean age=13.4 yrs. Idiopathic EOS has become more common ov

Take Home Message

Age at first EOS surgery increased to mean=7.7 years by 2017. Eighty-seven percent of patients underwent final fusion, at mean age=13.4 years. MCGRs now comprise more >80% of growth-friendly implants.



63. Magnetically-controlled Growing Rod Patients Have Similar HRQOL Scores Compared to Traditional Growing Rod Patients After Two Years of Treatment

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Summary

In 129 MCGR patients and 66 TGR patients with similar demographics and deformity severity, MCGR patients had worse pre-op EOSQ-24 domain scores compared to TGR patients. However, MCGR patients experienced the greatest improvement in domain scores and after two years of treatment all domains scores were statistically similar between groups.

Hypothesis

MCGR patients have better EOSQ-24 domain scores compared to TGR patients after 2 years of treatment.

Design

Multicenter retrospective cohort study.

Introduction

Since the introduction of magnetically-controlled growing rods (MCGR), early-onset scoliosis pa-tients have been afforded a reduction in the number of surgeries compared to the traditional grow-ing rod (TGR) technique. However, little is known about health-related quality of life (HRQoL) outcomes between these surgical techniques.

Methods

This retrospective multicenter study compared MCGR and TGR patients treated between 2008 and 2017. The EOSQ-24 was used to measure HRQOL. EOSQ-24 was administered at pre-op, 6-mo, 12-mo, 24-mo time points. Power analysis estimated 36 patients in each group to achieve 80% statistical power. A 10% difference in domain scores was considered statistically significant.

Results

195 patients were analyzed: TGR, n=66; MCGR, n=129. Pre-operatively TGR and MCGR groups had similar age (6.6 vs. 6.9 years), gender (67% vs. 54% female), and major curve size (75 vs 73 degrees). TGR group had more congenital patients (18% vs. 10%) and slightly higher incidence of developmental delay (36% vs. 29%) and neurological comorbidity (24% vs. 20%). TGR had mean 3.9 lengthenings; MCGR had mean 7.7 lenghenings. TGR had better pre-op scores in all domains with statistically significant differences in 8 of the 12 total domains. Compared to

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pre-op, MCGR had significant improvement in 8 domains at 6 months, 5 domains at 12 months, and 5 domains at 24 months. Comparatively, TGR had significant improvement in 2 domains at 6 months, 1 domain at 12 months, and 1 domain at 24 months. The only domain that had significant worsening from pre-op was Transfer at 6 months in TGR. At 24 months TGR and MCGR had statistically similar scores across all domains (Table 1).

Conclusion

MCGR patients had worse pre-op HRQOL scores compared to TGR patients despite having simi-lar demographics and deformity severity. MCGR patients experienced greater improvement in domain scores, and after two years of treatment all domains scores were statistically similar between groups.

Take Home Message

After 2 years of treatment TGR and MCGR patients had similar HRQOL scores across all EOSQ-24 domains.

Table 1. Mean EOSQ-24 domain scores by time point (**statistically significant difference*).

EOSQ-24 Domain	Group	Pre-op	6-month	12-month	24-month
General Health	TGR	73	74	72	74
	MCGR	69	74	72	71
Pain/Discomfort	TGR	76	74	72	70
	MCGR	69	75	73	71
Pulmonary Function	TGR	79	86	86	87
	MCGR	78	84	83	81
Transfer	TGR	**79***	69	74	75
	MCGR	**68**	71	73	69
Physical Function	TGR	**66***	69	66	68
	MCGR	**57**	68	67	66
Daily Living	TGR	**52***	**58***	51	54
	MCGR	**44**	**51**	49	53
Fatigue/Energy Level	TGR	**73***	75	70	71
	MCGR	**64**	74	68	67
Emotion	TGR	**78***	75	77	77
	MCGR	**68**	74	74	72
Parental Impact	TGR	**67***	71	70	68
	MCGR	**59**	69	69	66
Financial Impact	TGR	64	71	75	75
	MCGR	63	73	74	71
Child Satisfaction	TGR	**66***	69	70	68
	MCGR	**58**	71	69	66
Parent Satisfaction	TGR	**69***	70	73	67
	MCGR	**61**	65	71	66

64. Benefits of Medical Optimization Before Thoracolumbar Three-column Osteotomies: An Analysis of 618 Patients

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Summary

In a series of 618 patients, the rate of major medical complications, minor medical complications, and surgical readmissions/reoperations over the first 30-days was 8.4%, 19.4%, and 8.9%, respectively. A total of 27.7% of patients had inadequate optimization of preoperative hyponatremia, anemia, renal insufficiency, coagulopathy, or hypoalbuminemia. Lack of preoperative medical optimization was associated with increased medical complications (major and minor) and preoperative anemia and renal insufficiency individually had a strong association with major medical complications.

Hypothesis

Lack of medical optimization for thoracolumbar three-column osteotomies is rare, but associated with poor short-term outcomes.

Design

Retrospective review of a prospectively collected patient registry

Introduction

Thoracolumbar three-column osteotomies are associated with high postoperative morbidity. Preoperative modifiable risk factors have not been extensively studied, presumably secondary to limited sample sizes.

Methods

A retrospective review was conducted of a national cohort of patients undergoing thoracolumbar three-column osteotomy between 2013 and 2016. Post-operative complications, readmissions, and reoperations were observed for 30 days postoperatively. Potential patient-sided, risk factors including preoperative laboratory values were assessed and correlated with postoperative outcomes. This includes hyponatremia (serum sodium < 135 mEq/L), anemia (hematocrit < 30%), renal insufficiency (creatinine ≥ 1.2 mg/dL), coagulopathy (INR ≥ 1.2), or hypoalbuminemia (albumin < 3.5 g/dL). Patients were classified as medically optimized if their aforementioned laboratory values were within normal limits.

Results

A total of 618 patients who underwent thoracolumbar three-column osteotomies between 2013 and 2016 were identified. Complications, readmissions, and reoperations occurred at relatively high rates. 27.7% of patients were not medically optimized. Among patients with adequate preoperative optimization, 6.2% had major complications (P < 0.01), 16.3% had minor complications (P < 0.01), and 8.6% had reoperation or readmission related to surgical complication (P = 0.67). Preoperative renal insufficiency (odds ratio[OR]: 32.6, P = 0.003), preoperative anemia (OR: 249.9, P = 0.02 [Hct < 25]; OR: 38.3, P < 0.01 [Hct 25-30]), and chronic obstructive pulmonary disorder (COPD; OR: 5.7, P = 0.01) were associated with major complications.

Conclusion

Despite the high risk for complications associated with poor optimization, over 25% of patients who underwent thoracolumbar three-column osteotomies lacked preoperative optimization of correctable medical laboratory values

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Take Home Message

Lack of medical optimization before thoracolumbar three-column osteotomies is more common than previously thought, but associated with early postoperative complications.

Table 3: Effect of medical optimization on postoperative complications

	Frequency	Percentage	Major Complications			Minor Complications			Surgical Readmissions/ Reoperations		
			Rate	Rate for rest of cohort	P-value	Rate	Rate for rest of cohort	P-value	Rate	Rate for rest of cohort	P-value
Medical optimization of preoperative laboratory values: (Na ≥ 135, Hct ≥ 30, Cr < 1.2, INR < 1.2, Albumin ≥ 3.5)	453	73.3%	6.2%	14.6%	P < 0.01*	16.3%	27.9%	P < 0.01*	8.6%	9.7%	P = 0.67
Medical optimization of preoperative laboratory values AND absence of chronic obesity, diabetes mellitus, or chronic obstructive pulmonary disease	219	36.7%	3.0%	11.7%	P < 0.01*	11.6%	24.2%	P < 0.01*	6.0%	10.6%	P = 0.05*

Asterisks (*) indicate statistical significance (P < 0.05)

65. The 5-factor Modified Fragility Index (MFI-5) is Predictive of 30-day Postoperative Complications and Readmission in Patients with Adult Spinal Deformity (ASD)

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Summary

In adults spinal deformity (ASD) patients undergoing spinal fusion (SF), patient's mFI-5 score showed to be a useful predictor of postoperative complications and readmissions.

Hypothesis

mFI-5 is associated with 30-day postoperative outcomes for ASD patients.

Design

Retrospective cohort

Introduction

This study aimed to determine whether mFI-5 scores can be used as predictors of 30-day postoperative complications, reoperations, or readmissions to pre-operatively identify at-risk ASD patients undergoing SF.

Methods

Using ACS National Surgical Quality Improvement Project (NSQIP), patients with CPT codes for >7lvl fusion and patients with <7lvl fusion with concomitant ICD-9 for ASD were selected from 2008-2016. The 5 factor modified fragility index (mFI-5) uses 5 variables in NSQIP: congestive heart failure, insulin or non-insulin dependent diabetes, totally or partially dependent pre-operative functional status, history of COPD, and hypertension requiring medication. Patients with CPT codes for >7-level fusion and patients with <7 level fusion with concomitant ICD-9 for ASD were included from 2008-2016. Univariate analysis assessed differences in demographics and preop factors with post-hoc analysis using Bonferroni correction. Logistic regression was used to assess the correlation of mFI-5 scores with 30D postop outcomes.

Results

2,120 pts met criteria with a majority receiving a score of 1 or 2 (1-1058; 2-949; 3-113 pts.), excluding any groups with fewer than 20 patients. A majority were White (78.8%) and mean age varied across the mFI-5 score groups (1-45.82 yrs.; 2-62.59 yrs.; 3-65.33 yrs.; p≤0.004). Post-op pneumonia rates increased with mFI score (1-1.5%; 2-3.4%; 3-8.0%; $p < 0.05$). Patients with an MFI score greater than 1 had increased rates of UTI (1-2.0%; 2-4.7%; 3-8.8%; $p < 0.05$) and unplanned post-operative ventilation for >48 hours (1-0.9%; 2-3.4%; 3-3.5%; $p < 0.05$). Logistic regression revealed an mFI of 3 was associated with readmission (OR=2.4; p=0.022) & mortality (OR = 6.1, p = 0.008).

Conclusion

This study demonstrated that mFI scores correlated with postoperative pneumonia and UTI. An mFI-5 score of 3 was associated with post-operative readmission and mortality. Therefore, mFI-5 scores may be used for pre-operative risk stratification and 30-day postoperative planning.

Take Home Message

The mFI-5 score can be used to identify ASD patients at high risk for related readmissions and specific postoperative complications.

Complication	mFI = 1	mFI = 2	mFI = 3
Superficial Incisional SSI	0.8%[a]	1.9%[a,b]	3.5%[b]
Deep incisional SSI	1.0%[a]	1.5%[a]	2.7%[a]
Organ Space infection	62.0%[a]	64.4%[a]	64.4%[a]
Dehiscence	0.4%[a]	1.2%[a]	0.9%[a]
Pneumonia	1.5%[a]	3.4%[b]	8.0%[c]
Unplanned reintubation	62.2%[a]	65.1%[a]	67.3%[a]
Pulmonary Embolism	1.2%[a]	1.3%[a]	0%[a]
Ventilator for >48 hours	0.9%[a]	3.4%[b]	3.5%[b]
Progressive renal Insufficiency	0.1%[a]	0.2%[a]	0%[a]
Acute Renal Failure	0%[a]	0.1%[a]	0%[a]
Urinary Tract Infection	2.0%[a]	4.7%[b]	8.8%[b]
Stroke	0.2%[a]	0.7%[a,b]	1.8%[b]
Cardiac Arrest	0.3%[a]	0.5%[a]	0%[a]
Myocardial Infarction	0.3%[a]	0.6%[a]	0.9%[a]
Transfusion	38.8%[a]	47.0%[b]	42.5%[a,b]
Deep Vein Thrombosis	1.0%[a]	2.0%[a]	2.7%[a]
Systemic Sepsis	1.9%[a]	3.5%[a]	3.5%[a]
Shock	0.2%[a]	0.6%[a,b]	1.8%[b]

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Comparison of preoperative complications across the mFI-5 Groups. Values within a row with different superscripts vary significantly as quantified by the Bonferroni correction.

66. Surgical Risk Stratification Based on Preoperative Risk Factors in Adult Spinal Deformity

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Summary

Surgical risk stratification for ASD surgery was established base on the combination of demographic, radiographic, data and surgical invasiveness. Our risk-stratification scoring model successfully predicted complications after ASD surgery using patient demographics and radiographic parameters that would normally be collected routinely when considering surgical treatment for a patient with ASD. This simple, easy-to-read predictive model can help physicians identify patients with a high risk of postoperative complications, treat modifiable risk variables, and plan appropriate surgical strategies.

Hypothesis

Surgical risk for ASD surgery can be stratified with demographic and surgical invasiveness.

Design

Multicenter retrospective review of surgically treated 240 consecutive adult spinal deformity (ASD, >21y) patient who reached 2y follow-up.

Introduction

Corrective surgery for adult spinal deformity (ASD) improves health-related quality of life but has high complication rates. Predicting a patient's risk of perioperative and late postoperative complications is difficult, although several potential risk factors have been reported. This study aimed to establish an accurate, ASD-specific model for predicting the risk of postoperative complications, based on baseline demographic, radiographic, and surgical invasiveness data in a retrospective case series.

Methods

We analyzed demographic and medical data, including complications, for 151 adults with ASD who underwent surgery at our hospital and were followed for at least 2 years. Each surgical risk factor identified by univariate analyses was assigned a value based on its odds ratio, and the values of all risk factors were summed to obtain a surgical risk score (range 0–20). We stratified risk scores into grades (A–D) and analyzed their correlations with complications. We validated the model using data from 89 patients who underwent ASD surgery at two other hospitals.

Results

Complications developed in 48% of the patients in the model-building cohort. Univariate analyses identified 10 demographic, physical, and surgical risk indicators, with odds ratios from 5.4 to 1.4, for complications(frailty [OR 5.4], BMD [3.2], PSO [2.9], C7SVA [2.4], LIV at pelvis [2.3], Cobb angle [1.7], PI–LL [1.6], age [1.5], diabetes [1.4], and male [1.4]. Our risk-grading system showed good calibration and discrimination in the validation cohort; the complication rate increased with and correlated well with the risk grade using ROC curves ($r2 = 0.824$. AUROC of 0.815 [95% CI 0.722–0.907]).

Conclusion

This simple, ASD-specific model uses readily accessible indicators to predict a patient's risk of perioperative and postoperative complications, and can help surgeons adjust treatment strategies for best outcomes in high-risk patients.

Take Home Message

Easy-to-read predictive model can help physicians identify patients with a high risk of postoperative complications, treat modifiable risk variables, and plan appropriate surgical strategies for ASD surgery.

Table. Risk-grading system for surgical complications in ASD

Risk indicator		Score	Risk grade
Age	< 70 years	0	Total score: 0, 1
	70 - 75 years	1	
	> 75 years	2	
Gender	Female	0	
	Male	1	
BMD	T-score > -1.5	0	Total score: 2-6
	T-score ≤ -1.5	3	
Diabetes	No	0	
	Yes	1	
Frailty	Robust	0	
	Pre frail	2	Total score: 7-11
	Frail	5	
C7SVA	< 95mm	0	
	95 - 149mm	1	
	≧ 150mm	2	
Cobb angle	≤ 70°	0	Total score: >12
	> 70°	2	
LIV	L5 and above	0	
	Pelvis	2	
3-CO	No	0	
	Yes	2	

BMD, bone mineral density; mFI, Modified Frailty Index; C7SVA, C7 sagittal vertical axis; LIV, lower instrumented vertebra.
[a]Risk score is determined by adding the values for all applicable risk indicators (center column).

Risk-grading system for surgical complications in ASD

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67. Predictive Risk Calculators for Unplanned Readmissions and Reoperations Following Adult Spinal Deformity (ASD) Surgery

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Summary

Data from 1612 surgically treated ASD patients (57 surgeons) were used to build predictive models for unplanned readmissions (RA) and reoperations (RO). Cumulative risk estimates for RA varied from 3.17% to 44.2% at 2-years based on individual surgical/demographical characteristics. For RO it ranged from 2.67-51.9%. Patient-related factors and site/surgeon account for 60-70% of predictive weight.

Hypothesis

Predictive models can reliably estimate likelihood of unplanned RA and RO following ASD surgery.

Design

Combined analysis of two independent prospective, multi-center ASD databases with identical fixed data fields.

Introduction

The rates of RO and RA following ASD surgery are substantial and unsustainable. Identification of high-risk patients may reduce RO/RA and associated health care costs, thereby increasing the overall value of surgical care.

Methods

Surgical ASD patients with >2yFU were identified from 2 multinational registries. Demographic, radiographic, operative, baseline PROMs (ODI, SRS22, SF36), and complications data were analyzed. Event free survival (cumulative incidence) curves for RA and RO were modeled. Two predictive models (preop and immediately postop -including surgical data representing pre-discharge state) were created using random survival forest with 80/20 train/test sets. 101 variables were used.

Results

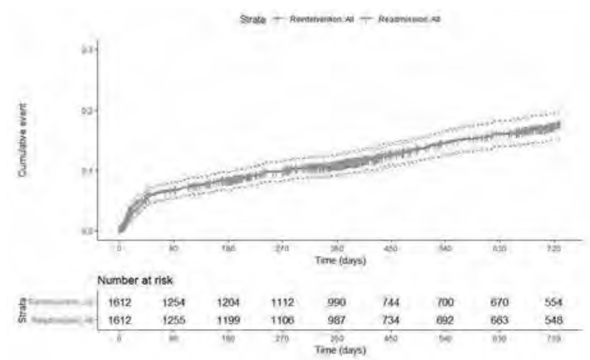
1612 ASD patients (76.6% women, 56.7 mean age, 10.4 levels fused, 55.1% pelvic fixation, 20.6% 3CO) operated by 57 surgeons (24 sites, 5 countries), with 2,047.9 observation-years, were analyzed. Missing value imputation was 14.59%. Kaplan-Meier estimates found the following 30 and 90d post-discharge estimates: RA 4.5% (3%-6.3%) and 6.5% (3.3%-7.6%); RO 4.9% (3.2%-6.6%) and 7.7% (5.3%-9.7%). Model C-statistic values were RO 67% (95%CI [59%-74%]) and RA 65% (95%CI [56%-73%]) proving successful model fit. Frailty (PM Weight 37%), sagittal deformity (PMW 30%), surgical invasiveness (PMW 15.6%), age (PMW 8%) and surgeon-site (PMW 8%) most strongly predicted RA. Frailty (PMW 51%), surgeon-site (PMW 15%), sagittal deformity (PMW 13.1%) and surgical invasiveness (PMW 7.4%) most strongly predicted RO.

Conclusion

Accurate preoperative, pre-discharge, 30 and 90-day post-surgical risk prediction of readmissions and reoperations is possible. Models demonstrate that patient-related factors account for >50% of model weight. Surgeon and site are especially relevant for reoperations.

Take Home Message

Accurate prediction models can provide point-of-care data to surgeons. These data may assist decision making to reduce costs and improve value in ASD surgery.



68. Increasing Cost Efficiency in Adult Spinal Deformity Surgery: Identifying Predictors of Lower Total Costs

Peter G. Passias, MD; Avery Brown, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Christopher P. Ames, MD; Douglas C. Burton, MD; Jeffrey L. Gum, MD; Robert A. Hart, MD; Richard Hostin, MD; Khaled M. Kebaish, MD, FRCS(C); Brian J. Neuman, MD; Shay Bess, MD; Breton G. Line, BS; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Eric O. Klineberg, MD; International Spine Study Group

Summary

Surgery for Adult Spinal Deformity (ASD) surgery often involves complex deformity correction. This study sought to identify predictors of lower total surgery costs for ASD patients. Our results showed that overall, low frailty, no prior spine surgery, no depression, and higher baseline SRS activity scores were predictive

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

of lower total surgery costs. Assessed by different preoperative levels of global deformity, decreased frailty and lack of comorbidities were associated with lower costs.

Hypothesis
Preoperative clinical, demographic, and surgical factors can predict cost of ASD surgery.

Design
Retrospective review

Introduction
It is unknown which preoperative patient factors predict lower total costs in ASD surgery.

Methods
Included: surgical ASD (scoliosis≥20°, SVA≥5cm, PT≥25°, or thoracic kyphosis ≥60°) patients with available frailty, demographic, and radiographic data at pre- and 3-years post op (3Y). Total costs for surgery were calculated using the PearlDiver database. A Conditional Variable Importance Table used non-replacement sampling set of 20,000 Conditional Inference trees to identify the top factors associated with lower cost surgery for low (LSVA), moderate (MSVA), and high (HSVA) Schwab modifier grades. LSVA were SVA<4 cm, MSVA 4 cm-9.5 cm, HSVA were >9.5 cm. Linear and Logistic regression assessed the relationship between significant predictors and the odds of lower cost surgery.

Results
Included: 311 ASD patients (59±15 yrs, 76%F). Surgical overview: 62% osteotomy, 54% decompression, and 11±4 levels fused. At 3Y, the potential cost of ASD surgery ranged from $57,607 to $116,312. Breakdown by modifier grades was: LSVA (49%), MSVA (17%), HSVA (36%). For all patients, factors associated with lower costs were: preop ODI < 50 (2.2 [1.5-3.2], p<0.001), SRS Activity > 1.5 (2.6 [1.4-4.9], p=0.002], no previous spine surgery (1.8 [1.2-2.6], p=0.003), frailty scores < 0.19 (2.9 [1.7-5.1], p<0.001), no moderate/severe SVA modifiers (1.6 [1.1-2.3], p=0.017), no moderate/severe PI-LL modifiers (1.6 [1.1-2.4], p=0.015), invasiveness scores below 80.8 (1.5 [1.02-2.2], p=0.04), and no depression (1.6 [1.03-2.3], p=0.03). Table 1 shows factors associated with lower surgery costs for LSVA, MSVA, and HSVA patients.

Conclusion
For ASD patients, low frailty, no prior spine surgery, no depression, and higher baseline SRS activity scores were predictive of lower total surgery costs. When assessed by baseline deformity, decreased frailty and the lack of comorbidities and risk factors such as cancer, smoking, or high BMI, were associated with lower costs.

Take Home Message
For ASD patients, low frailty, no prior spine surgery, no depression, and higher baseline SRS activity scores were predictive of lower total surgery costs.

SRS Schwab SVA Modifier Group	Variable	Sig.	O.R.	95% C.I.for EXP(B)	
				Lower	Upper
LSVA (0 modifier)	No baseline osteoporosis	p<0.001	8.87	2.47	25.09
	SRS Activity score > 1.5	p=0.007	6.76	1.68	27.18
	Age < 64 years	p=0.002	4.37	1.74	10.99
	Baseline ODI score < 50	p=0.025	2.83	1.14	7.04
	SRS total score > 2.58	p=0.004	3.93	1.54	10.18
	ASD Frailty Index score < 0.37	p=0.035	2.74	1.07	6.99
	Increasing surgical invasiveness	p=0.041	1.01	1.00	1.03
MSVA (+ modifier)	Surgical invasiveness score < 94.16	p=0.058	9.82	1.00	104.17
	No cancer	p=0.071	16.00	0.80	42.5
	ASD Frailty Index score < 0.30	p=0.210	3.80	0.48	30.42
HSVA (++ modifier)	No history of smoking	p=0.060	4.50	0.90	22.47
	BMI < 27.6 kg/m^2	p=0.060	2.84	0.94	8.60

69. Predicting ASD Surgeries That Exceed Medicare Allowable Payment Thresholds: A Comparison of Hospital Costs to What the Government Will Actually Pay

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Summary
Utilizing a prospective, multicenter ASD surgical database with actual, direct hospital cost data, we sought to develop a predictive model to identify patients with index episode of care cost being below Medicare reimbursement (profitable). A successful model with an area under the curve (AUC) 94.48% (CI: 91.59-97.38%) was constructed and the most predictive variables were number of levels fused, being coded in DRG 457, revision surgery, and institution (academic vs private).

Hypothesis
There are identifiable, potentially modifiable, geographic and patient-specific factors that determine if index ASD surgery costs are below the Medicare Allowable (MA) threshold and these can be applied in a predictive model.

Design
Retrospective multicenter cost analysis

Introduction
ASD surgery is associated with a high cost. Studies suggest that the actual direct hospital cost of ASD surgery is higher than the MA rate which is considered the benchmark reimbursement target for hospital systems. Our goal is to determine if index episode of care (iEOC) costs of ASD surgeries are below the MA threshold and identify predictors.

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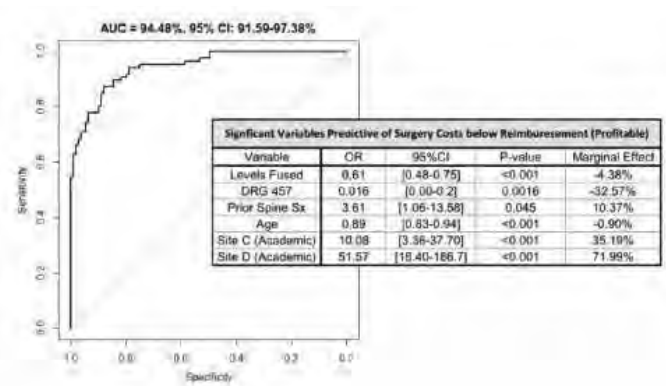
Methods
From a prospective, multicenter ASD database, patients undergoing long instrumented fusions (> 4 level) with cost data were identified. iEOC cost was actual direct hospital cost. MA rates were calculated using the year-appropriate CMS Inpatient Pricer Payment System Tool and were hospital specific. Demographic, HRQOL, radiographic, and surgical variables were analyzed. A predictive model was developed to identify variables that can predict iEOC<MA and an 80/20 split was utilized to train the model.

Results
Cost data was obtained from 4 of 11 centers with a total of 195 patients included in the model. 109 (55%) of patients had iEOC below the MA threshold. There was significant variation across the 4 centers in both the mean iEOC cost ($56,788 to $78,878,p<0.001) and reimbursement ($40,623 to $91,351,p<0.001) which was seen across deformity-specific DRGs (453,454,456,457). Academic centers were more likely to have iEOC costs below reimbursement (66.7% vs 8.9%,p<0.001). Negative predictors included number of levels fused and DRG 457 while having a revision surgery and at an academic center were positive predictors.

Conclusion
There is wide institutional variation in ASD reimbursement with an 56.8% increased likelihood getting reimbursed more than the cost of surgery (iEOC<MA) if done at an academic center. For a revision surgery, there is 10.4% increased likelihood. For each additional level fused and if DRG 457, there is a 4.4% and 32.6% decreased likelihood, respectively.

Take Home Message
We have successfully developed a predictive model (AUC 94.48%) to identify which patients undergoing ASD surgery will have index episode of care costs below the Medicare Allowable payment threshold.



Significant Variables Predictive of Surgery Costs below Reimburesement (Profitable)				
Variable	OR	95%CI	P-value	Marginal Effect
Levels Fused	0.61	[0.48-0.75]	<0.001	-4.38%
DRG 457	0.016	[0.00-0.2]	0.0016	-32.57%
Prior Spine Sx	3.61	[1.06-13.58]	0.045	10.37%
Age	0.89	[0.83-0.94]	<0.001	-0.90%
Site C (Academic)	10.08	[3.36-37.70]	<0.001	35.19%
Site D (Academic)	51.57	[18.40-186.7]	<0.001	71.99%

70. How Much Correction is Possible? Minimally Invasive Multilevel Lateral Lumbar Interbody Fusion Combined with Posterior Column Osteotomy using Stiff Rod (6.35 mm Cobalt Chrome) in Adult Spinal Deformity Surgery as Compared with Pedicle Subtraction Osteotomy

Jung-Hee Lee, MD, PhD; Ki-Young Lee, MD; Won-Ju Shin, MD; Dong-Gune Chang, MD, PhD; Sang Kyu Im, MD; Seong Jin Cho, MD

Summary
Lateral lumbar interbody fusion combined with posterior column osteotomy using stiff rod (6.35 mm Cobalt Chrome) is useful than pedicle subtraction osteotomy for the surgical correction of adult spinal deformity with sagittal imbalance.

Hypothesis
Although, recently minimally invasive techniques have been reported to be useful for surgical treatment of adult spinal deformity (ASD), few reports have directly compared it with pedicle subtraction osteotomy (PSO).

Design
Retrospective study.

Introduction
PSO is highly effective for sagittal correction in patients with ASD, but there are issues such as surgical complexity and long-term complications. The purpose of this study was to evaluate the radiological and clinical efficacies of lateral lumbar interbody fusion (LLIF) combined with posterior column osteotomy (PCO) using stiff rod (6.35 mm Cobalt Chrome; CoCr).

Methods
106 patients who were diagnosed ASD with sagittal imbalance and followed up for more than 2 years after sagittal correction were included. Comparative analysis was performed on the spinopelvic parameters and clinical outcomes of patients who underwent PSO (PSO group; n=65) and the patients who underwent multilevel pre-psoas LLIF, PCO, and open posterior spinal fusion with using a 6.35 mm CoCr rod (LLIF group; n=41).

Results
There were no differences in preoperative spinopelvic parameters between PSO group and LLIF group. Although there were no differences between the two groups in terms of postoperative SVA (-12.7 mm vs -16.5 mm), postoperative lumbar lordosis (-71.5° vs -72.6°), lumbar lordosis correction (78.0° vs 73.5°), sacral slope (46.3° vs 49.1°) and pelvic tilt (9.4° vs 7.2°), estimated blood loss was significantly lower in the LLIF group (2824 ml vs 1736 ml, P=0.000). No differences were observed in the clinical outcomes (ODI, VAS), proximal junctional kyphosis, and spinopelvic

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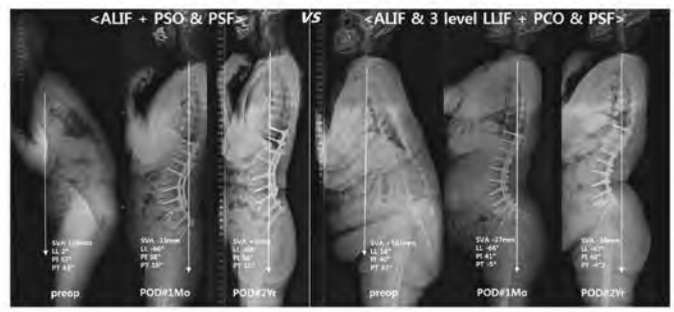
parameters between the two groups 2 years after the surgery, but reoperation due to pseudarthrosis was significantly higher in the PSO group (P=0.004).

Conclusion
Minimally invasive multilevel LLIF combined with PCO using a stiff rod leads to better clinical and radiological outcomes as much as PSO, accompanied by fewer long-term major complications, such as pseudarthrosis and reoperation.

Take Home Message
Minimally invasive multilevel LLIF with posterior column osteotomy is a very effective surgery for adult spinal deformity.



71. A Multi-ethnic Meta-analysis Defined the Association of rs12946942 with Progression of Adolescent Idiopathic Scoliosis*

Kazuki Takeda, MD, PhD; Nao Otomo, MD; Anna Grauers, MD, PhD; Yan-Hui Fan; Yoji Ogura, MD; Youhei Takahashi, MD; Elisabet Einarsdottir; Juha Kere; Morio Matsumoto, MD, PhD; Yong Qiu, MD; You-Qiang Song, PhD; Paul Gerdhem, MD, PhD; Shiro Ikegawa, MD, PhD; Kota Watanabe, MD, PhD

Summary
We conducted an international meta-analysis for severe adolescent idiopathic scoliosis (AIS) using the genotype datasets in four cohorts with different ethnicity. We analyzed 2,272 severe AIS cases and 13,859 controls in total, and found the significant association of rs12946942. In silico analyses suggested that SOX9 is the most likely susceptibility gene for AIS curve progression in the locus.

Hypothesis
rs12946942 is associated with severe AIS worldwide. SOX9 is the best candidate gene and rs12946942 affects the SOX9 expression of as a long-range locus control element.

Design
Prospective multicenter cohort study

Introduction
AIS is the most common type of scoliosis. Controlling its curve progression is the most important clinical task. Although recent genome-wide association studies (GWASs) identified several susceptibility loci associated with the development of AIS, the etiology of curve progression has been still unknown. Our previous GWAS has identified that rs12946942 showed significant association with severe AIS.

Methods
We recruited 2,272 severe AIS cases and 13,859 controls in Japan, Nanjing, Hong Kong and Scandinavia. Severe AIS was defined as Cobb's angle greater than 40 degrees at the time the subject was recruited in this study. The association of rs12946942 with severe AIS in each study was evaluated by the Cochrane-Armitage trend test. Data from the four studies were combined using the inverse variance method assuming a fixed effects model in the METAL software package. We evaluated the topologically associating domains (TADs) and the expression quantitative trait loci (eQTL) data from the Genotype-Tissue Expression (GTEx) project to identify the candidate susceptibility gene in the locus.

Results
We conducted the meta-analysis of rs12946942 using four cohorts. rs12946942 showed significant association: combined P = 7.23 x 10-13; odds ratio (OR) = 1.36; 95% confidence interval (CI) = 1.25 - 1.49. SOX9 was only included in the TAD and the lower SOX9 expression level was associated with risk allele (T allele) of rs12946942.

Conclusion
Our study suggests that SOX9 is associated with AIS curve progression via rs12946942 which affects the SOX9 expression.

Take Home Message
We conducted an international meta-analysis for more than 2000 severe adolescent idiopathic scoliosis patients and found the significant association of rs12946942.

72. Exploring Predictive Model of Plasma miRNAs on Curve Progression in Adolescent Idiopathic Scoliosis (AIS): A 6 Years Longitudinal Study*

Jiajun Zhang, PhD; Ka Yee Cheuk, PhD; Tsz-Ping Lam, MBBS; Yong Qiu, MD; Jack CY Cheng, MD; Wayne Y.W. Lee, PhD

Summary
The outstanding research question in AIS is to develop an early predictive model of curve progression for effective intervention and avoiding overtreatment. Circulating miRNAs are potential biomarker for complex diseases. Differentially expressed miRNAs were identified with microarray. We construct a plasma miRNA signature of AIS (miR-145, miR-96, miR-224) in a retrospective case-control cohort, which could significantly distinguish AIS

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from control. In longitudinal cohort, we demonstrate the prognostic value of plasma miR-96 in predicting curve progression

Hypothesis

Circulating miRNA(s) could be a new biomarker to predict curve progression in AIS.

Design

This study includes a retrospective case-control cohort and a longitudinal cohort

Introduction

AIS is a three-dimensional spinal deformity without clear etiopathogenesis. The outstanding research question is to improve the sensitivity and specificity of prognosticating curve progression in the early stage. As miRNA is stable and detectable in biofluids, miRNA-based diagnostic and prognostic biomarkers have been explored in clinical management. This study aimed to explore the prognostic value of plasma miRNAs for curve progression of AIS.

Methods

Subjects were recruited for two cohorts: 1) a case-control cohort of AIS girls (N=100) and healthy control (N=52); 2) a longitudinal cohort of AIS girls (N=128). We measured anthropometry and curve severity, and collected blood. BMD and bone qualities were measured by DXA and HR-pQCT, respectively. In longitudinal cohort, the subjects were followed up clinically every 6 months. Based on changes in the Cobb angle, subjects were defined into progressive (> or=6 degrees) or non-progressive group (<6 degrees) according to SRS criteria after completing the 6 years follow-up and reaching skeletal maturity. Differentially expressed miRNAs were analysed from microarray. miRNA expression was detected in plasma. Mann-Whitney, area under ROC curve (AUC) and logistic regression were used for statistical analysis.

Results

In case-control cohort, plasma miRNA signature (miR-145, miR-96, miR-224) of AIS were identified. AUC analysis showed miRNA targets could distinguish AIS from control significantly. In longitudinal cohort, progressive AIS had significantly reduced level of miR-96 and miR-145 in plasma that in stable AIS. Backward logistic regression analysis generated a model including plasma miR-96 level, which showed outstanding predictive accuracy with hazard ratio>2.

Conclusion

This is the first study to show that plasma miRNA could enhance the reliability of early prediction of curve progression of AIS.

Take Home Message

Result of the study shed light on potential of novel biomarkers in addition to bone quality parameters, which may improve prognostic power to AIS.

73. Genome-wide Association Study Identifies Novel Genetic Locus Associated with Curve Progression in AIS Patients*

Lei-Lei Xu, PhD; Zhichong Wu, PhD; Xu Sun, MD; Zhen Liu, MD; Yong Qiu, MD; Zezhang Zhu, MD

Summary

We investigated the genetic marker associated with curve progression in AIS on the basis of previously GWAS database. A total of 1220 patients were included in the study. Comparison of genome-wide genotype was performed between patients with different curve severity. We found a novel locus in OPRK1 gene remarkably associated with curve progression. Moreover, the mRNA expression level of OPRK1 was significantly correlated with curve severity. Functional role of OPRK1 in the progression of AIS is worthy of further investigation.

Hypothesis

Novel curve severity-related gene in AIS patients may be indentified by GWAS.

Design

Genome-wide association study

Introduction

In a recent GWAS performed in the Japanese AIS population, a functional variant in MIR4300HG was found remarkably associated with severe curve. Since the understanding of curve progression in AIS is currently limited, further investigation in different races is warranted to decipher its genetic architecture. We aimed to investigate the genetic marker predictive of curve progression in AIS from Chinese Han population.

Methods

600 female AIS patients with major thoracic curve were enrolled in the discovery stage of GWAS. 323 patients with curve more than 40 degrees were assigned to the progression group and the other 277 patients with curve less than 30 degrees were assigned to non-progression group. PLINK software package was used for association analysis to determine SNPs significantly associated with the curve progression, with a p value of 10-4 considered as putative significance. An independent cohort of 225 patients with severe curve and 395 patients with mild curve were then included in the replication stage. To analyze tissue expression of significantly associated gene, paraspinal muscles in the proximal region were collected from 152 patients during surgery.

Results

Principal cluster analysis showed that all the patients were clustered in the Han population, the genome inflation factor was 1.03. After quality control, 544,868 SNPs were finally included in the case-control association analysis. 21 SNPs were found to have a p value of less than 1.0 x 10-4, with 10 TagSNPs subse-

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quently included in the replication stage. SNP rs2717640 located in OPRK1 gene was successfully replicated. Patients with severe curve were found to have a remarkably lower frequency of allele C than those with mild curve (22.7% vs. 29.3%, p = 1.10 × 10-6) with an OR of 0.81. The mRNA expression level of OPRK1 was significantly correlated with curve severity.

Conclusion
New curve severity-related gene was found in this study with remarkable genome significance, which will serve as a fundamental work for future study on the progression of AIS.

Take Home Message
OPRK1 was found to be the new curve severity-related gene, which will serve as a fundamental work for future study on the progression of AIS.

74. LBX1 May Play a Role in the Development of AIS via Regulating the Proliferation and Differentiation of Myosatellite Cells*

Lei-Lei Xu, PhD; Zhichong Wu, PhD; Xu Sun, MD; Zhen Liu, MD; Yong Qiu, MD; Zezhang Zhu, MD

Summary
Previous studies showed that LBX1 is a susceptible gene of AIS. We investigated the influence of LBX1 on the bioactivity of myosatellite cells isolated from AIS patients. Transfected with lentivirus targeting LBX1, myosatellite cells were found to have significantly inhibited proliferation rate. Moreover, remarkably decreased number of Type I fiber was observed after the silencing of LBX1. These findings indicated that LBX1 may be involved in the etiology of AIS through regulation of myosatellite cells in the paraspinal muscles.

Hypothesis
LBX1 may regulates the proliferation and differentiation of myosatellite cells in AIS.

Design
An in vitro cytological study.

Introduction
LBX1 is a susceptible gene involved in the etiology of AIS in different populations. In our earlier study, a functional variant in the promoter region of LBX1 was confirmed to regulate the expression of LBX1 in the paraspinal muscles of AIS. Interestingly, AIS patients were reported to have abnormally distribution of Type I fiber in the bilateral paraspinal muscle. In this study, we aimed to investigate the influence of LBX1 on the bioactivity of myosatellite cells isolated from AIS patients.

Methods
Bilateral paraspinal muscles were collected from the 20 AIS patients and 10 age-matched CS patients during surgery. IHC staining was performed to determine the ratio of type I fiber to type II fiber. The expression of LBX1 was evaluated by qPCR to determine its relationship with the proportion of Type I fiber. Myosatellite cells were isolated from the paraspinal muscles. 5 cases of AIS cells transfected by LBX1 lentivirus and the other 5 cases transfected by empty vector randomly. Cell proliferation assays and cell differentiation assessment were performed. Cell viability was then compared between AIS and CS and between lentivirus-transfected group and blank group.

Results
IHC staining of the tissue sample showed that there was remarkably decreased proportion of Type I fiber in AIS as compared with CS. LBX1 expression was significantly correlated with proportion of Type I fibre. Myosatellite cells isolated from AIS presented lower viability than those of CS. In the lentivirus-transfected group, activated myosatellite cells were found to have significantly inhibited proliferation rate. Moreover, remarkably decreased number of Type I fiber was observed after the silencing of LBX1.

Conclusion
LBX1 may be involved in the etiology of AIS through regulation of myosatellite cells in the parapinal muscles. Disproportion of Type I fibre in paraspinal muscle may play a role in the occurrence of AIS. Further microarray analysis is warranted to determine the downstream pathway of LBX1.

Take Home Message
LBX1 may be involved in the etiology of AIS through regulation of myosatellite cells. Disproportion of Type I fibre in paraspinal muscle may contribute to the occurrence of AIS. .

75. Are Serum Ion Levels Elevated in Pediatric Patients with Spinal Implants vs. Controls?*

Smitha E. Mathew, MBBS; A. Noelle Larson, MD; Matthew P. Abdel, MD; Andre J. van Wijnen, PhD; Todd Milbrandt, MD, MS; Geoffrey F. Haft, MD

Summary
Serum titanium and cobalt levels are elevated in pediatric patients with titanium and cobalt chrome spinal instrumentation (fusion and growing spine devices) compared to controls with extremity implants placed for fracture or deformity treatment. Serum titanium and cobalt levels are similar to controls at baseline and increase after posterior instrumented spinal fusion.

Hypothesis
Serum titanium levels would be elevated in pediatric patients with

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

spinal implants, particularly growing spine devices compared to patients with extremity implants.

Design
Prospective multicenter study.

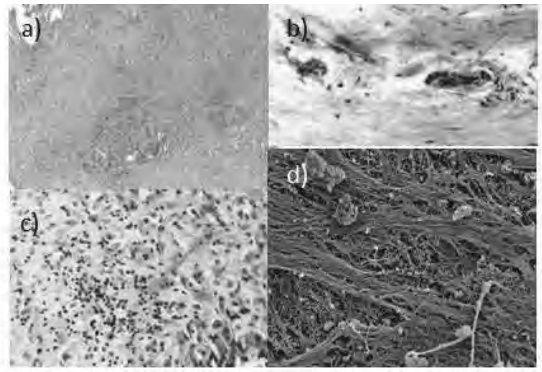
Introduction
Titanium (Ti) is thought to be among the most biocompatible metals. Using state-of-the-art assay tools, we assessed serum ion levels in 3 groups of pediatric patients: 1) those with Ti growing spine devices, 2) those with Ti screws and cobalt chrome instrumentation for fusion, 3) control patients with implants in the extremities.

Methods
Pediatric patients undergoing growing rod surgery or other leg/forearm implant removal (control group) had serum titanium, cobalt (Co), and chromium (Cr) ion levels drawn at the time of surgery. Intraoperative waste tissue specimens from the time of surgery were analyzed for the presence of metallic debris. Thirty-eight patients had at least one set of labs (11 growing devices, 11 spinal fusions, and 16 controls with extremity implants). Growing spine devices included 2 MCGRs, 4 rib-based, and 5 traditional growing rods. Seventeen patients had labs repeated three months later for validation purposes.

Results
Compared to controls, serum Ti levels were significantly elevated in patients with growing spine devices at 3.3 ng/ml vs. 0.69 ng/mL in controls with extremity implants (p=0.005). Cobalt level in the growing spine device group was elevated at 0.62 ng/mL vs. 0.28 ng/mL in controls (p=0.047). On matched pairs analysis, patients who had labs drawn before and after spinal implant placement had a statistically significant increase in serum Co levels (0.26 ng/ml vs. 1 ng/ml, respectively; p=0.044) and Ti levels (0.55 ng/mL vs. 3.5 ng/mL, respectively; p<0.001). There was a trend toward increased serum Ti levels in patients who had had Ti implants in place for longer (p=0.02). No differences were found in Cr levels among the groups. Tissue biopsies adjacent to Ti implants showed macrophage activity and the presence of metal debris (Fig. 1).

Conclusion
Serum Ti and Co levels were elevated in patients with spinal implants, especially those with growing spine devices.

Take Home Message
Although Ti and Co serum levels are elevated in children with spinal implants, the clinical significance remains to be determined.



a, b, c) H&E stain and **d)** SEM images of metal debris from pediatric tissue biopsy adjacent to implant.

76. TBX6-associated Congenital Scoliosis (TACS) as a Clinically Distinguishable Subtype of Congenital Scoliosis: Further Evidence Supporting the Compound Inheritance and TBX6 Gene Dosage Model*

Nan Wu, MD; Jiaqi Liu, MD; Kazuki Takeda, MD, PhD; Sen Zhao, BS; Terry Jianguo Zhang, MD; Feng Zhang, PhD; Zhihong Wu, MD; Shiro Ikegawa, MD, PhD; James R. Lupski, MD, PhD, DSc (hon); Guixing Qiu, MD; Deciphering Disorders Involving Scoliosis and COmorbidities Study (DISCO)

Summary
We previously revealed that a portion of sporadic congenital scoliosis (CS) could be genetically explained by a compound inheritance model: a TBX6 null allele in combination with a hypomorphic risk allele in trans (Wu et al., NEJM 2015). By retrospective analysis of 497 CS patients from multi-centers world-widely, followed by generation of bx6 gene-editing mice models (Yang et al., HMG, 2018), we firstly defined TACS (TBX6-associated congenital scoliosis) and reported that TACS is a distinguishable entity with consistent clinically features.

Hypothesis
Patients with the TBX6 compound inheritance model have clinically measurable endophenotypes.

Design
A retrospective multi-center study was used to study the genotype-phenotype correlation of patients with TBX6 mutations.

Introduction
The genetic basis of a significant portion of sporadic congenital scoliosis (CS) has been elucidated and explained by a model of compound inheritance: a TBX6 null allele (deletion CNV or nonsense/frameshift loss-of-function mutation) in combination with

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a hypomorphic risk allele in trans (Wu et al,. NEJM 2015), which has been validated in mouse model (Yang et al., HMG 2018).

Methods
Patients with congenital scoliosis (CS) from China (N = 345, cohort 1, Chinese) from the Deciphering Disorders Involving Scoliosis and COmorbidities (DISCO) study, Japan (N = 142, cohort 2, Japanese), and the United States (N = 10, cohort 3, Hispanic & Caucasian) were studied. Clinically measurable endophenotypes were compared according to the TBX6 genotypes. A mouse model for Tbx6 compound inheritance (N = 52) was investigated by micro-computed tomography. A clinical diagnostic algorithm (TACScore) was developed to assist in clinical recognition of TBX6-associated CS (TACS)

Results
In cohort 1, TACS patients (N = 33) were significantly younger at onset ($P = 0.02$), presented with one or more hemivertebrae/butterfly vertebrae ($P = 4.9 \times 10^{-8}$), and exhibited vertebral malformations involving the lower part of the spine (T8–S5, $P = 4.4 \times 10^{-3}$); these observations were confirmed in two independent cohorts. A clinically usable TACScore was developed with an area under the curve of 0.9 ($P = 1.6 \times 10^{-15}$). A Tbx6-/mh (mild-hypomorphic) mouse model recapitulated the human TACS phenotype (Figure 1).

Conclusion
TACS is a clinically distinguishable entity with consistent clinically measurable endophenotypes. The type and distribution of vertebral column abnormalities in TBX6/Tbx6 compound inheritance implicate subtle perturbations in gene dosage as a cause of spine developmental birth defects responsible for about 10% of CS.

Take Home Message
Patients with the TBX6 compound inheritance mutations can explain about 10% CS cases. TACS is a clinical entity defined by consistent measurable endophenotypes. The TACScore can guide clinical management of CS.

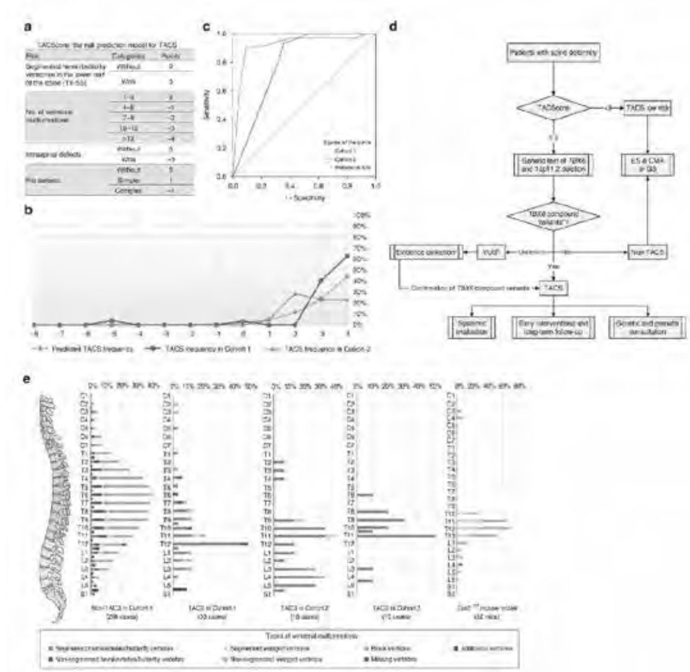


Figure 1. Development and validation of the risk prediction model and diagnostic pipeline of TACS

77. Tranexamic Acid In Pediatric Scoliosis Surgery (TRIPSS): A Prospective Randomized Trial Comparing High Dose And Low Dose Tranexamic Acid In Adolescent Idiopathic Scoliosis (AIS) Undergoing Posterior Spinal Fusion Surgery†

Mohd Shahnaz Hasan, MBBS, MAnes; Chris Yin Wei Chan, MD, MS; Siti Nadzrah Yunus, MBBS; Ching Choe Ng, MD, MAnaes; Chee Kidd Chiu, MBBS, MS; Mun Keong Kwan, MBBS, MS

Summary
The TRIPSS study was an IRB approved, ANZCTR registered prospective randomized double-blinded trial (166 AIS patients from a single center) designed to compare the efficacy of low dose (10 mg/kg loading dose, 1 mg/kg/h infusion) and high dose (30 mg/kg loading dose, 10 mg/kg/h infusion) Tranexamic Acid,TXA in reducing blood loss during Posterior Spinal Fusion surgery in AIS patients. Low dose TXA was found to be as efficacious as high dose TXA in reducing blood loss and allogenic transfusion

Hypothesis
High dose Tranexamic Acid (TXA) is more effective than low dose TXA.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Design

Prospective randomized double-blinded clinical trial

Introduction

Evidence on the optimal TXA dosing regimen in the pediatric population is scarce. This trial was designed to determine the clinical efficacy of high dose TXA against low dose TXA at reducing blood loss in AIS surgery.

Methods

This study, approved by the institutional review board and registered with the Australian New Zealand Clinical Trial Registry (ACTRN12617000663358) involved 166 AIS patients in a single center. They were randomized to receive either Group A, high dose TXA (30 mg/kg loading dose and 10 mg/kg/h infusion) or Group B, low dose TXA (10 mg/kg loading dose and 1 mg/kg/h infusion). Estimated blood loss (EBL) was compared between the 2 groups. Hemoglobin, hematocrit and fibrinogen levels were obtained at 3 perioperative time points; T1 (pre-operation), T2 (0-hour post-operation), and T3 (48-hour post-operation).

Results

The demographics, body anthropometry, curve magnitude, operative time, number of fused levels and length of incision were comparable. There was no significant difference in the total EBL between Group A (928.8 ± 406.1 ml) and Group B (918.1 ± 406.2 ml). The blood loss/spinal level fused (Group A, 80.9 ± 30.1 ml vs Group B, 82.8 ± 30.5 ml) and blood loss/ hour (Group A, 385.4 ± 141.2 ml vs Group B, 386.9 ± 145.4 ml) did not show any significant difference. The hemoglobin drift between T1 and T3 did not show any difference between Group A (3.01 (2.60,3.42) g/dL) and Group B (3.30 (2.89,3.71) g/dL) with p = 0.511. One patient from each group received allogenic blood transfusion postoperatively. No serious adverse events occurred in both groups.

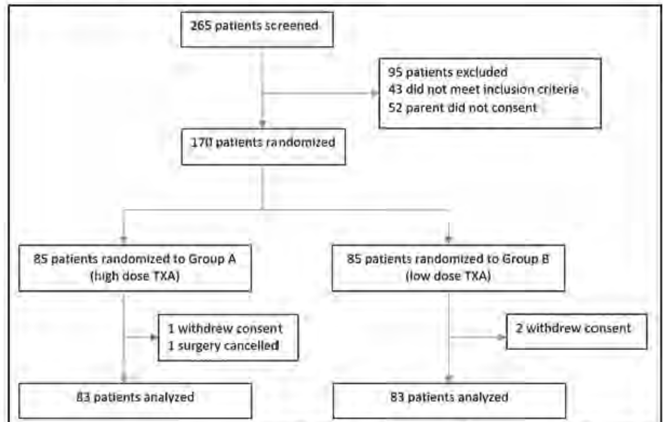
Conclusion

From the TRIPSS study, low dose TXA is as efficacious as high dose TXA in reducing blood loss and allogenic transfusion requirement in PSF for AIS patients.

Take Home Message

The TRIPSS study showed that Low dose TXA was as efficacious as high dose TXA in reducing blood loss and allogenic transfusion requirement in PSF for AIS patients.

CONSORT diagram and key important study parameters.



Variables	Treatment Group A (High dose TXA) n = 83	Treatment Group B (Low dose TXA) n = 83	p value
Total blood loss			
ml (mean ± SD)	928.84 ± 406.12	918.14 ± 406.22	0.865
ml/level (mean ± SD)	80.87 ± 30.12	82.84 ± 30.46	0.676
Perioperative allogenic transfusion, n (%)	1 (50)	1 (50)	0.497
Hemoglobin, g/dl (mean ± SD)			
T1(pre-operation)	13.76 ± 0.97	13.84 ± 1.11	0.483
T2(0-hour post-operation)	11.91 ± 1.17	11.72 ± 1.22	0.861
T3(48-hour post-operation)	10.75 ± 1.29	10.54 ± 1.09	0.256

SD: standard deviation, IQR: interquartile range, MAP: mean arterial pressure

CONSORT diagram and key important study parameters

78. Prospective Randomized Controlled Trial of Implant Density in AIS: Results of the Minimize Implants Maximize Outcomes Study†

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Summary

For 206 AIS patients with Lenke 1A curves who underwent posterior spinal instrumented fusion randomized to more screws (implant density > 1.8 screws per level fused) vs. fewer screws (implant density <1.4) at 3-month, 1-year, and 2-year follow-up, there was no statistically significant difference in % curve correction.

Hypothesis

Use of more screws vs. fewer screws would result in similar coronal

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

curve correction for Lenke 1A curve patterns treated with posterior spinal instrumented fusion.

Design
Prospective multicenter randomized trial.

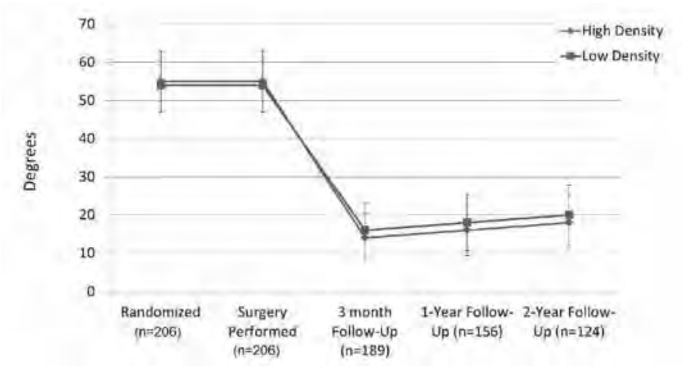
Introduction
The role of implant density (anchors per level fused) has not been prospectively studied for a large cohort of AIS patients. In the Minimize Implants Maximize Outcomes (MIMO) Clinical Trial of equivalence, patients with Lenke 1A curve patterns were randomized to more versus fewer screws (high or low density) to determine if there was a difference in percent coronal Cobb angle correction within a 10% margin.

Methods
14 sites accrued patients in the MIMO Clinical Trial (NCT01792609). Patients with Lenke 1A curves between 45-65 degrees were randomized to a high- (>1.8 screws per level fused, HD) vs. low- (<1.4 screws per level fused, LD) implant density and were followed for 2 years. Power analysis showed that 174 patients were needed to detect a difference in % correction with a 10% margin at each time point. Follow-up was performed at 3 month (189 patients), 1 year (156 patients), and 2 years (124 patients). Data was centrally collected and x-rays measured by trained reviewers.

Results
There was no difference in age, gender, preop curve magnitude, or race between the 2 groups. Mean % Cobb correction at 3 months was 74% in HD vs. 70% in LD (p=0.065, 95% CI -0.2 to 6.8%), 69% in HD vs. 66% in LD at 1 year (p=0.25, 95% CI, -1.7 to 6.7%), and 67% vs. 64% at 2 years (p=0.18, CI, -1.5 to 7.8%). There was no difference in operative time, blood loss, or length of stay amongst the two groups. There was no difference in pre- or postop thoracic kyphosis between the HD and LD groups. There were 6 reoperations in each group (p=1.0). Age was lower for patients who completed 2-year follow-up (11.6 years vs. 12.8, p<0.001), but there was no difference in race or preop curve magnitude.

Conclusion
For Lenke 1A curves between 45-65 degrees randomized to low- vs. high implant density, this prospective, randomized, controlled study showed equivalent % coronal curve correction.

Take Home Message
Given potential cost savings, surgeons could consider a low implant density construct (<1.4 screws/level fused) for posterior spinal fusion of Lenke 1A curves between 45-65 degrees.



Mean Major Thoracic Cobb Angle

79. The Analgesic Effect of Dexmedetomidine in Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Double Blinded Prospective Randomized Study†

Ajoy Prasad Shetty, MS, DNB; Ankith NV, MS; Rishi M. Kanna, MBBS, MS; S. Rajasekaran, PhD

Summary
A randomized double blinded clinical trial done in 60 patients undergoing posterior spinal fusion for adolescent idiopathic scoliosis to analyze the analgesic and opioid sparing effect of Dexmedetomedine (DEX). DEX, a highly selective centrally acting α2-adrenergic agonist reduced total opioid consumption with no additional complications. DEX administration reduced mean time to ambulation, post operative nausea- vomiting score and hospital stay in PSF patients. DEX can be used as a safe and effective adjunct to opioids in PSF surgery

Hypothesis
DEX a centrally acting α2-adrenergic agonist would provide adequate pain relief as well as reduce opioid requirement in PSF patients

Design
Prospective double blinded randomized study

Introduction
Post operative pain management in children after posterior spinal fusion (PSF) surgery is a challenge. Traditionally opioids with side-effects like nausea, vomiting, ileus, pruritus, respiratory depression were the mainstay for pain management. Adjunctive pain medications are necessary to decrease opioid use in PSF surgeries

Methods
63 AIS patients undergoing PSF were randomly allocated into 2 groups. Morphine (MOR) group received 10μg/kg/hr continuous infusion of morphine and Dexmedetomidine (DEX) group

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

received 0.4μg/kg/hr of Dexmedetomidine for 24hrs post surgery. Nursing staff blinded for study groups recorded hourly vital parameters (BP, PR, Spo2). Pain, post operative nausea vomiting and sedation were rated on numerical rating scales (NRS, PONV scale, SS).Total opioid requirement (TOR) was calculated for both the groups. Any post operative complications like ileus, bradycardia, hypotension, respiratory depression/desaturation were recorded

Results

Both the groups were comparable with respect to the age, sex, type of curve, cobb's angle, duration of surgery, blood loss and blood transfusion. Significant difference was found between the groups (MOR vs DEX) with respect to TOR (2.2mg/kg±0.65vs1.5±0.65), time to ambulation (56.6hr±12.7 vs 45.2hr±7.7), PONV (0.46±0.3vs0.16±0.1) and length of hospital stay (9.5days±1.9 vs8.2days±1.3). Requirement of enema or suppository for bowel opening was significantly more in MOR group (0.5 vs 0.2).There was no difference between the groups with respect to pain, sedation status. Complications like postoperative ileus, pleural effusion were more in the MOR group

Conclusion

Addition of adjunctive medication like DEX reduced opioid requirement and hospital stay in PSF patients. Considering the side effect profile of opioid, effective adjuncts like DEX can be incorporated safely in the pain management protocols

Take Home Message

Dexmedetomidine is a safe and effective adjunct for pain control following posterior spinal fusion in idiopathic scoliosis. Adjuncts reduce opioid consumption and lessen the side effects associated with opioids

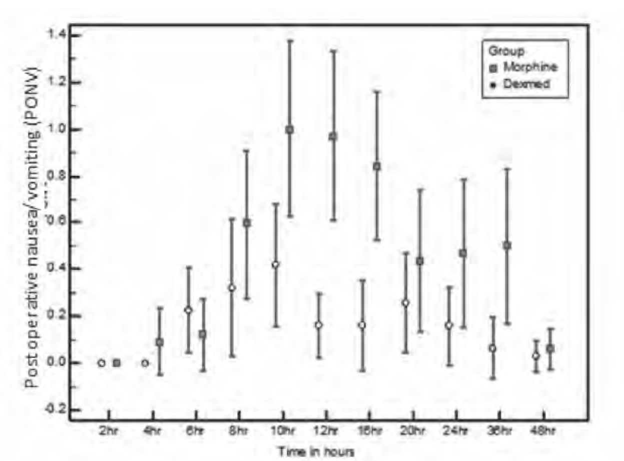


Chart showing the PONV scores in Morphine and Dexmedetomidine group in the first 48 hours after surgery

80. Health Related Quality of Life in Non-operated Patients with Adolescent Idiopathic Scoliosis in the Middle Years: Mean 25 Years Follow-up Study†

Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Hirokazu Shoji, MD; Tatsuki Mizouchi, MD; Naoto Endo, MD, PhD; Kazuhiro Hasegawa, MD, PhD

Summary

Non-surgical treated AIS patients showed significantly worse scores in SRS-22 self image compared to the controls. Patients with major thoracolumbar curve showed significantly worse scores in VAS for low back pain, ODI, and JOABPEQ walking ability and social function than those in patients with major thoracic curve and the controls.

Hypothesis

In natural history, AIS patients had worse HRQOL status compared to the controls in the middle years.

Design

A retrospective, long-term follow-up study

Introduction

The purpose of this study was to investigate the health related quality of life (HRQOL) status in middle-aged patients with adolescent idiopathic scoliosis (AIS) treated by non-surgical treatment.

Methods

Inclusion criteria were non-surgically treated patient with AIS, ≥ 30° major scoliosis at skeletal maturity (Risser grade ≥4), and ≥ 30 years of age at the time of the survey. One hundred seven AIS patients were included, and divided into 3 groups [single thoracic(T) group; n=50, single thoracolumbar(TL) group; n=19, and double-major(DM) curve group; n=38] based on the curve location at the skeletal maturity. The mean age of the participants was 14.9 years at skeletal maturity, and 39.8 years at the time of the survey. The mean duration between skeletal maturity and the survey was 24.9 years. Age- and sex-matched 321 volunteers were selected as the control group, and same HRQOL assessments were evaluated.

Results

There were no significant differences in age at survey, BMI, BMD of the femoral neck, and skeletal muscle mass index among the 4 groups. In all 3 groups, the major scoliosis progressed by about 0.5°/year from the time of skeletal maturity to the survey. The all scoliosis groups showed significantly worse scores in SRS-22 self-image than that in the control group ($p<0.0001$). The TL group showed significantly worse scores in low back pain VAS, ODI, Japanese Orthopaedic Association Back Pain Evaluation

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Questionnaire (JOABPEQ) walking ability and social function (all, p<0.05) at the survey.

Conclusion

In natural history, AIS patients with single thoracic curve maintain equal OL status compared to the controls. On the other hand, patients with thoracolumbar curve have severe low back pain as well as worse low back pain specific HRQOL status in the middle years.

Take Home Message

AIS patients with major thoracolumbar curve have clinically concerning LBP and physical disability, and periodic follow-ups into adulthood should be considered.

Table Comparison of the HRQOL assessments

	MT group (n=50	TL group (n=19)	DM group (n = 38)	Control (n=321)	p value
LBP VAS (0-100)	14.0 (18.7)	31.3 (31.1)	25.8 (23.9)	18.2 (22.9)	0.0111
ODI (%)	7.6 (8.5)	14.7 (16.4)	10.8 (9.4)	8.6 (9.4)	0.0259
JOABPEQ					
Pain	86.0 (22.7)	69.8 (35.9)	80.6 (26.4)	80.6 (29.4)	n.s.
Lumbar function	95.9 (10.0)	84.2 (28.1)	94.6 (11.7)	91.2 (17.5)	n.s.
Walking ability	99.3 (4.2)	82.4 (33.3)	97.7 (14.5)	94.5 (14.1)	0.0038
Social activity	91.8 (12.8)	77.1 (25.7)	84.1 (17.7)	87.9 (17.2)	0.0373
Mental health	64.6 (14.2)	53.8 (24.6)	59.8 (17.5)	55.9 (15.9)	0.0036
SRS-22					
Pain	4.2 (0.6)	3.9 (0.9)	4.1 (0.6)	4.2 (0.7)	n.s.
Self-image	2.8 (0.7)	2.7 (0.9)	2.8 (0.6)	3.5 (0.6)	<0.0001
Function	4.7 (0.4)	4.4 (0.9)	4.5 (0.5)	4.6 (0.5)	n.s.
Mental health	3.9 (0.6)	3.4 (1.2)	3.7 (0.7)	3.6 (0.7)	n.s.
SF-12 PCS	52. (6.9)	49.8 (16.1)	52.5 (9.3)	50.4 (12.0)	n.s.
MCS	49.5 (7.2)	47.1 (10.7)	48.9 (7.8)	46.5(8.8)	n.s.

* analysis by Kruskal-Wallis test, Chi-square test

81. Scheuermann Kyphosis 39 Year Follow-up from Diagnosis in Non-operated Patients†

Lærke C. Ragborg; Casper Dragsted, MD; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

Summary

We conducted a retrospective single center follow-up study on 55 patients diagnosed with Scheuermann Kyphosis (SK) in adolescence. Health related quality of life (HRQOL) measured with SRS-22r was compared with a normal population and between thoracic (Th) and thoracolumbar (TL) location. SK patients had lower scores in pain, self-image and SRS-22 subscore compared to normative data. We found no difference between the patients with Th and TL SK.

Hypothesis

Adult patients with SK have lower HRQOL compared to the general population and location of the kyphosis affects HRQOL.

Design

Retrospective single center follow-up.

Introduction

Previous studies have highlighted the impact on HRQOL in adolescent patients with SK; however, sparse information is available regarding the long-term effects of SK on HRQOL. Moreover, TL SK has been associated with increased back pain compared to Th SK.

Methods

Of a cohort of 242 patients seen for a pediatric spinal deformity in the years 1972-1982 in the outpatient clinic, 55 had radiologically verified SK. Of these, 50 were eligible for follow-up. Patients were contacted by e-mail, phone or regular mail. A total of 38 responded to the HRQOL questionnaire (SRS-22r), and anterior-posterior and sagittal full-spine radiographs were obtained in 34 of these patients. Four patients declined to participate, and 8 patients did not respond. Patients were divided into two groups according to location of the SK apex: Thoracic (Th) above Th10 and Thoracolumbar (TL) from Th10 and below. HRQOL for all SK patients were compared with normative data from a Scandinavian population.

Results

We included 28 females and 22 males with a mean follow-up of 39±1.6 years. The mean age at follow-up was 53±2.4 years and mean kyphosis was 60.5±15.6°. A total of 21(55%) were classified as TL and 17 (45%) as Th SK. We found a significantly lower score in the TL group for SRS-22r function domain (p=0.027) compared with the Th group, but no significant difference on the remaining domains and SRS-22r subscore (p>0.18). Patients had significantly lower mean scores compared to normative values on SRS-22r domains pain (4.09±0.6) (p=0.017) and self-image (3.95±0.82) (p=0.004) and overall on SRS-22r subscore (4.17±0.57) (p=0.042). We found no differences on the remaining domains.

Conclusion

We found a lower HRQOL in adult patients with SK 39 years after diagnosis regarding pain, self-image and overall quality of life compared with a background population. The location of the SK apex did not seem to have an overall impact on HRQOL.

Take Home Message

HRQOL is lower in adult patients with SK compared to the background population. The location of kyphosis does not seem to influence overall HRQOL.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

82. Quantitative Risk Analysis of Adolescent Idiopathic Scoliosis Patients Who Deferred Surgery†

Gabriel KP Liu, MD, FRCS; Gerald Fung; Si Jian Hui, MBBS; Jun Hao Tan, MBBS; Leok-Lim Lau, FRCS; Hee-Kit Wong, FRCS

Summary

This study aims to quantify risks accumulated in patients who choose to defer surgery. The clinical data of patients operated for curve ≥80° were traced back in time at various intervals from their surgery to the time they were first offered surgery. These earlier visit information were propensity matched to patients undergoing AIS surgery with similar presentations. These patients had significantly increased implant usage, surgical levels, operation time, blood loss and duration of hospital stay.

Hypothesis

Delayed surgical intervention in AIS pts with curve >50° increases operative risk.

Design

Retrospective Propensity Matched Case-Control Study

Introduction

Surgical treatment delay for AIS pt, due to patients' or parents' indecisiveness is not uncommon. This study aims to quantify the risk of surgical outcomes of AIS pts should they prefer to delay surgery.

Methods

587 post-surgical AIS patients were reviewed. All Cobb angle at the time of surgery were analysed and large curve with Cobb≥80° were selected and traced back in time(TBIT) to initial clinical presentation at Cobb:50-60° & 60-70°. Identified TBIT Cobb were matched using propensity score matching to the remaining small curve with operative Cobb≤70°. Matching was performed in 1:2 ratio based on age, gender, BMI, Risser, Cobb angle and Lenke classification. Only Lenke type1-4 was analysed.

Results

TBIT clinical data from 19 large curves of Cobb ≥80° were propensity score matched to 38 small curves. Large curve pts who would have been operated when TBIT Cobb:50-60° would benefit from reduced implants by 8screws (59%,p<0.001), implant density by 0.4screws/level (32%,p=0.001), surgical levels by 2 levels (17%,p=0.023), op time by 157mins (55%,p<0.001), blood loss by 518ml (102%,p=0.001), and hospital stay by 2days (36%,p=0.004. Lenke change was seen in 57% of pts when progressing from 50-80°, most commonly from Lenke Type 1 to 2 and 3. Similarly, large curve pts who would have been operated when TBIT Cobb: 60-70° would have less implants by 5screws (32%,p<0.087), implant density by 0.2screws/level (15%,p=0.177), surgical levels by 2 levels (17%, p=0.183), op time by 200mins (66%,p<0.004), blood loss by 803ml (130%,p=0.001), and hospital stay by 3days (53%,p=0.004). Lenke change was seen in 20% of patients as they progressed from 60-80°, most commonly from Lenke Type 2 to 6.

Conclusion

Patients who chose to defer surgery at 50-60° or 60-70° and subsequently progressed to ≥ 80°, would have an estimated increased risk of greater implant usage by 59% or 32%, implant density by 32% or 15%, surgical levels by 17% or 17%, operation time by 55% or 66%, blood loss by 102% or 130%, and hospital stay by 36% or 53%, respectively.

Take Home Message

Delayed surgical intervention in AIS patients with curve > 50° increases operative risk resulting in greater implant usage, more surgical levels, increased operation time, blood loss and longer hospital stay.

83. Prospective Follow-up of Anterior Vertebral Body Tethering (AVBT) for Idiopathic Scoliosis: Interim Results from an FDA IDE Study†

Amer F. Samdani, MD; Joshua M. Pahys, MD; Robert J. Ames, MD; Harsh Grewal, MD; Glenn Pelletier, MD; Randal R. Betz, MD; Steven W. Hwang, MD

Summary

In this report we present results from the first FDA IDE study on anterior vertebral body tethering (AVBT). Patients with immature thoracic idiopathic scoliosis underwent AVBT and demonstrated improvement in their coronal Cobb angles, maintenance of sagittal profile, and no measurable decline in pulmonary function. SRS outcome scores were high, but reoperations occurred in 9.6% of patients, mostly due to overcorrection.

Hypothesis

Patients treated with AVBT demonstrate progressive correction of their curve

Design

Prospective analysis of a retrospective cohort.

Introduction

Anterior vertebral body tethering (AVBT) has emerged as a novel treatment option for patients with idiopathic scoliosis. To date, all reports on its efficacy and safety have been retrospective. We present results from the first FDA IDE study on AVBT.

Methods

Eligible patients underwent AVBT at a single center from August 2011 to July 2015. Inclusion criteria included skeletally immature patients with Lenke 1A or B curves between 30 and 65°. Clinical

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

and radiographic parameters were collected until completion of the study (>18 years of age), with the latter measured by an independent reviewer.

Results
55 patients (47 female, 8 male) were enrolled in the study with mean age of 12.5 ± 1.3 years (range 10.1–15.0). Patients underwent a mean number of 7.5 ± 1.2 levels tethered with a mean operative time of 223 ± 80 minutes and EBL of 108 ± 87 ml. 53 patients had minimum 2 years of follow-up averaging 47.8 ± 14.3 months with mean Risser sign at follow-up of 4.3 ± 0.8 . A mean preoperative main thoracic Cobb angle of 39.7 ± 6.8° corrected to 18.9 ± 8.1° at first erect. At most recent follow-up, the Cobb angle further improved to 16.2 ± 14.0°. In the sagittal plane, T5-12 kyphosis measured 15.1 ± 9.6 pre-op, 16.3 ± 8.9 post-op, and 17.3 ± 12.4 at most recent follow-up. 86% of patients had curves < 30° at most recent follow-up. Pulmonary function remained stable.. At most recent follow-up SRS scores averaged 4.5 ± 0.4 and self-image scores averaged 4.4 ± 0.6. No major neurologic or pulmonary complications occurred. Revision surgery occurred in 5/53 patients (9.4%): 4 for overcorrection and 1 for adding on.

Conclusion
Anterior VBT is a promising technique that has emerged as a treatment option for patients with immature idiopathic scoliosis. These results represent the first results from a FDA approved IDE study with a mean follow-up greater than 3 years. The findings affirm the safety and efficacy of this technique, with opportunities for improvement with respect to reoperation rates.

Take Home Message
AVBT offers a treatment option for children with skeletally immature scoliosis. However, reoperations occur in 10% of patients and thus families should be appropriately counselled.

84. Clinical, Radiological and HRQoL Outcomes after Selective Thoracic Fusion with Minimum 15 Years Follow-up†

Sinan Kahraman, MD; Yunus Emre Akman, MD; Ayhan Mutlu, MD; Onur Levent Ulusoy, MD; Tunay Sanli, MA; Huseyin Ozturk, MD; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

Summary
The current study found that beyond 15 years post-op, spontaneous lumbar curve correction (SLCC) was maintained with an improvement of coronal balance seen in the compensatory lumbar curves. Degenerative changes of lumbar curve of selective thoracic fusion (STF) pts were mild and patients with STF showed higher HRQoL scores than with age-gender-BMI matched population at minimum 15 years follow up.

Hypothesis
SLCC will be maintained at 15 yrs after surgery with STF in AIS. HRQoL scores of those pts will be similar with an age-gender-BMI matched population.

Design
Retrospective

Introduction
The purpose of this study was to evaluate the min 15 yrs natural history of uninstrumented compensatory lumbar curves in pts who underwent posterior STF, measure the HRQoL scores beyond 15 yrs after surgery and compare them with an age,gender and BMI matched population.

Methods
Group A included 43 female AIS patients who underwent STF with mean age 33(27-42) yrs and a mean of follow-up of 18.7(15-28) yrs and mean BMI 22(18-29).Preop early postop, and f/up x-rays were reviewed for the natural behavior of lumbar curves. Group B included randomly 43 female healthy individuals with mean age 33(27-41), and mean BMI 22(17-33).HRQoL scores were compared between the two groups in the latest f/up. The disc height and degenerative changes evaluated by using the latest x-rays between groups.Mann Whitney-U test was used for statistics.

Results
Posterior fusion was performed in all 43, with all pedicle screws used in 41 and all-hook constructs in 2. Main TH curve correction improved from pre-op to early post op and maintained at latest f/up (55,6°-16,1°-16,9°). SLCC was also maintained beyond 15 yrs (39,9°-16,6°-17,1°).Two pts (4,6%) with decompensation in early postop improved and became compensated in latest f/up.Mean HRQoL scores, self-image and mental health scores were higher in group A than group B (p<0.05).SRS-22r pain, function, ODI and VAS scores, marital status, number of children were similar between the groups (p>0,05) .All disc heights except (T11-T12 and L5-S1) were significantly lower in Group A(p< 0,05).There was no significant difference between the groups for degenerative changes in the latest x-ray.

Conclusion
Despite disc height narrowing, uninstrumented lumbar curve in STF maintains SLCC and does not show any significant degenerative changes at an average of 18 years.HRQoL scores suggested that the psychological and functional well-being were quite good in the long term in AIS patients who have undergone STF when compared with an age–gender–BMI matched population.

Take Home Message
Degenerative changes of lumbar curve of STF pts were mild and patients with STF showed higher HRQoL scores than with age-gender-BMI matched population at minimum 15 years follow up

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

85. Using Humerus Ossification and Cobb Angle to Predict Progression to Surgery in Scoliosis Patients†

Don Li, MS; Jonathan Cui, MD, BS; Stephen G. DeVries, BS; Joseph Kahan, MD; Logan Petit, MD; Ronan Talty; Daniel R. Cooperman, MD; Brian G. Smith, MD

Summary
We present a simple equation, Cobb Angle – (10 x Humerus Stage), for using humerus ossification in combination with Curve size to predict progression to surgery in scoliosis patients. We show that risk of curve progression is extremely well stratified by our formula and perform multiple linear regression analysis to show that these factors along with age are significant predictors of progression. Since this method uses only information present on routine spine radiographs, we believe this method will significantly improve the evaluation of scoliosis patients without increasing radiation exposure, time or cost.

Hypothesis
We hypothesize that our novel system of classifying the ossification of the humeral head, combined with the Cobb angle, can effectively predict which scoliosis patients will progress to the surgical range.

Design
We analyzed data from 202 patients (176 female and 26 male) with adolescent idiopathic scoliosis who were followed at least every six months between 2007 and 2017.

Introduction
We have previously demonstrated that proximal humeral ossification patterns are a reliable method for assessing a patient's relationship to peak height velocity. Here we evaluate how this system and Cobb angle perform with regards to predicting progression to surgery and validate our approach using multiple linear regression.

Methods
We analyzed 410 radiographs from 202 patients with adolescent idiopathic scoliosis who were followed at least every 6 months between 2007 and 2017. All patients had either undergone surgery or had finished monitoring after skeletal maturity. Each patient's age, sex, treatment status, bracing status, and curve size during a visit were recorded. Visits without complete information, postsurgical films, and films taken in brace were excluded. Multiple linear regression was performed on the factors age, sex, Cobb angle, shoulder score, and Risser sign.

Results
We demonstrate that humerus stage strongly correlates with the probability of curve progression. As expected, smaller curves and more mature stages yielded low rates of surgery (grey boxes) whereas greater curves and less mature stages yielded high rates of surgery (white boxes). Furthermore, we discovered that a simple formula, Cobb Angle – (10 x Humerus Stage) could easily summarize the risk of progression to a surgical range. Multiple linear regression validated that age, Cobb angle, and shoulder score were statistically significant in the prediction of which patients would progress to the surgical range. Together, the five factors showed an R value of 0.80 demonstrating excellent overall model performance.

Conclusion
Humeral head ossification can be used in combination with Cobb angle to accurately predict the rate of progression to surgery in scoliosis patients. An easy to remember formula, Cobb Angle – (10 x Humerus Stage) correlates extremely well with the risk of progression to a surgical range.

Take Home Message
Curve size combined with humerus stage accurately predicts which scoliosis patients will progress to the surgical range. Data can be usefully summarized by the equation Cobb Angle – (10 x Humerus Stage).

Regression Variable	P-Value	Significance
Age	3.6 * 10^-7	Significant
Sex	0.69	Not Significant
Cobb Angle	4.5 * 10^-78	Highly Significant
Shoulder	0.049	Significant
Risser	0.070	Borderline Not Significant

Shoulder Score	Number of Observations	Percent Progression	Relative Risk (Compared to All)
All	410	36%	1.00
Stage 1	13	84%	2.33
Stage 2	33	60%	1.66
Stage 3	159	41%	1.14
Stage 4	130	30%	0.83
Stage 5	75	14%	0.39

86. Core Outcome Set for Adult Spinal Deformity: An Initiative of the Scoliosis Research Society

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Summary
Healthcare providers managing adult spinal deformity (ASD) are under increasing pressure to demonstrate the value (the ratio of outcomes to costs) of treatment provided in the evolving reimbursement systems. A feedback loop involving standardized

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

routine outcomes measurement across the full cycle of care is an important prerequisite for improvement of outcomes and evidence-based decisions about cost-effectiveness. A modified-Delphi study was performed among SRS members to define such a standard set of outcomes for ASD.

Hypothesis
Consensus can be reached on a global core outcome set for ASD.

Design
modified Delphi study

Introduction
Outcomes should be standardized, comparable, risk-adjusted and should cover near- and longer-term health to achieve their full potential. Agreement on which outcomes to measure and report in the treatment of ASD does not yet exist. Study aim: to define a standard core outcome set (COS).

Methods
An SRS grant funded global modified 7-round Delphi study was performed; 6 online and 1 final face-to-face meeting. 25 panelists (98% response) participated to reach consensus (≥75% agreement) about outcome domains, measurement instruments and factors influencing outcome (case-mix and risk). This project was registered in Core Outcome Measures in Effectiveness Trials (COMET) database, and guidelines for COS development were applied, using the frameworks of ICF (WHO) and Porter's three-tiered outcome hierarchy.

Results
Consensus was achieved on domains that encompass the full cycle of care, including: survival (30-day mortality), degree of health/recovery (aspects of functional status), time to recovery (e.g. time to return to work), disutility of care (e.g. operative mortality, surgical site infection, nerve root injury), sustainability of health (e.g. 30-day readmission), and long-term consequences (e.g. implant breakage). Consensus was reached to use SRS-22r, ODIv2.1a, EQ-5D, NRS pain scale as PROMs to capture pain, function and health-related quality of life (Table Assessments COS ASD). Risk and case-mix factors related to demographics (e.g. age, expectations), clinical status (e.g. smoking status), surgical indication (e.g. magnitude and type of spine deformity) and procedure (e.g. duration of surgery) were defined.

Conclusion
This is the first global COS identified for ASD. When implemented in routine clinical practice, this set can provide quality outcome information to drive the improvement cycle and facilitate data sharing across (inter-) national institutions, potentially increasing the ability to perform predictive modeling and help identify which patients will benefit most from which interventions.

Take Home Message
When universally applied, a standardized COS for routine clinical practice in ASD can be used for evaluation and comparison of healthcare delivery, ultimately enhancing daily clinical practice.

Table 1. assessment schedule core outcome set ASD

Assessment Category	Assessments	Baseline Clinician: Index procedure Patient: pre-surgery		Follow up (12 months post-surgery ± 3 months)	
		Patient Reported	Clinician reported	Patient reported	Clinician reported
PROMs	Demographics	X			
	Expectation treatment outcome - Item	X			
	EQ5D-3L	X		X	
	SRS-22r	X		X	
	ODI v2.1a	X		X	
	NPRS (0-10) Back & Leg	X		X	
	Time to return to work*			X	
	Time to achievement of functional status*			X	
Clinical status	Neurological function		X		X
	Magnitude of preoperative scoliosis or kyphosis		X		
	Clinical relevance label (Scoliosis Kyphosis, Sagittal malalignment, Neurological compression)		X		
	Height (kg) & Weight (cm)		X		
	ASA physical status classification system		X		
	Osteoporosis		X		
	Depression		X		
	Diabetes Mellitus		X		
	Cardiovascular Disease		X		
Surgical procedure and hospital stay	Primary versus revision surgery		X		
	Type of procedure		X		
	Type of osteotomies		X		
	Staged procedure		X		
	Nr. of spinal levels operated		X		
	Nr. of fused vertebrae		X		
	Pelvic fixation		X		
	Blood transfusion		X		
	Duration of surgery		X		
	Dural tear/CSF leakage		X		
	Length of hospital stay		X		
	Operative mortality		X		
	Return to OR during hospital stay		X		
	Surgical site infection		X		
	Spinal cord injury		X		
	Nerve root injury		X		
Long term clinical status	30-day mortality #				X
	30-day readmission (need for re-hospitalization) #				X
	Need for revision or re-operation				X
	Implant failure (migration or breakage)				X
	Pseudarthrosis				X
	Progression of curve under/above instrumentation				X
	Disability due to complication*				X
	Pain due to complication*				X

*no specific assessment method defined yet; # register in primary data source (EMR) after 30 days
**follow-up 6 months post-op (±2 months) is optional

Table Assessments COS ASD

87. Defining a Surgical Invasiveness Threshold for Major Complications Following Adult Spinal Deformity Surgery

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Summary
Increasingly invasive Adult Spinal Deformity (ASD) surgery is associated with a higher risk of major complications. Using a previously validated continuous scale for measuring surgical invasiveness (the ASD Surgical and Radiographic (ASD-SR) invasiveness

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index) we found there is an increase in the risk of major complications with an invasiveness score above 90. Patients who undergo ASD surgery with invasiveness above this threshold have 1.9 times greater likelihood of developing a major complication after controlling for baseline frailty and radiographic deformity.

Hypothesis

There is a surgical invasiveness threshold that predicts increased likelihood of major complications following surgical treatment of Adult Spinal Deformity (ASD).

Design

Retrospective review of a multicenter database

Introduction

The risk of complications following ASD surgery in relation to surgical invasiveness measured on a continuous scale is unknown

Methods

574/760 (76%) eligible ASD patients (>5 levels fused) were identified in a multicenter database with complete 2-year follow-up. Surgical invasiveness was calculated according to the ASD Surgical and Radiographic (ASD-SR) invasiveness score, which assigns values to 13 operative and radiographic factors. Youden's index identified the highest predicted probability cut-off of developing a major complication to be an ASD-SR of 90. Using this value, patients were divided into quartiles (Q1: ASD-SR 0-65; Q2: ASD-SR 66-89; Q3: ASD-SR 90-119; Q4: ASD-SR 120+). Odds of developing a major complication were analyzed after controlling for baseline frailty and radiographic deformity.

Results

Mean age of patients was 59 ± 14 years, 79% females. Mean levels fused were 11.2 ± 4.3. The overall risk of a major complication was 17% in Q1, 21% in Q2, 35% in Q3 and 33% in Q4 (p<0.001). Comparing the odds of a major complication by adjacent quartiles demonstrated a significant increase between Q2 and Q3 (OR 1.8, 95% CI 1.03, 2.98), while the risk going from Q1 to Q2, and Q3 to Q4 were not significant (p<0.05). Similarly, patients above an ASD-SR cutoff of 90 (Q3/Q4) were 1.9 times more likely to have a major complication than Q1/Q2 (OR 1.9, 95% CI 1.3 – 2.9). The mean ASD-SR scores above and below this threshold were 120.7 ± 25.4 and 63.4 ± 16.8, respectively. There were no significant differences in the odds of having a minor complication or inpatient medical complication between invasiveness groups (all p>0.05).

Conclusion

ASD patients have an increased risk of major complications above an ASD-SR score of 90, while the risk of minor complications and inpatient medical complications is not significantly increased. The ASD-SR score can be used as a tool to counsel patients regarding these increased risks.

Take Home Message

The increasing risk of major complications following increasingly invasive ASD surgery plateaus with the invasiveness of surgery higher than an ASD-SR score of 90.

Complication. n=574	Overall	LOW. n=296	HI. n=278	P Value
Major complication	155 (27%)	56 (19%)	99 (36%)	**<0.001**
Neurologic complication	86 (15%)	33 (11%)	53 (19%)	**0.008**
Implant-related	119 (21%)	51 (17%)	68 (24%)	**0.033**
Revision surgery	143 (25%)	60 (20%)	83 (30%)	**0.008**
Dural tear	54 (10%)	18 (6%)	36 (13%)	**0.011**
Minor complication	222 (39%)	108 (36%)	114 (41%)	0.266
DVT	8 (1.3%)	3 (1.0%)	5 (1.8%)	0.735
PE	16 (2.8%)	5 (1.8%)	11 (4.0%)	0.099
Ileus	34 (5.9%)	20 (6.7%)	14 (5.0%)	0.383
Infection (requiring reoperation)	19 (3.3%)	4 (1.4%)	10 (3.6%)	0.081
Pneumonia	7 (1.2%)	2 (0.7%)	5 (1.8%)	0.221
PJK	79 (14%)	34 (11%)	45 (16%)	0.102
Mean ASD-SR Score in LOW Invasiveness group: 63		**Mean ASD-SR Score in HIGH invasiveness group: 120**		
Example: T11-Pelvis, 6 Smith-Peterson Osteotomies, -9cm change in SVA, +1° change in TK, + 4.3° change in PT.		**Example:** T8-Pelvis, 3-column osteotomy, -2.3cm change in SVA, -5° change in TK, +3.8° change in PT.		

88. Normalization of Worst Preoperative PROMIS Domain Predicts Patient Satisfaction with ASD Management After Fusion Surgery

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Summary

In this longitudinal study of ASD fusion patients, 564 PROMIS and SRS questionnaires were completed by 232 unique patients, and relative risk analysis was utilized to examine the relationship between the status of patients' worst preoperative PROMIS domain and satisfaction at follow-up. Our analysis determined that patients whose worst preoperative PROMIS domain remained abnormal at follow-up were less likely to be satisfied than those whose worst domain had normalized at all time points up to 1 year after surgery.

Hypothesis

Normalization of patients' worst preoperative PROMIS domain will predict patient satisfaction with ASD management

Design

Longitudinal study

Introduction

Understanding how improvements in troublesome symptoms affect patient satisfaction is of great clinical use. PROMIS is a multi-dimensional assessment that measures patients' pain, physical function, fatigue, anxiety, depression, sleep disturbance, and social satisfaction. The SRS patient questionnaire measures satis-

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Podium Presentation Abstracts

faction on a 5 point scale. The objective of this study is to investigate the potential relationship between the status of patients' worst preoperative PROMIS domain and their SRS satisfaction score.

Methods
Patients undergoing surgery for adult spinal deformity completed PROMIS and SRS questionnaires preoperatively and at 6 wks and 3, 6, 12, and 24 mo postoperatively between 11/2014 and 1/2019 (n = 564 visits for 232 unique patients). The PROMIS domain with the worst preoperative score was identified for each patient, and normalization of this domain score (>40/100 for physical function/social satisfaction; <60/100 for all others), was tracked at each point of follow-up. Relative risk analysis was conducted at each time point to assess whether patients whose worst PROMIS domain score had remained abnormal were less likely to have a SRS satisfaction score of 5/5 compared to patients whose score had normalized.

Results
Patients whose worst preoperative PROMIS domain score remained abnormal were found to be significantly more likely to not be satisfied (SRS satisfaction score <5) than patients whose worst domain score had normalized at 6 wks (RR 2.60, p<0.0001), 3 mo (RR 2.43, p<0.0001), 6 mo (RR 1.90, p=0.0012), and 12 mo (1.80, p=0.0084), but not at 24 mo follow-up.

Conclusion
These results suggest that a primary influence on patient satisfaction with ASD fusion surgery is the status of their most bothersome preoperative complaint, as measured by the PROMIS questionnaire. Patients whose worst domain remained abnormal at follow-up were more likely at all time points except 24 mo follow-up to be unsatisfied than patients whose worst domain had achieved a normal range score.

Take Home Message
Patients whose worst preoperative PROMIS domain continued to score within the abnormal range at follow-up were significantly less likely to be satisfied with their ASD management at several time points.

89. Long-term Follow-up Surgical Outcome of Young Adult Idiopathic Scoliosis: Comparison with Adolescent Idiopathic Scoliosis Ten or More Years of Follow-up

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Summary
This study is the first over ten years follow-up on surgical outcomes of pedicle screw instrumentation (PSI) in young adult idiopathic scoliosis (AdIS) and adolescent idiopathic scoliosis (AIS) in single idiopathic thoracic scoliosis. We conclude that insignificant different curve change in instrumentation levels, but lumbar compensation curve progressed in the AIS group. Distal adding-on deformity did not occur in the adult group and growth over AIS patients.

Hypothesis
The outcome of deformity correction with PSI in adolescent and young adult idiopathic scoliosis with a minimum 10-year follow-up was satisfactory.

Design
A retrospective study

Introduction
Treatment of idiopathic scoliosis with pedicle screw instrumentation is safe and effective in adolescence. However, there have been few reports in adult idiopathic scoliotic patients. The purpose was to compare the long-term surgical outcome of adult idiopathic scoliosis patients and adolescent patients.

Methods
Sixty-nine idiopathic scoliosis patients (32 adults and 37 adolescents) treated by segmental pedicle screw instrumentation were analyzed retrospectively with a minimum Ten-years follow-up. The radiologic and clinical outcomes were analyzed. The deformity correction and spinal balance evaluated by preop and postop standing PA and lateral radiographs. Measurements were made preoperatively, in 1 month, 2, 5, ten years and most recent follow-up. The association of late complications and spinal alignment was analyzed.

Results
The average age at the time of operation was 29.8 years (18~34) in adult and 14.2years (12~17) in adolescents. The method of determining the fusion range was the same between the two groups. The preop thoracic coronal curves were 57.2±8.9° in adults and 49.6±9.3° in adolescents. Curve corrected to 17.9±9° in adults and 14.4±6.8° at 1month after surgery and 19.4±7.8° in adults and 16.1±5.6° at most recent follow-up. The last follow-up surgical curve correction was not significantly different in the two groups (P>0.05). The non-instrumented lumbar curve of was much corrected in AIS at one month. Progressed compensatory lumbar curve in AIS at most recent follow-up but the coronal imbalance was not differenced significantly in both groups. There are no late complications that need revision surgery in both groups. No thoracic hypokyphosis or junctional kyphosis did not occur at most recent. Distal adding-on deformity did not occur in the adult group, and growth over AIS patients.

Conclusion
Long term follow-up idiopathic scoliosis of young adults and adolescent with pedicle screws efficiently corrected.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Take Home Message

Suk's AIS classification can apply in deformity correction with pedicle screw instrumentation with Neglected young AIS

90. Patient-related and Radiographic Predictors of Inferior Health-Related Quality of Life Measures in Non-Operative Adult Spinal Deformity Patients

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Summary

Non-operative adult spinal deformity (ASD) patients have historically been associated with inferior long-term spinopelvic alignment and clinical outcomes. Predictors driving lower patient-reported outcome metrics (PROMs) in the non-operative population have yet to be sufficiently investigated. Our study aims to identify salient patient-related factors and radiographic parameters over 2-year follow-up associated with health-related quality of life (HRQL) deterioration in non-operative ASD patients. Progressive frailty, BMI, and radiographic progression were found to drive increased disability and pain scores over a 2-year period

Hypothesis

Deterioration of patient-related and/or radiographic measures drives inferior HRQLs in non-op ASD patients.

Design

Retrospective review

Introduction

Non-operative ASD patients have historically been associated with inferior long-term spinopelvic alignment and clinical outcomes

Methods

Non-operative (N-Op) patients who met criteria for ASD(>18yrs, scoliosis≥20°, SVA≥5cm, PT≥25°, TK >60°) with complete radiographic and outcome data at baseline and 2Y were included. N-op patients and operative (Op) patients were propensity-score matched (PSM) for BL disability and deformity. Patient-related factors [age, BMI, CCI, frailty index] and radiographic parameters [SVA, PI-LL, PT, TS-CL, CTPA] at BL & 2Y were analyzed as predictors for moderate to severe 2Y ODI (>20) & failing to meet MCID for 2Y SRS(>+0.4 from BL). Conditional Inference Decision Trees(CIDT) established cut-off values and Random Forest Analysis generated 5000 CIDT to compute a variable importance table for top predictors of inferior HRQLs.

Results

662 ASD pts (331 Op and 331 N-Op) with matched BL deformity and disability were included. No differences in BL age, BMI, CCI, ODI, and Schwab deformity modifiers were noted between groups. N-Op pts had higher 2Y ODI (27.9vs20.3,p<0.001), higher rate of Mod-Severe disability (29.3vs22.4%,p=0.05), lower SRS Total (3.47vs3.91,p<0.001), and higher rates of failure to reach SRS MCID (35.3vs15.7%,p<0.001) than Op at 2Y. Table 1 shows top overall predictors for Moderate-Severe ODI at 2Y for N-Op:[1]frailty index>2.8 [2]BMI>35 [3]T4PA>28o [4] CCI>1. Top radiographic predictors were T4PA>28o, C2-S1 SVA>93mm, and PT>17o, respectively. Top predictors for failure to reach 2Y SRS MCID for N-Op:[1] T12-S1 lordosis>53o[2] cSVA>28mm[3] C2-S1 angle>14.5o[4]TS-CL>12o[5]PT>23o. Top radiographic predictors were T12-S1, cSVA, C2-S1, and TS-CL, respectively.

Conclusion

When controlling for baseline deformity in Non-Op vs Op patients, subsequent deterioration in frailty, BMI, and radiographic progression over 2-year follow-up were found to drive suboptimal PROMs in Non-Op cohorts.

Take Home Message

ASD patients with non-operative treatment had significantly worse PROMs after 2-year follow-up compared to operative counterparts. Progression of frailty and radiographic malalignment were significant drivers of inferior HRQL metrics.

HRQL Measure	Overall Rank	Factor Associated with Outcome	Thresholds	OR	Confidence Interval (95%)		P
					Lower	Upper	
ODI (Moderate to Severe)	1	High frailty index	>2.8	269.2	36.31	1998.0	*<0.001
	2	High BMI	>35	36.1	4.65	279.89	*<0.001
	3	High T4PA	>28°	36.0	4.65	279.88	*<0.001
	4	High CCI	>1 and ≤3	25.6	10.32	63.26	*<0.001
	5	High C2-S1 SVA	>93mm	17.87	6.00	53.35	*<0.001
SRS (No MCID)	1	High T12-S1 angle	>53°	65.18	29.27	145.15	*<0.001
	2	High cSVA	>28mm	15.2	7.31	31.68	*<0.001
	3	High C2-S1 angle	>14.5°	14.19	7.28	27.68	*<0.001
	4	High TS-CL	>12°	8.78	5.18	14.88	*<0.001
	5	High PT	>23°	5.96	3.26	10.90	*<0.001

Table 1: Radiographic predictors at 2Y of inferior PROMs of ODI and SRS.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

91. Lower Satisfaction after Adult Spinal Deformity Surgery in Japan Compared with the US Despite Similar SRS22 Pain and Function Scores: A Propensity Score Matched Analysis

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Summary
In this analysis, with propensity-score matching for age, gender, levels fused, and post-operative spinal alignment, corrective spine surgery for ASD was similarly effective in the US and JP patients based on multiple measures of health-related quality of life, including SRS-22 and ODI. However, the satisfaction score was lower in JP compared to US. It is possible that differences in lifestyle and cultural expectations may impact satisfaction following ASD surgery.

Hypothesis
Surgical treatment for ASD provides similar health-related quality of life (HRQL) improvement in the US and Japan.

Design
Multicenter retrospective case series with propensity score matching

Introduction
Surgical outcomes of thoraco-lumbo-sacral (TLS) spinal fusion for adult spinal deformity (ASD) patients who live in Asian countries is poorly understood. We compared the clinical outcomes of surgical treatment for ASD between the United States (US) and Japan (JP) in a propensity-score matched cohort.

Methods
300 surgically-treated primary ASD patients (US:195, JP105) with age >50y, lower-most instrumented vertebra (LIV) at pelvis, and minimum 2y follow-up were consecutively included (US vs. JP; age: 65±9 vs 64±9y). Patients were propensity-score matched for age, gender, levels fused, and 2y post-op sagittal spinal alignment (C7SVA, PI-LL, PT). Demographic, surgical, and radiographic parameters were compared between US and JP.

Results
186 patients (93 in each group) were matched by propensity score and were almost identical within these parameters: age (US vs. JP: 66 ± 8 vs. 65 ± 7y), gender (female:90 vs.89%), level fused (10 ± 3 vs. 10 ± 2), 2y C7SVA (5 ± 5 vs. 5 ± 4 cm), 2y PI–LL (9° ± 15° vs. 9° ± 15°), and 2y PT (25° ± 10° vs. 24° ± 10°). The chi-square parameter of the Hosmer-Lemeshow test for this propensity-score matching was 13.4 and the p value was 0.34, indicating good model adaptation. ODI, SRS-22 function, and pain were similar at 2y between US and JP (ODI 27±19 vs. 28±14%, p=.72; SRS-22 function 3.6±0.9 vs. 3.6±0.7, p=.54; SRS-22 pain 3.6±1.0 vs. 3.8±0.8, p=.11). However, significantly lower satisfaction was observed in JP (SRS-22 satisfaction 4.3±0.9 vs. 4.0±0.8, p<.01).

Conclusion
Corrective spine surgery for ASD was similarly effective for the improvement of pain and function in US and JP patients. However, satisfaction scores were lower in JP compared to US, despite propensity matching to adjust for post-operative spinal alignment and number of vertebral levels fused. Differences in life style and cultural expectations may impact satisfaction following ASD surgery.

Take Home Message
ASD surgery was similarly effective for improvement of HRQL in US and JP. However, SRS22 satisfaction was lower in JP. Lifestyle and cultural expectations may impact satisfaction in ASD surgery.

92 Effects of Post-operative Complications in Complex Pediatric Spine Deformity on SRS Scores: Does Complication Adversely Affect Quality of Life of Patients?

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Summary
220 pts from a multicenter database base were investigated for the effect of post-operative complications on SRS Scores. Post op complication did not adversely affect SRS Scores. Significant improvement in baseline SRS domains at 2yr post op was observed in both groups with or without complications

Hypothesis
Post-operative complications in complex deformity patients adversely affect long term Health Related Quality of life (HRQoL)

Design
Retrospective Review of Prospective multi center database

Introduction
Post-operative complications remain a major concern after complex spine deformities surgeries and may affect the quality of life of patients. This study sought to investigate the effect of post-op complications on long-term HRQoL using the SRS-22 tool.

Methods
Data of 312 pts from 17 clinical sites were initially reviewed.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

All had curve >100 or 3CO91 pts were excluded due to incomplete pre-and post op SRS scores. Data analysis for 220 pts was performed in Stata 14 software. Paired t-test was performed to compare pre-op and 2years SRS scores. Analysis was stratified by post op complication status.

Results

220/312 Pts (125F,95M). Avg. age 14.7yrs (10-20yrs). Deformity etiology was 40.4% idiopathic and 39.5% congenital. 88% pts had apex deformity in the thoracic region. Avg. pre-op BMI was 19.4kgm-2. Pre-op coronal cobb averaged 88.38 (0-175deg), pre-op sag. cobb 94.7 (4-176deg). 41.8% underwent pre-op HGT at an average 70 days (6-181days). Surgery was staged in 42 patients. 107 pts had VCR, 126 SPOs, and 121 posterior thoracoplasty. 96.8% pts required blood transfusion-op. SRS scores in all domains improved significantly at 2yr follow-up (Table IA). 68 complications (neuro 34, wound 4, implant 16, radiographic 7 and infection 7) occurred in 64 patients (29%). There was no significant difference in the 2yr SRS scores between patients who had complication and those without complications (P>0.05). Significant improvement in baseline SRS domains and total scores were seen in both groups at 2y post op, (see Table IB).

Conclusion

Baseline SRS scores improved in all domains irrespective of complication status. Both surgeon and patient can be encouraged to address any major complication to achieve a resolution noting the final outcome is favorable to improve the quality of life of patients.

Take Home Message

Complications arising from treatment of complex spine patients should be aggressively and readily addressed with the understanding that final clinical outcome is still very favorable

Table 1A: Average changes in baseline SRS scores at 2years Post-Op (All patients, N=220)

	Pre-op	2yr	Δ	p-value
Function	3.29	4.13	0.83	P<0.01
Pain	3.36	4.12	0.76	P<0.01
Appearance	3.76	4.38	0.62	P<0.01
Mental	3.49	4.22	0.72	P<0.01
Satisfaction	3.14	4.50	1.36	P<0.01
SRS Total	3.42	4.27	0.84	P<0.01

Table IB: Average changes in baseline SRS scores at 2 years Post-Op (stratified by complication status)

	Complication Status: No (N=156)				Complication Status: Yes (N=64)			
SRS-Domains	Pre-op	2yr	Δ	p-value	Pre-op	2yr	Δ	p-value
Function	3.30	4.14	0.83	P<0.01	3.27	4.10	0.82	P<0.01
Pain	3.36	4.13	0.77	P<0.01	3.36	4.10	0.74	P<0.01
Appearance	3.76	4.41	0.65	P<0.01	3.77	4.32	0.55	P<0.01
Mental	3.49	4.24	0.74	P<0.01	3.50	4.18	0.68	P<0.01
Satisfaction	3.09	4.55	1.45	P<0.01	3.25	4.39	1.13	P<0.01
SRS Total	3.41	4.29	0.87	P<0.01	3.44	4.21	0.77	P<0.01

Changes in baseline SRS scores at 2years Post-Op stratified by complication status

93. Surgical Standardization Improves Safety, Efficiency, and Outcomes in AIS Surgery and is Reproducible

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Summary

Standardization of surgical steps, preoperative workup, postoperative management, and anesthesia significantly improves surgical outcomes, safety, and efficiency in AIS patients. This standardization process, including dedicated team, is transferable between institutions.

Hypothesis

Surgical standardization steps improves safety and efficiency and is transferable between institutions

Design

Retrospective chart and XR review

Introduction

Standardized protocols in high risk situations have been shown to increase patient safety and outcomes. Scoliosis surgery is a complex procedure with potential risk and complications. In 2011, we implemented a standardized approach including preop workup, dedicated scoliosis surgery team (anesthesia, scrub tech, nurse, neuromonitoring), surgical steps, and postop care. The purpose of this study was to determine if standardization improves AIS surgery outcomes and its reproducibility.

Methods

Retrospective review of a prospective AIS database from 2009-2018 at 2 institutions. Two groups without standardization (G1) vs. with standardization (G2). Demographic, XR, and periop outcomes were recorded. In 2015, surgeons changed institution and implemented protocol. Reproducibility was determined between institutions (GA vs. GB). Protocol was enhanced by addition of pediatric hospitalists (2016) and Duramorph based recovery pathway(2018). Median(IQR), Kruskal-Wallis, and Fisher's exact test were used.

Results

325 AIS patients-G1:44, G2:281. Age(p=0.21), BMI(p=0.48), preop Cobb(p=0.48), postop Cobb(p=0.09), and correction(73%vs68%,p=0.39) were similar. Standardized protocol patients had lower EBL (700vs325,p<0.001), shorter anesthesia (437vs384,p=0.004), and surgical time (310vs248,p<0.001) and LOS(7vs5,p<0.001) but similar levels fused (13vs12,p=0.42), fixation points (25vs23,p=0.27) and complication rate (p>0.05). GA (n=101) and GB (n=105) were compared. Age (p=0.21), BMI (p=0.48), preop Cobb (p=0.48), postop Cobb (p=0.09), correction (69vs67,p=0.39) and complication rate were similar (p>0.05).

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EBL (500vs325,p<0.001), fusion levels (13vs12,p=0.03), anesthesia (438vs357,p<0.001), surgical time (301vs226,p<0.001), and LOS (7vs4,p<0.001) were significantly lower in GB.

Conclusion
A standardized AIS approach including dedicated operative team, pre and postop management, and streamlined surgical steps improves outcomes and efficiency. This team based approach is flexible, responsive, and reproducible.

Take Home Message
A standardized approach to AIS surgery improved patient safety and outcomes and can be transferred between institutions.

94. Health-related Quality of Life of Idiopathic Scoliosis: Comparison of Untreated Patients, Surgically Treated Patients and Normal Controls

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Summary
Comparison of health related quality of life (HRQOL); surgically treated patients who had more than 5 years f/up showed significantly higher scores on the self-image, function, pain and mental health domains than untreated patients who had min 5 years f/up after diagnosis and normal controls. Comparison of surgically treated patients, Cobb ≥50° vs Cobb <50° did not show any differences for all domains.

Hypothesis
There is a significant effect of surgical treatment over idiopathic scoliosis patients' HRQOL

Design
Retrospective study with normal controls

Introduction
There is uncertainty about treatment effects of AIS patients' long term quality of life. The aim of this study is to evaluate and compare HRQOL in untreated AIS patients with min 5 years f/up after diagnosis, surgically treated AIS patients with more than 5 years f/up and normal control

Methods
209 surgically treated patients (Mean age 25yrs & BMI 20.4) (G1 105 pts; Cobb ≥50°, G2 104 pts; Cobb <50°) with posterior surgery and min 5 years f/up, 97 untreated patients (Mean age 27yrs & BMI 21.3) (G3; Cobb ≥20° and had min 5 years f/up after diagnosis),68 normal controls(G4; mean age 28yrs & BMI 22) were included. SRS-22r questionnaire domains(Pain, self-image, function and mental health) were used to measure HRQOL. One-way ANOVA were performed for statistical analysis

Results
Surgically treated patients(G1&G2) had significantly higher scores than untreated and normal control(pain; p<.01 and self-image; p<.05) according to SRS22r pain and self- image domains. Normal controls' scores were much better than untreated patients(pain; p<.01 and self-image; p<.05). According to function domain; surgically treated patients'(G1&G2) scores were significantly higher than untreated patients (p<.001) but similar with normal controls(p=.414). For mental health domain; surgically treated patients'(G1&G2) had higher scores than both untreated patients and normal controls. Whereas untreated patients and normal controls' outcomes were similar(p=.304). Subgroup analysis of surgically treated patients(Cobb ≥50° vs Cobb <50°) did not show any difference for all SRS-22r domains (p>0.05)Table1

Conclusion
Surgically treated patients showed significantly higher scores on the self-image, function, pain and mental health domains than untreated patients and normal controls. Surgically treated patients have similar functionality with normal controls but better than untreated patients. Comparison of surgically treated patients according to Cobb angle(≥50° vs <50°) did not show any differences for all domains

Take Home Message
Comparison of health related quality of life; surgically treated patients had higher scores on SRS-22r domains and Cobb angle did not show any differences for all domains

Table.1		Group	N	Mean	SD
Pain	Surgically treated (≥50°)	G1	105	22.02	2.87
	Surgically treated (<50°)	G2	104	21.93	2.59
	Untreated	G3	97	15.41	2.29
	Normal Controls	G4	68	18.95	5.82
Self-Image	Surgically treated (≥50°)	G1	105	20.42	3.53
	Surgically treated (<50°)	G2	104	20.41	3.38
	Untreated	G3	97	15.12	3.87
	Normal Controls	G4	68	18.58	5.76
Function	Surgically treated (≥50°)	G1	105	22.07	2.98
	Surgically treated (<50°)	G2	104	22.35	2.51
	Untreated	G3	97	18.49	3.97
	Normal Controls	G4	68	21.15	5.89
Mental Health	Surgically treated (≥50°)	G1	105	19.39	2.88
	Surgically treated (<50°)	G2	104	19.42	3.60
	Untreated	G3	97	15.70	2.61
	Normal Controls	G4	68	16.72	5.84

Mean values of HRQOL

Mean values of HRQOL

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95. Concomitant Low-grade Isthmic Spondylolisthesis Does Not Affect the Course of AIS

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Summary

Of 1531 consecutive teenagers with AIS, 120 were found to have low-grade L5 isthmic spondylolisthesis giving a prevalence of 7.8%. In comparison to a pair-matched AIS control group without spondylolisthesis, no differences were found concerning curve type, treatment modalities (observation, bracing, surgery), and outcome. Both pathologies can be treated separately according to generally accepted rules.

Hypothesis

Concomitant isthmic spondylolisthesis may affect the course and outcome of AIS

Design

Retrospecticve single-institution clinical and radiologic comparative study with pair-matched controls

Introduction

Spondylolisthesis with scoliosis occurs in 6.2-43% of patients. No data on clinical impact is available. Purpose was to determine the prevalence of the pathology and to study if it affects the course or outcome of AI

Methods

Study group (S): 120 patients with AIS and L5 slip of Ø15.0(8.3)% out of 1531 AIS patients, aged Ø13.9(1.8)y, primary curve Ø29.2(11.5)°. Control group(C): pair-matched for age, gender, Cobb angle, and apex level of the main curve. Radiographs, patient records, follow-up Ø4.4(4.3)y. Radiographic measurements by a single experienced spinal radiologist. Surgery data from patients' records and National Inpatient Registry; f-up Ø25.4(2.8)y. PROMs: ODI; NRS for pain; modif. SRS-24; WHOQoL; f-up Ø26.4(2.8)y. β^2statistics and t-tests, significancy level at <0.05.

Results

There was no difference between the study group (n=120) and the patients with AIS only (n=1411) concerning age (13.9y/13.8y), gender distribution(86.9%/83.3% female), primary Cobb angle (29.2°/28.9°),and curve type (Thoracic: 67.5%/62.1%; Th-lumbar: 25.0%/25.0%; Lumbar : 7.5%/13,0%). In comparison S/C: Back pain interfering with ADL had 4.2/1.7%, at admission and 2.6/4.2% at clinical follow-up (n.s.). Between groups S/C, no significant difference concerning treatment: bracing for scoliosis 48.3/46.6%, surgery for scoliosis 10.8/10.2%. Response rate for PROMs: 54.9/45.1%. Responders and non-responders were comparable in age, gender, Cobb angle, slip%, pain, f-up time. Outcomes were comparable: ODI: 5.6 / 6.2%; NRS-back pain 2.6/2.1, leg pain: 1.3/1.4; modif. SRS-24: 80.8/81.3; WHOQoL: Physical 81.0/78.5, Psychological 75.2/71.5, Social: 76.3/75.0, Environment 81.9/78.7. . In group S, 12/120(10%) patients had fusion for spondylolisthesis

Conclusion

In a consecutive series of 1531 teenagers with AIS, the prevalence of low-grade isthmic L5 spondylolisthesis was 7.8%. Compared to pair-matched controls, spondylolisthesis did not affect clinical or radiographic course or patients' outcome of AIS.

Take Home Message

Results prove the strategy to treat each of the two pathologies separately according to generally accepted rules.

96. How Does Pelvic Incidence Change in Low-Grade Spondylolisthesis in Association with Listhesis Progression?

Abdulmajeed Alzakri, MD, MS; Julie Joncas, RN; Hubert Labelle, MD, FRCS(C); Stefan Parent, MD, PhD; Soraya Barchi, BS; Jean-Marc Mac-Thiong, MD, PhD

Summary

We followed a cohort of 301 patients presenting with low-grade spondylolisthesis at a single institution for a minimum of two years. Pelvic incidence increased significantly during follow-up, but the changes in pelvic incidence were not associated with progression of spondylolisthesis in terms of slip percentage and lumbosacral angle. Pelvic incidence is not likely to be a risk factor for progression in low-grade spondylolisthesis.

Hypothesis

A change in pelvic incidence is related to progression of spondylolisthesis.

Design

Retrospective analysis of a prospective cohort of 301 patients with low-grade spondylolisthesis.

Introduction

Observational studies suggest that the majority of low-grade patients treated nonoperatively will have a successful clinical outcome. However, the changes in pelvic incidence as related to risk of progression remains unknown.

Methods

The complete records of 301 prospective patients (129 males 172 females) with low-grade spondylolisthesis aged 12.3 years ± 3.1 years were reviewed. Radiological parameters (pelvic incidence, lumbosacral angle and percentage of slip) were measured at the first visit and at a minimum 2-year follow-up. Patients with an in-

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crease in pelvic incidence by more than 5 degrees at last follow-up were included in group 1, and otherwise included in group 2.

Results
The average follow-up time is 4.6±2.3 years. The slip percentage was 14.6±8.8 at initial visit and 15.8±9 at last follow-up (P<0.05). There were 66 patients in group 1 and 233 patients in group 2. There was no difference in slip progression or lumbosacral progression between the two groups. The pelvic incidence was 56.1±12.9 at initial visit and 58.7±13.4 at last follow-up (P<0.05). There was a significant increase in pelvic incidence during follow-up. The change in pelvic incidence was not related to lumbosacral angle or slip percentage.

Conclusion
Pelvic incidence increased significantly during follow-up, but the changes in pelvic incidence were not associated with progression of spondylolisthesis in terms of slip percentage and lumbosacral angle. Pelvic incidence is not likely to be a risk factor for progression in low-grade spondylolisthesis.

Take Home Message
Pelvic incidence increases during growth. Pelvic incidence is not likely to be a risk factor for progression in low-grade spondylolisthesis.

97. Opportunities to Improve the Outcome of Surgical Treatment in High-Grade Spondylolisthesis

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, MS, PT; Hubert Labelle, MD, FRCS(C)

Summary
We studied the quality of life (QOL) of a prospective cohort of 61 young patients undergoing surgery for high-grade L5-S1 spondylolisthesis. Preoperative QOL was the most important predictor of postoperative QOL but it is non-modifiable. Decreasing L5 incidence to <64° was a significant modifiable predictor of postoperative QOL and balanced pelvis, and could be used intraoperatively as a guide to optimize the outcome. Correction of slip percentage and lumbosacral angle were not predictors of QOL or pelvic balance.

Hypothesis
Surgical reduction of high-grade L5-S1 spondylolisthesis is associated with improvement in quality of life (QOL) and pelvic balance in young patients

Design
Multicenter prospective cohort study

Introduction
The principles of surgical reduction for young patients with high-grade L5-S1 spondylolisthesis remain unclear, mainly because the associations between QOL, pelvic balance and goals of surgical reduction have not been investigated thoroughly.

Methods
A prospective cohort of 61 patients (14.4±2.7 years) with high-grade lumbosacral spondylolisthesis was followed for a minimum of 2 years after surgery. SRS-22 scores were assessed before surgery and at latest follow-up. Postoperative slip percentage, lumbosacral angle, L5 incidence and pelvic balance were measured. Achieving interbody fusion and fusion up to L4 and/or down to the ilium were also noted. Classification and regression tree analysis were used to identify predictors of improved postoperative QOL and pelvic balance.

Results
Achieving adequate postoperative pelvic balance was more likely with L5 incidence to <64°. Improved postoperative function and self-image were mainly associated with L5 incidence to <80°. Postoperative total, pain and mental health scores were mainly associated with corresponding preoperative scores. However, postoperative slip percentage and lumbosacral angle were not related to QOL or pelvic balance. Achieving interbody fusion and fusion up to L4 and/or down to the ilium were not predictive of postoperative pelvic balance or QOL.

Conclusion
Preoperative QOL was the most important predictor of postoperative QOL in young patients with high-grade spondylolisthesis, but it is non-modifiable. Decreasing L5 incidence to <64° was a significant modifiable predictor of postoperative QOL and adequate pelvic balance, and could be used intraoperatively as a guide to optimize the outcome. Correction of slip percentage and lumbosacral angle were not predictors of QOL or pelvic balance. Future study should include a larger number of patients to identify the optimal technique for performing surgical reduction.

Take Home Message
Decreasing L5 incidence to <64° could be used intraoperatively as a guide to optimize the outcome when performing surgical reduction of high-grade spondylolisthesis in young patients.

98. Spinal Deformity in Long-term Survivors of Childhood Sarcoma

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*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Summary

Major spinal deformities as a result of treatment occur in approximately one-third of long-term survivors of childhood sarcoma. Of 69 patients with spinal deformities after treatment of childhood sarcoma, 5.8% had major curves at the time of diagnosis, 29% before skeletal maturity, and 61% at final follow-up (average 35.6 years). Five required surgical correction. The average rate of progression in the growing spine was 2.16 degrees/yr; progression after maturity was 0.56 degrees/yr.

Hypothesis

Long-term sarcoma survivors may develop major spinal deformities before and after skeletal maturity as a result of treatment.

Design

Retrospective review.

Introduction

Spinal deformities can occur from treatment in survivors of childhood sarcoma. This study aimed to characterize these deformities, track progression, and identify risk factors

Methods

Medical records and imaging studies from 1964-2018 from the Lifetime Cohort Study identified 580 sarcoma survivors of whom 367 agreed to participate; 108 were diagnosed with spinal deformity (scoliotic minor [10 to 20 degrees] and major curves [>20 degrees] and kyphosis >50 degrees). After exclusion of patients without measurable imaging studies or follow-up images, the study group comprised 69 patients, 34 males and 35 females. Treatment of 42 primary axial sarcomas and 27 appendicular sarcomas was primary tumor resections (66), chemotherapy (67) and radiation therapy (44). Average clinical follow-up was 35.6 years; average radiographic follow-up, 19.8 years. Average age at tumor diagnosis was 10.2 years.

Results

At tumor diagnosis, 16 patients had spinal deformity, 12 minor curves and 4 major curves. Before maturity (18 years), 52 had spinal deformity, 20 with major curves. At last follow-up 69 patients had spine deformity with 42 having major curves. Major curves were found in 5.8% of the 69 patients at the time of diagnosis, 29% before maturity, and 61% at final follow-up. Surgical treatment was required for progressive deformity in 5 patients; all had rib resection during tumor treatment. The average rate of progression in growing spine was 2.16 degrees/yr and after maturity, 0.56 degrees/yr.

Conclusion

The frequency of spinal deformity in long-term sarcoma survivors was 29.4%; 5 required surgery for progressive deformity. The prevalence of major spinal deformity increased from 5.8% at diagnosis, 29% prior to maturity, and 61% at long-term follow-up. The rate of progression during growth was 2.16 degrees/yr and after maturity to final follow-up, 0.56 degrees/yr. Rib resection during tumor treatment appears to be a risk factor for deformity progression.

Take Home Message

Long-term sarcoma survivors, especially those with rib resection for tumor treatment, should be monitored with long-term follow-up to identify and, if necessary, treat spinal deformities that develop or progress.

99. Vertebra Plana in Children Can Be Due to Etiologies Other than Eosinophilic Granuloma

Fady Baky, MD; Todd Milbrandt, MD, MS; Matthew T. Houdek, MD; A. Noelle Larson, MD

Summary

Eosinophilic granuloma is a common cause of vertebra plana, but other etiologies must be considered. In a series of 27 pediatric patients presenting with vertebra plana, 19% had an underlying malignancy.

Hypothesis

Vertebra plana in children can be due to multiple etiologies other than eosinophilic granuloma.

Design

Retrospective review.

Introduction

Vertebra plana in the pediatric population presents a diagnostic dilemma for orthopedists. This radiographic finding historically was thought to be pathognomonic for eosinophilic granuloma (histiocytosis X); however, vertebra plana may also be caused by a range of other conditions.

Methods

Our institutional electronic medical record was searched between 1976 and 2017 for all patients under the age of 18 whose clinical record included the term "vertebra plana." Patients with a history of trauma were excluded. Medical records, imaging, pathology reports, and clinical outcomes were reviewed. Vertebral collapse was described using a previously described classification: Type 1 (<50% collapse), type II (50-100% collapse), type A (symmetrical) and type B (asymmetrical) collapse, the location of each lesion was reviewed (Table). Mean follow-up was 8.4 years.

Results

27 patients met inclusion criteria (mean age, 9.1 years; 12 females, 15 males). Twelve patients were diagnosed with eosinophilic granuloma (42%). An additional 6 patients had other neoplastic etiologies (21%), including acute lymphoblastic leukemia, primary germ cell tumor, and teratoma. 52% had type II lesions (>50% loss of height). Comparing patients with eosinophilic granuloma

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vs. those with other diagnoses, there was no difference in the frequency of type I (<50%) or type II (50-100% loss of height, p = 0.67), and no difference in the frequency of Type A symmetrical or Type B asymmetrical loss of height (p = 0.14). Multiple vertebral involvement was not related to diagnosis. Back pain was the most common initial complaint in both patients diagnosed with eosinophilic granuloma (83%) and those with other final diagnoses (73%) (p = 0.53). Thoracic vertebrae were the most commonly involved in both patients with eosinophilic granuloma (67%) and other diagnoses (64%).

Conclusion

Eosinophilic granuloma is a common cause of vertebra plana, but other etiologies must be considered. Moreover, pain, location, and degree of collapse were not predictive of the diagnosis.

Take Home Message

Patients presenting with vertebral plana and back pain need a comprehensive workup to determine diagnosis and treatment. 19% of vertebra plana patients had an underlying malignancy.

	Gender	Age	Level	Class	Presentation?	Diagnosis
1	M	6	L4	IIA	Back Pain	Eosinophilic Granuloma
2	F	11	T11	IIB	Back Pain	Eosinophilic Granuloma
3	F	13	T6, T8	IIA	Incidental Finding	Eosinophilic Granuloma
4	M	2	L1	IA	Back Pain	Primary Germ Cell Tumor
5	M	12	T7	IIA	Back Pain	Idiopathic
6	M	5	T4	IA	Orbital Swelling	Eosinophilic Granuloma
7	M	2	L4	IA	Back Pain	Eosinophilic Granuloma
8	M	12	T6	IA	Lower Extremity Deformity	Spondylometaphyseal Dysplasia
9	F	8	T7	IB	Back Pain	CRMO
10	F	15	T2	IA	Back Pain	Eosinophilic Granuloma
11	M	10	L2	IIA	Back Pain	Eosinophilic Granuloma
12	M	9	T12	IIA	Back Pain	Eosinophilic Granuloma
13	M	12	T10	IIA	Back Pain	Eosinophilic Granuloma
14	M	6	C4	IA	Neck Pain	Eosinophilic Granuloma
15	F	11	T7	IB	Back Pain	CRMO
16	F	3	L2	IIA	Sacral Mass	Teratoma
17	F	10	T5	IA	Back Pain	Eosinophilic Granuloma
18	M	0.2	L2	IIA	Prenatal Ultrasound	Osteogenesis Imperfecta
19	F	9	T4, T5, T6, T7	IIA	Back Pain	Idiopathic
20	F	10	T2	IA	Back Pain	Idiopathic
21	F	18	L5	IIB	Back Pain	Giant Cell Tumor
22	F	20	T3	IIB	Back Pain	CRMO
23	M	8	T10, T11, T12	IB	Back Pain	ALL
24	F	10	T8-L4	IB	Back Pain	ALL
25	M	11	T6	IIB	Back Pain	Eosinophilic Granuloma
26	M	0	T9-L2	IIA	Incidental Finding	Osteogenesis Imperfecta
27	M	16	L3	IA	Back Pain	Primary Rhabdomyosarcoma

100. Neurologic Deficit Improved with the Correction of Rotatory Subluxation using Pre-operative Halo-gravity Traction in Severe Neurofibromatosis Type 1 and Congenital Scoliosis

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Summary

Pre-operative Halo-gravity traction (HGT) has been proven to be helpful for the correction of coronal curve and sagittal kyphosis, improvement of pulmonary function and decrease of the rotatory subluxation (RS) in NF1 and CS patients. In the current study, we demonstrated that the neurologic deficit could benefit from the pre-operative HGT treatment as well. Therefore, the pre-operative HGT can be considered as an optimal and safe option for the neurologic deficit in severe NF1 and CS patients with RS.

Hypothesis

The pre-operative HGT is helpful for the improvement of neurologic deficit in severe NF1 and CS patients with RS.

Design

Retrospective review

Introduction

The RS is associated with more severe spinal deformity and more neurologic deficits in kyphoscoliosis. The objective of this study is to evaluate the efficacy and safety of pre-operative HGT in the treatment of neurologic deficit in severe NF1 and CS patients with RS.

Methods

NF1 and CS patients with neurologic deficit and RS undergoing HGT between June 2001 and September 2016 were reviewed. The coronal Cobb angle, sagittal global kyphosis (GK), RS measured on coronal plane (CRS) and on sagittal plane (SRS), and axial rotation (AR) were measured at pre-, post-traction and post-operation. The forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1), as well as neurologic function,were recorded at pre- and post-traction. The comparison between pre-traction and post-traction was performed using paired samples t test.

Results

A total of 15 patients including 8 NF1 and 7 CS patients were included in the study with an average age of 15.7±4.0 years. The average duration of HGT was 69.3±12.6 days, during which the average Cobb angle improved from 109.8±30.1° to 87.7±30.2° (P<0.001), and the GK decreased from 80.9±19.4° to 62.4±20.7° (P=0.003), respectively. At pre-traction, the CRS and SRS values were 9.9±5.5mm and 6.8±3.1mm, which significantly improved to 6.0±3.9mm (P<0.001) and 5.4±1.9mm (P<0.001), respectively.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

The average improvement in FVC and FEV1 were from 40.7% to 51.7% predicted and from 41.8% to 49/5% predicted, respectively. The Frankel scores were C in 5 patients and D in 4 patients at pre-traction. After HGT, the Frankel scores improved from C to D in 3 patients, from D to E in 2 patients. The Frankel scores of 2 patients with C and 2 patients with D were not significantly improved, and no deterioration in neurologic function was observed during HGT.

Conclusion

The pre-operative HGT is a safe option for severe NF1 and CS patients with neurologic deficit and RS

Take Home Message

The neurologic deficit can be improved with the correction of rotatory subluxation using pre-operative Halo-gravity traction in severe neurofibromatosis type 1 and congenital scoliosis.

101. Degenerative Paraspinal Muscles Impact Thoracic Spine Compensation in ASD Patients

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Summary

For adult spinal deformity (ASD) patients, compensatory flattening of thoracic kyphosis to maintain an erect posture has previously been hypothesized to vary with muscle quality. Using CT imaging to measure fat infiltration of the paraspinal musculature, this study shows a significant positive association between magnitude of thoracic kyphosis and extent of fat infiltration. Patients with a percentage of fat infiltration above 35% were older and heavier, and had larger TK, TPA and PT without a significant difference in lumbar deformity.

Hypothesis

Paraspinal muscle degeneration may reduce recruitment of thoracic compensation

Design

Retrospective review of a prospective database

Introduction

Flattening of the thoracic spine is a compensatory mechanism for adult spinal deformity (ASD). Studies show younger ASD patients recruit more thoracic flattening than older patients, which may be explained by differences in muscle quality

Methods

ASD patients with a spino-pelvic deformity (PI-LL + or ++), no previous thoracic fusion, and pre-op CT imaging were included. With CT Multi Planar Reconstructions (MPR), muscle analysis was conducted at T2, T10, and L3 (3 slices per level) by evaluating the cross sectional area (CSA) of the erectors as well the content of fat infiltration (Fat) (defined as -190 to 0 Hounsfield Units). The maximum fat infiltration (MaxFat) was determined by taking the muscle with the largest percentage of Fat. After Pearson correlation analysis, the cohort was separated into 2 groups: high Fat (HFat) and Low Fat (LFat) based on MaxFat threshold of 35%. Demographics and radiographic parameters including TK and PT were compared between groups

Results

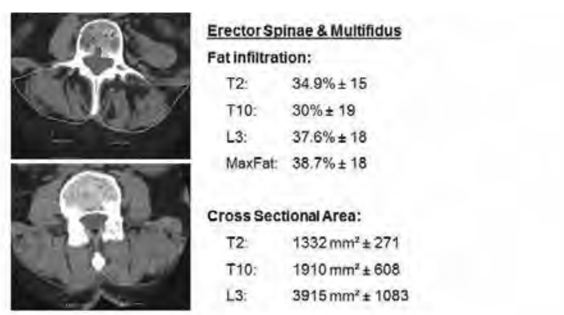
Included: 57 patients (mean age 61 yrs, 75%F, BMI 28), 26% of whom had a fused lumbar spine. Sagittal malalignment was severe, with 90% of PT modifiers and 75% of SVA modifiers qualifying as + or ++. TK correlated significantly with Fat at all levels (all r>-0.45), MaxFat (r=-0.47) and CSA at T10 (r=-0.341). PT was correlated significantly with MaxFat (r=0.333) and Fat only at T10(r=0.548). After grouping, 31 pts were HFat and 25 pts were LFat. HFat pts were older (64.2 vs 56.3, p=0.047), and had higher BMI (30.1 vs 25, p=0.002) than LFat; there were no differences in gender or revision status. HFat pts had a higher TPA (30.7° vs 23.7°), TK (-34.6° vs -22.9°) and PT (30.1° vs 25.2°), than LFat pts, but did not differ in lumbar deformity or other sagittal parameters

Conclusion

Patients with degenerative paraspinal muscles have less compensation in the thoracic spine, despite similar lumbar alignment, causing greater pelvic compensation. This may affect overall balance and gait

Take Home Message

Significant association was found between fat infiltration and lack of thoracic compensation in treated ASD patients. High fat infiltration was associated with a larger thoracic kyphosis without difference in PI-LL



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102. Association of Higher Frailty Score and Lower Self-care Activity with Sagittal Spinopelvic Malalignment in the Elderly Population

Tae Woo Kim, MD; Jae Keun Oh, MD; Jong Joo Lee, MD; Yoon Ha, MD

Summary

Frailty increases the risk of catastrophic declines in health among older adults. The aim of this study was to explore association between sagittal spinopelvic alignment and frailty in elderly patients with degenerative lumbar diseases. Eight-seven patients over the age of 75 years were retrospectively reviewed. Their radiographic parameters, activities of daily living(ADLs), instrumental ADLs and FRAIL scale were included in analysis. Higher FRAIL scale was associated with higher grades of sagittal spinopelvic malalignment and ADLs in the elderly.

Hypothesis

Higher FRAIL scale was associated with higher grades of sagittal spinopelvic malalignment and ADLs in the elderly population.

Design

A cross-sectional study

Introduction

Frailty increases the risk of catastrophic declines in health and function among older adults. The relationship between frailty and spinal health has not been well investigated. The aim of this study was assess the relationship between frailty, activities of daily living (ADLs), instrumental ADLs (IADLs) and sagittal spinopelvic parameters in elderly patients with degenerative lumbar diseases.

Methods

Eighty-seven patients over the age of 75 years were retrospectively reviewed. Their sagittal spinopelvic parameters (C7 sagittal vertical axis [SVA], T1 pelvic angle [T1PA], pelvic tilt [PT], pelvic incidence [PI], lumbar lordosis [LL]), FRAIL scale, ADLs, and IADLs were included in the analysis. Multiple regression analysis was performed to identify association between frailty and sagittal spinopelvic parameters.

Results

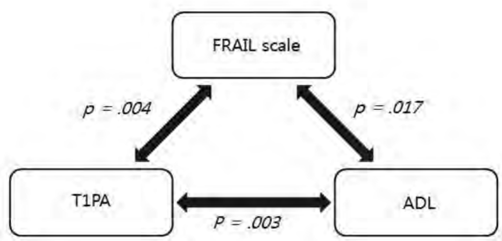
An average of 77.9±2.76 were recorded. Pearson analysis demonstrated that FRAIL scale had significantly correlations with SVA (r=.258, p=.016), T1PA (r=.309, p=.004), PT (r=.349, p=.001), PI–LL value (r=.371, p<.001), ADL (r=.255, p=.017). ADLs had correlations with T1PA (r=.311, p=.003), PT (r=.239, p=.026). IADL had correlations with SVA (r=.334, p=.002), T1PA (r=.345, p=.001), PT (r=.210, p=.050), PI-LL (r=.268, p=.012). Multiple regression analysis confirmed the associations between FRAIL scale and SVA, T1PA, PT, as well as PI-LL (β=.244, p=0.027; β=.269, p=3015; β=.316, p=.004; β=.335, p=.002, respectively).

Conclusion

Higher FRAIL scale was associated with higher grades of sagittal spinopelvic malalignment and ADLs elderly patients with degenerative lumbar diseases. Furthermore, higher ADL and IADL scores were associated with the severity of sagittal spinopelvic malalignment. Frailty, ADLs, and sagittal spinopelvic parameters were closely associated to each other in the elderly. Therefore, elderly population with sagittal spinopelvic malalignment should be carefully considered in frailty as well as activities of daily living.

Take Home Message

Frailty, ADLs, and sagittal spinopelvic parameters were closely associate to each other in the elderly patients with degenerative lumbar disease.



Relationship between three variables. T1PA is T1 pelvic angle, ADL is activities of daily living

103. Does Clinical Photography Influence Satisfaction with Surgery in Adult Patients Operated on Spinal Deformity?

Cristina Madrid de la Serna, MD; Alejandro Gomez-Rice, MD; Felisa Sanchez-Mariscal, PhD; Iria Vazquez Vecilla, MD; Lorenzo Zuniga, MD; Enrique Izquierdo, PhD

Summary

This is a non-concurrent prospective study approved by the Institutional Research Ethics Committee providing the first evidence that patient satisfaction and self- image may improve after adult spinal deformity surgery by the use of clinical photography. Patients experienced a statistically significant improvement in both SRS satisfaction and self-image domains after showing them their preop- and final follow up clinical photographs.

Hypothesis

Satisfaction and self-image in patients operated on for adult deformity is affected by showing patients their pre and postoperative full body photographs.

Design

Single center-single surgeon non concurrent prospective study

Introduction

Recently published data suggest that showing patients operated on

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adolescent idiopathic scoliosis or kyphosis their pre- and postoperative photographs may enhance their satisfaction and self-image, as measured by SRS 22 scores. No data exist for adult spinal deformity (ASD) surgery.

Methods

Inclusion criteria: age at surgery older than 25 years, longer than 2-year postoperative follow-up, having undergone a 5 or more levels fusion for idiopathic or degenerative scoliosis with main Cobb angle greater than 40º, sagittal and/or coronal imbalance greater than 5cm, T3-T12 kyphosis greater than 80º, thoracolumbar kyphosis greater than 20º. Exclusion criteria: tumours, neuromuscular, congenital or traumatic deformity. Two follow-up visits were arranged, 7 days apart. In the first visit patients completed the SRS-22 questionnaire and full body photographs were taken from anterior, posterior, and lateral views in both the upright and forward bending positions. In the second visit patients were asked to complete again questions 4, 6, 10, 14, 19 (self-image), 21 and 22 (satisfaction) of the SRS-22 after seeing their pre- and postoperative full body photographs.

Results

Thirty patients (28 female). Median age at surgery 50 (26-76). Median follow 51 months (24-120). Median fused levels was 13 (range 5-18). 24 posterior approaches, 6 combined anterior and posterior approaches. -SRS-22 at first visit: Activity 2.79 ± 0.75; Self-image 2.71 ± 0.82; Pain 2.53 ± 1.10; Mental Health 3.08 ± 0.77 Satisfaction 3.46 ± 1.20; Global 2.74 ± 0.72. -SRS22 at second visit: Self Image 2.9 ± 0.75; Satisfaction 4.02 ± 0.97. After seeing the pre and final follow-up photographs patients experienced an improvement in SRS-22 self-image (P=0.000) and satisfaction domains (P=0.011).

Conclusion

In patients operated on ASD, showing pre and postoperative photographs improves patient satisfaction with surgery and self-image.

Take Home Message

Introducing full body clinical photographs as a routine clinical tool in adult deformity patients undergoing surgery may enhance patient satisfaction with the care received.

104. What is the Optimal Postoperative Sagittal Alignment in Ankylosing Spondylitis-related Thoracolumbar Kyphosis Following One-level Pedicle Subtraction Osteotomy?

Jichen Huang, MD; Bangping Qian, MD; Yong Qiu, MD; Bin Wang, MD; Yang Yu, MD; Feng Zhenhua, MS; Junyin Qiu; Hongbin Ni, MD

Summary

To date, the optimal sagittal spinopelvic alignment following corrective osteotomy for thoracolumbar kyphosis caused by ankylosing spondylitis (AS) was still unclear. This study aimed to determine the optimal sagittal alignment in AS-related thoracolumbar kyphosis after one-level pedicle subtraction osteotomy (PSO).

Hypothesis

The optimal sagittal alignment at a minimum of two-year follow-up might be determined through regression analysis.

Design

A retrospective study.

Introduction

The study aimed to comprehensively investigate the relationship between radiographic parameters and clinical outcomes measured by Oswestry Disability Index (ODI) and Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) in thoracolumbar kyphosis caused by AS following PSO and to determine the optimal sagittal alignment at a minimum of two-year follow-up.

Methods

Ninety AS patients (82 males and 8 females) with thoracolumbar kyphosis who had undergone one-level PSO from March 2006 to August 2016 were included in this study. The spinopelvic parameters included TK, LL, GK, PT, SS, PI, SVA, SSA, TPA, SPA, and osteotomized vertebra angle (OVA). ODI<20 at the final follow-up was defined as good clinical outcome in this study.

Results

The average age at surgery was 34.8±9.8 years (range, 17-63 years). The mean follow-up period was 37.8±18.0 months (range, 24-120 months). The average correction of GK and OVA were 49.6°±8.5°and 39.2°±5.4°, respectively. At the final follow-up, PT and TPA were significantly positively associated with both ODI and BASDAI score (P<0.05). While SS, SSA, and SPA were significantly negatively correlated with the score of ODI (P<0.05), and BASDAI was negatively related to SPA (P<0.05). Predicting regression models of the clinically-relevant radiographic parameters were built based on the ODI score at the last follow-up as follows: PT=0.150×ODI+20.592, with r2=0.071; SSA= -0.116×ODI+110.247, with r2=0.044; TPA=0.151×ODI+17.790, with r2=0.063; SPA= -0.183×ODI+156.350, with r2=0.060.

Conclusion

Based on the regression models, the optimal sagittal alignment satisfying good clinical outcome (ODI<20) at a minimum of two-year follow-up was: PT<24°, SSA>108°, TPA<21°, and SPA>153°. Realizing the aforementioned realignment objectives may contribute to favourable clinical outcome for AS patients.

Take Home Message

The optimal sagittal alignment of AS patients with thoracolumbar kyphosis following one-level PSO was: PT<24°, SSA>108°,

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TPA<21°, and SPA>153°.

105. Clinical and Radiographic Outcomes in Patients with Severe and Rigid Kyphoscoliosis (>100 degrees) Treated without a 3-Column Osteotomy (3CO)

Isaac O. Karikari, MD; Kwadwo Poku Yankey, MD; Henry Ofori Duah, RN, MPH; Harry Akoto, MD, MB ChB; Irene Wulff, MD; Oheneba Boachie-Adjei, MD

Summary
Our study examined long term radiographic and clinical outcomes in patients with severe kyphoscoliosis treated without a 3CO.

Hypothesis
Patients with severe and rigid kyphoscoliosis with unfused anterior column can be realigned without a 3CO

Design
Retrospective review of prospectively collected data

Introduction
Patients with severe kyphoscoliosis are commonly thought to require a (3CO) for optimal radiographic and clinical outcomes

Methods
An analysis of consecutive patients with kyphoscoliosis ($>100^{0}$) treated without a 3CO from 2012-2015 was performed. Only patients with complete radiographic and clinical outcomes with a minimum of 2 year follow-up were included.

Results
A total of 28 patients (14 male and 14 female), mean age of 16.1± 3.0 years met the inclusion criteria. The mean preoperative scoliosis and kyphosis curves were 133^{0}±21 and 137^{0} ±35 respectively. Twenty-one pts underwent preoperative Halo-Gravity Traction (HGT) for a mean duration of 114 days ±36. HGT resulted in mean correction of 30% and 34% in the scoliotic and kyphotic curves (p<0.05). 27 patients underwent posterior-only fusion and 1 underwent an A/P fusion. The mean number of levels fused was 14.4±1.0. Posterior column osteotomies (PCO) and/or thoracoplasty were performed in 27 (96%) patients. Mean EBL and length of surgery was 1526±780ml and 288±88 mins respectively. At a mean follow-up of 3.7 years, there was a significant improvement in mean SRS-22 function scores (3.4 to 4.2; p<0.05), body image (2.5 to 4.1; p<0.05), mental (3.6 to 4; p=0.04) and satisfaction (2.7 to 4.2; p<0.05). The improvement in SRS-22 pain domain did not reach statistical significance (4.1 to 4.3; p=0.12), however VAS-Back (mean) demonstrated significant improvement (1.9 to 0.5; p=0.03). Scoliosis and kyphosis Cobb angles averaged 69.7^{0}±14 (50% correction) and 57.1^{0}±19 (60% correction) respectively at follow up (p<0.05). Postoperative complications included transient incomplete paraplegia in 2 patients and 1 wound infection. There were no deaths.

Conclusion
Patients with severe and rigid kyphoscoliosis can be successfully treated without a 3CO. Utilization of preoperative HGT, followed by PSF, PCO and thoracoplasty can provide safe and acceptable correction negating the need for a 3CO.

Take Home Message
Halo-Gravity traction coupled with posterior column osteotomy and/or thoracoplasty in patients with severe kyphoscoliosis with unfused anterior column can yield successful clinical and radiographic outcomes

106. Are We Neglecting Long Term Effects of Vertebral Shortening on Pulmonary Function in Spinal Tuberculosis?

Tushar Narayan Rathod, MBBS, MS, FCPS D Ortho; Nandan A. Marathe, MS

Summary
Loss of vertical height in spinal TB along with displacement of viscera, reduced chest compliance causes significant increase in the work of breathing leading to chronic respiratory failure. There has been no long term study done to assess the effect loss of VCH on pulmonary function in spinal TB. Though Shortening procedures are safer as compared to distraction for spinal cord, results of our study show direct correlation between reduction in the VCH and worsening pulmonary function in longterm.

Hypothesis
Loss of vertebral column height leads to impairment of pulmonary function.

Design
Retrospective observational study

Introduction
TB Spine accounts for 50% of skeletal TB in developing countries. Vertebral destruction causes thoraco-lumbar deformities leading to decrease in effective vertebral column height(VCH). Long term effects of the reduction in VCH on pulmonary function in Spinal TB are unknown. We are proposing a study to determine the relationship between loss of VCH and pulmonary function as quantified by SDI (spinal deformity index) and PFTs (pulmonary function test) respectively.

Methods
50 cases of dorso-lumbar tuberculosis followed up for more than 2 years were assessed at our tertiary care center from 2011-2016. Height loss was evaluated on lateral X-ray by Genant's method

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and SDI was calculated. Spirometry variables were assessed by PFT.

Results
Our study included 14 males and 36 females with a mean age of 27.9 years. Data entry was done using Microsoft excel and analyzed by Graphpad Instat. The mean value of spirometer parameters was evaluated, scatter plots made and correlation between SDI and PFT assessed using Spearman's Correlation coefficient. impairment patients with normal PFT had SDI of 2.7. 12 patients had mild, 14 patients had moderate and 10 patients had severe restrictive pattern with SDI of 3.83, 5.6 and 6.14 respectively. 3 patients had an obstructive pattern. Thus, PFT tests showed 72% had restrictive pattern and its severity directly correlated with increase in SDI ($p<0.05$).

Conclusion
Loss of vertebral column height remains a relatively neglected aspect in overall management of spinal TB. Our study emphasizes the need for early detection in TB spine to avoid long term adverse effects on pulmonary function.

Take Home Message
Due restraints should be exercised in the management of multilevel TB spine to avoid vertebral column shortening which has an unfavourable impact on pulmonary function.

107. 3D-Printed Spinal Orthosis in Management of Adolescent Idiopathic Scoliosis: A Randomized Controlled Trial

Yang Min Lin, MS; Jason Pui Yin Cheung, MBBS, FRCS, MS; Kenneth MC Cheung, MD; M S. Wong, PhD

Summary
A randomized controlled trial between conventional and 3D-printed orthoses for adolescent idiopathic scoliosis (AIS) was conducted. No differences in Cobb angle were observed between groups. 3D-printed orthoses led to improved BrQ scores and improved compliance.

Hypothesis
3D-printed spinal orthoses are equal in effectiveness to fabricated orthoses with increased patient acceptance.

Design
Randomized controlled trial.

Introduction
With the recent advancements in the computer-aided manufacture, 3D printing technology can be applied for more versatile fabrication of spinal orthoses such as reduced weight and thickness. This may enhance brace compliance and subsequent treatment outcomes. The application of 3D printing technology in orthotic treatment requires study to confirm its clinical effectiveness and patient's acceptance. Thus, this study aimed to investigate the clinical effectiveness of 3D-printed spinal orthoses and its patient's acceptance.

Methods
A randomized controlled trial was conducted on 30 patients with moderate AIS (Cobb 25-45°). Equal number of patients were randomly assigned to 3D-printed orthoses (3O) with mean age of 12.3 and Cobb 32.7° or the conventional orthoses (CO) with mean age of 12.5 and Cobb 29.6°. The patients' quality of life was assessed using the SRS-22, TAPS, BrQ at the baseline, 1-month and 3-month of orthotic treatment. Thermal sensors were used to measure compliance. The immediate in-orthosis X-ray was used for correction analysis.

Results
All patients completed the follow-up without dropouts. There were no significant differences in terms of SRS-22 or Cobb angle correction. Comparable in-orthosis correction was observed between the 3O group (12.2°, 36.8%, $p<0.01$) and CO group (13.1°, 44.7%, $p=0.01$).The results of BrQ school activity was 10.4 significantly higher in the 3O group at the 1-month follow-up (88.0 vs. 77.6, $p<0.05$). Daily wearing hours was 0.3 slightly longer in the 3O group than the CO group (17.2 vs. 16.9 hrs).

Conclusion
3D-printed orthoses, which were lighter and thinner in design, provided similar clinical effectiveness with improved patient perceived outcomes and brace compliance. Longer-term follow-up is needed to observe for any further changes in compliance and quality of life measures.

Take Home Message
3D-printed spinal orthoses improve patient perceived outcomes and compliance with equal effectiveness as conventional orthoses.

108. Curve Correction is Significantly Greater with Braces Optimized Using CAD/CAM and FEM after 2 Years of Treatment: A Randomized Controlled Trial

Aymeric Guy, MS; Elisabeth Audet-Duchesne; Soraya Barchi, BS; Hubert Labelle, MD, FRCS(C); Carl-Eric Aubin, PhD, ScD (h.c.), P.Eng

Summary
We performed a randomized controlled trial, which demonstrated that braces designed using a combination of CAD/CAM and finite element modeling (FEM) are more effective at the first in-brace evaluation. The current study compared the correction after 2 years of treatment. Fifty-three patients in the control group

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received standard CAD/CAM braces while 49 patients in the test group received custom braces further improved through FEM. CAD/CAM + FEM braces maintained their superior effectiveness after 2 years.

Hypothesis
For AIS patient, braces designed using CAD/CAM and FEM are more effective than standard CAD/CAM braces after 2 years of treatment.

Design
Prospective single center randomized controlled trial.

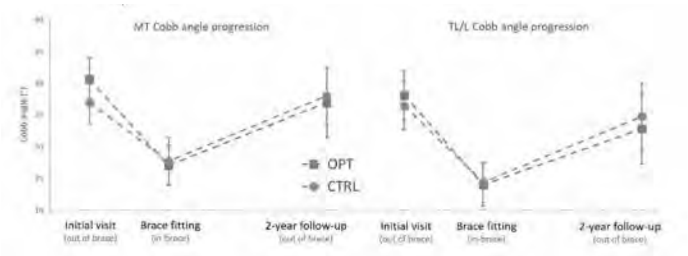
Introduction
Recent studies showed that bracing is effective in preventing the progression of scoliotic curves. However, orthotic concepts and their effectiveness differ due to the varying expertise of orthotists, even with computer-assisted technologies (CAD/CAM).

Methods
We enrolled 102 AIS patients according to standardized SRS bracing criteria, then randomly assigned them to two groups. Fifty-three patients in the control group (CTRL) received a brace designed using state-of-the-art CAD/CAM. Forty-nine patients in the test group (OPT) received a custom simulated brace constructed from 3D reconstructions of the spine, rib cage, and pelvis obtained from biplanar X-rays at the initial visit; OPT braces were iteratively simulated prior to fabrication to maximize curve correction while minimizing contact area and material used. For both groups, we compared Cobb angles at the initial visit, at brace fitting, and out of brace at a visit after 2 years of treatment.

Results
Both groups were similar in terms of age, sex, weight, and curve type, but the initial curve for the OPT group was slightly greater on average: thoracic (MT) and lumbar (TL/L) Cobb angles were 31° and 28° respectively for the OPT group, vs. 27° and 26° for the CTRL group. Immediate in-brace correction was significantly different ($p < 0.05$): 43% (MT) and 51% (TL/L) for the OPT group, vs. 34% (MT) and 44% (TL/L) on average for the CTRL group. At the 2-year visit (mean 25 months; range: 20-45), out-of-brace thoracic curves worsened on average by 5% for the CTRL group but improved by 12% for the OPT group ($p < 0.05$), while lumbar curves improved by 7% for the CTRL group and by 20% for the OPT group ($p < 0.05$).

Conclusion
Braces combining CAD/CAM and FEM improved immediate correction, and remained superior to standard CAD/CAM braces after 2 years of treatment.

Take Home Message
This study confirms the greater effectiveness of braces designed with patient-specific CAD/CAM and FEM, which corrected scoliotic curves better than the current state of the art after 2 years.



Average Cobb angle progression at the three studied time points

109. Effectiveness of Providence Night-time Bracing compared to Full-time Boston Bracing for Adolescent Idiopathic Scoliosis. A Matched Cohort Study

Ane Simony, MD, PhD; Mikkel ø. Andersen, MD; Stig Mindedahl Jespersen, MD, PhD; Leah Yacat Carreon, MD, MS

Summary
Previous studies report excellent results with Providence Night-time bracing (PNB) in AIS patients. This study compares the outcome after PNB compared to Full time Boston brace (FBB) in a matched cohort of AIS patients.

Hypothesis
The clinical outcome after Providence Night-time bracing are comparable to Full time Boston Braces, in the conservative treatment of Adolescent Idiopathic Patients.

Design
A matched cohort study

Introduction
Providence Night-time Bracing (PNB) is an alternative nonsurgical method to Full time Boston Bracing (FBB) for AIS Patients. Recent studies have shown a dose response curve with the FBB, that is longer brace wear is more effective at preventing curve progression. However, due to limitations with daily function, a night time brace may increase compliance. The aim of the study was to compare the outcomes between PNB and FBB in a matched cohort of AIS patients.

Methods
71 consecutive AIS patients received treatment, with PNB. Treatment was administered according to the SRS criteria. The clinical outcome of PNB was determined 2 years after brace weaning. The patients treated with PNB was then matched according to age, sex, curve type, apex and Cobb prior to treatment with a cohort of AIS patients, treated with FBB.

Results
71 consecutive PNB patients, 61 females and 10 males where matched, with 71 patients treated with FBB. The demograph-

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ics were similar between the two cohorts. The Cobb angle after completion of treatment and the amount of curve correction was similar between the two groups. However, 6 patients in the PNB had surgery, 2 for cosmesis and 4 for curve progression.

Conclusion

Curve progression after PNB was comparable to FBB. Night time bracing seems effective in the treatment of AIS and might reduce the psychological stress of the AIS patients during puberty. The difference seen in the rate of surgery between the 2 groups, reflects the change in surgical mangement from 1990 to 2018, where surgery is indicated at 40°

Take Home Message

Providence Night time Bracing, are effective in the conservative treatment of Adolescent Idiopathic Scoliosis. This study reports comparable outcome between Providence Night time Bracing and Boston Full time Bracing.

110. The Impact of Sagittal Balance and Spinopelvic Parameters on the Development of Proximal Junctional Kyphosis Following Posterior Spinal Fusion for Adult Spinal Deformity

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Summary

Patients with a postoperative PI-LL mismatch > 10° had significantly increased rates of proximal junctional kyphosis (PJK) after posterior spinal fusion for adult spinal deformity (ASD), and the odds of developing PJK increased as the magnitude of the PI-LL mismatch increased.

Hypothesis

We hypothesize that patients with a PI-LL mismatch > 10° following posterior spinal fusion for ASD will have greater odds of developing PJK compared with patients with a post-operative PI-LL mismatch < 10°.

Design

Retrospective cohort study.

Introduction

Minimizing the difference between pelvic incidence (PI) and lumbar lordosis (LL) has been associated with improved clinical outcomes following deformity-correcting spinal fusion. However, the association with PJK remains unexplored.

Methods

Consecutive patients who underwent elective posterior spinal fusion for ASD at a single academic institution from 2008 to 2014 with a minimum of 2 years of follow-up were identified. Preoperative, first postoperative, and final postoperative standing radiographs were reviewed, and PI, LL, and PJK were assessed. Two common methods of measuring PJK were used. Multivariate logistic regression was used to test the association between increasing degrees of PI and LL mismatch (>10°, >20°, and >30° mismatch) and development of PJK while controlling for differences in patient and operative characteristics.

Results

142 patients fulfilled inclusion criteria. Average follow up length was 52.8 ± 29.1 months (Range 24 to 120 months). Compared with patients who had PL and LL within 10° immediately after surgery, those with a PI-LL mismatch > 10° (UIV+1 p=0.001; UIV+2 p=0.008), > 20° (UIV+1 p<0.001; UIV+2 p<0.001), and >30° (UIV+1 p<0.001; UIV+2 p<0.001) had significantly increased rates of PJK, with a larger mismatch corresponding to greater odds of PJK. Similarly, significantly increased rates of PJK were found with PI-LL mismatch >10°, >20°, and >30° at final follow-up (multivariate p-value range <0.001 to 0.031).

Conclusion

Following posterior spinal fusion for ASD, patients with a postoperative PI-LL mismatch > 10° developed PJK at greater rates than patients with PI and LL within degrees. As the PI-LL mismatch increased, the odds of developing PJK also increased.

Take Home Message

Patients with a postoperative PI-LL mismatch > 10° developed PJK at greater rates than patients with PI and LL within degrees following posterior spinal fusion for adult spinal deformity.

Table 1. Multivariate analysis for association of pelvic incidence and lumbar lordosis with proximal junctional kyphosis

	PJK measured at UIV + 1 Multivariate analysis		PJK measured at UIV + 2 Multivariate analysis	
	OR	p-value	OR	p-value
PREoperative PI - LL difference > 10 degrees	0.61	0.325	1.10	0.852
PREoperative PI - LL difference > 20 degrees	0.52	0.152	0.73	0.521
PREoperative PI - LL difference > 30 degrees	0.60	0.258	1.01	0.990
POSToperative PI - LL difference > 10 degrees	**4.53**	**0.001**	**3.62**	**0.008**
POSToperative PI - LL difference > 20 degrees	**12.32**	**<0.001**	**6.28**	**<0.001**
POSToperative PI - LL difference > 30 degrees	**15.85**	**<0.001**	**11.28**	**<0.001**
FINAL PI - LL difference > 10 degrees	**4.31**	**0.031**	3.23	0.080
FINAL PI - LL difference > 20 degrees	**10.16**	**<0.001**	**8.65**	**<0.001**
FINAL PI - LL difference > 30 degrees	**26.43**	**<0.001**	**15.04**	**<0.001**
Change in PREoperative to POSToperative PI - LL	1.01	0.701	1.00	0.986
Change in PREoperative to FINAL PI - LL	0.97	0.287	0.99	0.594
Change in POSToperative to FINAL PI - LL	0.97	0.530	1.00	0.913

***PI LL difference < 10 degrees used as reference**

At two levels above the upper instrumented vertebra (UIV+2), kyphosis greater than 10° and more than a 10° increase from the preoperative film was defined as PJK.

At UIV+1, PJK was defined as a greater than 15° increase from the preoperative film.

Table 1

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111. Are We Better at Preventing PJK Today? A Comparison of Incidence 5-7 Years Later

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Summary

In a study of over 500 patients comparing PJK rates from 2009-2011 versus 2016-2018, no differences were noted in the rate of PJK or in the PJK angles through time (38% vs. 34%, 13.8 deg +/- 9.8 vs. 14.5 deg +/- 9.0, respectively). While there were differences in operative techniques and strategies evidenced by the utilization of different interbody techniques, osteotomies and bone graft products through time, PJK incidence has stayed the same.

Hypothesis

Rates of PJK are lower today compared to a historical cohort

Design

Retrospective Study

Introduction

Much research has focused on the etiology of PJK and with the evolution of our knowledge, there have been modifications to surgical techniques and radiographic aims in an attempt to minimize the risk for PJK development

Methods

A multicenter database of Adult Spinal Deformity patients was analyzed for the following inclusion criteria: fusions >5 levels, LIV S1/Ilium with at least 6 weeks follow up (f/u) for the assessment of PJK. A historical cohort of patients from 2009-2011 (Group P) were compared to those from 2016-2018 (Group T) for the rates of PJK. Patient demographics, operative details, radiographic and clinical outcomes were compared between groups. Unpaired T-Tests were utilized followed by a multivariate analysis to eliminate confounding variables.

Results

504 patients were included for analysis (Group P, n=210 vs. Group T, n=294). Group T were older patients (65 vs. 62, p<0.01), with a higher CCI and ASA compared to Group P (p<0.01) with a larger PI-LL mismatch (24 vs. 20, p=0.02) and TPA (28 vs. 26, p=0.03) at baseline. Statistically significant differences in the surgical strategies were noted between cohorts, with a higher number of ALIFs, LLIFs, Allograft and BMP usage in the T group versus P (all p<0.05) and a lower prevalence of 3CO utilization (17.7% vs. 29.5%, p<0.01). There were no differences in the rates of PJK or in the PJK angle between groups (P 38% vs. T 34%, p=0.43; P 13.8 deg +/- 9.8 vs. T 14.5 deg +/- 9.0, p=0.39). No differences were noted in the radiographic outcomes post-operatively. When controlling for confounding variables (age, CCI and ASA, surgical strategies and 3CO), there were no significant differences in PJK rates between the cohorts (p=0.2). The prevalence of revision cases for PJK was also similar between time points (25 vs. 23)

Conclusion

Despite tremendous research efforts to understand the etiology and prevention strategies for PJK, no differences were seen in the rates of PJK when comparing a cohort from 2009-2011 to 2016-2018.

Take Home Message

No differences were seen in the PJK rates when comparing a historical cohort versus present day cohorts indicating significant work is still necessary in elucidating strategies for PJK prevention

112. Cement Augmentation at UIV and Prophylactic Vertebroplasty at UIV+1 for the Prevention of PJK and PJF in Adult Spinal Deformity Surgery with Osteoporosis: A Retrospective Analysis of 161 Patients with a Mean Follow-up of 6 Years

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Summary

Cement augmentation at the upper instrumented level (UIV) and prophylactic vertebroplasty at the supra-adjacent level (UIV+1) provided satisfactory radiographic outcomes and the occurrence of proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) was avoided in %91,8 of the patients who were operated due to adult spinal deformity with osteoporosis, with a mean follow up of 6 years.

Hypothesis

Cement augmentation at upper instrumented level and PVP at the supra-adjacent level provides satisfactory radiological outcomes regarding the occurrence of PJK and PJF in adult spinal deformity with osteoporosis.

Design

Retrospective

Introduction

PJK and PJF are common problems after long-segment (more than 5 levels) thoracolumbar instrumented fusions in the treatment of adult spinal deformity with osteoporosis. Cement augmentation at UIV and PVP at UIV+1 has been recommended for the prevention of PJK or PJF previously. However these reports were performed in smaller patient groups with shorter follow-up

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periods. This study aimed to evaluate the radiographic outcomes of cement augmentation at UIV and PVP at UIV+1 regarding PJK and PJF in adult spinal deformity surgery performed in 161 patients after mean follow-up of 6 years.

Methods

From 2006 through 2016, cement augmentation at UIV and PVP at UIV+1 due to adult spinal deformity with osteoporosis was performed in 253 patients. 161 of these patients [(102 F, 59 M), mean age 67 (51-82)] were included in the study. Inclusion criteria were age 50 years or older, fusion extending at least 5 vertebral levels that ended between T7 and L1, a preop T score of -2,5, a minimum follow up of 2 years.

Results

The mean follow up was 61 (24-138) months. In 13 patients (8.2%) a fracture at UIV+1 developed. Ten (6%) of these patients underwent revision surgery whereas 3 have been conservatively followed up.

Conclusion

This study is the first study with a large patient group with mid-term follow up, who has underwent cement augmentation at UIV and prophylactic vertebroplasty (PVP) at UIV+1 due to adult spinal surgery with osteoporosis. Our study suggests that this technique provided satisfactory radiological outcomes (91,8% success) regarding the occurrence of PJK and PJF in surgery due to adult spinal deformity with osteoporosis..

Take Home Message

Cement augmentation at upper instrumented level and PVP at the supra-adjacent level in thoracolumbar instrumented fusions in adult spinal deformity with osteoporosis may help decreasing PJK and PJF rates.

113. Comparing and Contrasting the Clinical Utility of Sagittal Spine Alignment Classification Frameworks: Roussouly vs. SRS-Schwab

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Summary

For surgical adult spinal deformity(ASD) patients, incorporating restoration of appropriate Roussouly Classificaion shape into surgical planning may improve outcomes. With the introduction and use of the SRS-Schwab ASD classification system, it's important to compare the utility of both classification frameworks as they relate to outcomes. While achieving optimal theoretical Roussouly type was not associated with improved postoperative outcomes, both improving in SRS-Schwab modifiers and matching Roussouly type was associated with lower complication rates and substantial clinical improvement by 2-years postop.

Hypothesis

Schwab and Roussouly systems differ in clinical utility.

Design

Retrospective review

Introduction

It's important to compare the utility of sagittal alignment classification frameworks as they relate to ASD patient outcomes.

Methods

ASD patients were grouped by "theoretical" Roussouly type(1: PI<45°, LL apex below L4; 2: PI<45°, LL apex above L4-L5 space; 3: 45°<PI<60°; 4: PI>60°) and "current" (1: SS<35°, LL apex below L4; 2: PI<35°, LL apex above L4-L5; 3: 35°<PI<45°; 4: PI>45°), as published. Outcomes of those that mismatched "theoretical" and "current" types at both pre- and 2-years post-op(2Y) were compared to those of preop mismatched patients that matched at 2Y(Matched). Subanalysis compared those who improved in Schwab modifiers to those who did not.

Results

Included: 515 ASD patients(59±14yrs, 80%F). Preop breakdown of "current" Roussouly types: Type 1 (10%), 2 (54%), 3 (24%), 4 (12%). Preop mismatch between "current" and "theoretical" types was 60%. By 2Y, 16% of patients matched Roussouly types. Matched and Mismatched did not differ in rates of reaching MCID for any HRQL metrics by 2Y(ODI, PCS, SRS Activity and Pain), nor rates of complications, reop, or PJK (all p>0.05), though Mismatched showed a trend of higher instrumentation failure(17% vs 26%,p=0.08). By 2Y, 28% of patients improved in PT modifier, 37% in SVA, and 46% in PI-LL. Patients that improved in PT modifier reached MCID at higher rates for ODI and SRS Activity by 2Y, and had lower rates of instrumentation failure than those that did not (Table 1). Patients that both Matched Roussouly and improved in all Schwab modifiers by 2Y met ODI and SRS-Activity MCID at higher rates than patients that did not. Match patients that improved in Schwab PT had less renal, infection, and neurologic complications; Match patients that improved in Schwab SVA had superior SF-36 and fewer cardiopulmonary complications at 2Y (all p<0.05) than patients that did not.

Conclusion

Combined, both Roussouly and Schwab systems may offer utility in establishing targets for realignment.

Take Home Message

Alone, restoration of appropriate Roussouly spinal shape wasn't

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associated with superior clinical outcomes. Patients that matched Roussouly type and improved in Schwab modifiers had superior 2-year complication and clinical outcomes.

	No Improvement in Schwab PT Modifier	Improvement in Schwab PT Modifier	p-value
Minimum Clinically Important Difference (MCID) for 2-year health-related quality of life assessments			
ODI (% reaching MCID)	48.1%	57.9%	**P=0.045***
PCS (% reaching MCID)	59.1%	62.3%	P=0.518
SRS Activity (% reaching MCID)	63.6%	75.4%	**P=0.012***
SRS Pain (% reaching MCID)	65.3%	69.0%	P=0.426
Complications			
Any complication	67.8%	60.7%	P=0.124
Proximal junctional kyphosis (PJK)	14.6%	11.0%	P=0.289
Instrumentation failure	23.8%	15.9%	**P=0.049***
Reoperation	22.4%	19.3%	P=0.438

Table 1. Differences in complication outcomes and 2-year postoperative health-related quality of life outcomes between patients who improved in SRS-Schwab PT modifier, and patients that did not.

114. Restoring the Ideal Roussouly Sagittal Profile in Adult Scoliosis Surgery Decreases the Risk of Mechanical Complications

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Summary

A group of adult scoliosis operated patients were retrospectively analyzed from a multicenter adult deformity database. Patients with and without mechanical complications were compared looking especially at the restoration of the ideal sagittal profile as described by Roussouly. After univariate and multivariable analysis we concluded that surgery should restore the ideal sagittal shape dictated by pelvic incidence to decrease the rate of mechanical complications, particularly in patients older than 65, instrumented to the pelvis.

Hypothesis

Proper restoration of the sagittal profile according to Roussouly classification can decrease the rate of mechanical complications in adult scoliosis (AS) surgery

Design

Retrospective analysis of AS patients recorded in a prospective multicenter database

Introduction

Optimizing global sagittal alignment in adult deformity improves patient's quality of life and decreases the rate of complications. However, there is still no data proving if restoring the ideal sagittal distribution (proposed by Roussouly) in AS patients, leads to any additional benefit, especially regarding mechanical complications

Methods

Demographic and radiographic (preoperative and 6-week postoperative) data of a cohort of AS patients were analyzed. Patients with and without mechanical complications were compared looking especially at the surgical restoration of the ideal sagittal profile. Univariate and multivariable analysis was performed to identify the causes of mechanical complications at 2-yr minimum follow-up.

Results

96 AS patients were analyzed. 39 patients suffered a mechanical complication (18 PJK, 11 pseudoarthrosis, 10 screw pull-out), 57 patients had no mechanical complications. 72% of patients not matching ideal Roussouly type (R-type) suffered mechanical complications compared to 15% of postoperatively matched patients (P<0.001). Univariate analysis showed that older patients 64.9±13 vs 40.7±15.6 years (P<0.001), postop higher Global 27ºvs14.7º and Pelvic 25ºvs16º Tilt (P<0.001), upper instrumented level at the thoracolumbar junction (62% vs 21%) (P<0.001), instrumentation to the Iliac (76% vs 6%) (P<0.001), and postoperative R-type mismatch (72% vs 15%) (P<0.001), significantly increased the rate of mechanical complications. Multivariable logistic regression analysis selected: postoperative Roussouly-type mismatch (OR=41.9; 95%CI=5.5-315.7; p<0.001), Iliac instrumentation (OR=19.4; 95%CI=2.6-142.5; P=0.004), and age (OR=1; 95%CI=1-1.1; P=0.004), as the most important variable

Conclusion

AS surgery should adjust the ideal Roussouly sagittal shape to decrease the rate of mechanical complications, especially in patients older than 65, instrumented to the pelvis.

Take Home Message

The surgical restoration of the ideal sagittal profile according to the patient pelvic incidence in adult scoliosis is important to decrease the rate of mechanical complications

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Table 2. Comparison of postoperative parameters

	Mechanical complications	No mechanical complications	P value
Sagittal parameters			
Pelvic Incidence (º)	55.1º ± 13.6	56.7º ± 12.8	0.538
Pelvic Tilt (º)	25.4º ± 8.8	16.4º ± 9.7	0.000*
Sacral Slope (º)	29.3º ± 11.4	40º ± 10.3	0.000*
PI-LL mismatch (º)	6.9º ± 16.4	2º ± 20.1	0.217
Global Tilt (º)	27.1º ± 13.7	14.7± 10.6	0.000 *
Postoperative sagittal profile matching			
Match	15.1%	84.9%	0.000*
Unmatch	72%	27.9%	
Upper instrumented vertebra			
Proximal Th (T2-T5)	21.6%	78.4%	0.000*
ThL junction (T9-L2)	62%	37.8%	
Lower instrumented vertebra			
Iliac	76.6%	23.4%	0.000*
Above Iliac	6.1%	93.9%	
Postoperative Roussouly-type			
Higher than ideal	77.4%	22.6%	0.000*
Same than ideal	15.1%	84.9%	
Lower than ideal	58.3%	41.7%	
Postoperative Lumbar apex			
Higher than ideal	55.6%	44.4%	0.009*
Same than ideal	20%	80%	
Lower than ideal	38.1%	61.9%	
Postoperative Inflexion point			
Higher than ideal	40.6%	59.4%	0.126
Same than ideal	29.4%	70.6%	
Lower than ideal	57.9%	42.1%	

* statistical significance

115. Outcomes of Surgical Treatment for 138 Patients with Severe Sagittal Deformity at a Minimum 2-Year Follow Up

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Summary

A retrospective review of a prospective, multicenter adult spinal deformity (ASD) database was performed evaluating the 2yr outcomes of patients undergoing surgical correction of severe sagittal deformity (SVA ≥15cm, PI-LL ≥30deg, and/or lumbar kyphosis ≥5deg). All 2yr radiographic and HRQOL measures were significantly improved (p<0.05) except for coronal C7 plumb line. Most patients met HRQOL MCID/SCB. The complication rate was 74.6% for at least 1 complication with 11.6% having ≥4 complications and 33.3% having at least 1 major complication.

Hypothesis

Patients (pts) with severe sagittal deformity have favorable outcomes following surgical correction.

Design

Retrospective review of a prospective, multicenter adult spinal deformity (ASD) database

Introduction

Operative treatment of ASD can be very challenging with high complication rates. It's well established that pts benefit from such treatment. However the surgical outcomes for pts with severe sagittal deformity have not been reported.

Methods

Inclusion criteria: operative pts age≥18, SVA≥15cm, PI-LL≥30deg, and/or lumbar kyphosis ≥5deg with min 2yr follow up. Health-related quality of life (HRQOL) scores: Oswestry Disability Index-(ODI), Short form-36(SF36), Scoliosis Research Society(SRS22), back/leg pain numerical rating scale(NRS) and min clinically important difference (MCID)/substantial clinical benefit(SCB) for pts eligible to meet it. Radiographic values: max coronal cobb angle, coronal C7 plumb line, pelvic tilt, mismatch between pelvic incidence and lumbar lordosis, thoracic kyphosis, C7 sagittal vertical axis. Demographic, frailty, surgical, and complication data were also collected. Comparisons between 2yr postop and baseline HRQOL/radiographic data were made. P<0.05 was significant.

Results

138 pts included from 502 operative patients (54.3% Female, avg age 63.3±11.5yrs). Avg baseline frailty score was 4.1±1.4 indicating pts were frail. 71(51.4%) of the pts had a prior fusion. 89.9% posterior fusion only, avg 11.5±4.1 post levels fused. 44.9% had 3-column osteotomy. 2 standard deviations for SVA=14.8cm. All 2yr postop radiographic parameters were significantly improved compared to baseline(p<0.05) except coronal C7 plumb line(p>0.05). All 2yr HRQOL measures were significantly improved compared to baseline(p<0.004). 46.6-73.8% of pts met either MCID/SCB for all HRQOL(see table). 74.6% of pts had at least 1 complication, 11.6% had 4 or more complications, 33.3% had min 1 major complication, and 42(30.4%) had a postop revision.

Conclusion

Pts with severe sagittal malalignment benefit from surgical correction at 2yrs postop both radiographically and clinically despite having a high complication rate.

Take Home Message

Patients with severe sagittal malalignment benefit from surgical correction at 2yrs postop but with a high complication rate that these patients need to be informed of preoperatively.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Table: MCID and SCB results

HRQOL measure	# Eligible patients	# (%)
MCID		
ODI	134	71 (53.4%)
PCS	All	78 (61.9%)
SRS Activity	135	88 (67.2%)
SRS Pain	136	92 (69.7%)
SRS Appearance	134	96 (73.8%)
SRS Mental	132	66 (51.2%)
Back Pain	137	63 (69.7%)
Leg Pain	113	92 (64.8%)
SCB		
ODI	134	62 (46.6%)
PCS	All	75 (59.5%)
Back Pain NRS	134	87 (67.4%)
Leg Pain NRS	108	63 (63.0%)

116. Comprehensive Alignment Planning (CAP) for Adult Spinal Deformity (ASD) More Effectively Predicts Surgical Outcomes and Proximal Junctional Kyphosis than Previo us Classifications

Renaud Lafage, MS; Justin S. Smith, MD, PhD; Jonathan Charles Elysée, BS; Peter G. Passias, MD; Shay Bess, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Richard Hostin, MD; Gregory M. Mundis Jr., MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

Summary

Previous study highlighted GAP inability to effectively predict PJK when it's effect are removed. While age-adjusted thresholds show significant difference, parameters are analyzed individually and do not provide overall guideline. By combining both approach into a single score, this method allow to show significant differences in CAP score between PJK groups while patients with a sub-optimal score showed worst post-operative outcomes. CAP method can provide a sweet-spot by maximizing outcome without increase mechanical failures.

Hypothesis

Combining GAP and age-alignment thresholds improves the evaluation of sagittal plane

Design

Retrospective review of a prospective ASD database

Introduction

A recent study revealed the ability and limitations of 2 methodologies of analysis to predict PJK (Age-alignment and GAP). The purpose of the current study was to investigate a hybrid approach by combining both methods into a single score.

Methods

Multi-center ASD database was evaluated for surgically treated ASD pts with 1) fusion minimum 5 levels, 2) fusion to pelvis, and 3) minimum 2 year follow up. The CAP scoring methodology was created by assigning numerical values to the difference between each patient's postoperative sagittal alignment and ideal alignment as defined by previously reported age generational norms for PI-LL, PT, and TPA as describe in the figure. Post-operatively, PJK severity was categorized as None, PJK (angle 10°), Severe-PJK (28°), and PJF (PJK treated surgically). Postop HRQOL and PJK severity between each GAP and CAP categories were evaluated.

Results

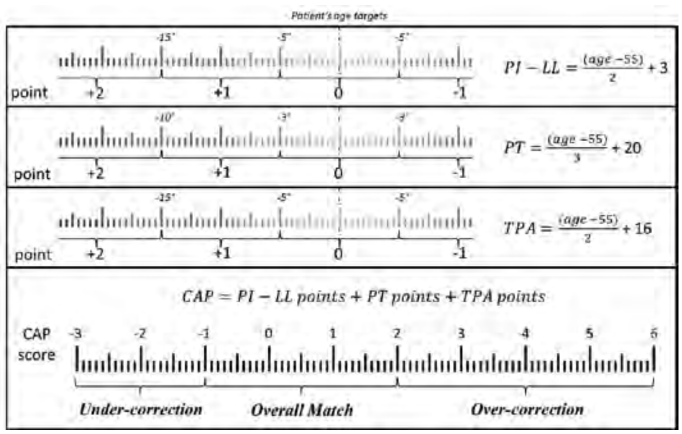
409/667 pts meeting inclusion criteria were evaluated. Pre-operatively most of the pts had moderate to severe deformity per SRS-Schwab modifiers (PT: 26°, PI-LL=20°, and SVA=80mm). At 2 years, mean CAP score increased from -0.8±2.4 to +0.8±2.9 ($p<0.001$); 24.5% of the pts were under-corrected, 38.3% over-corrected, and 37.5% matched their age-adjusted target. Post-operatively, HRQOL differences between CAP groups included ODI ($p=0.025$), SF36 MCS ($p=0.014$), SRS Pain ($p=0.029$) and SRS Total ($p=0.043$), while GAP was unable to discern HROQOL differences between GAP categories. PJK occurred in 37.9% of pts, severe PJK in 9.8%, and PJF in 6.6%. CAP score increased as PJK worsened (CAP=0.63 for no PJK, 1.42 for PJK, 2.31 for severe PJK, and 3.5 for PJF, $p<0.001$), however GAP score was unable to identify severity of PJK

Conclusion

Evaluation of the CAP score showed improvement in PJK predictability and association with post-operative HRQOL. This tool may aid ASD planning by targeting alignment associated with minimum complications and optimize surgical outcomes.

Take Home Message

Combination of both GAP and age-alignment provide a better solution than individual method. Under-corrected patient showed a significantly worst postoperative outcome while overcorrected patient demonstrated an increase in PJK rate



117. Does the Global Alignment and Proportion Score Overestimate Mechanical Complications after Adult Spinal Deformity Correction?

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Summary

The GAP score utilizes sagittal parameters to predict mechanical complications after spinal deformity surgery. Postop radiographs from 67 adult patients were analyzed using the GAP score. Rates of mechanical complications in the disproportioned groups were fewer (30-39% vs. 36-100%) but rates in the proportioned group were larger (19% vs. 4%) than in the original study.

Hypothesis

There will be a difference between the rates of mechanical complications for patients with a Proportioned Alignment vs. Disproportioned Alignment after Spinal Deformity Surgery.

Design

Retrospective Cohort

Introduction

The GAP score utilizes sagittal parameters to prognosticate the development of mechanical complications after spinal deformity surgery. We aimed to validate this score at our spinal deformity center.

Methods

Adult patients with spinal deformity and at least 4 levels of posterior fusion with a minimum 2 years of follow up were included. 6 week postop standing radiographs were used to calculate the GAP score. χ^2 analysis was performed to compare rates of mechanical complications for statistical independence. Statistical significance was set at $p<0.05$.

Results

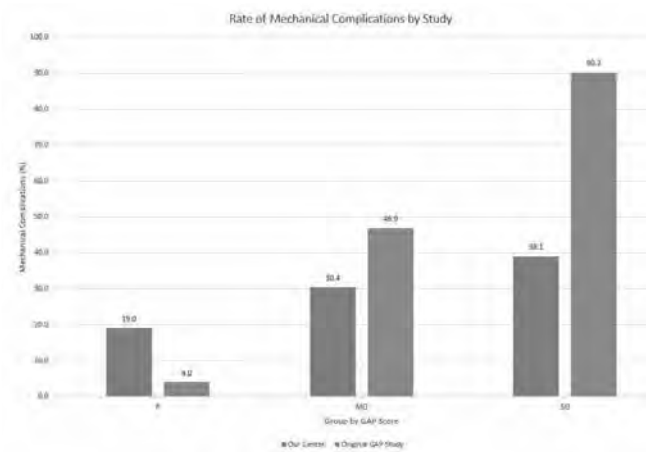
67 patients were included with mean age of 52.4 years (Range 18-75 years) and mean follow-up of 746 days (SD 204 days, Range 50-1209 days). Patients with less than 2 years of follow-up were included only if they had an early mechanical complication. 20/67 (29.8%) had a mechanical complication. 21/67 (31.3%) patients were in the Proportioned (P), 23/67 (34.3%) patients were in the Moderately Disproportioned (MD) group, and 23/67 (34.3%) were in the Severely Disproportioned (SD) group. The rate of mechanical complications for P patients was 19.0%, the rate of mechanical complications for MD patients was 30.3%, and the SD group was 39.1%. When comparing the rate of complications between P and Disproportioned Patients (MD and SD combined) there was no statistically significant difference (χ^2 1.70, p=0.19).

Conclusion

The rates of mechanical complications between MD and SD groups (30.3% and 39%) were less than those observed in the original GAP study (MD 36.4-57.1%, SD 72.7-100%) though our rate within the P group was higher (19% vs. 4.0%). There was no statistically significant difference in the rate of mechanical complications between the P, MD, and SD groups. Thus the GAP score did not show generalizability towards our patient population.

Take Home Message

The predicted rate of mechanical complications from the GAP score overestimated the observed rate in patients with disproportioned alignment at our deformity center.



118. Modified Global Alignment and Proportion Scoring with Body Mass Index and Bone Mineral Density (GAPBB) for Prediction of Mechanical Complication after Adult Spinal Deformity Surgery: Retrospective Analysis of 203 Patients

Kyung Hyun Kim, MD; Sung Hyun Noh, MD; UnYong Choi, MD

Summary

Modified Global Alignment and Proportion Scoring with Body Mass Index and Bone Mineral Density system is a new model created by combining BMI and BMD in the GAP score for predicting mechanical complications after ASD surgery. This system may help to predict incidence of mechanical complications in ASD surgery.

Hypothesis

GAPBB can predict mechanical complication more than other systems.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Design
Retrospective study

Introduction
The Scoliosis Research Society (SRS) – Schwab classification, the Global Alignment and Proportion (GAP) score, and age-adjusted alignment goals were used to predicting complication of ASD surgery and present taget values. But these systems were not enough until now. The aim of the study was to improve the predictability of mechanical complications after ASD surgery for using modified global alignment and proportion scoring with body mass index and bone mineral density (GAPBB).

Methods
Between January 2009 and December 2016, two hundred three succeeding patients with sagittal imbalance who underwent ASD surgery included. The patients were performed posterior spinal fusion and instrumentation as ASD surgery over 4 levels and follow-up periods were over 2 years. The GAPBB was developed and validated in groups of patients randomly assigned to derivation (n = 125, 61.6%) and validation (n = 78, 38.4%) cohorts. The receiver operating characteristic (ROC) curve was obtained and the area under the curve (AUC) was calculated. GAPBB was created for predicting complications using the variables contained in the selected model.

Results
In derivation cohort, 55 patients (44%) had mechanical complication after ASD surgery and in validation cohort, 34 patients (43%) experienced mechanical complication. The AUC of SRS-Schwab classification, GAP score, age-adjusted alignment goals, and GAPBB were 0.532 (95% confidence interval [CI], 0.463-0.602), 0.798 (95% CI, 0.720-0.877), 0.568 (95% CI, 0.495-0.641), and 0.885 (95% CI 0.828-0.941). In validation cohort, the AUC of GAPBB was 0.951(95% CI0.909-0.992). GAPBB was fitted in the Hosmer-Lemeshow fitness test, which show how well the calculation charts were calibrated.

Conclusion
GAPBB system is a new model created by combining BMI and BMD in the GAP score for predicting mechanical complications after ASD surgery. This system may help to predict incidence of mechanical complications in ASD surgery.

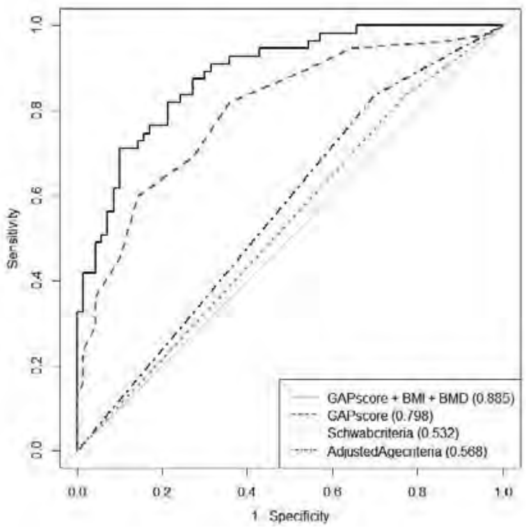


Figure 1. The receiver operating characteristic (ROC) curve of four system were obtained and the area under the curve (AUC) of four system were calculated.

119. The Impact of Segmental Kyphosis in the Upper Thoracic Motion Segments of Instrumented Posterior Spinal Fusions for Idiopathic Scoliosis on the Development of Proximal Junctional Kyphosis

Justin S. Roth, DO; Scott John Luhmann, MD

Summary
100 consecutive IS patients were evaluated for PJK after PSF at a minimum 2-years postoperatively. PJK after PSF for IS occurred in 25% of patients. Greater preoperative thoracic kyphosis and UIV-2, and postoperative UIV-1 and UIV-2 were associated with higher frequencies of PJK. Higher UIV levels (T2 vs. T4) had a protective effect against PJK. Based on this study the preservation of segmental kyphosis within the cephalad two levels of the PSF did not minimize the occurrence of PJK.

Hypothesis
Preservation of kyphosis within the cephalad two levels of instrumented posterior spinal fusions (PSF), for idiopathic scoliosis (IS), would be associated with lower frequency of proximal junctional kyphosis (PJK) at two-years postoperatively.

Design
Retrospective, case series

Introduction
Previous studies on PJK in IS have reported conflicting findings;

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none have evaluated the relationship between segmental kyphosis within the cephalad instrumented construct and PJK.

Methods
100 consecutive patients undergoing PSF for IS by a single surgeon with minimum 2-years follow-up were evaluated. Radiographic evaluation focused on sagittal alignment of the upper instrumented vertebrae (UIV), the 1 and 2 vertebrae cephalad (UIV+1, UIV+2) and caudal (UIV-1, UIV-2). The cephalad ligaments and the facet joints immediately cranial to the UIV were left intact.

Results
There were 78 females and 22 males whose mean age was 14.6 (+/- 2.1) years at surgery; mean follow-up was 3.9 (2 to 9.3) years. The overall frequency of PJK was 25% (25/100) at final follow-up. Preoperative mean coronal Cobb measured 63° (40° to 107°) with a mean 66% correction at final follow-up. UIV was T2 (n=15), T3 (n=45) or T4 (n=37). More caudal UIVs were associated with PJK development (p=0.004): T2 (13%), T3 (22%) and T4 (35%). Greater preoperative thoracic kyphosis and UIV-2 values were more likely to develop PJK (p=0.019 and p=0.004, respectively). Postoperatively, larger values for UIV-1 (p≤0.001) and UIV-2 (p=0.002) were associated with PJK at final follow-up. Instrumented changes in UIV-1 and UIV-2 (preoperatively to immediately post-op) did not influence the development of PJK.

Conclusion
In this study greater preoperative thoracic kyphosis and UIV-2, and postoperative UIV-1 and UIV-2 were associated with higher frequencies of PJK. Changes in UIV-1 and UIV-2 at surgery were not related to PJK. Higher UIV levels (T2 vs. T4) had a protective effect against PJK. Based on this study the preservation of segmental kyphosis within the cephalad two levels of the PSF did not minimize the occurrence of PJK.

Take Home Message
PJK after PSF for IS occurred in 25% of patients. Preservation of segmental kyphosis within the cephalad two levels of PSFs did not minimize the occurrence of PJK.

	Pre-op	Immediate Post-op	Final follow-up
Number (%) of cohort with PJK	n/a	11 (11%)	25 (25%)
Mean (STD) values for entire cohort			
UIV+2	10.7° (6.7°)	11.7° (7.2°)	16.2° (9.2°)
UIV+1	8.0° (4.1°)	9.6° (5.8°)	13.3° (7.1°)
UIV-1	9.2° (4.9°)	9.1° (4.9°)	10.9° (5.0°)
UIV-2	13.6° (7.3°)	12.6° (6.2°)	14.6° (6.1°)
Mean (STD) values for those patients (n=25) who developed PJK by final follow-up			
UIV+2	9.2° (6.0°)	16.8° (5.4°)	26.3° (7.4°)
UIV+1	8.2° (4.3°)	13.8° (5.8°)	20.4° (6.5°)
UIV-1	10.7° (5.0°)	11.6° (4.1°)	14.0° (5.0°)
UIV-2	17.1° (9.6°)	15.7° (5.8°)	17.9° (5.9°)
Mean (STD) values for those patients (n=75) who did NOT develop PJK by final follow-up			
UIV+2	11.2° (6.8°)	10.0° (6.9°)	12.8° (7.0°)
UIV+1	8.0° (4.1°)	8.1° (5.1°)	10.9° (5.6°)
UIV-1	8.6° (4.7°)	8.2° (4.9°)	9.9° (4.5°)
UIV-2	12.4° (6.0°)	11.5° (6.0°)	13.5° (5.8°)

Table 1: UIV+2, UIV+1, UIV-1 and UIV-2 values

120. Thoracolumbar Junction Orientation: A Novel Guideline for Sagittal Correction to Reduce Proximal Junctional Kyphosis in Adult Spinal Deformity Patients with UIV at the Thoracolumbar Junction

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Summary
The present study suggests thoracolumbar junction orientation (TLJO): thoracolumbar slope(TLS) and tilt(TLT) as a modifiable risk factor of proximal junctional kyphosis(PJK). The change of TLJO can reflect pelvic-lumbar realignment and influence reciprocal increase of thoracic kyphosis and the development of PJK. Surgical effort to reduce the change of TLS below 9.4 degree may has a role to prevent from developing PJK in the adult spinal deformity surgery patients with stop at thoracolumbar junction.

Hypothesis
The novel sagittal parameter, thoracolumbar junction orientation (TLJO): thoracolumbar slope(TLS) and tilt(TLT) might be a modifiable risk factor of proximal junctional kyphosis(PJK). The excessive change of TLJO after realignment may have a critical role in the development of PJK.

Design
retrospective cohort

Introduction
This study aims to determine a predictive model for reciprocal thoracic kyphosis and proximal junctional kyphosis (PJK) based on the novel sagittal parameters of the thoracolumbar junction orientation (TLJO, thoracolumbar slope [TLS] and thoracolumbar tilt [TLT])

Methods
127 patients fused from sacrum to T10-L2 as UIV were included (min 2yr F/U). TK (T5-T12), PI, SS, PT, LL and proximal junctional angle (PJA) were measured pre-operatively, 6 weeks post-operatively, and at final follow-up. TLJO was measured by TLS and TLT. Changes between time-points were determined (preop-6week=ΔParameter[Pre-6wk] and preop-final follow/up=ΔParameter[Pre-Final]). SRS and ODI questionnaires were evaluated at final follow-up. Patients were divided into two groups based on the presence of PJK (ΔPJA[Pre-Final]>15°). Independent T-Tests and ROC curves were used to investigate the significance of differences and cut-off values. Pearson correlations and linear regressions were used to analyze the entire cohort to determine the relationship between the changes in parameters.

Results
Compared to patients without PJK (n=100; 78.7%), those with

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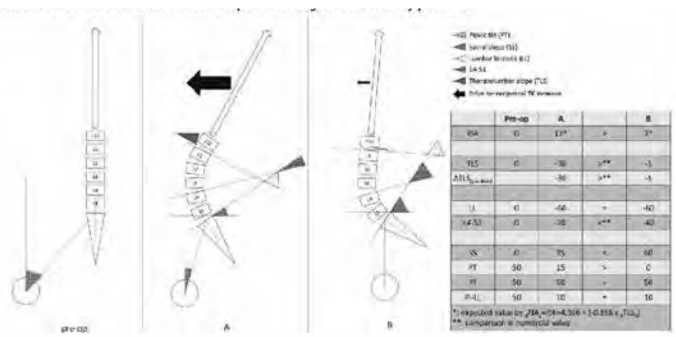
PJK (n=27; 21.3%) had significantly lower SRS scores in average, pain, mental health and significantly greater ΔTK[Pre-Final], ΔLL[Pre-6wk], ΔTLS[Pre-6wk]. To maintain in the non-PJK group, ROC curves demonstrated a cut-off value of -9.4° for ΔTLS[Pre-6wk]. PJK was significantly correlated with ΔTK[Pre-Final] and ΔTLS[Pre-6wk]. The linear correlation revealed that ΔTLS[Pre-6wk] < -25.3° is the risk factor of PJK > 15°.

Conclusion
As change of TLS reflects lumbopelvic realignment and influences reciprocal TK, reducing the change of TLS may be a sagittal realignment guideline to reduce the risk of PJK.

Take Home Message
As change of thoracolumbar junctional orientation reflects lumbopelvic realignment and influences reciprocal TK, reducing its change may be a sagittal realignment guideline to reduce the risk of proximal junctional kyphosis.



121. Vertebral Column Resection Improves the Sagittal Plane Greater than Other Techniques but Risks Symptomatic Junctional Kyphosis

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Summary
In a series of 228 patients with severe pediatric spinal deformity, the VCR group (n=110) had greater improvement in the S-DAR (16.9 to 5.7) vs those who did not have a VCR (12.2 to 6.3) (p<0.01). However, the incidence of junctional kyphosis requiring intervention was significantly higher (7.3 vs 0.8%)(p<0.016). More powerful correction in the sagittal plane with a VCR adds risk for the development of symptomatic junctional kyphosis and a careful assessment of the sagittal plane is necessary.

Hypothesis
The incidence of sagittal plane complications following surgery for severe pediatric spinal deformity is significant and affects patient outcomes.

Design
Prospective multicenter international observational study.

Introduction
The surgical treatment of severe pediatric spinal deformity is challenging with significant risks including neurologic and coronal decompensation which have been well-characterized. However, sagittal plane analysis has been lacking for these patients despite anecdotal reports of significant challenges with proximal (PJK) and distal junctional kyphosis (DJK).

Methods
The multi-center database of pediatric severe spine deformity patients in which the preop curves were either greater than 100° or patients who had a VCR was reviewed. All sagittal parameters were analyzed to determine improvement in radiographic parameters and determining the incidence of PJK or DJK occurred. Differences between VCR and no VCR patients were assessed.

Results
There were 228 patients who had 2 year data for review. 110 had a VCR and 118 did not. Preoperatively, the VCR group had a greater Sagittal-Deformity Angular Ratio (S-DAR) (16.9 vs 12.2, p<0.001), and measured T10-L2 (25.4 vs 9.2°, p=0.02) without differences in other preoperative sagittal plane parameters including T2-T12 kyphosis (65.6° vs 67.5°), lumbar lordosis (63.3° vs 68.2°), and sagittal balance or pelvic parameters. The followup lateral radiographs demonstrate improved S-DAR correction in the VCR group resulting in similar 2 year S-DAR (5.7 vs 6.3). Other sagittal parameters were similar including T5-T12 (36.4° vs 40.5°) and there was improvement of the sagittal vertebral alignment (2.2 to 0.1 vs 2.0 vs 0.3). However, the incidence of PJK or DJK requiring further intervention was significantly higher in the VCR group (8 of 102 (7.3%)) vs the no VCR group (1 of 117 (0.8%)) (p<0.016).

Conclusion
Patients who have a larger deformities including S-DAR will often require a VCR procedure to maximize correction, however, more attention should be paid to the sagittal plane to avoid junctional kyphosis requiring repeat surgical intervention.

Take Home Message
Vertebral column resection results in improved correction of the S-DAR but does result in a higher incidence of junctional kyphosis requiring revision (7.3 vs 1.8%)(p<0.01).

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

122. Evaluation of Global Alignment and Proportion Score in an Adult Spinal Deformity Database

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Summary
Global Alignment and Proportion Score (GAP) has been shown to predict mechanical complications in adult spinal deformity. (ASD). We evaluated the GAP score in an independent ASD database. GAP Score was useful in predicting mechanical complications. Rates of mechanical complications were as follows: in proportioned (GAP-P) 23.8%, moderately disproportioned (GAP-MD) 55.7% and severely disproportioned (GAP-SD) 66.1% of patients.

Hypothesis
Global Alignment and Proportion Score predicts mechanical complications

Design
Retrospective review

Introduction
Sagittal spinopelvic alignment has been associated with PROs and mechanical complications. Linear numerical values of pelvic tilt and lumbar lordosis with different pelvic incidences may be misleading. The use of relative measurements embedded in a weighted scoring of GAP has been described. The purpose of our study was to evaluate the validity of the GAP score in an independent database.

Methods
ASD pts. who had ≥5 levels fusion to the sacrum from 2004-2014 were included. Demographic, clinical, surgical and X-ray data were recorded. Cochran-Armitage tests were used to analyze mechanical complication trends across GAP categories. Uni/multi-variable logistic regression were used to obtain Odds Ratios of predictor (GAP categories) and the outcome (mechanical complication). The GAP score was tested using the area under the receiver operating characteristic curve, sensitivity, specificity, positive predictive value, negative predictive value and accuracy in predicting mechanical complications.

Results
338/657 pts. (295F, 43M) with a avg. age of 58±10 met the inclusion criteria. Mean f/u was 55 mos (24-138). All mechanical complications were included from minor proximal compression fracture and iliac screw disengagement. Common complications were rod failure in 25.4% (86/338) pts, 23 pts (6.8%) implant complication at the L-S junction, PJF in 45 pts. (13.3%) and PJK in 20 pts (5.9%). Mechanical complication in (GAP-P) 23.8%, (GAP-MD) 55.7% and (GAP-SD) 66.1% pts. AUC for the GAP score was 0.653 (95% CI, 0.59 to 0.71, p<0.001). GAP Score had 60.5% sensitivity, 76.2% specificity, 89.1% positive predictive value, 37.4% negative predictive value, and 64.2% accuracy in predicting mechanical complications. Post-op alignment of GAP-MD and GAP-SD resulted in 3.6 and 4.6 folds of more odds in incurring a mechanical complication compared to GAP-P.

Conclusion
Lower GAP scores were assoc. with lower rates of mechanical complications. Both crude and adjusted odds ratios were high.

Take Home Message
GAP Score is useful in predicting mechanical complications in an independent database. A trend was observed in which lower GAP scores were associated with lower rates of mechanical complications.

123. Global Alignment and Proportion (GAP) Scores in an Asymptomatic Nonoperative Cohort

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Summary
The Global Alignment and Proportion (GAP) score, developed from a cohort of surgical adult spinal deformity (ASD) patients, proposes lumbosacral and global sagittal plane alignment targets. This analysis of an asymptomatic, nonoperative cohort found 41% of subjects classified as moderately or severely disproportioned. A refined understanding of alignment targets and their implications for mechanical failure and quality of life outcomes is needed.

Hypothesis
Asymptomatic adults will be "proportioned" (<=2) according to the Global Alignment and Proportion (GAP) score

Design
Observational cohort

Introduction
The GAP score classifies lumbopelvic and global sagittal alignment and may predict mechanical complications after spinal deformity surgery. It was developed in a population of surgical spinal deformity patients and has not been assessed in an asymptomatic population.

Methods
Full body anteroposterior and lateral radiographs were obtained for 120 asymptomatic volunteers. Demographics and sagittal radiographic parameters (PI, SS, L1-S1 Lordosis, L4-S1 Lordosis,

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

and Global Tilt) were measured and GAP scores calculated (www.gapcalculator.com). A Mann-Whitney U Test compared groups.

Results

85 individuals (20 males and 65 females, mean age 48 ± 16 yrs (22-77 yrs), BMI 27 ± 6 (19-45) were included for analysis (Table 1). The mean (2) and median (1) GAP scores were that of a proportioned spine (interquartile range 0-3). 59% (62) were proportioned, 22% (18) were moderately disproportioned, and 19% (5) were severely disproportioned. The mean relative pelvic version (RPV), relative lumbar lordosis (RLL), lumbar distribution index (LDI), and relative spinopelvic alignment (RSA) were all considered aligned, although the mean RLL and LDI scores were both greater than 1. When partitioned by age (<60 yo and 60 >= yo), younger patients had lower mean GAP scores (Younger: mean 1, median 0; Older: 3, 2; p<0.001) and were more frequently normally proportioned.

Conclusion

The mean and median GAP scores in this asymptomatic, nonoperative cohort were classified as normally proportioned. However, a large percentage (41%) of asymptomatic volunteers were moderately (22%) or severely disproportioned (19%). Older patients (>=60) had higher scores, indicating some disproportion. There were also a small number of severely sagittally misaligned and poorly proportioned, yet asymptomatic patients.

Take Home Message

In a series of asymptomatic adults, 41% were moderately or severely disproportioned. Further refinement of individualized alignment targets is needed to understand effects on quality of life and mechanical failure.

N	85	
Gender		
Male	20	
Female	65	
	Mean ± SD	Min - Max
Age (yrs)	48 ± 16	22 - 77
BMI	27 ± 6	19 - 45
Thoracolumbar parameters		
PI	50.2 ± 12.0	9.0 - 80.0
SS	36.9 ± 7.9	21.0 - 60.0
PT	14.3 ± 8.6	-6.0 - 47.0
L1-S1 Lordosis	58.2 ± 11.3	32.0 - 81.0
L4-S1 Lordosis	35.4 ± 7.9	14.0 - 53.0
Global Tilt	9.3 ± 9.6	-14.0 - 31.0
GAP Score	2 ± 2	0 - 10
GAP Score Components		
Age (y)	0 ± 0	0 - 1
Relative Pelvic Version (°)	-1.7 ± 6.1	-16.3 - 23.7
RPV Score	0 ± 1	0 - 3
Relative Lumbar Lordosis (°)	-1.0 ± 11.0	-28.5 - 35.4
RLL Score	1 ± 1	0 - 3
Lumbar Distribution Index (%)	61% ± 14%	3% - 89%
LDI Score	0 ± 1	0 - 3
Relative Spinopelvic Alignment (°)	1.5 ± 6.7	-13.4 - 20.1
RSA Score	0 ± 0	0 - 1

Table. Demographic, Radiographic Data, and GAP Score

124. The Impact of Lordosis Distribution and Sagittal Harmony on Postoperative Mechanical Complications after a Lumbar PSO

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Summary

We analyzed the impact of postoperative ideal (based on patient's Pelvic Incidence) lordosis distribution and ideal sagittal harmony in a consecutive series of 87 patients undergoing a single level lumbar PSO. With a mean follow-up of 4.5 yrs, we found 40.2% of postoperative mechanical complications. Over other multiple analyzed risk factors, multivariate analysis determined that age, ideal sagittal shape restoration, and ideal lumbar apex positioning after a lumbar PSO, were the most important variables associated with mechanical complications.

Hypothesis

Restoring the ideal lordosis distribution after a lumbar PSO helps avoiding postoperative mechanical complications

Design

Retrospective analysis of prospectively collected adult deformity patients undergoing L-PSO.

Introduction

Many variables have been associated with mechanical complications after L-PSO. However, the impact of postoperative ideal (based on patient's PI) lordosis distribution and ideal sagittal harmony is still underexplored.

Methods

We analyzed the following risk factors: age, ASA score, gender, PSO level, interbody cages, rod material, rod diameter, number of rods, upper instrumented vertebra, lower instrumented vertebra, PI-LL mismatch, Global Tilt (GT), postoperative level of Lumbar Apex (LApex), postoperative level of Inflexion Point (InfxP), and postoperative type of Roussouly sagittal profile (R-type). The last three variables depended on the level of PSO, and final pelvic version, and they were compared to ideal. Univariate and multivariate analysis were performed to identify risks for mechanical complications (minimum 2-yr follow-up).

Results

87 patients were included. Mean follow-up was 4.5±1.7 yrs. 40.2% suffered postoperative mechanical complications (7 PJK, 4 PJF, 18 pseudoarthrosis, 6 screw pull-out). Time to compli-

cations was x=584±416 days from surgery. Univariate analysis showed that: age (63 vs 57 yrs;P=0.04), preop-GT (50.7° vs 38.7°;P<0.001), postop-GT (28.9° vs 23.4°; P=0.018), postoperative LApex location mismatched from ideal (77.8% vs 22.2%;P=0.036), and postoperative R-type mismatched from ideal (67.6% vs 22.6%;P<0.001), were significantly related to mechanical complications. Multivariate analysis selected as the most important variables: postoperative R-type mismatched from ideal OR=11.3 (95%CI=3.9-32.6; P<0.001), age OR=1.05 (95%CI=1-1.1;P=0.03), and LApex matching OR=0.5 (95%CI=0.27-0.97;P=0.04). The further the LApex was from its ideal position, the higher the risk of mechanical complications (P=0.036)

Conclusion

Over other multiple suspected risk factors, proper lumbar apex position and sagittal shape ideal restoration played an important role in postoperative mechanical complications after L-PSO.

Take Home Message

Restoring the ideal lordosis distribution and sagittal harmony after lumbar PSO plays an important role in postoperative mechanical complications

Lumbar PSO Complications

125. Preop Opioid Use is Associated with Worse Postop Outcomes and Chronic Opioid Use in Non-Revision Adult Scoliosis Patients: Corroboration of Two Independent Multi-center Studies

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Summary

Two independent, multi-center prospective ASD studies demonstrated agreement that preop opioid use and increased frequency of use in adult scoliosis patients with no history of prior surgery and no sagittal malalignment is associated with worse preop pain, worse postop pain, and worse outcomes. Continued 2 year postop opioid usage was approximately 50% in both datasets for daily preop opioid users compared to 13% in nonusers. Attempts should be made to discontinue preop and postop adult scoliosis opioid usage.

Hypothesis

Two year outcomes are not different for preop opioid daily, weekly and nonusers after ASD surgery.

Design

Comparative analysis of datasets from two prospective multi-center ASD studies

Introduction

Sagittal malalignment and failed surgery are established etiologies for ASD pain. The impact of preop opioid usage on outcomes and persistent postop opioid use for primary adult scoliosis is poorly understood.

Methods

Adult scoliosis patients age >18 years, no prior spine surgery, no sagittal malalignment (as per SRS ASD classification) were identified from 2 independent prospective databases and assessed for preop non-opioid (NON) vs. opioid use and amount of use (DAILY vs. WEEKLY). Patients were treated surgically and pre and postop demographic, radiographic data, patient reported outcome measures and postop opioid usage evaluated, minimum 2 year follow up.

Results

Database 1 (D1; 102/102 patients; mean follow up 2.1+0.2yr) and Database 2 (D2; 116/168 patients, mean follow up 3.3 years) demonstrated similar preop demographic and radiographic parameters for NON, DAILY and WEEKLY (p>0.05; Table). DAILY had greater preop NRS back and leg pain, and worse preop PCS and MCS than NON (p<0.05; Table). Levels fused and postop spinal alignment was not different between groups (p> 0.05). DAILY had worse postop NRS back pain (D1=4.1, D2=4.9), worse PCS (D1=38.8, D2=41.9), and worse MCS (D1=49.7, D2=45.4) than NON and WEEKLY (p<0.05, Table). Continued 2 year postop opioid usage for DAILY was approximately 50% (D1=50.0%, D2=47.8%) compared to 13% for NON (D1=13.8%, D2=13.1%; p<0.05; Table).

Conclusion

Dataset comparison from 2 independent, multi-center prospective ASD studies demonstrated increased frequency of preop opioid use in adult scoliosis patients with no history of prior surgery and no sagittal malalignment is associated with worse postop pain, worse outcomes and continued opioid use. Attempts should be made to discontinue preop and postop adult scoliosis opioid usage.

Take Home Message

Two independent, multi-center prospective studies demonstrated preop opioid use and increased opioid use frequency among adult scoliosis patients is associated with worse postop outcomes and continued opioid use.

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	Database 1 NON (n=65)	Database 1 Daily (n=24)	Database 1 Weekly (n=13)	P value	Database 2 NON (n=84)	Database 2 Daily (n=24)	Database 2 Weekly (n=8)	P value
Age (years)	56.9	60.4	57.9	>0.05	46.3[1]	54.7[1]	52.1	0.0443[1]
BMI	25.8	28.6	25.5	>0.05	24.9	25.5	23.0	>0.05
Smoking history	1.6%	4.2%	0%	>0.05	7.9%	12.5%	0.0%	>0.05
Depression	24.5%	41.7%	30.8%	>0.05	14.7%	25.0%	37.5%	>0.05
Preop scoliosis (degrees)	56.4[1]	46.6[1]	54.3	0.010[1]	57.4	54.1	57.1	>0.05
Postop scoliosis (degrees)	25.9[1]	17.7[1]	23.3	0.026[1]	24.2[1]	19.7[1]	29.1	0.0446[1]
Preop SVA (mm)	7.9	11.1	2.8	>0.05	-4.1	-9.5	-11.6	>0.05
Postop SVA (mm)	2.9	11.2	2.6	>0.05	-2.2	-3.4	-22.0	>0.05
Preop PI-LL (degrees)	10.0	12.3	10.9	>0.05	0.5	-0.5	-0.2	>0.05
Postop PI-LL (degrees)	3.1	3.7	2.5	>0.05	-0.9	-5.4	-11.5	>0.05
Preop back pain (NRS)	5.4[1]	7.0[1]	5.8	0.004[1]	6.1[1]	7.4[1]	6.9	0.0391[1]
Postop back pain (NRS)	2.7	4.1	2.5	>0.05	3.4[1]	4.9[1]	5.0	0.0238[1]
Preop leg pain (NRS)	3.2[1]	5.0[1]	3.2	0.036[1]	2.9[1]	4.6	5.8[1]	0.0402[1]
Postop leg pain (NRS)	1.8	2.1	1.9	>0.05	1.8	3.3	2.6	>0.05
Preop PCS	38.4[1,2]	28.5[1]	30.9[2]	0.000[1], 0.011[2]	40.7[1]	31.3[1]	37.5	0.0007[1]
Postop PCS	46.3[1]	38.8[1]	43.8	0.007[1]	46.7	41.9	40.8	>0.05
Preop MCS	53.2[1,2]	41.8[1]	46.5[2]	0.000[1], 0.031[2]	49.5[1]	41.2[1]	44.3	0.0072[1]
Postop MCS	54.2	49.7	55.5	>0.05	53.9[2]	45.4[1,2]	57.7[1]	0.0135[1], 0.0038[2]
Preop Self-image SRS	2.9[1]	2.4[1]	2.7	0.003[1]	2.7	2.5	2.5	>0.05
Postop Self-image SRS	4.1	3.8	3.9	>0.05	4.1[1]	3.6[1]	4.0	0.0245[1]
Preop SRS satisfaction	3.0	3.5	2.5	>0.05	2.8	2.9	2.9	>0.05
Postop SRS satisfaction	4.3	4.0	4.2	>0.05	4.3	4.3	3.8	>0.05
Continued opioid use at 2 year follow up	13.8%[1]	50%[1]	30.8%	0.0004[1]	13.1%[1,2]	47.8%[1]	50.0%[2]	0.0003[1], 0.0069[2]

126. Preoperative Opioid Therapy Poorly Controls Pain in Non-revision Adult Spinal Deformity (ASD) and Increases Risk for Chronic Postoperative Opioid Usage

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Summary

Evaluation of 227 surgically treated non-revision ASD patients demonstrated that despite similar demographic and radiographic parameters and similar surgery, OPIOID had greater preop pain scores, greater postop pain scores and greater risk for postop opioid usage than NON. Relative risk of opioid usage at 2yrs postop was 5.0 for preop daily users and 2.8 for preop weekly users compared to preop nonusers. Preop opioid therapy poorly controls pain in ASD and increases risk for postop pain and chronic usage.

Hypothesis

Preop opioid therapy poorly controls pain and increases risk for chronic opioid use compared to preop non-opioid users

Design

Analysis of a prospective multi-center ASD database

Introduction

Reasons for pain among ASD patients with no prior history of spine surgery is incompletely understood. Preop opioid therapy is controversial and problematic

Methods

ASD patients (age >18 years, no history of spine surgery) enrolled into a prospective multi-center ASD database were assessed for preop opioid (OPIOID) vs non-opioid (NON) use, organized into SRS deformity type, treated surgically, and evaluated minimum 2 years postop. Pre and postop demographic, radiographic data, pain values and postop opioid usage was evaluated.

Results

227/393 patients, (mean follow up 3.3 years) eligible for study were evaluated. Comparison of scoliosis patients (thoracic, lumbar or double type deformities) demonstrated OPIOID (n=32) had similar preop age, BMI, smoking history, scoliosis magnitude, and sagittal spinopelvic parameters as NON (n=95; p>0.05), however OPIOID had greater preop NRS back pain (7.3 vs 6.1), leg pain (4.9 vs 3.1), and worse SF-36 bodily pain (31.8 vs 39.8) than NON (p<0.05, respectively). Comparison of sagittal/mixed deformities demonstrated OPIOID (n=55) had similar preop age, BMI, ASA grade, smoking history and sagittal spinopelvic parameters as NON (n=45; p>0.05), however OPIOID had greater preop NRS back pain (7.8 vs 7.0), leg pain (5.8 vs. 3.8), and worse SF-36 bodily pain (29.3 vs 35.6) than NON (p<0.05, respectively). At two years postop OPIOID had greater pain scores than NON and greater persistent opioid usage (50%) vs NON (13.5%; p<0.05). Relative risk for 2 year postop opioid usage was 5.0 for daily preop users and 2.8 for weekly preop users compared to NON.

Conclusion

Evaluation of non-revision ASD patients demonstrated that despite similar demographics, spinal deformity and surgical treatment, OPIOID had greater preop and postop pain and greater risk for postop opioid usage than NON. Preop opioid therapy should be avoided in non-revision ASD.

Take Home Message

Preop opioid therapy poorly controls pain in non-revision ASD and increases the risk for continued opioid usage at 2 years postop compared to similar ASD patients not using preop opioids.

127. Post-op Opioid Cessation in ASD Patients Using Opioids Pre-op is Associated with Improved Outcomes and Satisfaction

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Summary

296 (54.11%) of 547 adult spinal deformity (ASD) patients un-

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

dergoing surgery reported using opioids preoperatively. Of these, 57.8% decreased or ceased opioid use 2-years postoperatively. At baseline, these patients had better SF-36 MCS scores and underwent fewer 3-colum osteotomies (3CO). At 2-years postoperatively, these patients had improved HRQL scores, were more likely to reach MCID, and were more satisfied.

Hypothesis
A significant number of surgical ASD patients are using opioids preop and there will be identifiable factors associated with cessation or decreased use.

Design
Retrospective review of a prospective multicenter database of ASD patients.

Introduction
The opioid crisis in the US is catastrophic. A large number of patients use opioids preop. We aim to compare outcomes in those who cease and those who continue opioids post op.

Methods
Opioid use was measured using the SRS-22r Q11. Surgical ASD patients using opioids pre-op (daily or weekly), with 2-year follow up were analyzed and divided based on 2-year opioid use: decreased/ceased vs continued. Groups were compared in regards to demographics, radiographic parameters, HRQL, surgery invasiveness, complications, re-operations, and satisfaction.

Results
296 patients reported using opioids preop. At 2-years, 171 (57.8%) had decreased or ceased use. Those who decreased/ceased had a higher proportion of females. There was no other statistically significant difference in demographics or radiographic parameters. Those who decreased/ceased opioids had higher baseline SF-36 MCS – vitality (38.31 vs 35.69, p=0.03), with no difference in the remainder of the baseline HRQL scores. There were less 3COs performed in those who decreased/ceased. The groups had similar major complications, re-operations, and post-op radiographic parameters. Patients that reduced/ceased had significantly higher HRQL 2 years post op : back NSR (3.47 vs 5.3, p=0.0001), leg NSR (2.7 vs 3.95, p=0.0006), SF-36 MCS (50.61 vs 44.62, p=0.0002), SF-36 PCS (39.98vs 31.19, p=0.0001), and ODI (27.9 vs 44.62, p=0.0001). They were more likely to reach MCID (ODI 68.64% vs 27.42%, PCS 75.47% vs 39.17% p=0.0001) and be satisfied with surgery (84.7% vs 71.3%, p=0.003).

Conclusion
In ASD patients using opioids pre-op, only 57.8% will decrease or cease use at 2-years despite similar correction, complications and reoperations. Those who decrease or cease post op have better HRQL scores and are more satisfied with surgery. Future research should focus on identifying those at risk of continued opioid use and developing strategies for successfully tapering.

Take Home Message
54.11% of ASD patients undergoing surgery reported using opioids preoperatively. Of these, only 57.8% decreased or ceased opioid use 2-years postoperatively, despite similar correction, complications and reoperations.

	Decreased/Ceased Opioids (n=171)	Continued Opioids (n=125)	p
Patient demographics			
Gender (female)	**83.83%**	**72.00%**	**0.014**
History of depression	31.36%	37.60%	0.264
BMI	27.94	28.84	0.19
CCI	1.83	2.07	0.24
Age	61.8	61.32	0.72
Prior spine surgery	61.21%	64.00%	0.627
Smoking	8.07%	5.88%	0.48
Baseline HRQL			
Baseline back NRS	7.75	7.78	0.86
Baseline leg NRS	5.56	5.35	0.68
Baseline MCS - vitality	**38.31**	**35.69**	**0.033**
Baseline PCS	28.89	27.83	0.27
Baseline ODI	51.24	53.21	0.289
Baseline radiographic parameters			
Baseline PI-LL	20.11	19.86	0.92
Baseline PT	25.73	26.48	0.53
Baseline SVA	83.01	81.46	0.77
Surgical parameters			
Levels fused	11.41	11.39	0.94
PSO	13.45%	25.60%	0.013
Complications			
Major complications	29.24%	38.40%	0.1
Reoperation	28.07%	32.00%	0.46
2-year radiographic parameters			
2y PI-LL	3.57	3.8	0.91
2y PT	22.68	22.47	0.85
2y SVA	37.02	42.43	0.44
2-year HRQL			
2y back NRS	**3.47**	**5.3**	**0.0001**
2y leg NRS	**2.7**	**3.95**	**0.0006**
2y MCS	**50.61**	**44.75**	**0.0002**
2y PCS	**39.98**	**31.19**	**0.0001**
Reaching PCS MCID	**75.47%**	**39.17%**	**0.0001**
2y ODI	**27.9**	**44.62**	**0.0001**
Reaching ODI MCID	**68.64%**	**27.42%**	**0.0001**
Satisfaction	**84.71%**	**71.31%**	**0.005**

128. Complications of Posterior Vertebral Column Resection for Severe Spinal Deformity with More Than Two-year Follow-up: A Single-center Experiences

<u>Qianyu Zhuang, MD</u>; Jiangguo Zhang, MD; Wang Shengru, MD

Summary
A retrospective study of prospective database from a consecutive series of 126 patients undergoing posterior vertebral column resection (PVCR) by the single surgeon with a minimum follow-up of 2 years

Hypothesis
PVCR can offer significant improvements in both local deformity correction and global radiographic alignment at more than 2 years, with acceptable complications rate.

Design
Retrospective analysis of prospective database.

Introduction

Previous complications studies of PVCR indicated that this technique was challenging but effective for spinal cord decompression and deformity correction. However, most of these studies are based on either multicenter data with unavoidable internal bias or single center data from a relatively small sample set (<70 patients.)

Methods

We reviewed 126 patients undergoing PVCR by a single surgeon prior to December 31th, 2016, at a single institution. Standard preoperative and perioperative data were collected at a minimum follow-up of 2 years. Patients were divided into the pediatric cohort and the adult cohort according to the age. Complications were categorized as neurological, medical, implant, wound, and alignment.

Results

A total of 126 patients were available for analysis: 78 (61.9%) were pediatric patients, and 48 (38.1%) were adult patients. The mean age was 10.1 ± 4 years for the pediatric cohort and 36.9 ± 12.8 years for the adult cohort. The mean follow-up period was 40.4 months. There was significant improvement in both coronal and sagittal deformity: 68% correction for scoliosis and 66.7% for kyphosis. Of the 126 patients, 67(53.2%) experienced complications, 18(14.2%) presented intraoperative MEP Alert, and 9 (7.1%) suffered postoperative neurological deficits. 20(15.8%) patients developed alignment complications, with 4(3.2%) underwent revision surgery. 7(5.6%) presented pseudarthrosis with rod breakage during follow-up and all received revision surgery. The overall revision rate in this cohort were 7.9% (10 cases).

Conclusion

Our results demonstrated that PVCR, even in experienced hands in spine deformity center, is still challenging with relatively high complication rate. Surgical, neurological and alignment complications are the three biggest concerns for this powerful but highly technical demanding technique.

Take Home Message

PVCR, even in experienced hands in spine deformity center, is still challenging with relatively high complication rate. Surgical, neurological and alignment complications are the three biggest concerns.

Complications	Pediatric cohort (<18 years old)	Adult cohort (>18 years old)	Total	Outcome
Neurological				
Intraoperative MEPs changes	9	9	18	9 presented post-op motor deficit
Postoperative neurological deficit	4	5	9	3 completely recover post-op 6 months 5 completely recover post-op 3 months 1 completely recover before discharge
Nerve root irritation	3	3	6	Resolved within 2 weeks after surgery
Impaired bladder Function	4	4	8	4 resolved within 2 weeks after surgery 4 resolved within 1 month after surgery
Surgical				
Intraoperative Excessive bleeding (>1500ml)	15	25	40	No related complication
CSF leakage	0	2	2	Resolved
Prolonged respiratory support	3	1	4	Resolved
Pleural effusion	7	3	10	Resolved 3 underwent chest tube placement
Pneumothorax	2	0	2	Resolved
Wound				
Deep wound infection	0	2	2	Resolved 1 underwent debridement surgery
Superficial wound problem	1	1	2	Resolved
Implant				
Pedicle screw malposition	0	2	2	Screw position adjusted, with no neurological deficit
Pseudarthrosis (rod fracture)	3	4	7	7 underwent revision surgery 5 used iliac crest autobone
Alignment				
Radiographic PJK	10	5	15	12 Under close observation with no symptom 3 underwent revision surgery
Distal Junctional Kyphosis	0	2	2	Under close observation with no symptom
Distal Adding on	3	0	3	2 under close observation with no symptom 1 underwent revision surgery
Medical				
Cardiac problem	0	1	1	Resolved before discharge
Pulmonary infection	0	2	2	Resolved before discharge
Coagulation dysfunction	6	0	6	Resolved before discharge
Liver dysfunction	0	3	3	Resolved before discharge
Pancreatitis	1	1	2	Resolved before discharge
Urinary infection	0	1	1	Resolved before discharge
Ileus	0	3	3	Resolved before discharge

Table 1. Incidence and Outcomes of Complications of Pediatric and Adult Cohorts.

129. Comprehensive Complication Classification for Adult Spinal Deformity: Complication Timing and the Impact on Outcomes at 2 Years

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Summary

The timing and impact of complications over time is important to understand for patients, payors and providers. Most medical and operative complications occur proximate to the index surgical intervention. Neurologic, Implant and radiographic complications continue to occur over-time and affect the quality of life for the patient at 2 years. When controlling for baseline age, deformity and disability; these complications impact 2-year outcome measures.

Hypothesis

Different complications types may occur at different time points and may have a significant effect on patients' outcomes

Design

Retrospective review

Introduction

Complications may occur at any timepoint. Understanding the

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

timing of specific complications may be helpful to guide patients and surgeons. The impact of those complications on health outcomes at 2yrs is critically important

Methods
Inclusion criteria: age >18yrs, ASD, min 2yr f/u with 2yr HRQL. Complications were categorized by event & time from index surgery. Kaplan-Meier estimation to determine the complication event occurrence over-time was plotted. The groups (with & without complications) were then propensity matched by age, disability(ODI, PCS), frailty & deformity(PI-LL) to determine if there were any effects of complication at 2yrs

Results
584/732 patients met inclusion criteria (mean age 58.6yrs, 78% female, mean BMI 27.5, mean CCI 1.64, mean ODI 43.5). 70.9% had least one complication event over the 2yr period, with an avg of 1.45 events per patient. The most common were Radiographic(31.6%), Implant(28.5%) & Operative(25.9%). Kaplan-Meier plots revealed that while most occurred near the index operation including cardiopulmonary, gastrointestinal, operative, infection; others continue to occur over-time, including neurologic, radiographic & implant complications. Patients with complications (after propensity matching) have significant worse outcome scores for PCS(43 v 40; p<0.05) and SF-physical functioning(41 v 38; P<0.05) at 2yrs with a trend in increasing SRS-pain and SF36 body pain(p=0.055). Subanalysis for specific complication type found no differences at 2yrs for cardiopulmonary, gastrointestinal, operative or neurologic; but significantly worse outcomes for implant & radiographic (P<0.05) perhaps due to continued occurrence over-time & proximity to outcome metric

Conclusion
Complications occur over-time & can be predicted by type. Implant, radiographic & neurologic complications continue to occur over time, & need to be followed closely. Complication type is critical & those that occur later & increase over time are more impactful for patients at 2yrs.

Take Home Message
Complication occurrence over time is predicted by the primary complication type, and complications that continue over-time are more likely to affect outcomes at 2 years.

130. Incidence and Risk Factors for Rod Fracture after Three-column Osteotomy in Severe Spinal Kyphoscoliosis

Yong Qiu, MD; Sanqiang Xia, PhD; Zezhang Zhu, MD; Benlong Shi, PhD; Zhen Liu, MD; Junyin Qiu; Feng Zhenhua, MS; Hongbin Ni, MD

Summary
The prevalence of rod fracture (RF) after three-column osteotomy (3-CO) was 6.8%. The mean time-point of RF was 28.6 months (range from 8 to 96 months) post-operatively, 70% of RFs occur within 2 years after surgery. The risk factors of RF after 3-CO were instrumentation crossing both thoracolumbar and lumbosacral junctions, residual kyphosis, malposition of titanium mesh cage, pseudoarthrosis and coronal imbalance.

Hypothesis
Patients with severe kyphoscoliosis undergoing 3-CO have a higher risk of rod fracture during the follow-up.

Design
Retrospective single-center study

Introduction
It has been reported that the prevalence of RF is high in severe kyphoscoliosis after 3-CO. However, the incidence and risk factors for RF after 3-CO in severe kyphoscoliosis involving a large number of cases at 1 institution were not precisely investigated.

Methods
Patients older than 10 years old with severe kyphoscoliosis undergoing 3-CO and more than 5-levels fusion from June 2003 to October 2016 were reviewed. The incidence, time-point and risk factors of RF were analyzed.

Results
A total of 533 patients were included in the study, of whom 36 patients (6.8%) sustained a RF including 17 (47.2%) congenital scoliosis (CS), 11 (30.6%) ankylosing spondylitis (AS) related kyphosis and 4 (11.1%) degenerative scoliosis (DS) patients. Considering the types of osteotomy, RF occurred in 55.6% (20/36) patients with pedicle subtraction osteotomy (PSO), 2.8% (1/36) patients with SRS-Schwab grade IV osteotomy, 33.3% (12/36) patients with vertebral column resection (VCR) and 8.3% (3/36) patients with SRS-Schwab grade VI osteotomy, respectively. The mean time-point of RF was 28.6 months post-operation (range, 8-96 months), which was within 2 years after surgery in 69.4% patients. A unilateral RF was identified in 22 (61.1%) patients and a bilateral RF in 14 (38.9%) patients. The risk factors of RF after 3-CO were revealed including instrumentation crossing both thoracolumbar and lumbosacral junctions (15/36, 41.7%), residual kyphosis (10/36, 27.8%), malposition of titanium mesh cage (4/36, 11.1%), pseudoarthrosis (3/36, 8.3%) and coronal imbalance (2/36, 5.6%).

Conclusion
The overall prevalence of RF after 3-CO was 6.8%. Risk factors of RF after 3-CO were instrumentation crossing both thoracolumbar and lumbosacral junctions, residual kyphosis, malposition of titanium mesh cage, pseudoarthrosis and coronal imbalance.

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Take Home Message
RF occurred in 5.3% patients undergoing 3-CO with risk factors including instrumentation crossing thoracolumbar and lumbosacral junctions, residual kyphosis, cage malposition, pseudoarthrosis, coronal imbalance.

131. Safety and Efficacy of Osteotomy for Congenital Spinal Deformity Associated with Split Spinal Cord Malformation

Hua Hui, MD; Dingjun Hao, MD, PhD

Summary
56 consecutive patients, who had progressive congenital spinal deformity (CSD) associated with split spinal cord malformation, had one stage osteotomy surgery and posterior fusion surgery. the minimal follow up period was 24 months. The mean major coronal curves were corrected from an average of 76.5o to 28.4 o with a correction rate of 62.9%.There was no permanent neurological compromise. The osteotomy for CSD associated with SSCM may provide a satisfactory option to effectively improve the spinal deformity

Hypothesis
The osteotomy for progressive congenital spinal deformity patients associated with SSCM may provide a satisfactory option to effectively improve the spinal deformity without significant complications and without the necessity of the resection of bony spur in the Type I SSCM

Design
Patients had one stage osteotomy surgery. Preoperatively data and follow-up data at 12 months and 24 months were collected. Medical records and radiological studies were respectively reviewed to access clinical and radiological outcomes and surgery-related complications.

Introduction
The aim of this study is to retrospectively evaluate the safety and efficacy of osteotomy for 56 consecutive patients, who had progressive congenital spinal deformity (CSD) associated with split spinal cord malformation (SSCM).

Methods
The osteotomy was done directly in all patients and was composed of hemivertebrae resection in 17, pedicle subtraction osteotomy (PSO) in 26, and vertebral column resection (VCR) (the level of osteotomy was above the bony spur in the patients of type I) in 13; after the corrective stage of surgery, posterior fusion surgery was performed in all patients

Results
The mean major coronal curves were corrected from an average of 76.5o to 28.4 o with a correction rate of 62.9%. The mean apical vertebral translation in coronal curves was corrected from an average of 54.1mm to 22.1mm with a correction rate of 59.1%.The mean thoracic trunk shift in major coronal curves were corrected from an average of 22.2mm to 8.1mm with a correction rate of 63.5%.There was 1 patient who turned to paralysis post surgery and recovered with partial uroclepsia at 24 months follow up. and there was no permanent neurological compromise. The neurological status of 17 patients who had TCS was improved in 8 patients and unchanged in the other patients at latest follow-up.

Conclusion
The osteotomy for CSD associated with SSCM may provide a satisfactory option to effectively improve the spinal deformity without significant complications and without the necessity of the resection of bony spur in the Type I SSCM

Take Home Message
The osteotomy for CSD associated with SSCM may provide a satisfactory option, and without the necessity of the resection of bony spur in the Type I SSCM.

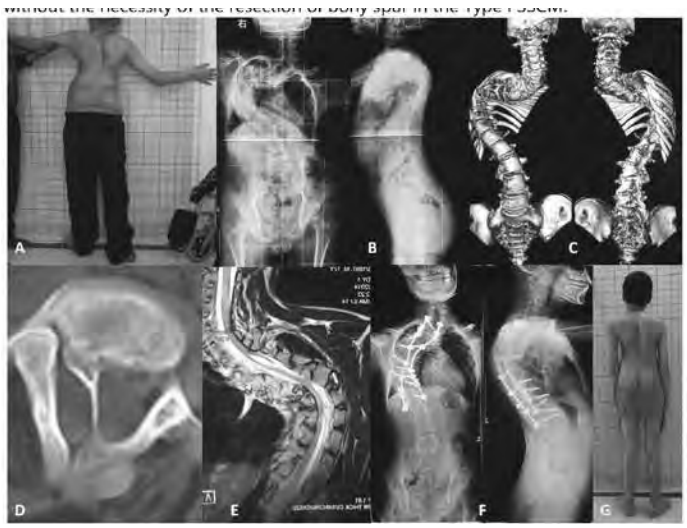

Fig. A. Before the operation B. Initial AP and lateral standing X-rays of the patient. C.3D-CT scan image. D. CT scan of the cross-section of the vertebral body. E. MRI of the spine .F. Standing AP and Lateral X-rays 2 years after surgery, G. 2 years after

132. Efficacy of Halo-femoral Traction after Posterior Spinal Release in Correction Surgery of Severe Kyphoscoliosis: A Comparison with Pre-operative Halo-gravity Traction

Bo Shi, MD, PhD; Zezhang Zhu, MD; Benlong Shi, PhD; Zhen Liu, MD; Bin Wang, MD; Junyin Qiu; Feng Zhenhua, MS; Yong Qiu, MD

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Summary
Patients with severe kyphoscoliosis (SK) underwent first-stage Halo-femoral traction (HFT) after posterior spinal release and second-stage posterior spinal correction surgery could achieve better correction of coronal and sagittal deformities than traditional pre-operative Halo-gravity traction (HGT). Therefore, the HFT after posterior spinal release can be considered as an alternative option for SK patients.

Hypothesis
For SK, posterior spinal release followed by HFT could improve the spinal flexibility and reduce the difficulty of the correction surgery, which could get satisfactory correction rate during the longitudinal follow-up.

Design
Retrospective review

Introduction
The surgical treatment for SK has been a challenge for decades. Pre-operative HGT has been proven to be practically effective for SK patients. However, the efficacy of HFT after posterior spinal release has not been detailed investigated yet. The objective of this study was to compare the radiographic and clinical outcomes of HFT after posterior spinal release versus single-stage pre-operative HGT followed by posterior correction in patients with severe and rigid kyphoscoliosis.

Methods
30 (13 M, 17F) patients treated with posterior spinal release, HFT and posterior correction at the second stage for severe spinal kyphoscoliosis (R+HF group) between 2013 and 2015 were retrospectively reviewed, and 30 age-, gender-, Cobb angle-, curvature-, osteotomy- and etiology-matched patients undergoing posterior spinal fusion surgery after pre-operative HGT (HG group) were included as control group. The radiographic outcome was evaluated with coronal Cobb angle, global kyphosis, coronal balance and SVA, while the clinical outcome was assessed using SRS-22 questionnaire.

Results
The pre-operative Cobb angle and flexibility were similar between 2 groups (123.5±12.7° vs 123.1±14.1°, P=0.909). At the end of traction, higher correction rate was found in R+HF group than HG group (31.8%±7.8 vs 19.3%±12.9, P=0.000). The post-operative correction rate in R+HF group was higher than HG group (44.7%±7.8 vs 39.0%±12.8, P=0.042). Compared with pre-operative SRS-22 scores, significant improvement of SRS-22 scores at post-operation was found both of R+HF group and HG group and there was no statistical difference between two groups. No neurological complication was observed in 2 groups.

Conclusion
Compared with pre-operative HGT, the HFT after posterior spinal release can provide better correction rate for SK.

Take Home Message
The first-stage Halo-femoral traction (HFT) after posterior spinal release and second-stage posterior spinal correction could achieve better correction rate than the traditional pre-operative HGT.

133. Does Thoracoplasty Adversely Affect Long Term Lung Function in Complex Pediatric Spine Deformity?

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Summary
107 pts from a multicenter database base were investigated for pulmonary outcomes after thoracoplasty. Thoracoplasty did not adversely affect long term pulmonary outcomes and complication rates after 2years follow up.

Hypothesis
Posterior thoracoplasty adversely affect long term pulmonary function in complex spine surgery.

Design
Retrospective Review of Prospective multi center database

Introduction
Complex spine deformities may be associated with rib hump causing body image concerns among patients. Surgical correction of deformity may include thoracoplasty to correct the rotation prominence. Some surgeons refrain from performing thoracoplasty due to purported negative effect on pulmonary function. There is paucity of literature on the effect of thoracoplasty on long term pulmonary function in paediatric with complex spine deformity

Methods
Reviewed data of 312 patients (>100⁰, with or without 3CO) or (<100⁰ with 3CO) from an international multicenter database. Data of patients with complete radiographic and pulmonary function assessment with a minimum of 2-year follow-up were analyzed. Paired t-test was performed to compare pre-op and two yrs PFT results. PFT comparison was stratified based on thoracoplasty status.

Results
107/312 pts (45M and 62F), mean age of 15yrs years met the inclusion criteria. Etiologies were 42% idiopathic and 35%

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congenital. Pre-op coronal cobb 89.23deg (SD=44.2), Pre-op sag cobb 101.92deg (SD=38.4). Average surgical time was 391min (SD=167), EBL 1469ml (SD=862), fusion levels 12 (5-19). Thoracoplasty, Grp 1, (61pts). No Thoracoplasty Grp 2 (46 pts) with equal number of 3CO (25 pts vs 21 pts). 2yr post op coronal cobb correction was 43% and 40% in sagittal plane. Pre-op avg FVC predicted % (M=64%, SD=26.3) was not significantly different from 2yr post of FVC predicted % (M=59, SD=22.5, p=0.065). Pre-op FEV1 predicted % (M=59.4%, SD=20.4) was not significantly different from 2yr post of FEV1 predicted % (M=58.4, SD=20.1, p=0.68). Preop/2yr Post-op values; Grp1 vs Grp 2 : FVC; 64%/57% vs 64%/62% and FEV1; 60%/57% vs 59%/60% were not significantly different (p>0.05). In Grp 1, 3CO had no effect on final PFTs

Conclusion

The study shows that thoracoplasty can be safely performed to achieve desired rib hump deformity correction in complex spine surgery without adversely affecting long term pulmonary function.

Take Home Message

Patient with complex spine deformity have restricted PFT. Access to the spine during exposure may necessitate Thoracoplasty. Besides improving cosmesis, thoracoplasty has no negative impact on long-term pulmonary function

134. Is Postoperative Imaging Prior to Discharge Necessary Following Idiopathic Scoliosis Surgery?

Terrence G. Ishmael, MBBS; Daniel J. Sucato, MD, MS; Kiley Frazier Poppino, BS; Chan-Hee Jo, PhD

Summary

Imaging plays a vital role in the management of AIS. When and how often to obtain radiographs is unclear. Routine postoperative radiographs prior to discharge from hospital may provide information as to curve characteristics after instrumentation and presence of intrathoracic pathology. This information is not clinically relevant nor does it lead to unplanned return to the operating room.

Hypothesis

"Standing postoperative radiographs prior to discharge do not alter treatment after spinal fusion for AIS.

Design

Retrospective

Introduction

While imaging plays a vital role in the management of AIS, when and how often to obtain radiographs after surgery is unclear. This study seeks to identify whether a standing postoperative x-ray prior to discharge after AIS surgery is necessary.

Methods

Radiographic and medical records were reviewed in a consecutive series of AIS patients who underwent a posterior spinal fusion/instrumentation (PSFI) at a single institution. The presence of intrathoracic and intra-abdominal pathology were documented by staff radiologists. Differences in radiographic measurements between the standing radiograph prior to discharge and the 6 weeks, 3 months, 6 months, 1 year and 2 years were observed.

Results

There were 200 patients at an average age of 13.9 yrs at surgery (166 F:34 M). The average preop curve was 64.2°, with 11 levels fused and length of stay (LOS) of 3.3 days. On the inpatient standing radiographs, 28 patients (14%) had intrathoracic findings: atelectasis (n=18), small pleural effusion (n=9), and consolidation (n=1), intra-abdominal finding (n=0) without difference in LOS compared to patients without findings. 7 patients (3.5%) required revision at 29.7 months postop: set plug disengagement (n=3), prominent proximal hook (n=2), adding-on (n=1), or pseudoarthrosis (n=1). In the no intervention group, statistically significant but clinically small differences were seen between the inpatient and 6 week, and 2 year radiographs in main thoracic curves (23.7° v 24.7°,p=0.008; 23.6° v 26.1°,p<0.001), without differences in coronal or sagittal balance. In the intervention group, differences were noted only in lumbar curves between the inpatient and 6 weeks, 3 months radiographs, respectively (17.0° v 21.8°,p=0.026; 21° v 27°,p=0.012). The reason for revision was not associated with these radiographic changes.

Conclusion

While postoperative x-rays prior to discharge may be routine practice, the data suggests that a standing radiograph following a PSFI for AIS is not helpful in patient care decision making and does not influence outcome.

Take Home Message

Radiographs prior to discharge from the hospital after surgery for AIS are not clinically necessary as they do not provide information to help manage the patient.

135. Surgeon Volume Affects Short- and Long-term Surgical Outcomes in Idiopathic Scoliosis

Vishal Sarwahi, MD; Alexander M. Satin, MD; Dean C. Perfetti, MD; Jesse Galina, BS; Sayyida Hasan, BS; Jeffrey Goldstein, MD; Terry D. Amaral, MD

Summary

Higher average annual surgeon volume for long-segment (>4 vertebrae) pediatric spinal fusions corresponds to improved short- and long-term outcomes in idiopathic scoliosis surgery

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Hypothesis
Surgeons with larger average annual volumes have better short and long term surgical outcomes in AIS

Design
SPARCS inpatient database

Introduction
Spinal deformity surgery involves learned skills that require significant training and repetition. Surgeon and hospital volume have been shown to correlate with outcomes following cervical and lumbar spine surgery. However, there is limited literature regarding the impact of surgeon volume on long-term outcomes following pediatric idiopathic spinal deformity correction.

Methods
SPARCS was analyzed from 2004 - 2015 to identify pediatric patients who underwent primary spinal arthrodesis procedures. Patients with fusion lengths less than 4 vertebrae were excluded. Surgeon volume was stratified into high and low volume surgeons, with high volume surgeons performing more than 15 long-segment pediatric spinal fusions per year. ICD-9 codes were used to extract the index fusion procedure, diagnosis, and to identify patient demographics, re-operation procedures and re-operation diagnoses. Patients with a diagnosis of idiopathic scoliosis were longitudinally followed until September 2015, corresponding to a min two-year follow-up, to determine the incidence of short- and long-term complications. Multivariate analyses were used to identify the odds of complication or revision.

Results
In total, there were 3,910 patients and 223 surgeons. 13 high-volume surgeons performed 52.9% of all fusion procedures during this period. High volume surgeons averaged greater than 15 cases per year over the study duration, with a one-year max of 51 cases. High volume surgeons performed more medium length fusions (p=0.009) and had shorter length of stays (p<0.001) than low volume surgeons. Low volume surgeons were more likely to face inpatient surgical complications (p=0.047) and revision at 5- and 10 years.

Conclusion
Low volume surgeons experience significantly greater odds of inpatient surgical complications, and revision during long term follow-up with a significantly increased revision rate at 5 and 10 years postop and hardware malfunction at 10 years post-operatively.

Take Home Message
Surgeons with large average annual volumes have better short and long term surgical outcomes than low volume surgeons.

136. Risk Factors that Decrease Complete Recovery in Idiopathic Scoliosis Surgery Associated Neurological Injuries

Swamy Kurra, MBBS; Harman Chopra, BS; Jinhui Shi, MD; Stephen A. Albanese, MD; Elizabeth A. Demers Lavelle, MD; William F. Lavelle, MD

Summary
Postoperative hypotension, complete cord injuries, and no IONM use have negative effects on NI recovery rates in IS population.

Hypothesis
The purpose of the study was to analyze the Scoliosis Research Society Morbidity and Mortality (SRS M&M) to determine the factors that decrease the IS surgeries associated NI recovery rates.

Design
Reviewed SRS M & M databases IS patients (aged between10 and 30 yrs.) who had perioperative neurological deficits from correction surgery between 2009 and 2015.

Introduction
Neurological injuries (NI) are devastating complications of idiopathic scoliosis (IS) surgeries. The factors impeding the recovery status of such NI have been poorly studied in the literature.

Methods
Statistical analyses were made to compare the types of NI recovery status (complete, partial and no change) with NI event occurring relative to timing of surgery, intraoperative blood loss, type of surgical approach, staged surgeries, osteotomies, intraoperative neurophysiological monitoring (IONM) used (yes/no), intra- and postoperative hypotension (yes/no), type of neurological injury (cord, root or both), type of cord injury (complete or incomplete), and level of neurological injury (cervical, thoracic or lumbar).

Results
Study sample=209 NI patients; gender distribution: males (n=53; 25%), females (n=155, 74%). Recovery rates distribution (complete=146 (74%); partial=39 (19%); no change=12 (6%). Length of follow-up showed no statistical difference among the recovery status types, p =0.09. Complete recovery rates were significantly higher with IONM patients (77% vs. no IONM = 57%, p=0.06), No postoperative hypotension patients (77%) vs. yes postop hypotension (56%), p=0.06. Complete cord injuries significantly reduced the complete recovery rates (55% vs. incomplete cord injuries 78%, p<0.05) Table 1. Remaining analyzed variables showed no statistical differences for recovery status.

Conclusion
Postoperative hypotension, complete cord injuries, and no IONM use during surgeries have reduced NI recovery rates in IS population.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Take Home Message
Postoperative hypotension, complete cord injuries, and no IONM use during surgeries have reduced NI recovery rates in IS population.

Table 1: Summary of Influencing Factors of NI Recovery Rates

	n		Complete recovery	Partial recovery	No recovery	p value
Length of follow-up (days)	186		174	141	206	0.09
IONM	198	Yes (n=168)	129 (77%)	30 (18%)	9 (5%)	0.06
		No (n=30)	17 (57%)	10 (33%)	3 (10%)	
Postoperative Hypotension	191	Yes (n=16)	9 (56%)	4 (25%)	3 (18%)	0.06
		No (n=175)	135 (77%)	31 (17%)	9 (5%)	
Cord Injuries	140	Complete (n=30)	17 (55%)	6 (19%)	7 (22%)	<0.01
		Incomplete (n=110)	86 (78%)	21 (19%)	3 (3%)	

Table 1: Summary of Influencing Factors of NI Recovery Rates

137. Pedicle Screw Plowing in Adolescent Idiopathic Scoliosis: How Common is it, and is it a Problem?

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Summary
We retrospectively studied 1,057 patients from a large, multicenter AIS database. Two blinded observers independently reviewed postoperative radiographs to assess whether intraoperative plowing of pedicle screws had occurred during reduction. These results were then correlated to preoperative characteristics and patient outcomes. Screw plowing was observed in 4.5% of patients and was most common at the lowest instrumented vertebra. It was associated with increased rates of revision surgery for loss of fixation to bone.

Hypothesis
Pedicle screw plowing is most common at the lowest instrumented vertebra (LIV) and is associated with increased rates of revision surgery.

Design
Retrospective review of multicenter database

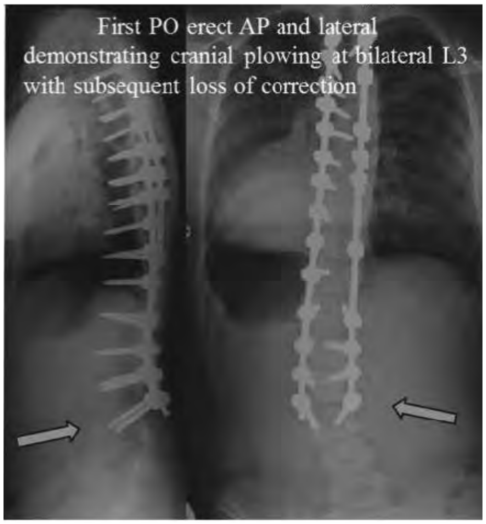
Introduction
Correction of adolescent idiopathic scoliosis (AIS) requires intraoperative rod reduction maneuvers that can cause screws to lose their alignment as they "plow" through the pedicle craniocaudally. We sought to develop a standard definition of screw plowing and identify its incidence and associations in AIS pts.

Methods
A representative sample of posteriorly fused AIS pts were reviewed from a multicenter database. Preoperative (PA) and first postoperative erect (PA and lateral) films were evaluated twice: once by their own surgeon and once by the senior author. Evaluators judged whether plowing had occurred and whether it resulted in LOC. Plowing was defined as either (1) >25 degs sagittal angulation compared to the pedicle axis, or (2) entry outside the pedicle projection.

Results
1,057 pts from 1996-2015 were analyzed, who had a total of 19,569 screws. 48 pts (4.5%) were judged to have >1 plowed screw by both observers. 830 (78.5%) had no plowing, and 179 (16.9%) were judged to have plowing by only one observer. 72 screws (0.4%) were agreed plowed. Consensus plowing was most common through the cranial cortex (65/72 screws, 90%) and was most common at the LIV (17/72 screws, 24%). Resulting LOC was observed in 13 pts and was most common at the LIV (12/17 LIV screws with LOC vs. 2/55 non-LIV screws with LOC, $p<0.0001$). Interrater reliability was $\kappa=0.83$ for the presence of plowing and $\kappa=0.99$ for each screw. Intrarater reliability for the presence of plowing (assessed at 1 yr apart by the senior author, on a 416 pt subgroup) was $\kappa=0.90$. Rate of revision for loss of fixation was >15x higher in the plowed group (6.3%) than the non-plowed group (0.36%) (3/48 vs. 3/830, $p=0.003$). No difference in SRS-24 scores was detected at 2-yr follow-up.

Conclusion
Pedicle screw plowing in AIS occurs in 4.5% of pts and 0.4% of screws. It is most common at the LIV and is associated with increased rates of revision surgery for loss of fixation to bone.

Take Home Message
Pedicle screw plowing in AIS occurs in 4.5% of pts. It is most common at the LIV and is associated with increased rates of revision surgery for loss of fixation.



138. Hounsfield Units Value is a Better Predictor of Pedicle Screw Loosening than the T-score of DXA in Patients with Lumbar Degenerative Diseases

Da Zou, MD; Weishi Li, MD

Summary
Vertebral Hounsfield unit(HU) is a better predictor of pedicle screw loosening than the T-score of DXA among patients aged≥50 years old with lumbar degenerative diseases(LDD)

Hypothesis
The T-score is inaccurate in patients with LDD. The measurement of vertebral HU is less affected by lumbar degeneration, thus it is a better predictor of pedicle screw loosening

Design
This is a retrospective study

Introduction
Pedicle screw loosening is a common complication after pedicle screw fixation in osteoporotic patients. The T-score of DXA is widely used to identify osteoporosis preoperatively, but it can be falsely overestimated because of lumbar degenerative changes. Vertebral HU has been proved to be a better tool for evaluating bone mineral density(BMD) in patients with LDD.

Methods
We reviewed 252 patients ≥ 50 years old who underwent posterior lumbar fusion with pedicle screw fixation for LDD. . The criteria for screw loosening: presence of a radiolucent zone ≥ 1mm thick around the screw in lumbar x-ray at 12 months follow-up. The DXA criterion for osteoporosis: lowest T-score≤ -2.5. The HU criterion for osteoporosis: L1≤110HU or L2≤100HU or L3≤85HU or L1≤80HU. ROC analysis was used to evaluate the validity of predicting screw loosening

Results
The screw loosening rate was 30.6%(77/252). According to the DXA criterion, the prevalence of osteoporosis was 35.3%, and screw loosening rate was higher in osteoporotic patients than non-osteoporotic patients(39.3% vs. 25.8%, P=0.026). Among non-osteoporotic patients, 37 patients met the HU criterion for osteoporosis, they had higher rate of screw loosening than the rest patients(43.2% vs. 20.6%,P=0.006). T-score showed no significant difference between loosening group and non-loosening group(-2.1±1.5 vs. -1.7±1.6, P=0.074). The average vertebral HU value of L1-L4 was significantly lower in the loosening group(106.8±34.4 vs. 129.8±45.7;P<0.001) . The AUC for predicting screw loosening was 0.64-0.68(P<0.001) for the L1-L4, and 0.574 for T-score(P=0.062).

Conclusion
Vertebral Hounsfield unit(HU) is a better predictor of pedicle screw loosening than the T-score of DXA among patients aged≥50 years old with lumbar degenerative diseases

Take Home Message
T-score alone was not enough for evaluating BMD before lumbar surgery. Vertebral Hounsfield unit(HU) is a better predictor of pedicle screw loosening than T-score

139. Is Performing a Definitive Fusion for Scoliosis in Juvenile Cerebral Palsy (CP) Patients a Good Long-term Surgical Option?

Roland Howard, MD; Tracey P. Bastrom, MA; Madeline Cross, MPH; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Firoz Miyanji, MD, FRCS(C); Amer F. Samdani, MD; Peter O. Newton, MD; Burt Yaszay, MD

Summary
Progressive scoliosis in skeletally immature CP patients requires the surgeon to balance continued growth with risks of progression or repeated procedures. Performing a definitive fusion results in improved coronal deformity, pelvic obliquity, and CPCHILD outcomes scores that remain stable at the 5-year mark.

Hypothesis
Postoperative curve correction will be maintained at 5-year follow-up (f/u) without major adverse outcomes in skeletally immature CP patients who undergo definitive fusion.

Design
Retrospective review of prospective multicenter registry.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Introduction
Progressive scoliosis in skeletally immature CP patients presents a unique challenge given the spectrum of CP severity and associated thresholds before surgical fixation becomes warranted. Growth-sparing instrumentation is an option for skeletally immature patients. However, in juvenile patients with CP, the risks of curve progression and/or repeated surgical procedures must be balanced with the desire to facilitate growth.

Methods
CP patients who underwent definitive fusion before age 10 with minimum of 5yr f/u from a prospective, multicenter study were included. Preop, 1st erect postop, and 5yr radiographic data were collected. Demographics, surgical data and complication data were analyzed in addition to CP CHILD outcome scores at preop and 5 years. Repeated measures ANOVA was employed to analyze radiographic measures. Paired t-test was utilized to compare outcomes. Significance was set at p=0.05.

Results
20 patients met inclusion – 17 female and 3 male, average age of 9.94 (range 8.25 – 10) years. 85% of patients had spastic CP with GMFCS level 5. There were 18 posterior fusions, 1 anterior fusion, and 1 posterior with open release. 80% had distal instrumentation to the ilium and 20% had distal fixation between L4-S1. Correction of curve magnitude (p≤0.001), kyphosis (p=0.027) and pelvic obliquity (p≤0.001) all showed statistically significant improvement. From immediate postop to 5 yr f/u there was no significant change in major curve magnitude (p=0.638), thoracic kyphosis (p=0.1) or pelvic obliquity (p=0.28). Personal care, mobility, comfort, and total score were found to improve from preop to 5yr f/u (Table 1). No patients needed reoperation in the cohort.

Conclusion
Progressive scoliosis in juvenile CP patients presents a real challenge. Performing a definitive fusion is a viable option that achieves a good correction and remain stable at 5 years postop.

Take Home Message
Definitive fusion is a good option for surgical curve correction of CP patients with severe major curves in the setting of skeletal immaturity (age 8 – 10yrs).

Table. Comparison of outcomes between preoperative and 5-year radiographic and CPchild Outcome Scores

	Preoperative	1st Postop	5years postop	p-Value
	Radiographic Measurements			
Major Curve Magnitude	84 ± 20	28 ± 12	31 ± 16	**<0.001**
T2-T12 Kyphosis	41 ± 27	34 ± 13	31 ± 14	**0.027**
Pelvic Obliquity	32 ± 14	8 ± 6	10 ± 6	**<0.001**
	Outcome Domains			
Personal Care	36 ± 13		45 ± 13	**0.052**
Positioning, Transferring & Mobility	29 ± 13		44 ± 14	**0.004**
Comfort & Emotions	78 ± 12		89 ± 13	**0.019**
Communication & Social Interaction	45 ± 32		36 ± 29	0.25
Health	49 ± 16		55 ± 13	0.21
Overall QOL	64 ± 22		64 ± 26	1
Total Score	48 ± 11		57 ± 13	**0.047**
HUI3 Overall Utility Score	-0.25 ± 0.084		-0.12 ± 0.26	0.154

Table. Comparison of outcomes between preoperative and 5-year radiographic and CPchild Outcome Scores

140. Posterior Spinal Fusion in Children with Cerebral Palsy Moves Underweight Children Up the CP Growth Chart

Keith Baldwin, MD; Joshua M. Pahys, MD; David A. Spiegel, MD; John (Jack) M. Flynn, MD; Paul D. Sponseller, MD, MBA; Mark F. Abel, MD; Harms Study Group; Patrick J. Cahill, MD

Summary
Patients with cerebral palsy (CP) are at risk for cachexia, malnutrition, and other GI disorders. Spinal deformity causes a decrease in space available for digestion. We studied the change in weight percentile in patients who underwent spinal correction surgery.

Hypothesis
CP patients who are underweight prior to scoliosis correction will have improved weight percentile post-operatively.

Design
Retrospective Cohort

Introduction
Cachexia and low body mass index is common among children with CP. Many interventions are undertaken to assist the child's nourishment and help obtain a more normal body mass. Long thoracolumbar scoliosis with a large pelvic obliquity is also common among children with CP, and may impair feeding. We hypothesize that weight percentile will improve following scoliosis correction in patients who are underweight prior to surgery.

Methods
We retrospectively reviewed a prospectively collected multi-center cohort of surgically treated patients with CP and scoliosis. Patients

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

with at least 2 years of follow-up and GMFCS IV & V were included. Percentiles on the CP specific growth chart for which each child belonged were plotted based on the patient's age, weight, gender, GMFCS level, and tube feeding status. We then assessed percentile change in patients between pre op visit, 1 year, 2 year and for those with available data, 5 year follow up visits.

Results

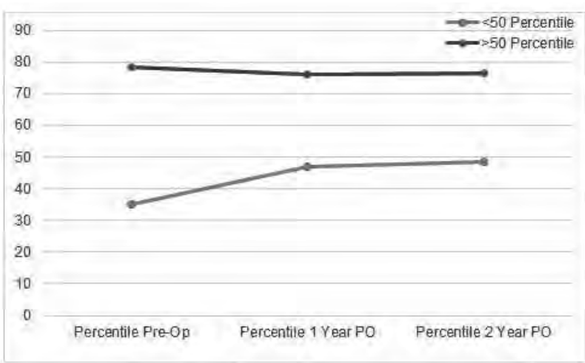
211 patients were included, 109 had complete 2-year data, and 37 patients had 5-year data. We found that patients under the 50th percentile pre operatively increased their percentile on the CP growth chart 12.1 percentiles (95% CI; 6.7, 17.5 p value <0.001), whereas patients that began at the 50th percentile or above did not change significantly. These changes were stable at 5 years. Although regression analysis showed that Cobb correction, pelvic obliquity correction, and hyperlordosis were not independent predictors of the change, we noted that curves that remained over 40 degrees following correction experienced 13.3 percentile less weight gain than those with a better correction.

Conclusion

Data presented here suggests that corrective spinal surgery may improve weight percentile in patients who start out at 50 percentile and lower. Patients with 40 degrees or greater of residual scoliosis may experience less weight gain benefit from spinal fusion than those with a better correction.

Take Home Message

Corrective spinal surgery in underweight CP patients may improve weight percentile for those who start out at the 50th percentile, but less so for those with residual scoliosis post-operatively.



Two-year data shows significant weight gain in patients post-fusion who are less than 50th percentile pre-operatively (p <0.01).

141. Postoperative Enteral Feeding in Cerebral Palsy Patients After Spinal Fusion: How Long Should We Wait?

Bram Verhofste, MD; Jay Berry, MD; Nicholas D. Fletcher, MD; Patricia E. Miller, MS; Brigid Garrity, MS, MPH; Michelle Claire Marks, MS, PT; Suken A. Shah, MD; Burt Yaszay, MD; Peter O. Newton, MD; Amer F. Samdani, MD; Firoz Miyanji, MD, FRCS(C); Mark F. Abel, MD; Paul D. Sponseller, MD, MBA; Michael P. Glotzbecker, MD

Summary

Postoperative gastrointestinal (GI) complications such as pancreatitis and ileus are not uncommon after spinal fusion in patients with cerebral palsy. The type of enteral feeding and the post-op day feeding was initiated were strongly associated to the incidence of GI complications and length of stay (LOS). Patients with pre- and postoperative g-tubes (GT) were at greatest risk for complications. Delayed initiation of feeding was associated with increased LOS.

Hypothesis

Patients with an earlier initiation of enteral feeds will experience a decreased likelihood of gastrointestinal complications and shorter length of stay.

Design

Retrospective review of a prospective cohort.

Introduction

Gastrointestinal disorders are common in patients with cerebral palsy. The association between preoperative nutritional status and postoperative recovery is well documented, but few have examined the immediate postoperative fasting period. Prolonged postoperative fasting has been associated with increased GI complications and LOS. The objective of this study is to examine trends of postoperative fasting in cerebral palsy patients undergoing spinal fusion.

Methods

A prospective, multi-center database of patients with cerebral palsy undergoing spinal fusion was queried. 425 patients (56% male) with a mean age of 14 (± 2.9) years and a median of 17 levels fused were analyzed. 417 patients with complete feeding data were identified and all gastrointestinal complications were recorded. Demographics, surgical characteristics, method of feeding, initiation of feeding and LOS were evaluated.

Results

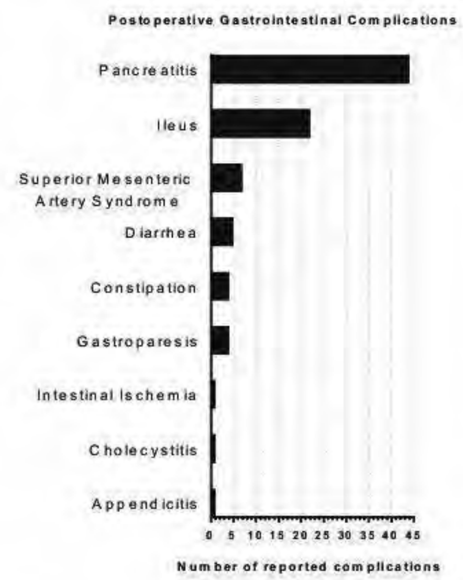
89 gastrointestinal complications occurred in 70 patients (16.8%), with pancreatitis (n=44) and ileus (n=22) the most frequent. 26 patients (26/70, 37.1%) experienced a complication prior to feeding start. Nearly all of these (25/26, 96.2%) patients developed pancreatitis, 3 also developed ileus and 1 developed ileus

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

alone. Patients with postoperative GT had 4.2 times odds of a GI complication compared to oral alone (OR=4.20; 95% CI=1.86–9.48; p<0.001). Similarly, patients with a GT and oral feeding postoperatively had 3 times odds of a GI complication compared to oral alone (OR=3.02; 95% CI=1.11–8.26; p=0.03). For each additional day that feeding was delayed, LOS increased by 6% (95% CI=4% - 8%; p<0.001) controlling for the presence of GI complication, complication timing (occurring prior to feeding start), EBL, levels fused, and preoperative curve severity.

Conclusion
Type of postoperative feeding was strongly correlated to the incidence of GI complications and delayed initiation of post-operative feeding was associated with increased LOS.

Take Home Message
An earlier timing of enteral feeding postoperatively was associated with decreased hospitalization length. Patients with g-tubes were at greatest risk for gastrointestinal complications and longer hospital admission.



Postoperative Gastrointestinal Complications in Patients with Cerebral Palsy after Spinal Fusion

142. An Enhanced Surgical Protocol Can Drastically Reduce Surgical Site Infections in NM Patients

Vishal Sarwahi, MD; Sayyida Hasan, BS; Michelle Kars, MD; Jesse Galina, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD

Summary
Implementing enhanced standardization of surgical protocol, it is possible to reduce the rate of neuromuscular infections after spinal surgery.

Hypothesis
Rates of surgical infection in NM patients can be mitigated

Design
Ambispective

Introduction
Historically, NM patients are a high risk group, surgically, with high complication rates, most notably infection. Due to these comorbidities, complication risks are not modifiable.

Methods
All pediatric scoliosis patients undergoing posterior spinal fusion with pedicle screws from 2005-2018 were reviewed. XR and demo data were collected. EBL, levels fused, transfusion, infection, and surgical time were collected. In 2015, the surgeons changed institutions and changed surgical management protocols. The same parameters and outcome from surgical data were compared between Institution A and Institution B.

Results
Median Cobb in AIS was 54°, and NM was 66°. Levels fused: AIS - 12 and NM -15. EBL: AIS - 500 and NM – 800(p=0.04). Surgical time was 266 and 373, respectively. Transfusion rate: AIS- 18% and NM-84%. These parameters were significant. NM patients were significantly more likely to have infection than AIS patients(p=0.03). The rate of infection was significantly different between Institution A and Institution B(p=0.01). The parameters within these institutions were similar. Median Cobb in Institution A for AIS was 55° and in Institution B, it was 52. Similarly, Institution A median Cobb for NM was 57° and in Institution B it was 56°. Complication rates were similar between the two institutions(p =0.477). However, Institution A had a significantly higher transfusion rate and surgical time than Institution B(p=0.001,p<0.001,respectively). Within Insitution B, the rate of infection between AIS(1.6%) and NM(5.4%) patients were similar(p=0.08). All radiographic and surgical parameters were significantly different(p<0.05).

Conclusion
As expected, the rate of infection of NM patients is significantly higher than AIS patients, overall. However, the enhanced surgical protocols developed during the move from Institution A to Institution B, significantly decreased the overall infection rate. In fact, surgical rates in neuromuscular patients approached AIS patients.

Take Home Message
Neuromuscular infection rate can be decreased with an enhanced surgical protocol.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

143. Standardizing Surgical Approach With a Dedicated Team Improves Surgical Outcomes in Neuromuscular Scoliosis

Vishal Sarwahi, MD; Jesse Galina, BS; Benita Liao, MD; Sayyida Hasan, BS; Melanie A. Smith, cPNP; Aaron M. Atlas, BS; Michelle Kars, MD; Alexa Vetere, PA-C; Terry D. Amaral, MD

Summary
This study shows the implementation of a dedicated protocol and team approach to pre, intra, and postoperative care of NMS patients leads to improved outcomes.

Hypothesis
A standardized protocol improves patient outcomes in NMS patients

Design
Retrospective Review

Introduction
Neuromuscular scoliosis (NMS) have a higher risk of complications due to comorbidities. We utilize a NMS specific protocol including extensive preop workup and optimization, standardized anesthesia protocols, streamlined surgical steps, postop PICU and respiratory management. The purpose of this study is to evaluate a comprehensive surgical management plan utilizing dedicated teams and protocols.

Methods
A 2 institution retrospective review of NMS patients from 2009-2018. Two groups: without standardization (S1) vs. with standardization (S2). Demographic, XR, and periop outcomes recorded. Comprehensive protocol included preop nutritional and pulmonary tests, seizure control, and dedicated evaluation by preop and anesthesia team. Intraop, team has standardized anesthesia protocol, fluid optimization, plastic surgery closure, drain insertion site, and occlusive, impermeable dressings. Postop, PICU, pain, pulmonary, and nutrition management are used. Analysis determined if outcomes were reproducible (G1vsG2). Median(IQR), Kruskal-Wallis, and Fisher's exact test were used.

Results
85 NMS patients in three groups were similar in age (p=0.82), BMI (p=0.89), preop Cobb (p=0.99), postop Cobb (p=0.72), preop kyphosis (p=0.13), postop kyphosis (p=0.64) and complication rate (p=0.19). S1 and S2 had similar EBL (p=0.32), but significantly shorter surgical time (418vs355, p=0.03). S2 had significantly shorter LOS (11vs8, p<0.001). After switching institutions, age (p=0.77), BMI (p=0.89), preop Cobb (p=0.99), kyphosis (p=0.13), postop Cobb (p=0.17) and kyphosis (p=0.94) were similar. EBL (p=0.48), levels fused (p=0.39), anesthesia (p=0.903) and surgical (p=0.61) time, and complication rate (p=0.15) were similar. LOS was significantly shorter for G2 (9vs5, p<0.001).

Conclusion
In NMS patients, a standardized approach can help improve surgical outcomes with decreased EBL, surgical time, and LOS. These significant benefits between two institutions continue to improve with time and can be implemented between institutions with reproducible outcomes.

Take Home Message
Dedicated teams and protocols can improve outcomes in neuromuscular scoliosis patients

144. Residual Lumbar Hyperlordosis is Associated with Worsened Hip Status 5 Years after CP Scoliosis Correction

Aaron J. Buckland, MBBS, FRACS; Herbert Kerr Graham, MD, FRCS; Dainn Woo, BS; Dennis Vasquez-Montes, MS; Michelle Claire Marks, MS, PT; Peter O. Newton, MD; Thomas J. Errico, MD; Paul D. Sponseller, MD, MBA

Summary
Non-ambulant children with cerebral palsy (CP – GMCFS IV or V) have high rates of spastic hip disease and neuromuscular scoliosis, both sources of progressive deformity and pain. This study investigates the relationship between spinal alignment after spinal fusion (lumbar lordosis (LL), thoracic kyphosis (TK), global sagittal alignment (C7-S1 SVA)) and worsening postoperative hip status in non-ambulatory CP children. Postoperative lumbar hyperlordosis >60deg was the only independent spinal parameter associated with worsening hip status at 5yr follow-up (OR=2.61, p=0.015).

Hypothesis
Postoperative hyperlordosis increases the risk of worsening hip status (WHS) in non-ambulant CP children.

Design
Retrospective review of prospective multicenter study of operative non-ambulant CP patients.

Introduction
Non-ambulant children (GMFCS IV/V) have high rates of both spastic hip disease and neuromuscular scoliosis. Adult literature suggests that increasing LL retroverts the acetabulum in total hip arthroplasty resulting in increased risk of hip dislocation, however this has not previously been identified in CP children.

Methods
Worsening hip status (WHS) was defined by permutations comparing baseline (BL) and 1, 2, and 5Y hip status, including a change from normal at BL to subluxated/dislocated/resected; or subluxated at BL to dislocated/resected at postop visits. Associations between WHS and age, sex, coronal (major Cobb, pelvic obliquity) and sagittal alignment (TK, T12-S1 LL, C7-S1

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SVA), Risser grade, resting hip position, levels fused and fusion to sacrum were assessed. Receiver operator curves identified cutoffs at which parameters were most significantly correlated with WHS and logistic regression for odds ratios.

Results

Of 142 patients (age 13.7±2.5, 48%F), 106 had no change and 36 had WHS at 5yrs. 7 had spinal reoperations. ROC analysis and multivariate regression showed that the only parameter associated with WHS was LL >60°(OR=2.61(CI 1.19-5.75, p=.015). The WHS group had more LL at BL and postop(44oand 58o) than the no change group(36o and 50o). Age(p=0.214), sex(p=0.955), Risser(p=0.205), major coronal cobb (p=0.907), TK(p=0.717), C7-S1 SVA(p=0.320), levels fused(p=0.064), fusion to the sacrum(p=.548), pelvic obliquity(p=0.652), hip position(p=.284) or reoperation(p=.304) were not associated with WHS.

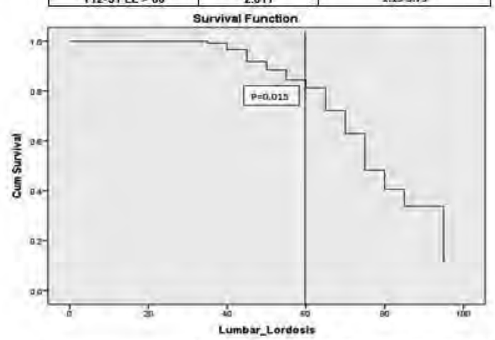
Conclusion

Worse hip status at 5yr postop spinal fusion is associated with hyperlordosis (>60deg) in non-ambulant CP patients. The likely mechanism is via resultant fixed anterior pelvic tilt and acetabular retroversion causing femoroacetabular impingement.

Take Home Message

Residual Lumbar Hyperlordosis (>60deg) increases the risk of worsening hip status 5yrs post-spinal fusion in non-ambulant CP children, most likely due to anterior pelvic tilt and functional acetabular retroversion.

Significant Parameters and ROC Cut-off	Odds Ratio	Confidence Interval
T12-S1 LL > 60	2.611	1.19-5.75



	Worse hip status	No change	Total Cohort
Baseline	44.4°	35.6°	37.0°
First Post-operative	57.7°	50.5°	52.4°

Figure 1. Survival curve showing point of LL where risk of worse hip status significantly increases.

Survival curve showing point of LL where risk of worse hip status significantly increases.

145. Proximal Anchor Fixation in Magnetically Controlled Growing Rods (MCGR): What is the Impact of Anchor Selection & Density?

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Summary

Among conventional distraction-based spine deformity instrumentation techniques, less rigid rib-based constructs portend a lower risk of rod breakage compared to spine-based constructs. Regardless of proximal fixation, having greater than 5 proximal anchors is reported to be protective against device migration. MCGRs have become more popular because they circumvent the need for repeat operations for lengthening but are recognizably more rigid. In this study we analyze the impact of MCGR proximal anchor location and density on radiographic outcomes and complication rates.

Hypothesis

Curve correction will be similar regardless of proximal anchor selection, and a higher proximal anchor density will be associated with lower incidence of device complications when using the MCGR.

Design

Retrospective cohort study

Introduction

Research on the MCGR has revolved around their efficacy and safety. The evidence behind choosing the location and density of proximal anchors comes from data using traditional growing rod and rib-based distraction techniques. Thus, there is much debate regarding the optimal quantity and location of proximal anchors for MCGR given its unique sagittal profile.

Methods

This retrospective multicenter study included early-onset scoliosis patients treated with MCGR who were age <10 at index surgery with a minimum 2-year follow-up. Comparisons of sagittal and coronal plane correction at 2 years and complication rates were made based on proximal fixation type, proximal anchor density, and type of case (primary, conversion).

Results

Eighty-four patients who had undergone MCGR (75% primary) at a median age of 6.8 years were included. Median follow-up time was 2.8 years and similar between rib and spine-based patients. Proximal anchor fixation was rib-based in 46 patients (55%), spine-based in 32 patients (39%), or rib and spine-based in 6 patients (7%). Major curve correction at two years was significantly (p=0.04) higher in spine-based (22 degrees) than rib-based constructs (13 degrees). Complication rates were similar between rib-based and spine-based constructs (p=0.61), though there was

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a trend towards higher risk of device migration with rib-based fixation (17.4% vs 6.3%, p =0.18). Having 5+ proximal anchors did not significantly decrease the risk of complications, including device migration (12.8% vs. 13.3%).

Conclusion

Although rib-based constructs afford less rigidity than spine-based constructs, there is similar risk of rod breakage and other complications in the setting of MCGR. Spine-based constructs maintain better correction in the coronal plane using this new technology. This study suggests that having 5+ MCGR proximal anchors does not protect against proximal device migration or other complications.

Take Home Message

When using the MCGR, proximal spine anchors impart superior deformity correction and proximal anchor density does not impact the risk of device complications.

	Correction (°)		Complications (%)		
	Major curve	Minor curve	Rod Breakage	Proximal Anchor Pull-Out	Device Migration
Proximal Fixation					
Rib (n=46)	13	3.5	4.3	8.7	17.4
Spine (n=32)	22	8	9.4	6.3	6.3
p-value	0.04	0.02	0.40	1.00	0.18
Proximal Anchor Density					
<5 proximal anchors (n=39)	15	5	7.7	10.3	12.8
≥5 proximal anchors (n=45)	24	5	6.7	4.4	13.3
p-value	0.12	0.98	1.00	0.41	0.94
Type of Surgery					
Primary (n=64)	24	6	6.3	7.8	12.5
Conversion (n=20)	-0.5	2	10.0	5.0	15
p-value	0.00	0.08	0.63	1.00	0.72

Figure 1. Surgical Outcomes and Complications After MCGR. Median and p-values provided.

146. Risk Factors for Proximal Junctional Kyphosis (PJK) in Children with Neuromuscular Scoliosis

Brandon J. Toll, BA; Shashank V. Gandhi, MD; Amir Amanullah, BS; Amer F. Samdani, MD; M. Burhan Janjua, MD; Joshua M. Pahys, MD; Steven W. Hwang, MD

Summary

Proximal junctional kyphosis is common in adult deformity but has not been reported in children with neuromuscular scoliosis. In our retrospective cohort, 27% of patients with NMS had radiographic PJK (7% revision rate). Those managed with halo gravity traction or with decreased proximal kyphosis pre-op, increased C2 sagittal translation, or loss of primary curve correction were found to be at higher risk of developing PJK. These data can assist surgeons in identifying high-risk patients and modifying treatment protocols.

Hypothesis

To evaluate risk factors associated with PJK in children treated surgically for neuromuscular scoliosis (NMS).

Design

Single center retrospective cohort analysis.

Introduction

PJK is a common cause of reoperation in adult deformity but has been less well reported in pediatric NMS. We wished to characterize risk factors associated with the development of PJK in pediatric NMS.

Methods

Data were retrospectively collected from a single-center cohort of 60 consecutive patients having undergone spinal fusion for NMS with a minimum of 2 year follow-up. PJK was defined as > 15° increase between the inferior end plate of the upper instrumented vertebra (UIV) and the superior end plate of the vertebra two segments above. Regression analyses as well as binary correlational models and student's t-tests were employed for further statistical analysis.

Results

The present cohort consisted of 29 boys and 31 girls with a mean age at surgery of 14±2.7 years. The most prevalent diagnoses were spinal cord injury (23%) and cerebral palsy (20%). Analysis reflected an overall radiographic PJK rate of 27% (n=16) and a clinically symptomatic rate of 7% (n=4). 100% of symptomatic patients required reoperations for PJK. No significant association was identified with previously suggested risk factors such as extent of rostral fixation (p=0.750), rod metal type (p=0.776), laminar hooks (p=0.654), implant density (p=0.386), non-ambulatory functional status (p=0.254), or pelvic fixation (p=0.746). Significant risk factors for development of PJK included: perioperative use of halo gravity traction (38%, p=0.029), greater postoperative C2 sagittal translation (p=0.030), decreased proximal kyphosis preoperatively (p=0.002), and loss of correction of primary curve magnitude at follow-up (p=0.047). Increase in lumbar lordosis from post-op to last follow-up trended towards significance (p=0.055).

Conclusion

27% of patients with NMS developed PJK and 7% had revision surgery. Those treated with halo gravity traction or with greater postoperative C2 sagittal translation, loss of primary curve correction, and smaller preoperative proximal kyphosis had the greatest risk of developing PJK.

Take Home Message

In pediatric neuromuscular scoliosis, radiographic PJK was observed in 27% of patients with 7% having clinical symptoms and requiring revision surgery.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

147. Consider these Factors to End Fusion Short of the Pelvis in Children with CP Scoliosis

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Summary

Our analysis of a multi center registry of 72 children fused short of the pelvis identified successful radiographic outcomes in 2/3 of cases. Preoperative pelvic obliquity of greater than 16 degrees , GMFCS of 5 with at least one subluxed hip, and preoperative T5-T12 sagittal curve of less than 38 degrees all independently predicted failure, and may be indications for fusion to the pelvis.

Hypothesis

Properly selected patients with cerebral palsy (CP) scoliosis can be safely fused short of the pelvis.

Design

Prognostic Level II-cohort study

Introduction

Fusion to the pelvis is often but not always needed in patients with CP scoliosis. Recent studies have indicated a higher rate of infection in patients fused to the pelvis. We sought to define criteria to select patients who may be successfully fused short of the pelvis.

Methods

This was a multi-center analysis of children with CP who underwent posterior spinal fusion (PSF) short of the pelvis, with 2-year follow-up. Patients were classified into "Success" or "Failure" groups. Failure was defined as 2-year postoperative pelvic obliquity ≥10 degrees, distal implant dislodgement, or reoperation for increasing deformity. Univariate analysis and binary logistic regression were performed with significance set at $p<0.05$.

Results

72 children with CP were fused short of the pelvis. The mean age was 14.2±2.6 years. Fusion short of the pelvis resulted in a successful outcome in 47 (65%) cases. Using univariate logistic regression and resulting ROC curves for prediction of failure, the Youden Index was calculated to establish cutoff values with maximum sensitivity and specificity for continuous variables of interest. Preop pelvic obliquity, coronal Cobb angle, major curve vertebral apex, and T5-T12 sagittal deformity were dichotomized based on their respective cutoffs . Controlling for univariate predictors of failure with $p<0.2$, preoperative pelvic obliquity >16 degrees, T5-T12 sagittal deformity <38 degrees, and GMFCS 5 with at least 1 subluxed hip all independently predicted failure to a significant degree in multivariate analysis (Table 1). Area under the curve was 0.85.

Conclusion

Indications for PSF short of the pelvis are controversial in the surgical management of CP scoliosis. In our analysis, successful, long-term radiographic outcomes were achieved in 2/3 of children with CP who underwent PSF short of the pelvis. Children with pelvic obliquity ≤16 degrees, GMFCS of 4 or less without the presence of a subluxed hip, and with T5-T12 sagittal curve of ≥ 38 degrees may be ideal candidates for sparing the pelvis during PSF.

Take Home Message

Preoperative pelvic-obliquity ≤16 degrees, T5-T12 sagittal curve of ≥38 degrees, and GMFCS <5 without subluxed hip may be indications for fusing short of the pelvis in pediatric CP scoliosis.

Variable	Odds Ratio	Confidence Interval	p-value
Pelvic Obliquity			
≤16°	Reference		
>16°	7.95	1.62-39.0	0.01*
Coronal Cobb Angle			
≤64°	Reference		
>64°	1.71	0.41-7.07	0.46
Curve Apex			
T11 and above	Reference		
Below T11	1.98	0.47-8.32	0.35
Sagittal T5-T12 Deformity			
≥38°	Reference		
<38°	8.51	1.64-44.3	0.01*
Functional Status GMFCS 5 w/ ≥1 subluxed hip			
No	Reference		
Yes	9.34	1.50-58.1	0.02*
Independent Sitter			
Yes	Reference		
No	2.28	.428-12.2	0.33

Table 1. Multivariate logistic regression model to determine predictors of surgical failure in children with CP scoliosis undergoing PSF short of the pelvis

An example of failure due to pelvic obliquity ≥10 degrees at 2 year postop.

Table 1. Multivariate logistic regression model to determine predictors of surgical failure in children with CP scoliosis undergoing PSF short of the pelvis; Figure depicting an example of failure due to pelvic obliquity ≥10 degrees at 2 year postop

148. Mortality in Pediatric Spinal Deformity: 242 Patients with 40-year Follow-up

Casper Dragsted, MD; Soren Ohrt-Nissen, MD, PhD; Lærke C. Ragborg; Thomas Andersen, MD, PhD; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

Summary

Few studies have assessed long-term mortality in pediatric spinal deformity after introduction of modern treatment principles. We conducted a retrospective study of 242 patients with pediatric spinal deformity treated at our institution from 1972-1983. Survival

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status was retrieved on all patients at mean 40±3.3 years follow-up. Mortality was assessed in Adolescent Idiopathic Scoliosis (AIS) and Early-Onset Scoliosis (EOS) patients with Kaplan Meier survival-analysis. We found no difference in long-term mortality between patients with idiopathic EOS and patients with AIS.

Hypothesis
There is no difference in long-term mortality between patients with EOS and AIS.

Design
Long-term observational cohort study.

Introduction
Untreated infantile (IS) and juvenile idiopathic scoliosis (JIS) have been associated with increased mortality due to pulmonary complications. However, few studies have assessed long-term mortality in pediatric spinal deformity after introduction of modern treatment principles with bracing and instrumentation.

Methods
We conducted a retrospective study of 242 patients with pediatric spinal deformity treated at our institution from 1972-1983. All patients were originally registered in a local archive with a Civil Registration Number and a diagnosis. Full medical records were available in 230 patients, and used to verify diagnoses and treatment. Survival-status was retrieved from the National Civil Registration System. The population consisted of 145 patients with AIS, 6 with IS and 11 with JIS, 12 with congenital/structural scoliosis, 9 with neuromuscular scoliosis, 4 with syndromic scoliosis and 55 with Scheuermann Kyphosis (SK). Date of diagnosis was defined as the time of first radiographic examination. Mortality was assessed in AIS and EOS patients with Kaplan Meier survival-analysis.

Results
Mean follow-up from diagnosis was 40±3.3 years and 76% were females. Out of the 187 patients with scoliosis, 87 were treated with a brace and 30 underwent posterior instrumented spinal fusion. Of all 242 patients, 16 had emigrated and 15 patients died: 4 AIS, 4 neuromuscular, 2 congenital/structural, 1 JIS and 4 SK patients. Patients died median 26 years (range 1.3-44.8) from diagnosis and only one patient with scoliosis who was diagnosed with muscular dystrophy died within the first 15 years from diagnosis. Moreover, only one idiopathic EOS patient died during follow-up from a progressive Parkinson's disease. There was a trend towards a higher mortality in EOS patients (p=0.08); however, this was due to deaths in patients with a neuromuscular or congenital/structural etiology.

Conclusion
We found no difference in mortality between EOS and AIS patients.

Take Home Message
There is no difference in long-term mortality between patients with idiopathic EOS and patients with AIS after introduction of modern treatment principles for pediatric spinal deformity.

149. Influence of Surgical Treatment on Pulmonary Function in Congenital Spinal Deformity: A Long-term Follow-up Study

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Summary
A long-term follow-up study of pulmonary function (PF) was performed in patients with congenital scoliosis. 90 patients were grouped by age at fusion considering the length of fusion segments. Fusion at age <10 years (early fusion) did not significantly decrease PF (%VC) or Thoracic height compared with late fusion if the fusion length was within 6 segments. Thus, early fusion may be acceptable in pediatric patients with congenital spinal deformity (CSD) who can be treated with shorter fusion.

Hypothesis
Early short fusion (□6 segments) in pediatric patients with CSD is associated with acceptable PF.

Design
Retrospective single-center cohort study. Primary outcomes were %VC based on arm span instead of height and Thoracic Height (TH) at final follow-up (FU).

Introduction
All long-term FU studies of postop. respiratory function (RF) following surgical treatment for CSD were based on analysis of RF data for a relatively small number of pts.; therefore, do not fully demonstrate how to treat CSD with early spine fusion (SF) or the limits in terms of RF.

Methods
The inclusion criteria were: 1) CSD, 2) surgical treatment, 3) aged <18 years at the time of surgery, and 4) a minimum 9-year FU. Of 118 consecutive pts., 90 pts. (36 males, 54 females) met the above criteria and participated in this study (FU rate 76.3%). Pts. were divided into 2 groups based on their age at SF: early fusion (EF, age at surgery □9) and late fusion (LF, age at surgery 10–17). Clinical characteristics were compared between the two groups considering a fusion area shorter or longer than 6 segments, and a fusion length in thoracic spine.

Results
The study population comprised 40 and 50 pts. who underwent EF and LF, respectively. There were no significant differences in terms of sex, surgical approach, fusion area, or FU period between the two groups. However, there were significant differences in

vertebral anomalies (p = 0.0367), BMI (p < 0.0001), and preop. main scoliosis magnitude (p = 0.0027). Despite no significant differences in %VC (p = 0.3504), FEV1.0 (p = 0.0866), or TH (p = 0.2373) in all pts, EF showed a significant decrease in %VC (p = 0.0165) and TH (p = 0.0086) relative to LF when SF extended beyond 6 segments. The EF group showed comparable %VC (p = 0.7848) and TH (p = 0.6084) to the LF group in cases of SF within 6 segments. Furthermore, longer involvement of thoracic SF in EF was associated with decreased %VC (p < 0.0001) and TH (p < 0.0001) relative to shorter SF in the thoracic spine.

Conclusion

Longer SF at age <10 should be avoided, particularly in pts. requiring longer thoracic SF. EF may be acceptable in pediatric pts. with CSD who can be treated with shorter SF.

Take Home Message

Spine fusion at age <10 years may be acceptable in pediatric patients with CSD who can be treated with shorter fusion.

Table. Comparison of % VC and TH between EF and LF

	Fusion ≦6 segments			Fusion ≧7 segments		
	EF	LF	p value	EF	LF	p value
%VC	78.7±10.4	80.4±13.0	p=0.7848	46.6±13.9	58.6±20.4	p=0.0165
TH(cm)	22.7±19.3	22.2±19.9	p=0.6084	18.3±28.7	20.2±34.8	p=0.0086

150. Neurological Deficit in Delayed Presentation of Congenital Vertebral Deformities (CVD): An Analysis of Risk Factors and Surgical Outcome

S. Rajasekaran, PhD; Rajesh Rajavelu, MS, MS (ortho); Ajoy Prasad Shetty, MS, DNB

Summary

Prospective case control study was done in 33 patients having congenital vertebral deformity (CVD) and neurodeficit and 30 controls having CVD and without neurodeficit to analyze the influence of risk factors for developing neurodeficit. Surgical intervention and outcome were compared. A delay in presentation beyond 14 years of age, apex > T6, type I anomaly and signal hyperintensity in cord were high risk factors for developing neurodeficit. Patient with ambulatory capacity (>ASIA D) before surgery have better prognosis.

Hypothesis

Late presentation in CVD with high thoracic apex would lead to neurological deficit

Design

Prospective case control study

Introduction

CVD present either as a progressive deformity or with neurological deficit. Though the latter is reported to be rare; in Indian scenario it's not uncommon and there is paucity of literature on neurodeficit in delayed presentation, especially pertaining to the risk factors and surgical outcome

Methods

CVD with neurodeficit(case) and without neurodeficit(control) from 2008 to 2018 was included in the study. Age at onset deficit was noted in cases. Radiographs and CT were analyzed for the type of the anomaly, position of the apex, curve magnitude and deformity angular ratio (DAR). MRI was analyzed for hyper-intensity signal(SI) change in the cord. Neurology was graded using ASIA scale before and after surgery. The influence of risk factors on neurodeficit and outcome following surgery was analyzed statistically

Results

33 cases with a mean age of onset of neurodeficit of 19.3 years and 30 controls with a mean age of presentation of 13.5 years were studied over a mean follow-up period of 3 years. There were 39 males and 24 females. Type I anomaly was common among cases(57.57%). Apical level > T6 was found in 54.5% of cases whereas only 6.7% among controls (P-<0.001) with no significant difference in magnitude of curve. 39.3 % of cases had cord SI change versus 3.3% in controls. 4 had ASIA C and 20 had ASIA D in cases, while in controls it was 1, 6 respectively and 2 had ASIA A neurology. 24 cases (Group A) and 30 controls underwent vertebral column resection(VCR) and fusion, while 9 cases underwent circumferential decompression and In-situ fusion(Group B). 5 patients in Group A had post-operative neurological worsening and none in Group B or controls with no correlation to DAR

Conclusion

CVD with a delay in presentation >14 years of age, apex > above T6, type I anomaly and SI change in cord are high risk factors for developing a neurodeficit. Stability rather than deformity correction is paramount in these cases. Patient with ambulatory capacity(>ASIA D) have better prognosis

Take Home Message

Congenital vertebral deformity with high thoracic apex, type I anomaly and hyperintensity signal change in cord (T2 W MRI) needs surgical intervention before skeletal maturity

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

151. Spinal MRI Utilization in Patients with Early Onset Scoliosis Review of a Large Multi-Center Database

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Summary
MRI scans of the spine were obtained in 62% of EOS patients at a mean age of 5.8 years in this multi-center cohort. Presumed idiopathic patients (38%) had an MRI more frequently in comparison to other etiologies. When comparing within an etiology congenital patients (74%) had the highest rate of MRI. The overall MRI abnormality rate was 24%. Other demographics were similar between patients who had undergone MRI and those who had not.

Hypothesis
Spinal MRIs are obtained in a majority of EOS patients prior to treatment at academic centers.

Design
Retrospective review of a multi-center database.

Introduction
MRI of the spine is a necessary consideration during the treatment of EOS, as abnormalities are more commonly seen in this population. However, since sedation is frequently required, the decision and timing can be complex. Utilization of this imaging modality across the EOS spectrum has not been well described. The purpose of this study was to report on the patterns of MRI utilization in patients with EOS in a multi-center setting.

Methods
A retrospective review of a multi-center EOS registry was performed. Patients with incomplete or unverifiable data and those with structural deformities secondary to infection and tumor were excluded. Demographics, major curve size prior to treatment, type of treatment and use of MRI were examined.

Results
Of 1,929 total registry subjects, 1,343 (70%) patients managed at 21 institutions by 50 surgeons met inclusion criteria. Etiologic breakdown of this cohort was: Idiopathic or Idiopathic like: 446 (33%), Syndromic: 369 (28%), Neuromuscular: 317 (23%), and Congenital: 211 (16%). Mean age at treatment was 6.3±3.5years and major curve size prior to treatment was 66±25°. Surgery was performed in 75% of patients. MRI was obtained in 62% of patients at a mean age of 5.8±4.0years. The rate of abnormalities identified on MRI was 24%. MRI utilization was significantly variable across etiologies; however, pre-treatment major curve, treatment type, and age at treatment showed no association with MRI utilization (Table 1).

Conclusion
This study demonstrated that MRI of the spine was obtained in 62% of EOS patients prior to treatment at an average age of 5.8 years. MRI utilization varied based on etiology, occurring most often in presumed idiopathic and least often in neuromuscular patients. Age, major curve and need for operative treatment were not predictive of MRI use. These findings are the first to characterize global MRI utilization patterns and provide a foundation for the development of best practice guidelines for use of MRI in children with EOS.

Take Home Message
Across a multi-center cohort MRI of the spine was obtained in 62% (836/1343) of EOS patients at an average 5.8 years of age, with etiology being the single differentiating factor.

Table 1 Demographic Characteristics

	MRI Obtained n = 836 (62%)	No MRI Obtained n = 507 (38%)	P value
Between Etiology:			
Idiopathic	314 (38%)	132 (26%)	
Syndromic	232 (28%)	137 (27%)	p<0.001
Neuromuscular	134 (16%)	183 (36%)	
Congenital	156 (18%)	55 (11%)	
Within Etiology:			
Idiopathic	314 (70%)	132 (30%)	
Syndromic	232 (63%)	137 (37%)	NS
Neuromuscular	134 (42%)	183 (58%)	
Congenital	156 (74%)	55 (26%)	
Major Curve (prior to treatment) - °	65.0±24.0	67.0±25.6	NS
Age at Treatment - years	6.2±3.4	6.5±3.5	NS
Treatment Type			
Operative	634(63%)	374 (37%)	NS
Non-Operative	202(60%)	133 (40%)	

152. Surgery for Severe Pediatric Spinal Deformity has a Significant Rate of Revision: A Prospective Multi-center Cohort Study

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Summary
Surgical correction of severe spinal deformity is challenging. The revision rates of all pts who had a minimum of 2yrs f/u was 13% for instrumentation and fusion complications in severe pediatric deformity pts (minimum 100° or planned VCR).

Hypothesis
Pediatric patients with severe spinal deformities treated surgically

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

have a significant rate of revisions for instrumentation and fusion complications.

Design
Prospective observational multi center cohort of pediatric patients treated surgically for severe spinal deformity

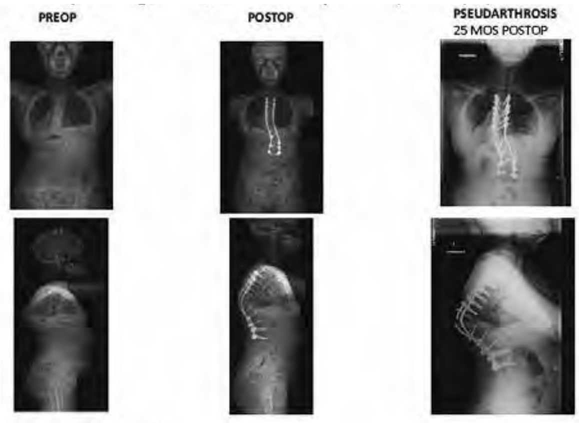
Introduction
Surgical treatment of severe pediatric deformity can be extremely challenging due to difficulties with instrumentation placement in small patients, stress on implants due to correction of severe deformities, and use of three column osteotomies. We investigated the instrumentation and fusion related complications in these complex spine deformity surgical cases.

Methods
Patients with severe spinal deformity (minimum 100° or planned VCR) were included with min. 2 yrs f/u from 17 centers. Complications with or without revision due to pseudarthrosis, instrumentation failure, infection requiring instrumentation removal and progression of deformity were all analyzed.

Results
228/312 pts had a min of 2 yrs f/u. 29 pts (13%) had complications associated with instrumentation or fusion. 22 pts (10%) had 27 revisions. The avg. time for all revisions was 16 mos (0-36) after index surgery; 3 pts were revised 2x and 1 pt 3x. The 27 revisions included 5 pts with loss of fixation, revised an avg. of 21 mos po (1-35). 4 pts with pseudarthrosis were revised an avg. of 21 mos po (13-28). 1 pt was revised for prominent instrumentation at 27 mos po, and 5 pts for deep infection between 1-27 mos, avg. 15 mos. 8 pts. had revisions for deformity progression at an avg of 13 mos (1-36). 1 pt. was revised for a mal-positioned screw a few days po, and 1 at 12 mos po for implant/instrum failure. 8 patients had complications that did not require revisions. These included 1 with prominent implants, 1 with a mal-positioned screw in the disc space, 3 had progressive deformity including PJK , 1 pt for implant prominence, 1 for loss of fixation, and 2 implant failures .

Conclusion
Pediatric pts with severe spinal deformity are at significant risk for revision surgery at a rate of 13% within 2 years. The ave. time for revision surgery was 16 mos po..

Take Home Message
Surgical treatment of severe pediatric spinal deformity has a significant revision rate of 13% with min 2 yrs. Long term f/u is necessary in this patient population.



Pseudarthrosis requiring revision at 25 months po

153. Outcomes of Definitive Spine Fusion Using All Pedicle Screw For Borderline Immature Patients With Severe Idiopathic Early Onset Scoliosis

Hany Abdel Gawwad Soliman, MD; Sarah Y. Abozaid, MD; Faisal El-Sherief, MD; Ashraf Abdelaziz, PhD

Summary
This is a prospective analysis of the outcomes of 34 borderline immature patients with severe idiopathic early onset scoliosis (IEOS) treated with definitive spine fusion using all pedicle screw. Definitive fusion achieved 70.5% mean final correction of the major coronal curve. The Scoliosis Research Society 22 revision (SRS-22r) score and Body Image Disturbance Questionnaire-Scoliosis version (BIDQ-S) scores significantly improved after definitive fusion for borderline immature patients with severe IEOS over a two years follow-up.

Hypothesis
Definitive instrumented spine fusion can effectively treat severe IEOS in borderline immature patients.

Design
A prospective study

Introduction
Severe IEOS lead to significant morbidity and body image changes. Two treatment options for severe IEOS in borderline immature patients: growth-sparing techniques or definitive spine fusion. Previous studies showed high complication rate with growth sparing techniques but no previous study investigated the outcomes of definitive fusion in borderline immature patients with severe IEOS.

Methods
Inclusion criteria: IEOS, major curve ≥ 90°, no previous spine

surgery, no intraspinal anomalies. Patient underwent instrumented spinal fusion with all pedicle screw, multiple Ponte osteotomies performed for all patients. All patients completed SRS-22r Arabic version questionnaire and BIDQ-S questionnaire preoperative as baseline and at 2 years follow-up.

Results

A total of 34 (13 males, 21 females) borderline immature patients with severe IEOS met inclusion criteria (mean age, 9.5 years; range, 8.5 - 10.5 years) were included. Mean coronal Cobb angle improved significantly (P < 0.001) from 107 ± 12.5 to 26.8 ± 6.8 (Figure 1). The mean thoracic kyphosis correction improved from 57.2 ± 15.8 to 31.2 ± 4.4. SRS 22r total score improved significantly (P < 0.001) from 2.5 ± 1 to 4.3 ± 0.7 with the greatest increases in self-image (improved from 1.7 ± 0.7 to 4.3 ± 0.7) and satisfaction (improved from 1.6 ± 0.4 to 4.5 ± 0.5) domains. BIDQ-S scores improved significantly (P β 0.001) from 4.1 ± 0.3 to 1.6 ± 0.3 (Figure 1). No complications were recorded at 2 years follow-up

Conclusion

Definitive fusion using all pedicle screw technique can effectively treat severe IEOS in borderline immature patients with lower complication rates than reported for growth sparing techniques.

Take Home Message

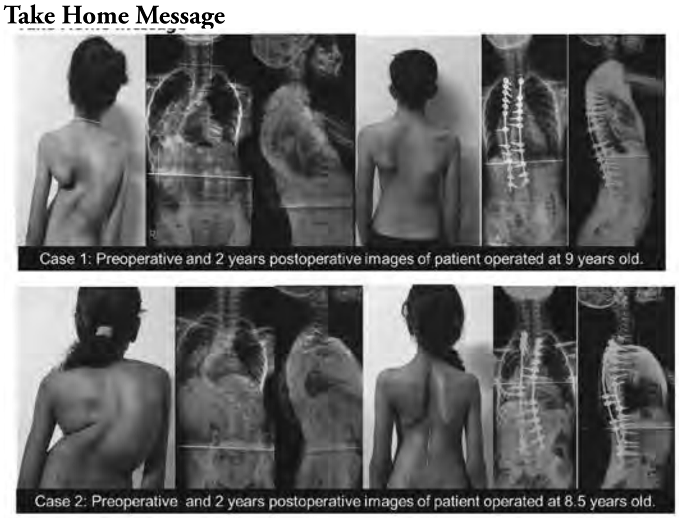


Figure 1: Improvement in body image, coronal and sagittal curves after definitive fusion of borderline immature patients with severe idiopathic early onset scoliosis

154. Comparison of Serial Casting vs. Brace Treatment for Early Onset Scoliosis

Ying Li, MD; Chelsea K. Graham, BS; Christopher B. Robbins, PhD; George H. Thompson, MD; Peter F. Sturm, MD, MBA; John B. Emans, MD; Paul D. Sponseller, MD, MBA; Michael P. Glotzbecker, MD; Children's Spine Study Group; Growing Spine Study Group

Summary

Serial casting can lead to curve improvement whereas brace treatment can only prevent curve progression in children with idiopathic and neuromuscular early onset scoliosis (EOS). Complications and rates of conversion to surgery are similar.

Hypothesis

Casting results in superior radiographic outcomes compared to bracing in children with EOS.

Design

Multicenter retrospective review.

Introduction

Previous reports have demonstrated the effectiveness of casting for EOS. Brace treatment for EOS has not been studied. The purpose of this study was to compare radiographic outcomes, complications, and rates of conversion to surgery in children with EOS treated with casting and bracing.

Methods

Children 2 to 6 years of age with idiopathic or neuromuscular EOS treated with casting or bracing were identified. Patients who had prior treatment for EOS, and incomplete brace wear compliance data and pre- and post-treatment radiographic data were excluded. Chi-square, independent t-test, and Mann-Whitney U test were conducted.

Results

81 patients (43 cast, 38 brace) were analyzed. Demographic and radiographic data are shown in the Table. Although the cast patients were younger than the brace patients at the start of treatment (3.6 vs 5.4 years, p<0.0001), they had a significantly larger major curve magnitude (52 vs 30 degs, p<0.0001). At the most recent follow-up, the cast and brace groups had a similar major curve magnitude (33 vs 32 degs), meaning that casting resulted in curve improvement while bracing only maintained the curve (Δ -19 vs 2 degs, p<0.0001). T1-T12 and T1-S1 length increased in both groups. The cast and brace patients had similar complications (2 vs 0) and conversions to surgery (5 vs 4). Sub-analysis showed that while casting resulted in curve improvement regardless of EOS etiology, bracing was able to prevent curve progression in patients with idiopathic EOS but not in patients with non-idiopathic EOS (Δ -3 vs 23 degs).

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Conclusion
Casting can lead to curve improvement in children with idiopathic and neuromuscular EOS, whereas brace treatment can only maintain the curve. Limitations of this retrospective study include the inability to control for brace design and compliance. A prospective study that includes patient-reported outcomes is necessary to further compare casting and bracing for EOS.

Take Home Message
Serial casting can lead to curve improvement whereas bracing can only prevent curve progression in children with idiopathic and neuromuscular EOS. Complications and rates of conversion to surgery are similar.

	Cast (n = 43)	Brace (n = 38)	p-value
Gender [n (%)]			0.405
Male	15 (35)	10 (26)	
Female	28 (65)	28 (74)	
Diagnosis [n (%)]			0.184
Idiopathic	32 (74)	31 (81)	
Intrathecal abnormality (syrinx, Chiari)	6 (14)	1 (3)	
Neuromuscular	5 (12)	6 (16)	
Age at start of treatment (years)	3.6 ± 1.5	5.4 ± 1.1	**<0.0001**
Duration of follow-up (years)	1.6 ± 1.4	3.8 ± 1.9	**<0.0001**
Average number of casts	5 ± 3	N/A	N/A
Brace wear compliance (hours)	N/A		N/A
Prescribed wear time		17.3 ± 4.0	
Reported wear time		15.2 ± 4.9	
Radiographic measures at start of treatment			
Major curve (degree)	52	30	**<0.0001**
T1-T12 length (millimeters)	162	185	**<0.0001**
T1-S1 length (millimeters)	259	297	**<0.0001**
Radiographic measures at most recent follow-up			
Major curve (degree)	33	32	0.318
T1-T12 length (millimeters)	168	211	**<0.0001**
T1-S1 length (millimeters)	271	340	**<0.0001**
Difference in radiographic measures from start of treatment to most recent follow-up			
Major curve (degree)	-19	2	**<0.0001**
T1-T12 length (millimeters)	12	26	**0.006**
T1-S1 length (millimeters)	20	43	**0.004**

155. Comparison of Surgical Outcomes Between Early Definitive Spinal Fusion and Growing Rod in Patients with Early Onset and Dystrophic Scoliosis in Neurofibromatosis Type 1: A Multicenter Study

Ryoji Tauchi, MD; Noriaki Kawakami, MD; Koki Uno, MD, PhD; Teppei Suzuki, MD, PhD; Toshiaki Kotani, MD, PhD; Takuya Yamamoto, MD, PhD; Hideki Murakami, MD, PhD; Satoru Demura, MD; Kazuki Kawakami, B.Kin

Summary
We compared the surgical outcomes between early spinal fusion (EF) and growing rod (GR) for early onset scoliosis (EOS) with Neurofibromatosis type 1 (NF-1). The advantages of GR regarding growth preservation was not seen when it was compared to EF in NF-I (Dystrophic type). EF demonstrated better scoliosis correction and FVC without significant shorter trunk height than GR.

Hypothesis
Relatively longer EF can be accepted in EOS patients with NF-1 in terms of better control of dystrophic change compared with GR.

Design
Retroespective comparative study

Introduction
It is challenging to treat EOS patients with progressive dystrophic type of neurofibromatosis (NF-1). No previous studies have compared early definitive spinal fusion (EF) with growing rod (GR) for EOS with NF-1.

Methods
This was a retrospective multicenter study. 28 EOS patients with dystrophic type of NF-1 who underwent EF (18 pts) or GR (10 pts.) were investigated in this study. We compared age at 1st surgery and final follow-up (FU), total number of surgeries, coronal Cobb angles, complication rates, T1-S1 length, T1-T12 length, and pulmonary function tests (forced vital capacity: FVC) between the two groups.

Results
The two groups did not show significant differences in FU period (p=0,178), major Cobb angle (p=0.225), and thoracic kyphosis (0.167). However, significant differences were recognized in age at the first op. (p=0.018), age at final follow-up (p=0.03), preop. height (p=0.002), preop. T1-S length (p<0.001) and age at final fusion (p=0.036). Although spine fusion in the EF group was performed when the patients were on average 5 years younger than the EF group with shorter length of fusion area (p=0.011), scoliosis at the final FU for the EF group was significantly smaller than that of the GR group (p=0.006) with a better correction rate (p=0.04). Furthermore, T1-S1 length and T1-T12 length at the final FU were not significantly different between two groups with a better FVC in the EF group (p=0.03). Complications were seen in 56% of the EF group and in 60% of the GR group.

Conclusion
Early fusion is still a viable option for progressive EOS with dystrophic type of NF-1 even in the growth-friendly era, as progression of dystrophic change in NF-1 is hard to suppress during growth-preserving treatment, such as GR. Surgeons should consider the best procedure for each patient taking into account the severity of dystrophic change when treating EOS with NF-1.

Take Home Message
The potential caveats of EF such as shorter trunk height and cardiopulmonary comorbidities may not be as pronounced when compared against GR in pts with NF-I (dystrophic type).

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	Early Fusion group (EF)	Growing Rod (GR) group	p value
Patients	18	10	
Sex	Male 9, Female 9	Male 7, Female 3	
Age at the 1st op.	7.4 (5~9)	5.8 (2~8)	0.018
Age at Final FU	20.7 (14~34)	16.3 (12~22)	0.036
Fusion segments	13 (4~23)	16 (13~23)	0.011
Preop. Cobb angle	70 (41~105)	83 (58~113)	0.225
Final Cobb angle	31 (17~58)	49 (32~89)	0.006
Final T1-T12 (cm)	21.9 (14.0~24.6)	21.7 (17.5~25.4)	0.533
Final T1-S (cm)	36.1 (27.0~44.9)	35.8 (30.5~41.6)	0.774
Postop. FVC (L)	2.26 (0.82~3.96)	1.46 (0.92~2.08)	0.030

156. Law of Temporary Diminishing Distraction Gains: The Phenomenon of Temporary Diminished Distraction Lengths with Magnetically Controlled Growing Rods that is Reverted with Rod Exchange

Jason Pui Yin Cheung, MBBS, FRCS, MS; Bow H. Cora, PA-C, BS; Kenneth MC Cheung, MD

Summary
This is a prospective radiographic analysis of 24 patients with Early Onset Scoliosis (EOS) who underwent magnetically controlled growing rod (MCGR) surgery and distracted monthly. We demonstrated that achieved rod lengthening gradually reduces with gain in length of the rod. With rod exchange, the original intended distractions can be achieved. We propose such, "Law of Temporary Diminishing Distraction Gains" is related to rod factors and not patient factors and should be distinguished from the Law of Diminishing Returns..

Hypothesis
The rate of achieved length gain with MCGR reduces with rod usage but returns to baseline after rod exchange.

Design
Prospective study.

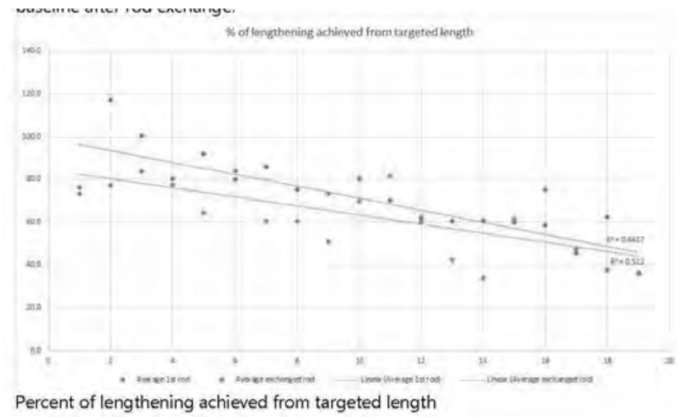
Introduction
MCGRs have been shown to achieve similar clinical and radiological outcomes as traditional growing rods. Divergence between targeted (lengthening amount input in the external remote controller) and achieved (measured length on radiographs) distractions has been observed with increased distractions of the MCGR. This may be related to reduced distraction forces as the rod lengthens. The relationship of this reduced rate of achieved lengthening with remaining rod length has yet to be explored.

Methods
EOS patients who underwent MCGRs with minimum 2-year follow-up during the period between 12/2009 and 5/2018 were included in this study. All patients underwent a monthly distraction protocol of 2mm at each visit. Correlation (R2) between percentage of lengthening achieved from targeted length was identified, as well as its relationship with timing of rod exchanges.

Results
A total of 24 patients fulfilled the inclusion criteria. The mean age at index surgery was 9.3 years and mean postoperative follow-up was 56 ± 30 months. Of these, 10 patients had at least one rod exchange which occurred at 39 ± 14 months. A decrease in rate of achieved lengthening was observed when compared with targeted distractions. The achieved lengthening drops from 86% of targeted length at the first distraction to only 50.3% at the 19th distraction episode for the first set of rods. After rod exchange, the average achieved lengthening went back up to 81.3% of the targeted length but subsequently had a gradual reduction to 35% at the 19th distraction episode.

Conclusion
We propose a "Law of Temporary Diminishing Distraction Gains" with the MCGR that users should be aware of when monitoring rod lengthening. Diminishing distraction length gains with increased length of rod is observed which is independent of patient factors. This is only temporary as the rates of achieved lengthening returns to baseline after rod exchange.

Take Home Message
MCGR follows a "Law of Temporary Diminishing Distraction Gains" whereby achieved rod lengthening gradually reduces with gain in length of the rod and reverts back to baseline after rod exchange.



Percent of lengthening achieved from targeted length

157. Awake Serial Body Casting for the Management of Infantile Idiopathic Scoliosis (IIS)

Scott M. LaValva, BA; Noriaki Kawakami, MD; Jigar S. Gandhi, PharmD; Kazuaki Morishita; Peter F. Sturm, MD, MBA; Sumeet Garg, MD; Michael P. Glotzbecker, MD; Jason Brett Anari, MD; John (Jack) M. Flynn, MD; Children's Spine Study Group; Growing Spine Study Group; Patrick J. Cahill, MD

Summary

Serial body casting for IIS has traditionally been performed under general anesthesia (GA). However, reports of neurotoxic effects of anesthetics in young children have prompted physicians to consider instead performing these procedures while patients are awake and distracted by electronic devices. The present study is the first to compare the outcomes of each method.

Hypothesis

There will be similar radiographic outcomes in patients who were casted under GA and those who were awake.

Design

Retrospective Cohort Study

Introduction

The use of electronic devices to distract children during serial casting procedures for IIS has been proposed as an alternative to GA. However, there are no published reports comparing the radiographic and clinical outcomes of casting with and without the use of GA.

Methods

Patients from a multicenter registry who underwent serial casting for IIS were included. The patients were divided into asleep (GA) and awake (no GA) cohorts. Patients in the awake cohort were treated at a single center. Comparisons were made between pre- and post-casting major and compensatory cobb angles (CAs), deformity angular ratio (DAR), and spine height in each cohort. The rates of successful casting (> 10 deg. major CA improvement), major curve progression (worsening), and incidence of casting abandonment for surgical intervention were also compared.

Results

One-hundred and thirty patients (54% females; mean age 2.0 years) with IIS who underwent serial casting were included. Overall, the mean duration of casting was 2.7+/-1.6 years. 101 of 130 (77%) patients were asleep during the casting procedures, while 29 (22%) were awake. Despite more severe baseline curve magnitude in the awake cohort, there were no significant differences between cohorts with respect to major and minor CA, DAR, or coronal balance upon casting cessation. There were significant improvements in the major CA in both the asleep (45→33 [27%]; p<0.001) and awake (55→39.5 [28%]; p<0.001) cohorts. The rate of successful casting was 49% in the asleep cohort compared to 72% in the awake cohort (p=0.023), while the rate of curve progression (worsening) was similar (18% vs. 17%). There was a higher overall rate of conversion to surgery in the awake (38%) versus asleep (18%) cohort (p=0.022), though the rate of conversion at two years post-initiation of casting was similar (0 vs. 7%; p=0.348).

Conclusion

Patients who underwent awake serial casting had similar radiographic outcomes compared to those who were under GA during the procedures.

Take Home Message

Awake serial casting may provide a safe and effective alternative to the use of general anesthesia for serial casting in patients with idiopathic infantile scoliosis.

	Awake			Asleep		
Variable	**Pre**	**Post**	**P-value**	**Pre**	**Post**	**P-value**
Major CA	55 (51 – 56.3)	39.5 (23.3 – 49.3)	<0.001	45 (37.5 – 58.5)	33 (15 – 52)	0.001
% Change in Median Major CA	28.2%			26.7%		
DAR	7.0 (5.4 – 8.5)	5.1 (3.3 – 7.1)	0.031	5.5 (4.2 – 7.5)	4.9 (2 – 7.5)	0.029
Minor Cobb	37 (31.5 – 42.3)	28 (17 – 42.5)	0.059	27 (18 – 35)	24 (13.2 – 36)	0.220
Coronal Balance	1.1 (0.7 – 2.0)	1.0 (0.2 – 1.5)	0.150	0.8 (0.4 – 1.8)	1.1 (0.7 – 1.5)	0.366
T Spine Height	13.5 (12.5 – 15.0)	16.3 (14.8 – 17.6)	< 0.001	13.2 (12.1 – 14.6)	16.4 (14.8 – 18.2)	< 0.001
L Spine Height	10.8 (9.2 – 11.7)	13.9 (12.1 – 14.6)	< 0.001	7.8 (7.2 – 8.5)	9.5 (8.7 – 10.9)	< 0.001
Maximum Sagittal Kyphosis	29 (17.5 – 42)	25 (18 – 30)	0.231	35 (22.5 – 40.5)	40 (26 – 45)	0.259
Lumbar Lordosis	47.5 (36.5 – 69.3)	44.5 (42.5 – 56.3)	1.000	42.9 (46.8 – 31.5)	46 (28 – 58.5)	0.631

Table I. Comparison of pre- and post- casting radiographic measures in awake and asleep cohorts.

158. Elevated Serum Titanium Levels in Children with Early Onset Scoliosis Treated with Growth-sparing Instrumentation

Ying Li, MD; Chelsea K. Graham, BS; Christopher B. Robbins, PhD; Michelle S. Caird, MD; Frances A. Farley, MD

Summary

Elevated serum titanium (Ti) levels are present in children with early onset scoliosis (EOS) treated with growth-sparing instrumentation (GSI). Rib-based growing constructs (RBGC) may release more Ti than traditional growing rods (TGR) and magnetically controlled growing rods (MCGR).

Hypothesis

EOS patients treated with GSI have elevated serum Ti levels.

Design

Prospective cross-sectional case series.

Introduction

A previous study showed significantly higher serum Ti levels in EOS patients treated with TGR and MCGR compared to controls. Children with RBGC were not assessed. The purpose of this study was to evaluate serum Ti levels in EOS patients treated with TGR, MCGR, and RBGC.

Methods

Serum Ti levels were collected from patients with GSI who were enrolled in an EOS database. Blood samples were collected at a clinic visit or lengthening/exchange procedure between April and

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December 2018. The normal range for serum Ti is 0-1 ng/mL. Analyses were conducted using ANOVA and Bonferroni post hoc test.

Results

23 patients (2 TGR, 8 MCGR, 13 RBGC) were analyzed. There was a significant difference in age at time of blood sample collection and serum Ti level between the groups (Table). The RBGC patients had a significantly higher serum Ti level than the TGR patients (7.6 vs 1.5, p=0.046). There was no difference in serum Ti level when the MCGR group was compared to the TGR and RBGC groups. Time from implant insertion to blood sample collection, number of rods currently implanted, total number of rods implanted throughout treatment, and number of lengthenings per patient were similar between the groups.

Conclusion

Elevated serum Ti levels may be present in EOS patients treated with all forms of GSI. Although our TGR patients had indwelling implants for the longest period of time, they had the lowest serum Ti level. Repetitive chest wall motion during respiration may lead to continued wear and metal ion release with RBGC. The significance of elevated serum Ti levels in children is unclear. Additional studies should be conducted to evaluate serial serum Ti and possibly tissue Ti levels in a larger population of EOS patients with different types of GSI.

Take Home Message

Elevated serum titanium levels are present in children with EOS treated with growth-sparing instrumentation. RBGC may release more titanium than TGR and MCGR.

	TGR (n = 2)	MCGR (n = 8)	RBGC (n = 13)	p-value
Age (years)	12.5	9.8	7.5	**0.015**
Serum titanium level (ng/mL)				**0.021**
Mean ± SD	1.5 ± 0.7	4.5 ± 2.1	7.6 ± 3.7	
Range	1-2	2-8	2-15	
Time from implant insertion to blood sample (years)				0.097
Mean	7.9	2.0	5.4	
Range	2.3-13.4	0.9-3.2	1.3-10.7	
Current number of rods	2.0	2.0	1.6	0.095
Total number of rods implanted during treatment	5.5	2.8	4.9	0.066
Number of lengthenings per patient				0.920
Mean	6.0	6.8	7.2	
Range	3-9	3-12	2-18	

TGR, traditional growing rods; MCGR, magnetically controlled growing rods; RBGC, rib-based growing constructs; SD, standard deviation

159. Bigger is Better: Larger Thoracic Height is Associated with Increased Health Related Quality of Life at Skeletal Maturity

Hiroko Matsumoto, PhDc; Matthew E. Simhon, BS; Sumeet Garg, MD; Amer F. Samdani, MD; John T. Smith, MD; Paul D. Sponseller, MD, MBA; Michael G. Vitale, MD, MPH; Benjamin D. Roye, MD, MPH; Children's Spine Study Group; Growing Spine Study Group

Summary

An association between thoracic height and health related quality of life (HRQoL) at skeletal maturity was examined in 469 patients with early onset scoliosis (EOS) queried from multi-center registries. For the group, thoracic heights >18 cm at skeletal maturity were associated with increased HRQoL, however for the idiopathic subgroup this threshold was 20cm.

Hypothesis

In patients with EOS, larger thoracic height at skeletal maturity is associated with increased HRQoL.

Design

Cross-sectional Study

Introduction

Current literature suggests a minimum thoracic height of 18 cm to 22 cm to avoid poor pulmonary function and related health outcomes. The purpose of this study is to evaluate the association between thoracic height and health related quality of life (HRQoL) at skeletal maturity in patients with EOS.

Methods

Patients with EOS who reached skeletal maturity from 2005 to 2018 were identified in two registries including 32 centers. Thoracic height from T1 to T12 at skeletal maturity and Early Onset Scoliosis 24 Item Questionnaire (EOSQ-24) scores were collected. The EOSQ-24 domains included HRQoL of patients, parental impact, financial impact and patient and parental satisfaction.

Results

469 patients (mean age: 14.9, female: 77.4%) were identified. 29.4% patients were of congenital etiology, 20.5% neuromuscular, 13.6% syndromic, 35.2% idiopathic, and 1.3% other. When patients were grouped by thoracic height at skeletal maturity, all EOSQ-24 domains increased after a threshold of 18cm (p-values <.005) (Figure 1). When stratified by etiology, the 18cm cutoff held for patients with congenital, neuromuscular and syndromic EOS. The cutoff for patients with idiopathic EOS was 20cm. For all patients, after the threshold was met, HRQoL continued to improve with increases in thoracic height at skeletal maturity.

Conclusion

Once 18 cm is achieved, HRQoL continues to improve as thoracic height increases in skeletally mature patients with non-idiopathic

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EOS. Thus, this threshold was not driven by the generally healthier and larger idiopathic patients (2-3 cm taller thoracic height on average). Patients with idiopathic EOS had a higher threshold, possibly due to their larger average size and higher care giver expectations for HRQoL.

Take Home Message

The positive association between thoracic height and HRQoL at skeletal maturity supports the principle of maximizing thoracic height in EOS patients.

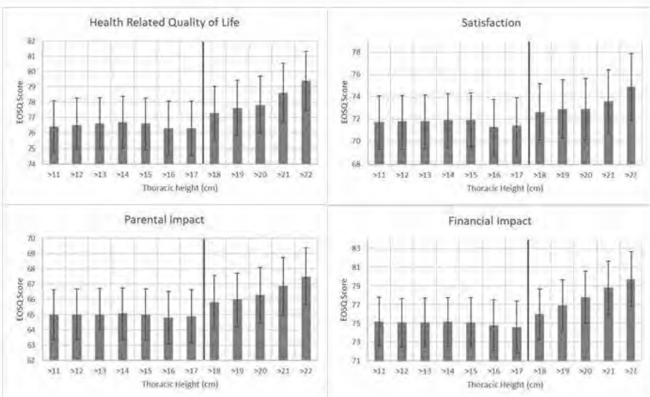

Figure 1. Average EOSQ-24 domain scores at skeletal maturity by thoracic height

Figure 1. Average EOSQ-24 domain scores at skeletal maturity by thoracic height

160. Outcomes of Instrumented Cervical Spinal Fusion in Children with Os Odontoideum

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Summary

Outcomes of spinal fusion for os odontoideum were evaluated on 71 children. 28 children (39%) showed neurologic deficit before the surgery. Instrumented cervical spine fusion with/o decompression of the neural elements improved neurologic function, but was associated with 30% risk of complications including non-union and new neurologic deficits. New neurologic deficits occurred only in the dystopic subgroup. Thirty-four (48%) children had neck pain preoperatively and ten (14%) at final follow-up.

Hypothesis

Children presenting with os odontoideum associated upper cervical instability benefit from cervical spinal fusion.

Design

A retrospective, multicenter study.

Introduction

The outcomes of spinal fusion for os odontoideum in children are not well documented.

Methods

71 children (mean age at surgery 11.0 yrs, range 1.5-18.7 years; 33 orthotopic, 38 dystopic) who underwent instrumented cervical spine fusion for os odontoideum with a minimum two-year follow-up (mean 3.5 yrs range, 2.0-11.9 yrs) were identified. Patients with skeletal dysplasias were excluded. 37 had associated syndromes: Down (17), other chromosomal (6), CP (4), congenital scoliosis (2), multiple congenital anomalies (2), and other (7). Indication for cervical spine fusion was AAD ≥5 mm or SAC ≤13mm. 5 had preop halo traction. 50 underwent C1-C2 and 21 occipitocervical instrumented fusion using a rigid instrumentation (64) or non-rigid instrumentation (sublaminar wires, seven). 19 (26%) underwent posterior spinal cord decompression and one anterior odontoidectomy.

Results

69 (96%) children had spinal fusion at FFU. A surgical complication was observed in 21 (30%): non-union (12), new neurologic deficit (4), CSF leak (2), symptomatic hardware necessitating removal (2), vertebral artery injury (1), and bony regrowth requiring de-compression (1). All four new neurologic deficits occurred in patients with dystopic type of os odontoideum (p=0.052 as compared with orthotopic). 34 (48%) children had neck pain preoperatively and ten (14%) at FFU. 9 (13%) children required ≥1 revision surgery: non-union (9), hardware removal (2), and CSF leak (1). Risk of non-union was higher in children receiving a non-rigid than rigid cervical instrumentation (3/7 vs. 9/64, p=0.054). 28 children (39%) showed neurologic deficit before the surgery. JOA upper (UE) and lower extremity (LE) scores showed a significant improvement from preop to FFU (mean UE 3.4 preop vs. 3.6 FFU; LE 3.3 vs. 3.7, p<0.05).

Conclusion

Instrumented spinal fusion improved neurologic function, but was associated with 30% risk of complications including non-union and new neurologic deficits. New neurologic deficits occurred only in the dystopic subgroup.

Take Home Message

Children presenting with os odontoideum associated with upper cervical instability benefit from instrumented cervical spinal fusion. 39% had a neurologic deficit preoperatively and neurologic function improved from preop to FFU.

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161. Cervical Spine Fusion in Children: A Retrospective Analysis of Complication Free Survivorship

Sean M. Kelly, MD, DO; Denise R. Lopez, MSNARNP; Jonathan H. Phillips, MD, MBBS

Summary
A 20 year review of children's cervical spine surgery revealed a 74% complication free survival rate. Long term follow up revealed a significant mortality approaching 10% and a reoperation rate and residual neurological deficit of 30% and 24%. ASA grades were low at III on average. Long term follow up is necessary to assess true outcomes in children's cervical spine surgery. These children are medically complex and challenging in their surgical management.

Hypothesis
Long term follow up of children's cervical spine surgery in under reported and poorly understood

Design
Retrospective case series

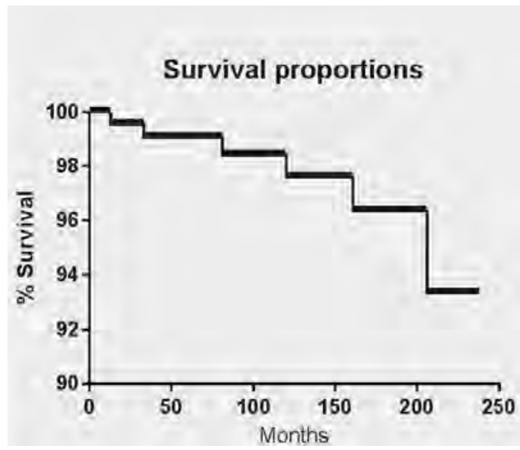
Introduction
Long term studies of cervical spine surgery in children are rare. Much of the pediatric literature addresses surgical techniques rather than outcomes. This report details a 20 year experience with longer term follow up and rates of complications including mortality

Methods
A 20-year retrospective review was performed on all children who underwent cervical spine fusion at a single center. Primary outcome was survivorship utilizing the Kaplan-Meier estimator. Secondary outcomes included incidences of: neurological deficit (ND); cord signal change (CSC) on preop MRI; intraop neuro-monitoring alert (NMA); reoperation (RO) and residual deficit (RD) rates. We also report: mean age at index operation; mean follow up; mean ASA score; mean number of levels fused; rigid vs. nonrigid fixation; bone graft usage; and halo vest augmentation postop. Statistical analyses student T-test and Chi Square were performed for continuous and categorical test variables, respectively. A minimum 2 years follow up was required for inclusion.

Results
A total of 48 patients were analyzed, 31 qualified for inclusion. 4 patients died (8%) at 3, 5, 8, and 14 yrs postop. No deaths were a direct result of orthopedic complications. Incidence of: ND:52%; CSC on MRI:36%; NMA:22%; RO and RD rates 30% and 24%. Mean age at index 10 yrs 5 mo (range 7 mo – 23 yrs); mean ASA score: III; mean # of levels fused: 2.6; rigid fixation: 81%; iliac bone graft: 98%; augmentation with a halo vest: 69%; mean follow up: 5 yrs 10 mo, (2 – 20 yrs); and 2-year follow up: 67%. Students T-test demonstrated significance in those with postop complications (74%) presenting at a mean age 11 yrs 7 mo (+/- 4 yrs 10 mo), while those without (26%) presenting at a mean age 6 yrs 10 mo (+/- 4 yrs 4 mo; p = 0.021).

Conclusion
Long term followup is need to demonstrate accurate outcomes in children's cervical spine surgery. About three quarters of these patients have no complications.

Take Home Message
Children with cervical spine conditions represent a medically complex group who require long term surveillance for complications and adverse outcomes. Surgical management in this group is challenging.



Survival curve of patient population over 20 years.

162. Are Posterior Osteotomies Warranted when Managing Mild Flexible Cervical Deformity?

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Summary
Mild flexible cervical deformity (CD) treated with posterior or ant/post approach were evaluated for impact of posterior osteotomies (PO) on radiographic and clinical outcomes. Use of PO in correcting mild flexible adult CD did not differentially improve radiographic correction when compared to not using osteotomies, regardless of concomitant anterior approach application, and was associated with higher EBL, number of levels fused, and postop

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neck pain. However, complication rates were similar with and without POs.

Hypothesis
The use of POs when correcting mild flexible CD may not lead to improved outcomes and results in greater risk.

Design
Prospective multicenter database review

Introduction
Correction of mild flexible CD via posterior approach has been described with/without the use of POs. It is unclear whether use of POs is necessary to achieve desirable radiographic and clinical outcomes, or justified relative to risk

Methods
Prospective database of operative CD patients was analyzed. Inclusion criteria were cervical kyphosis>10˚, cervical scoliosis>10˚, cSVA>4cm or CBVA>25˚. Mild deformity was defined by cSVA of 3-5cm and/or kyphosis of <15˚; flexibility defined by C2-7 angular change>5˚ on preop flex/ex xrays. Groups were categorized by use of PO or NPO (no PO)

Results
98 pts met inclusion criteria (PO 67; NPO 31) with similar avg age (60.2/62.8yrs p=0.206). Combined ant/post approach was higher in the NPO group (61.3% v. 34.3%;p=0.012). Preop cSVA (43.6/40.8;p=0.59), T1S (34/30.7;p=0.501), C2-7 lordosis (-6.2/-11.1; p=0.114), and mJOA (13.3/13.8;p=0.422) were similar, but NDI (54.8/44.4;p=0.011) was higher in PO. In PO vs. NPO, kyphosis apex was cervical in 45%/71%, cerv-thor in 34%/26%, and thoracic 15%/0 (p=0.043). In the PO group, grade 1-3 PO were used in 43 (64%) and grade 4-6 in 24 (36%). When adjusting for use of ant approach, at 1yr postop cSVA (37.9/35;p=0.452) and C2-7 lordosis (11/6.8;p=0.41) were similar, but NRS neck was higher in PO (5.7/3; p<0.001). cSVA (37.7/36.4;p=0.867) and C2-7 lordosis (7.7/10.3;p=0.313) were similar at 2yr, but NRS neck (5.3/2.6;p=0.022) was greater with PO and ΔTS-CL (2.5/-14.2;p=0.027), and C2S(0.9/-17.3;p=0.009) were greater with NPO. EBL(1071/614cc;p=0.002) and levels fused (9.2/7.2;p=0.006) were higher with PO, but OR time (442/359min;p=0.127), complications (63.2%/76.9%;p=0.409) and 2yr mJOA (13.4/14.5;p=0.243) were similar between groups

Conclusion
Use of POs in correcting mild flexible adult CD may not be necessary to achieve desirable radiographic correction, regardless of ant approach, and are associated with higher EBL, # of levels fused, and 1&2yr neck pain. The apex of kyphosis may further influence the decision and potential need for POs.

Take Home Message
Posterior osteotomies were associated with higher EBL, levels fused, and postop neck pain, without evident improvements in clinical or radiographic outcomes, than when compared to employing posterior reconstruction without osteotomies.

163. Risk Factors for Progression of Osseous Cervical Congenital Scoliosis

Amir Amanullah, BS; Brandon J. Toll, BA; Joshua M. Pahys, MD; Amer F. Samdani, MD; Steven W. Hwang, MD

Summary
Although thoracolumbar congenital scoliosis is well described in the literature, there is a paucity of knowledge in congenital cervical scoliosis from osseous deformity. We retrospectively reviewed 38 pediatric patients to identify risk factors associated with cervical curve progression. 26% of patients' cervical spine curves progressed over a mean of 3 years, whereas the remaining 74% remained stable. Our results suggest that patients with greater T1 tilt and occiput-C2 angle in the sagittal plane at presentation are more likely to progress.

Hypothesis
Specific cervical radiographic measures may predict which congenital cervical curves have the greatest risk of progression.

Design
Single-center retrospective study

Introduction
Thoracolumbar congenital scoliosis has been well described; however, there is no literature exploring the natural history and progression of osseous cervical congenital scoliosis (CCS) in children. We investigated risk factors for progression of deformity in CCS.

Methods
Medical records were retrospectively reviewed for 38 pediatric patients with CCS and a minimum of 2 years of follow-up. Curve progression was defined as >10° increase in cervical Cobb angle at last follow-up interval after presentation. Patients were then divided into two cohorts: 1) stable curve (SC, n=28), and 2) progression of Cobb angle (PC, n=10). Cohorts were compared using Student-t tests.

Results
38 patients were included (16 female, 22 male) with a mean age at presentation of 5.6 ± 4.1 years. 26.3% had progression with a mean follow-up of 3.06 ± 2.99 years. The congenital deformities were quite varied, but the apex of cervical deformity was most commonly C5 and C6 with a mean cervical curve of 17.6 ± 16.6°. Over time, the entire cohort had a mean increase in the cervical Cobb of 7.1 ± 6.0° (p<0.001) and a decrease in the occiput-C2 (OC2) angle of 6.8 ± 13.6° (p=0.01). Other radiographic and demographic measures did not change significantly aside from increases in age, height and weight. When comparing the two cohorts at presentation, T1 tilt was significantly larger in the PC

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cohort (34.5 ± 15.4° vs. 25.1 ± 8.6°, p=0.029) and OC2 angle was also larger in the PC cohort (36.6 ± 12.3° vs. 23.9 ± 14.7°, p=0.026). At presentation, age, cervical, thoracic and lumbar curve magnitudes, radiographic measures of translation, and cervical measures were not significantly different between groups. At last follow-up, no statistically significant difference was found between the two cohorts as well.

Conclusion

26% of osseous congenital cervical scoliosis curves progressed over time. Patients with greater T1 tilt and OC2 angle were more likely to have progression of cervical deformity.

Take Home Message

26% of osseous congenital cervical scoliosis curves progressed >10° within 3 years of follow-up. Greater T1 tilt and occiput-C2 angle were associated with increased likelihood of curve progression.

	At Presentation			Last follow-up			Interval change Δ		
	Stable Curve (N=28)	Progression (N=10)	p-value	Stable Curve (N=28)	Progression (N=10)	p-value	Stable Curve (N=28)	Progression (N=10)	p-value
Age (yr)	5.9 ± 4.1	4.4 ± 4.2	0.536	8.8 ± 3.5	8.4 ± 4.6	0.769	2.9 ± 2.8	3.4 ± 3.5	0.663
Weight (kg)	18.9 ± 9.9	17.4 ± 9.7	0.712	25.5 ± 11.7	28.2 ± 13.7	0.563	5.4 ± 6.7	9.4 ± 13.1	0.276
Height (cm)	102.0 ± 18.6	98.2 ± 26.0	0.654	121.3 ± 18.6	123.6 ± 28.6	0.805	17.5 ± 16.3	24.8 ± 35.5	0.690
Cervical Cobb (°)	18.5 ± 17.6	15.1 ± 14.1	0.594	23.8 ± 19.9	25.2 ± 6.6	0.841	4.1 ± 3.9	14.4 ± 4.1	<0.005
Thoracic Cobb (°)	26.2 ± 19.1	32.5 ± 22.9	0.532	38.7 ± 22.9	42.2 ± 24.9	0.763	10.3 ± 13.6	9.7 ± 13.0	0.936
Lumbar Cobb (°)	23.8 ± 12.3	20.8 ± 14.6	0.734	31.4 ± 16.9	31.4 ± 5.5	0.994	7.00 ± 14.7	10.6 ± 9.2	0.704
C2 CSVL (mm)	13.5 ± 23.3	16.1 ± 19.6	0.824	16.1 ± 27.2	20.3 ± 13.7	0.727	1.2 ± 24.5	13.2 ± 25.8	0.424
C7 CSVL (mm)	13.8 ± 28.8	17.2 ± 38.8	0.839	16.9 ± 31.6	17.5 ± 28.6	0.965	1.2 ± 17.4	18.0 ± 61.2	0.401
C2 SVA (mm)	34.8 ± 43.3	48.6 ± 25.5	0.557	43.0 ± 28.4	6.8 ± 33.7	0.051	18.9 ± 48.4	-48.4 ± 35.0	0.053
C7 SVA (mm)	33.3 ± 37.4	41.4 ± 31.4	0.702	34.8 ± 29.1	1.4 ± 42.4	0.124	12.6 ± 54.4	-46.9 ± 43.2	0.120
Thoracic Kyphosis (°)	41.9 ± 12.5	43.5 ± 12.9	0.814	39.9 ± 9.8	44.8 ± 19.4	0.485	-0.6 ± 7.8	0.3 ± 13.2	0.862
Lumbar Lordosis (°)	47.8 ± 14.2	46.4 ± 8.1	0.840	57.0 ± 15.8	52.3 ± 10.2	0.521	11.2 ± 14.5	8.7 ± 13.9	0.746
T1 Tilt (°)	25.1 ± 8.6	34.5 ± 15.4	0.029	24.8 ± 7.4	28.1 ± 7.6	0.244	0.2 ± 7.5	-6.8 ± 15.3	0.217
Cervical Kyphosis (°)	-9.5 ± 20.3	-5.9 ± 21.6	0.661	-9.9 ± 25.9	-5.9 ± 22.8	0.684	-1.7 ± 21.4	1.6 ± 19.9	0.699
T1S - CK (°)	33.4 ± 26.2	40.5 ± 32.4	0.518	34.6 ± 29.6	34.1 ± 26.1	0.959	4.7 ± 12.7	-8.4 ± 28.0	0.081
OC2 (°)	23.9 ± 14.7	36.6 ± 12.3	0.026	18.9 ± 11.3	20.9 ± 14.7	0.682	-3.2 ± 11.9	-15.2 ± 14.1	0.024
C2T3 (°)	18.5 ± 13.0	18.9 ± 17.4	0.943	19.8 ± 16.8	15.6 ± 13.4	0.502	0.9 ± 10.7	-3.9 ± 9.5	0.252

164. The Influence of Spinopelvic Morphologies on Sagittal Spinal Alignment: An Analysis of the Incidence Angle of Inflection Points

Sung Hoon Choi, MD; Chang Ju Hwang, MD, PhD; Jae Hwan Cho, MD, PhD; Seung Min Son, MD, PhD; Tae Sik Goh, MD, PhD; Jung Sub Lee, MD, PhD; Dong-Ho Lee, MD, PhD

Summary

The incidence angle of inflection points (IAIPs), represent the geometrical sum from the pelvis to a given spinal level, correlated with various regional parameters, including PI. Moving from the low IAIP group to the high IAIP group, progressive increases in PI, PT, C7SVA, and IAIPs, and decreases in LL, TK, C07L, and SS/PI were observed (p < 0.001). The subjects in the low IAIP group were affected by SS/PI, and those in the high IAIP group were affected by PT.

Hypothesis

The hypotheses of this study were that specific spinopelvic morphologies affect the following spinal sagittal alignments and that the sagittal pattern varies according to the incidence angle of inflection point (IAIP).

Design

Prospective observational study

Introduction

Recent studies are focused on a radiographic parameter that reflects global spinal alignment and/or relevant with pelvic incidence (PI). PI-LL is known to be equal to L1 incidence, as the geometrical sum from the pelvis to the L1 vertebra.

Methods

Whole-spine standing radiographs of 244 patients were analyzed. The incidences of L1, T1, C2, and C1 (L1I, T1I, C2I, and C1I) were defined as the angle between a line from the center of the femoral heads through the midpoint of the sacral superior endplate and a line perpendicular to each L1, T1 superior endplate, C2 inferior endplate, and C1 ring, respectively. Pearson correlation, linear regression, one-way analysis of variance (ANOVA) and receiver-operator characteristic curves were used to analyze which specific spinopelvic morphologies affect the quartiles of L1I and C1I, and cutoff values were analyzed.

Results

IAIPs significantly correlated with not only cervical and thoracolumbar parameters but also non-adjacent IAIPs, including PI (p<0.01). Each IAIP was equal to both the geometrical sum from PI to each given spinal level. In the ANOVA, moving from the low IAIP group to the high IAIP group, we found progressive increases in PI, PT, C7SVA, L1I, T1I, C2I, and C1I, and decreases in LL, TK, C07L, and SS/PI (p < 0.001). The low IAIP group showed high area under curve (AUC) by SS/PI, and an AUC of 0.898, with a sensitivity of 86.2% and a specificity of 80.9%. The high IAIP group showed a high AUC of 0.942 by PT, with a sensitivity of 93.0% and specificity of 81.5%.

Conclusion

IAIPs are novel PI-relevant radiographic parameters that reflect global spinal alignment and are equal to the geometrical sum from the pelvis to given spinal levels. An anteverted pelvis requires more lordotic curve by low IAIPs, and a retroverted pelvis requires less lordotic curve by high IAIPs.

Take Home Message

There are different patterns of sagittal alignment according to spinopelvic morphologies. The IAIPs are useful radiographic parameters representing both spinopelvic morphologies and sagittal spinal alignment.

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Method used to measure incidence angle of inflection points; L1I, L1 incidence; T1I, T1 incidence; C2I, C2 incidence; C1I, C1 incidence

165. Sagittal Cervical Alignment After Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: Five-year Follow-up

Joshua M. Pahys, MD; Steven W. Hwang, MD; Suken A. Shah, MD; Patrick J. Cahill, MD; Peter O. Newton, MD; Harms Study Group; Amer F. Samdani, MD

Summary

Cervical kyphosis (CK) has been linked to reduced quality of life measures in adults, but the impact on AIS patients is unknown. Nearly all patients with CK two years after PSF remained kyphotic at five years postop (97%). All radiographic parameters were maintained from two to five years postoperative, except for T1 slope, which decreased significantly in CK patients compared to cervical lordosis patients. This finding may be akin to pelvic retroversion frequently demonstrated in patients with lumbar sagittal imbalance.

Hypothesis

The presence of cervical kyphosis (CK) persists from early to mid-term postop followup after posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS).

Design

Retrospective review of a prospectively collected multicenter database.

Introduction

CK is strongly associated with reduced health related quality of life measures in adults, however its effects in the AIS population is unknown. Our prior study demonstrated that inadequate restoration of thoracic kyphosis TK (T2-T12<40°), and a lower T1 slope resulted in a significantly higher incidence of CK two years after PSF. This study evaluates the evolution of this malalignment at 5 years postop.

Methods

We identified 48 AIS patients with 5 year follow up after PSF. CK was defined as a positive: C2-C7 Cobb>0°, while cervical lordosis (CL) was negative: C2-C7 Cobb<0°.

Results

The majority of patients with cervical kyphosis (CK) preop remained kyphotic at two years postop (80%). CK present at 2 years persisted in almost all patients (97%) at 5 years postop. 78% of patients with CL at 2 years remained lordotic at 5 years postop. The CK group demonstrated a significantly greater decrease in T1 tilt from 2 to 5 years postop compared to CL patients (p=0.001). There were no other significant radiographic changes in CK and CL patients from two to five years postop. Complications/reoperations and SRS outcome scores were similar for both groups.

Conclusion

Cervical kyphosis (CK) present 2 years after posterior spinal fusion (PSF) for AIS persisted 5 years after surgery in 97% of patients. All radiographic parameters for CK and CL groups remained unchanged from two to five years postop with the exception of T1 slope, which decreased significantly in CK patients compared to patients with cervical lordosis. The progressive loss of T1 slope may represent a possible compensatory mechanism of the cervicothoracic junction, similar to pelvic retroversion seen with sagittal imbalance of the lumbar spine. Persistent cervical kyphosis did not significantly impact complication or reoperation rates compared to patients with cervical lordosis in these mid-term results.

Take Home Message

Cervical kyphosis initially present after posterior spinal fusion for adolescent idiopathic scoliosis persisted in nearly all patients (97%) at five-year follow-up.

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	2yr PO Cervical Kyphosis (C2-C7 Cobb>0°)	2yr PO Cervical Lordosis (C2-C7 Cobb<0°)	p value
Preop C2-C7 Sagittal Cobb	4.9°	(-)5.2°	0.005
2yr PO C2-C7 Sagittal Cobb	12.2°	(-)8.3°	<0.001
5yr PO C2-C7 Sagittal Cobb	12.1°	(-)3.8°	<0.001
Preop T2-T12 Sagittal Cobb	30.6°	32.3°	0.6
5yr PO T2-T12 Sagittal Cobb	29.7°	36.7°	0.03
Preop T1 Slope	20.2°	24.6°	0.1
2yr PO T1 Slope	17.3°	25.7°	<0.001
5yr PO T1 Slope	10.9°	17.9°	0.01
2yr PO: 2years postoperative 5yr PO: 5years postoperative			

166. The Effect of Different Strategies and Correction Maneuvers in AIS Surgery

Tom P. Schlösser, MD, PhD; Kariman Abelin Genevois, MD, PhD; Jelle Frederik Homans, MD; Saba Pasha, PhD; Pierre Roussouly, MD; Suken A. Shah, MD; René M. Castelein, MD, PhD

Summary

Adolescent idiopathic scoliosis (AIS) is a complex 3-D spinal deformity, characterized by rotation, coronal deviation and relative lordosis. Comparison of the pre- and postoperative shape of the mainthoracic curve between three different 'scoliosis schools' performing their own preferred technique, showed that derotational strategies lead to more coronal correction and less apical axial rotation, but sacrifices in the sagittal plane by relatively more thoracolumbar lordosis or a higher inflection point and therefore a higher risk for PJK or less lordosis preservation.

Hypothesis

The complete surgical cascade of different 'schools for AIS surgery' (in the United States, France and the Netherlands) have a different effect on the 3-D morphology of the primary, main thoracic curve and could explain the differences in onset of PJK.

Design

Multinational experience-based retrospective cohort study

Introduction

Adolescent idiopathic scoliosis (AIS) is a complex 3-D deformity of the spine, characterized by rotation, coronal deviation and relative lordosis of the thoracic spine. It is generally believed that the 3-D correction of this spinal shape in AIS surgery is determined by the correction manoeuvre, but also that patient position, surgical releases, instrumentation strategy as well as rod contouring may be contributing factors to postoperative spinal alignment.

Methods

Three consecutive series of patients who underwent posterior scoliosis surgery for classical thoracic AIS curves (Lenke 1-4) were collected in 3 different major scoliosis clinics (n=193). Patients were treated according to the local surgical expertise. Pre- and postoperative main thoracic curve morphology were determined by coronal Cobb angle, thoracic sagittal alignment (T1-T12, T4-T12, inflection point, Abelin curve type), and PJK angle at follow-up.

Results

Pre-operative major curve magnitudes were not different between the cohorts. The French strategy (primarily using translation manoeuvres, higher UIV) resulted in 59% Cobb angle correction versus 75% in the USA (derotation manoeuvres, full implant density) versus 70% in the Netherlands (derotation, low density) (P<.001). Despite similar postoperative T4-T12 kyphosis (22.4, 21.7 vs 20.6 degrees), the American strategy led to significantly more thoracolumbar lordosis whereas the Dutch strategy led to a higher inflection point. At 1-2yr follow-up, PJK angle was higher and C7 slope lower in the American and Dutch as compared to the French cohort (P<.001)

Conclusion

It seems that derotational strategies lead to more coronal correction, however, it demands low thoracic lordosis creation and therefore higher risk for PJK. A translation manoeuvre, however, results in a sagittal harmonious spine, but significantly less coronal and axial correction.

Take Home Message

Based on comparison of three different 'scoliosis schools', it seems that if you focus on correction in the one plane in AIS surgery, you may sacrifice in the other.

	French cohort (n=98)	*American cohort (n=44)*	*Dutch Cohort (n=51)*	*P*
Demographics				
Females, n (%)	93 (95)	33 (75)	41 (80)	.002*
Age at surgery	14.5±1.7	14.4±1.7	15.5±2.2	.005*
Follow-up in months	22±13	20±7	15±7	.002*
Preoperative parameters				
MT curve (degrees)	60±14	58±12	61±14	.501
MT apex, mode	T7	T6	T7	.019*
Abelin type 1 (normokyphosis)	36 (37%)	16 (36%)	29 (57%)	.08
Sagittal T1-T12 angle	25±14	24±14	29±6	.16
Sagittal T4-T12 angle	20±15	16±14	23±8	.036*
Sagittal T10-L2 angle	-1±9	-6±11	1±7	.002*
Inflection point	T12-L1	T12-L1	T12-L1	.19
Surgical details				
UIV, mode	T2	T3	T3	<.001*
LIV, mode	L2	L3	L3	.003*
Technique	Primarily translation	Primarily derotation	Primarily derotation	
	Low implant density	High implant density	Low implant density	
Postoperative parameters (first erect radiograph)				
MT Cobb angle	25±9	14±7	18±8	<.001*
Abelin type 1 (normokyphosis)	55 (56%)	23 (52%)	24 (47%)	.318
Sagittal T1-T12 angle	28±8	30±11	27±8	.19
Sagittal T4-T12 angle	22±7	22±6	21±8	.40
Sagittal T10-L2 angle	-4±5	-7±9	-5±8	.047
Inflection point	T12-L1	T12-L1	T11-T12	<.001
Follow-up parameters				
Proximal junctional angle	3±4	6±7	9±7	<.001
C7 slope	16±7	11±7	14±7	<.001

Table 1. Comparison of demographics, surgical details and pre-

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and postoperative sagittal alignment in cohorts of primary thoracic AIS patients in three different coutries.

167. Impact of Lowest Instrumented Vertebra Selection on Trunk Range of Motion after Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Joshua M. Pahys, MD; Ross Chafetz, PhD, DPT; Spencer Warshauer, MS; Amer F. Samdani, MD; John P. Gaughan, PhD; Steven W. Hwang, MD

Summary

Previous studies have reported varying results on the impact that posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) has on trunk motion. 52 consecutive AIS patients underwent trunk kinematic evaluation preoperatively and six months after PSF at a single institution. A progressive and statistically significant loss of trunk motion was demonstrated with each more caudal lowest instrumented vertebra (LIV). Patients lost an average 8^0 of lumbar motion with each additional lumbar level fused.

Hypothesis

Each more caudal lowest instrumented vertebra (LIV) in posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) will result in a progressive and significant loss of trunk motion.

Design

Retrospective analysis of a prospectively collected, single institution trunk kinematic database.

Introduction

Studies have reported conflicting results on the impact on trunk range of motion (ROM) following PSF for AIS. This study seeks to identify a relationship between the LIV and trunk ROM in AIS patients after PSF.

Methods

We identified 52 consecutive AIS patients who underwent PSF and had a preop and 6 month postop kinematic evaluation. Patients were classified into 5 groups based on their LIV (T11/T12, L1, L2, L3, and L4). Trunk kinematics utilizing a previously published three-segment spine model were completed for flexion, extension, bilateral side bending, and bilateral rotation.

Results

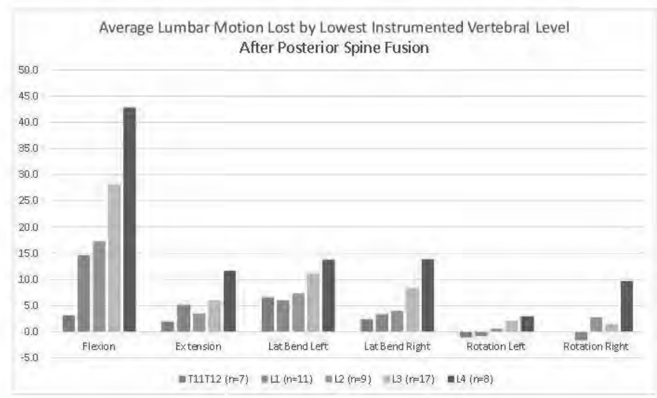
There were 41 females and 11 males, mean age of 14.5+/-2 years. The mean preop thoracic and lumbar Cobb was 63.2^0+/-17.8^0 and 43.4^0+/-16^0, respectively. The distribution of LIV was: T11/12: 7; L1: 11; L2: 9; L3: 7; L4: 8. Mean 6 month postop thoracic and lumbar Cobb was 18.2^0+/-9.2^0 and 12.6^0+/-8.3^0, respectively. A significant loss was noted for all motions by the lowest level of fusion ($p<0.005$) except for extension and left rotation. The greatest loss was in forward flexion with a mean motion loss per LIV of L1: 15%, L2: 25%, L3: 39%, and L4: 65%. Linear regression demonstrated 8^0 of lumbar flexion loss per additional fused level.

Conclusion

Trunk motion was significantly reduced in all planes 6 months after posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS), with the greatest loss occurring in forward flexion. As the lowest instrumented vertebra (LIV) extended caudally from T11/T12 to L4, the patients lost a mean 4.4% to 59.5% of lumbar flexion, respectively. Lumbar motion loss averaged 8^0 for every additional lumbar level fused. Thus, this spine model is sensitive to evaluate motion loss as it relates to LIV and can help educate patients on the anticipated changes that occur after spinal fusion.

Take Home Message

Following posterior spinal fusion adolescent idiopathic scoliosis patients lose approximately 8^0 of lumbar trunk motion for each additional lumbar level fused with the greatest loss occurring in forward flexion.



168. Pathologic Sagittal Alignment is Already Present in Early Stages of Adolescent Idiopathic Scoliosis (AIS)

Tom P. Schlösser, MD, PhD; René M. Castelein, MD, PhD; Pierre Grobost, MD; Suken A. Shah, MD; Kariman Abelin Genevois, MD, PhD

Summary

Lordotic deformation, rotation and lateral deviation are integral parts of the complex three-dimensional deformity in AIS. Classification of 192 mild, 253 severe AIS and 156 controls according to the recently introduced Abelin-Genevois classification showed that even in mild AIS, the sum of rotated apical and junctional zones present as a pathological pattern in the midsagittal plane in 55% of the curves versus 6% in normal controls. In severe thoracic AIS, 63% had a pathological sagittal pattern.

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Hypothesis

Sagittal malalignment of the thoracic spine in AIS occurs much earlier on than at the point of severe spinal deformation.

Design

Epidemiological, cross-sectional study

Introduction

The complex three-dimensional spinal deformity in AIS consists of rotated, lordotic apical areas and neutral junctional zones and could lead to modifications of the presentation of the thoracic sagittal profile. The Abelin-Genevois classification system differentiates 4 specific patterns of sagittal alignment in AIS.

Methods

Sagittal spinal morphology of the thoracic spine in mild (n=192, major curve 10-20 degrees) and severe (n= 253, >45 degrees) AIS patients was studied in an international consortium. Sagittal patterns were compared to 156 non-scoliotic adolescents, stratified to before, at or after the adolescent growth spurt. Outcomes were epidemiology of Abelin-Genevois sagittal curve types and kyphosis characteristics (T4-T12 thoracic kyphosis, T10-L2 angle, C7 slope, location of the apex of kyphosis and of the inflection point).

Results

In severe thoracic AIS, 63% had a pathological sagittal profile. Hypokyphosis (type 2a) was the most prevalent curve type, hypokyphosis+thoracolumbar kyphosis (type 2b) occurred more frequently in high-PI and primary lumbar curves, whereas cervicothoracic kyphosis (type 3) occurred more in double thoracic curves. Even in mild thoracic AIS, 49% of the curves already exhibited thoracic hypokyphosis (type 2a), whereas 13% of mild (thoraco)lumbar curves had a pathological sagittal pattern. Only 6% of the normal adolescents had a pathological pattern (p<0.001).

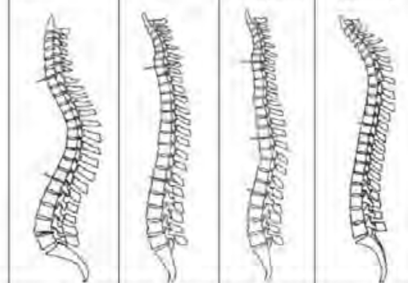
Conclusion

This study revealed that specific pathological sagittal patterns are often already present in AIS at the earliest stage of the disease, whereas those are rare in non-scoliotic adolescents, before, during and after the growth spurt. This could provide useful information for risk of progression.

Take Home Message

Sagittal 'malalignment' is an integral part of the development of AIS and also at an early stage, and also early treatment should address the sagittal pathological patterns of the disease.

	n	Type 1 (normokyphosis)	Type 2a (hypokyphosis)	Type 2b (hypokyphosis + TL kyphosis)	Type 3 (cervicothoracic kyphosis)	P
Mild AIS, n (%)	**192**	**113 (59)**	**67 (35)**	**10 (5)**	**2 (1)**	
Thoracic	128	58 (45)	63 (49)	5 (1)	3 (2)	<.001
(Thoraco)lumbar	64	55 (86)	4 (6)	5 (8)	0 (0)	
Severe AIS	**253**	*112 (44)*	*95 (38)*	*20 (8)*	*26 (10)*	
Lenke 1	111	43 (39)	56 (50)	2 (2)	10 (9)	
Lenke 2	41	14 (34)	13 (32)	2 (5)	12 (29)	<.001
Lenke 3/4	42	24 (57)	12 (29)	5 (12)	1 (2)	
Lenke 5/6	59	31 (53)	14 (24)	11 (19)	3 (5)	
Non-scoliotic adolescents	**156**	**147 (94)**	**6 (4)**	**2 (1)**	**1 (1)**	
Before PHV	74	67 (91)	5 (7)	1 (1)	1 (1)	0.47
At PHV	37	36 (97)	1 (3)	0 (0)	0 (0)	
After PHV	45	44 (98)	0 (0)	1 (2)	0 (0)	



Distribution of pathological (type 2a, 2b and 3) sagittal alignment and normokyphosis (type 1) in AIS patients and non-scoliotic adolescents.

169. Penetration into the Intervertebral Disc of Antibiotics Used for Perioperative Prophylaxis in Spine Surgery: Implications for the Current Standard and for the Treatment of Disc Infections

Manu Capoor, MD; Andrew McDowell, PhD; Martin Solansky; Martina Zapletalova, PhD; Todd Alamin, MD; Michael F. Coscia, MD; Steven R. Garfin, MD; Radim Jancalek, MD, PhD; Filip Ruzicka, PhD; Jeffrey C. Wang, MD; Christof Birkenmaier, MD; Ondrej Slaby, PhD

Summary

The electric charge of antibiotic molecules is a key factor influencing their penetration into the intervertebral disc. We found significant and also clinically relevant differences in intradiscal concentrations between the commonly used compounds Vancomycin, Clindamycin and Cefazolin in nucleus material retrieved during standard microdiscectomies. Especially on the background that the skin of the human back harbours a particular microbiome, the recommendations for perioperative prophylaxis as well as for the treatment of infections may need to be reexamined.

Hypothesis

Intervertebral discs are avascular, have low pH and disc infections differ from infections of other tissues. The intradiscal penetration of typically used antibiotics and hence their effectiveness may also differ. This could have clinically relevant implications.

*Hibbs Award Nominee for Best Basic Research Paper †Hibbs Award Nominee for Clinical Research Paper

Design
clinical investigational, non-interventional study

Introduction
A high prevalence of Propionibacterium acnes (P. acnes) colonization in intervertebral disc material obtained from patients undergoing discectomy or microdiscectomy has led to the suggestion that this prominent human skin and oral commensal may exacerbate the pathology of degenerative disc disease. This hypothesis, in turn, raises the possibility that antibiotics could play an role in treating this debilitating condition. In addition, the existence of low-grade disc infections with P. acnes, which is not consistently sensitive to cephalosporins, challenges the current recommendations as to which antibiotic should be used for perioperative prophylaxis in spinals surgery. To date, however, little information about antibiotic penetration into the intervertebral disc is available.

Methods
Nucleus pulposus material from 54 microdiscectomy patients that had received prophylactic cefazolin (n=25), clindamycin (n=17) or vancomycin (n=12) was analyzed by means of high-performance liquid chromatography (HPLC), with cefaclor serving as an internal standard, to determine the concentration of antibiotic penetrating into the disc tissue.

Results
Intervertebral disc tissues from patients receiving the positively charged antibiotic clindamycin contained a significantly greater percentage of the antibacterial dose than the nucleus material from patients receiving the negatively charged cefazolin ($p<0.0001$) and vancomycin, which has a slight positive charge ($p<0.0001$).

Conclusion
Positively charged antibiotics appear more appropriate for future studies investigating potential options for the treatment of low-virulent disc infections with P. acnes. The current standards for perioperative antibiotic prophylaxis in spinal surgery probably should be reexamined.

Take Home Message
The expanding knowledge about low-grade disc infections (beyond the better-known pyogenic infections) underlines the already existing need to reexamine currently established standards of perioperative antibiotic prophylaxis in spine surgery.

Antibiotic (charge) (mw)	Patients (*N*)	Antibiotic dose (g)	Disc concentration (ug/ml of antibiotic/ml disc tissue)[a]		Penetration rate (% of antibiotic dose/ml of disc tissue)[a]	
Cefazolin (1−) [454.50]	25	2	59.91	±25.79	3.0	±1.0
Clindamycin (1+) [424.98]	17	0.6	68.20	±46.79	9.1	±4.9
Vancomycin (0/1+) [477.60]	12	1	10.65	±4.88	1.5	±0.6

[a](mean ± SD)

Antibiotic	Disc concentration	CMAX	Antibiotic accumulates	MIC[a]	MBC[a]	MBEC[a]
Cefazolin	59.9	404.0 [40]	No	NA[b]	NA[b]	NA[b]
Clindamycin	68.2	10.9 [41]	Yes	0.125	512	128
Vancomycin	10.6	63.0 [42]	No	1.0	8	512

CMAX maximum serum concentration, *MIC* minimum inhibitory concentration, *MBC* minimal bactericidal concentration, *MBEC* minimal biofilm eradication concentration. Note: all values are in μg/ml

[a]*P. acnes* MIC, MBC, MBEC reference values from [39]

[b]*P. acnes* MIC, MBC, MBEC for cefazolin were not found in any literature searches on PubMed

Penetration of intervertebral disc tissue by antibiotics, disc antibiotic concentrations and MIC, MBC and MBEC values for P. acnes

170. LncRNA SULT1C2A Regulates Foxo4 in Vitamin A Deficiency Induced Congenital Scoliosis by Targeting rno-miR-466c-5p through PI3K-ATK Pathway

<u>Chong Chen, MD</u>; Haining Tan, MD; Jiaqi Bi, PhD; Tianhua Rong, MD; Youxi Lin, MD; Jinqian Liang, MD, PhD; Jianxiong Shen, MD

Summary
In summary, we found dynamic changes in the expression of the SULT1C2A-rno-miR-466c-5p-Foxo4 axis in Vitamin A deficiency induced congenital scoliosis (VAD-CS) rats, suggesting that the spatiotemporal changes of the SULT1C2A-rno-miR-466c-5p-Foxo4 axis are important for somitogenesis in CS and regulating the PI3K-ATK signaling pathway.

Hypothesis
Long non-coding RNAs (lncRNAs) might act as a ceRNA implicated in embryo development of VAD-CS.

Design
In this study, we investigated the role and mechanisms of a specific lncRNA, SULT1C2A, in somitogenesis in a rat model of vitamin A deficiency (VAD)-induced CS.

Introduction
Congenital scoliosis (CS) is caused by anomalous vertebrae development, but the pathogenesis of CS remains unclear. We performed sequencing data analysis to build ceRNA networks in embryonic tissues of rats with VAD-CS. Long non-coding RNAs (lncRNAs) have been implicated in embryo development, but

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their role in CS remains unknown. Vitamin A deficiency (VAD) during pregnancy can induce CS in postnatal rats.

Methods
The competitive endogenous RNA (ceRNA) mechanism was validated by bioinformatics analysis and a dual luciferase reporter gene assay. SULT1C2A, rno-miR-466c-5p, and Foxo4 expression in embryos was detected by quantitative RT-PCR (qRT-PCR) and northern blot analysis. Western blot analysis was performed to measure PI3K, AKT and phosphorylated AKT expression.

Results
SULT1C2A expression was down-regulated in VAD-CS rats, accompanied by increased rno-miR-466c-5p and decreased Foxo4 expression. Luciferase reporter assays showed that SULT1C2A functioned as a ceRNA to inhibit rno-miR-466c-5p expression by direct binding. rno-miR-466c-5p inhibited Foxo4 expression by binding to its 3'untranslated region (UTR). The spatiotemporal expression of the SULT1C2A-rno-miR-466c-5p-Foxo4 axis was dynamically altered on gestational days (GD) 3, 8, 11, 15, and 21. Western blot analysis shows the down-regulation of p-AKT in the VAD group at GD 3, 8, and 11 and PI3K in GD 11, which colsed related to the period of somitogenesis.

Conclusion
SULT1C2A enhanced Foxo4 expression by negatively modulating rno-miR-466c-5p expression via the PI3K-ATK signaling pathway. Our findings suggest that SULT1C2A may be a potential target for treating CS.

Take Home Message
SULT1C2A as the first CS-somitogenesis-related lncRNA involving in the mechanism as a ceRNA regulator through PI3K-AKT signaling pathway

Diagram showing the spatiotemporal expression of the SULT1C2A-rno-miR-466c-5p-Foxo4 axis. rno-miR-466c-5p acts on Foxo4 to reduce PI3K and p-AKT during somitogenesis, and these effects are subsequently reversed by SULT1C2A as a ceRNA.

171. Effects of Cyclic Loading on Polyester Tethers for Prophylactic Treatment of Proximal Junctional Kyphosis

Damon Mar, PhD; Steven J. Clary, BS; Brant Stephen Ansley, MS, PA; Joshua Bunch, MD; Douglas C. Burton, MD; Terence E. McIff, PhD, MBA

Summary
This study tested woven polyester tethers to determine the effects of cyclic loading on tether stretch and failure properties using loads ranging from physiologically-derived loads to tether failure limits. Significant increases in tether stretch and stiffness were observed with increasing cyclic loads. Tether stretch may lead to loss of both adjacent level stabilization and motion restriction. Tether stretch should be expected throughout activities of daily living and should be a consideration in preoperative planning for tethering techniques.

Hypothesis
With cyclic loading, polyester tethers will exhibit increased stretch and stiffness and reduced ultimate tensile force.

Design
Biomechanical study.

Introduction
Ligamentous augmentation is becoming a common technique to prevent proximal junctional kyphosis (PJK) in adult spinal fusions. There is a lack of data regarding the effects of cyclic loading on polyester tether mechanical properties. The goal of this study was to quantify changes in tether stretch, stiffness, and failure characteristics after cyclic loading.

Methods
The study tested 5mm polyester tethers looped through 2.5mm holes in two test materials: 1) 8mm-thick synthetic cortical bone and 2) cadaveric L1 spinous processes. Tether length was 50mm for all tests. Baseline ultimate tensile force and elongation at failure were determined first by loading directly to failure (n=5). Cyclic testing was then done for 1000 cycles at three loads (n=5 each): 1%, 25%, and 50% of average baseline failure force. Tether elongation and stiffness were calculated for cycles 1, 10, 100, and 1000. Tethers were then loaded to failure to determine ultimate tensile force and elongation. Cadaver specimens were cyclically loaded to the 25% load for 1000 cycles and then tested to failure. The 25% load most closely matches tether forces previously reported for typical lifting tasks.

Results
Average baseline failure was 663N at 7.2mm of elongation. Greater loading led to significant elongation and increased stiffness (both $p<0.001$). Failure occurred in 80% of the 50%-loaded tests at cycle 225 on average. The 25%-loaded cadaveric specimens

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exhibited significantly less increase in stiffness ($p<0.05$ for cycles 1 and 10, $p<0.01$ for cycles 100 and 1000). Bone compaction, the difference between synthetic and cadaver loop elongation, was 0.27, 0.29, 0.32, and 0.56mm for cycles 1, 10, 100, and 1000 respectively.

Conclusion

Polyester tethers stretch significantly when loaded to physiological ranges. Anticipation of tether stretch may be an important consideration for a tethering strategy to prevent PJK.

Take Home Message

Polyester tethers stretch significantly when loaded to physiological ranges. Anticipation of tether stretch may be an important consideration for a tethering strategy to prevent PJK.

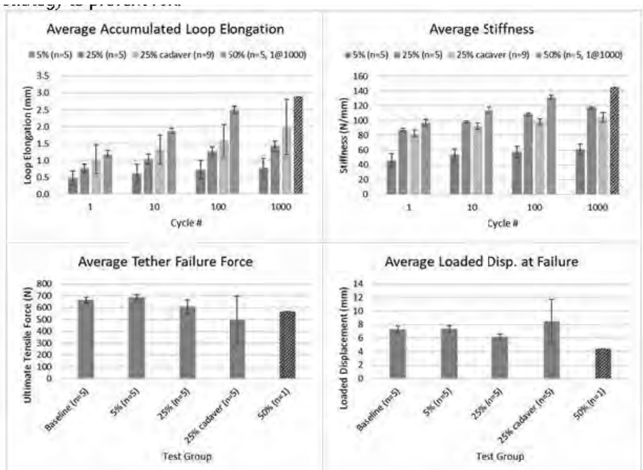

Figure 1: Cyclic results (top) and failure results (bottom) for the synthetic and cadaver tests (25% only).

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Notes

E-Poster Abstracts

The Scoliosis Research Society gratefully acknowledges Stryker for their support of the Annual Meeting Live Webcast

201. How Does Pelvic Incidence Changes in Low-grade Spondylolisthesis in Association with Listhesis Progression

Abdulmajeed Alzakri, MD, MS; Julie Joncas, RN; Hubert Labelle, MD, FRCS(C); Stefan Parent, MD, PhD; Soraya Barchi, BS; Jean-Marc Mac-Thiong, MD, PhD

Summary
We reviewed, in a single pediatric center, a cohort of 301 patients presented to our clinic for low-grade spondylolisthesis (LGS). Pelvic parameters and listhesis percentage were assessed at the first visit and at a minimum 2 years follow-up. The spondylolisthesis progression is not related to the change in the pelvic incidence during the time.

Hypothesis
A change in pelvic incidence is related to progression of spondylolisthesis.

Design
Retrospective analysis of a prospective cohort of 301 patients with low-grade spondylolisthesis.

Introduction
Observational studies suggest that the majority of low-grade patients treated nonoperatively will have a successful clinical outcome. However, the changes in pelvic incidence as related to risk of progression remains unknown.

Methods
The complete records of 301 prospective patients (129 males 172 females) with low-grade spondylolisthesis aged 12.3 years ± 3.1 years were reviewed. Radiological parameters (pelvic incidence, lumbosacral angle and percentage of slip) were measured at the first visit and at a minimum 2-year follow-up. Patients with an increase in pelvic incidence by more than 5 degrees at last follow-up were included in group 1, and otherwise included in group 2.

Results
The average follow-up time is 4.6±2.3 years. The slip percentage was 14.6±8.8 at initial visit and 15.8±9 at last follow-up ($P<0.05$). There were 66 patients in group 1 and 233 patients in group 2. There was no difference in slip progression or lumbosacral progression between the two groups. The pelvic incidence was 56.1±12.9 at initial visit and 58.7±13.4 at last follow-up ($P<0.05$). There was a significant increase in pelvic incidence during follow-up. The change in pelvic incidence was not related to lumbosacral angle or slip percentage.

Conclusion
Pelvic incidence increased significantly during follow-up, but the changes in pelvic incidence were not associated with progression of spondylolisthesis in terms of slip percentage and lumbosacral angle. Pelvic incidence is not likely to be a risk factor for progression in low-grade spondylolisthesis.

Take Home Message
Pelvic incidence increases during growth. Pelvic incidence is not likely to be a risk factor for progression in low-grade spondylolisthesis.

202. Allogeneic Blood Transfusion Following AIS Surgery Decreases 50% Using Quality-improvement Strategies

Christopher B. McLeod, DO; Kiley Frazier Poppino, BS; Tyler Mange, BS; Daniel J. Sucato, MD, MS; Brandon A. Ramo, MD

Summary
Perioperative allogenic blood transfusion (ALBT) occurred at a rate of 18.2% in AIS surgery over a three-year period. Five risk factors were identified to assist with the preoperative prediction of a transfusion event. Following this cohort analysis and demonstration of variability in transfusion practice amongst providers, implementation of blood management strategies including preoperative anemia screening, restrictive transfusion triggers and controlled intraoperative hypotension decreased transfusion rates by 50.7% in a 12-month period.

Hypothesis
At risk transfusion patients can be predicted preoperatively and implementation of organizational wide strategies can limit ALBT in posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS).

Design
Retrospective review (n=402), prospective review (n=89)

Introduction
ALBT carries increased risk for morbidity and mortality. This study sought to evaluate the rate and risk factors for ALBT in AIS patients that underwent PSF and implement standardized patient blood management.

Methods
A retrospective review of AIS patients (n=402) who underwent a PSF at a single institution from 2015-2017 was conducted. Following current state analysis and identification of predictors of ALBT risk, quality strategies were developed to guide staff on transfusion practice, and transfusion rate post intervention was tracked (n=89).

Results
ALBT occurred in 73/402 patients (18.2%) prior to implementation of blood management strategies, with the majority occurring intraoperatively (41%) or within 24 hours of surgery completion (25%). Significant variation was noted in surgeon ALBT rate (2.4-35.8%, p=0.002). On multivariate analysis, ALBT patients were

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster
The Goldstein Award is presented to the best clinical research poster at the Annual Meeting. The Moe Award is presented to the best basic research poster at the Annual Meeting. The Program Committee selects the nominees based on abstracts and selects the winners based on final posters.

identified as younger, with decreased BMI, decreased preop hemoglobin, larger Cobb angle, and increased levels fused. Transfusion was more likely with greater estimated blood loss (770 v 448 mL, p<0.001), and longer surgeries (269.5 v 236.6 min, p<0.01). A multi-disciplinary transfusion taskforce was formed to standardize perioperative blood management. Through application of the Delphi method, consensus was reached on preoperative anemia screening guidelines, restrictive transfusion triggers, and goal intraoperative mean arterial pressures. Implementation of standardized patient blood management has led to a positive downward trend in transfusion by 50.7% (18.2% to 8.98%) over a 12-month period (n=89).

Conclusion
ALBT occurred at a rate of 18.2% prior to implementation and was associated with several risk factors. Evaluation of ALBT rate and identification of patient-specific factors resulted in institutional change in practice. Organizational wide strategies incrementally improved ALBT transfusion rate by 50.7%.

Take Home Message
The development of a preoperative ABLT risk screening and standardization of blood management can allow appropriate planning for AIS surgery and lead to a decreased ALBT practice.

203. Dynamic Spine Posture in Adolescents Idiopathic Scoliosis Patients*

Sebastien Pesenti, MD, PhD; Solène Prost, MD; Guillaume Authier; Elke Viehweger, MD, PhD; Benjamin Blondel, MD, PhD; Jean-Luc Jouve, MD

Summary
122 AIS patients were compared to 24 healthy adolescents through gait analysis. Trunk kinematics showed differences in AIS patients, especially the shoulders line being orientated toward the left during gait with a decreased forward leaning of the trunk.

Hypothesis
Spinal deformity alters dynamic posture in adolescent idiopathic scoliosis (AIS) patients

Design
Prospective study

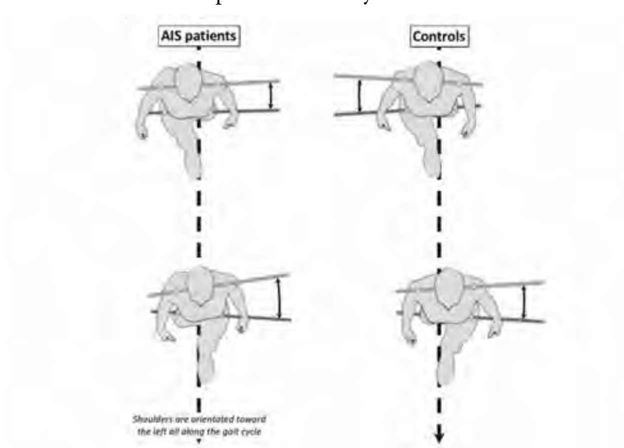
Introduction
AIS is known to alter postural control. However, changes in dynamic posture of these patients, especially its impact during daily life activities remains unclear. Using gait analysis, it is possible to determine changes in spine kinematics induced by spinal deformity.

Methods
122 consecutive AIS patients planned for surgical correction were prospectively enrolled in this study. The day before surgery, AP and lateral x-rays and gait analysis were performed. Dynamic parameters evaluated were: shoulders line orientation, pelvis orientation, acromion-pelvis angle (APA), coronal and sagittal vertical axis (CVA, SVA). Dynamic parameters were compared to 24 healthy adolescents.

Results
Average Cobb angle was 52°, 88 patients were classified as Lenke 1, 12 Lenke 3 and 22 Lenke 5. Compared to control group, AIS patients had shoulders orientated toward the left (0° vs -7°, p<0.01) while the pelvis was orientated toward the right (0° vs 1°, p=0.01). The APA was significantly lower (toward the left) in AIS patients (-2 vs -6°, p<0.01). Except for CVA (8 vs -9mm, p=0.04), there was no difference in trunk rotation according to major curve location. The SVA was significantly lower in AIS patients (60 vs 44mm, p=0.02). Dynamic changes were significantly correlated to Cobb angle (R=0.461, p<0.01).

Conclusion
This is the largest series of gait analysis in AIS patients. The upper trunk rotation during walking was opposed to vertebral rotation. These results can be in line with described somatosensory disorders which could be responsible for the spinal deformity. Clarifying the relation between gait abnormalities and spinal deformity could be of major importance, especially for prognostic purpose.

Take Home Message
AIS patients have abnormal dynamic spinal posture that does not seem to be related to spinal deformity.



Schematic representation of transversal gait pattern in AIS patients (left) compared to normal gait (right)

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

204. Does Pregnancy Lead to Loss of Correction after Posterior Spinal Fusion?

Summary

Pawel Grabala, MD; Suken A. Shah, MD; Ilkka J. Helenius, MD, PhD; A. Noelle Larson, MD; Michal Latalski, MD, PhD; Jacob M. Buchowski, MD, MS

Summary

In this controlled cohort series of patients with AIS who underwent surgery and became pregnant, on average, 5 years after surgery, we saw no detrimental radiographic, clinical, or patient-related outcomes after pregnancy and delivery. This provides information useful for counseling patients and their families about these concerns.

Hypothesis

Pregnancy does not result in loss of correction for women who underwent posterior spinal fusion for idiopathic scoliosis.

Design

A retrospective study with cohort group comparison. Patients underwent scoliosis surgery in 1999 – 2014.

Introduction

Patients and their families frequently ask about long-term outcomes after scoliosis surgery, impact on pregnancy, and future curve progression after pregnancy. There is insufficient evidence on this topic.

Methods

Women were recruited from four centers for this study with the following inclusion criteria: age 16-40 years who underwent surgery for scoliosis in adolescence and subsequent pregnancy (SPG). The study population was compared to women who underwent scoliosis surgery but had not yet become pregnant (SNP). Queries regarding curve before surgery, after surgery, before pregnancy, and up to 1 year after delivery, at FFU – minimum 2 years after surgery. Additional patient-related outcomes measures were performed with SRS-22r.

Results

128 patients were enrolled: SPG – 62 and SNP – 66. Average age at the time of scoliosis surgery was 16 years. Mean time of delivery after scoliosis surgery was 5 years (range 2 – 12 SD 2.80). The mean preoperative Cobb angle of main curvature was 65° (SD 12), after surgery 18° (SD 9), at the final follow-up (FFU) 20° (SD 8) for SNP, and 67° (SD 11), 17° (SD 9), and 20° (SD 8), respectively for SPG. The mean preoperative thoracic kyphosis (T5-T12) was 26.5° (SD 11.9) for SPG and 24.7° (SD 14.5) for SNP, after surgery 19.2° (SD 9.5) for SPG, 18.8 (SD 8.9) for SNP and at FFU respectively 20.3° (SD 9) for SPG, and 21.3° (SD 8.5) for SNP. Screw density was 1.6 (SD 0.2). No significant loss of correction at FFU after pregnancy was noted in either group. The SRS-22r total outcomes scores were 3.88 for SPG and 4.02 for SNP (P>0.05).

Conclusion

Women who have undergone surgery for scoliosis and have had one or more pregnancies do not appear to have curve progression or deterioration in longer term outcomes compared to control patients who have not become pregnant.

Take Home Message

Providers can counsel patients who have had surgery for AIS that they are not expected to have detrimental radiographic or clinical effects after pregnancy due to their scoliosis surgery.

205. The Impact of Global Spinal Alignment on Standing Spinopelvic Alignment after Total Hip Arthroplasty

Deeptee Jain, MD; Edem J. Abotsi, BA; Dennis Vasquez-Montes, MS; Themistocles S. Protopsaltis, MD; Elizabeth L. Lord, MD; Peter G. Passias, MD; Aaron J. Buckland, MBBS, FRACS

Summary

We compared spinopelvic parameters pre- vs post-operatively in 93 patients who underwent total hip replacement (THA), and then further examined the impact of global spine deformity, as measured by T1 pelvic angle (TPA), on this change. We found that overall patients had increased pelvic tilt (PT) and decreased lumbar lordosis (LL) with THA. Preoperative sagittal deformity impacted this change, as patients with TPA >20 demonstrated decreased PT and decreased spinal sagittal deformity as demonstrated by T1PA.

Hypothesis

THA would change standing spinopelvic alignment and spinal deformity would impact this change.

Design

Retrospective cohort study.

Introduction

There is increasing work examining the interactions between hip arthritis and spinal malalignment. It is unclear how total hip arthroplasty (THA) affects standing spinopelvic alignment.

Methods

Patients who underwent THA for osteoarthritis with both preoperative and postoperative standing full body radiographs. Standing spinopelvic parameters were measured both pre- and postoperatively. Pre- and postoperative alignment were compared by paired t-test. The severity of preoperative thoracolumbar deformity was measured using TPA, and sub-analysis comparing preoperative TPA severity and changes in standing spinal alignment was analyzed using linear regression. Patients were then separated into low

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

and high TPA (<20 or >/=20deg) and the same parameters were compared between groups by t-test.

Results

There were 93 patients included (mean age 58.6 yrs, 54%F, mean BMI 28.3 kg/m2). Overall, the following significant changes were found from preoperative to postoperative: PT (17.1 vs 19.2, p=0.05), LL (-48.7 vs -46.1, p=0.045), CL (-7.5 vs. -5.1, p =.049). Preoperative TPA was significantly associated with the change in PT (beta = -0.29, p = 0.002), PI-LL (beta = -0.45, p = 0.003), TS-CL (beta = -0.29, p=0.004), and TPA (beta = -0.27, p =0.001). In comparing high TPA patients (n=28) to low TPA patients (n=55), high TPA patients decreased PT, PI-LL, TS-CL, and TPA, whereas low TPA patients increased these measures (-1.6 vs 3.8, p = 0.022; -4.7 vs 4.7, p = .012, -4.1 vs 2.4, p=0.009, -2.2 vs 2.4, p=0.025, respectively).

Conclusion

Spinopelvic parameters change after THA, with increased pelvic retroversion and decreased lumbar lordosis. Preoperative spinal sagittal deformity impacts this change.

Take Home Message

Spinopelvic parameters change after THA, with increased pelvic retroversion and decreased lumbar lordosis. Preoperative spinal sagittal deformity impacts this change.

	Mean values of parameters				Correlation of change in parameter with preoperative TPA		Change in parameters based on TPA group		
	Baseline	Follow-up	Change	p value	Coeff.	p value	Low TPA	High TPA	p value
PT	17.1	19.2	2.2	**0.05**	-0.29	**0.002**	3.8	-1.6	**0.022**
PI	53.5	53.3	-0.2	0.81	-0.28	**0.008**	0.9	-2.8	0.051
LL	-48.7	-46.1	2.6	**0.04**	-0.04	0.665	2.5	2.7	0.93
PI-LL	4.1	6.0	1.9	0.27	-0.45	**0.003**	4.7	-4.7	**0.012**
T10-L2	2.3	3.0	0.8	0.35	-0.09	0.210	17.7	13.0	0.38
TK	35.5	33.6	-1.9	0.14	-0.02	0.840	-1.2	-3.6	0.38
C2-C7	-7.5	-5.1	2.4	**0.05**	-0.19	0.980	3.9	-0.9	0.07
TS-CL	19.6	20.0	0.5	0.69	-0.29	**0.004**	2.4	-4.1	**0.009**
SVA	40.7	33.2	-7.4	0.07	-0.29	0.404	-6.5	-9.5	0.73
TPA	16.0	17.1	1.0	0.27	-0.27	**0.001**	2.4	-2.2	**0.025**

206. Preoperative Halo Skeletal Traction for Severe Scoliosis†

Chang Ju Hwang, MD, PhD; Dong-Gyun Kim, MD; Dong-Ho Lee, MD, PhD; Choon Sung Lee, MD, PhD; Jae Woo Park, MD; Jae Hwan Cho, MD, PhD

Summary

Although severe scoliosis has been safely and effectively corrected by preoperative halo skeletal traction (HST), knowledge about the traction duration and factors related to the correction rate is limited. We operated 59 patients by applying preoperative HST followed by surgery for the management of severe scoliosis to obtain good outcomes. Traction for ≥ 3 weeks did not significantly affect curvature correction. Halo-femoral traction with heavy traction weight was effective in patients with a small height and low weight.

Hypothesis

Haloskeletal traction is effective technique for severe scoliosis

Design

Retrospective case control study

Introduction

Surgical treatment of severe scoliosis is challenging and carries risks that can be reduced using preoperative halo skeletal traction (HST). The safety and efficacy of deformity correction by HST prior to definite fusion surgery is well-known. However, knowledge about the traction duration and factors associated with the HST correction rate is limited.

Methods

We retrospectively reviewed the clinical and radiographic data of 59 patients who underwent preoperative HST due to severe spinal deformity. We analyzed changes in the correction rate over time using HST and assessed related factors by dividing patients into two groups based on differences between post-halotraction and post-bending angles: Group A (post-halo < post-bending) and Group B (post-halo > post-bending). The grouping was based on the difference between the two correction rate was more than 8° that is the maximum measurement error when measuring the Cobb angle.

Results

The mean Cobb angle improved from 96.9° ± 14.7° preoperatively to 72.9° ± 15.8° post-bending to 63.3° ± 12.2° post-traction and 32.49° ± 11.5° postoperatively. The coronal correction of the major curve (change in curve from start to each week/total change in curve after traction) was 28.2% at 1 week (n = 59), 34.0% at 2 weeks (n = 58), 33.8% at 3 weeks (n = 41), and 32.2% at 4 weeks (n = 13); a significant difference was noted between the 1st and 2nd weeks (P < 0.001, < 0.001, 0.244, and 0.082, respectively). Compared with Group A, Group B had a lower height (154.9 vs. 144.4 cm, P = 0.029), lower body weight (49.1 vs. 39.4 kg, P = 0.017), high traction/body weight ratio (0.41 vs. 0.47, P = 0.025), and more halo-femoral traction (0 vs. 6, P = 0.018).

Conclusion

In severe scoliosis, safe and effective correction was successfully obtained through preoperative HST. Traction for ≥3 weeks was not necessary for optimal traction. In patients with low height and weight, halo-femoral traction with a heavy traction weight was effective. These factors must be considered while applying HST for rigid severe scoliosis.

Take Home Message

Traction for ≥3 weeks did not affect curvature correction. Height, weight, traction/weight ratio, and traction method are associated with high rates of scoliosis correction

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207. Trust Your Instincts (But Don't Bet the Bank) When Referring Pediatric Patients for Spinal MRI

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Summary
We enrolled 344 patients referred for spinal MRI for the purposes of identifying clinical or radiographic characteristics predictive of MRI abnormality. While radiologists reported abnormalities in 225 (65%), the abnormality was clinically consequential in only 93 (27%). Fifty-two (15%) had their working diagnosis changed by the identification of spinal cord abnormality. The only predictor of spinal cord abnormality was curve magnitude at presentation in patients with presumed IS. Back pain was specifically not a predictor of consequential MRI abnormality.

Hypothesis
Consequential abnormality on spinal MRI can be predicted by patient diagnosis and complaint.

Design
Single institution, retrospective review of prospectively collected data.

Introduction
The indications for, and likelihood of identifying significant pathology on, spinal MRI in patients with presumptive idiopathic scoliosis and/or complaints of back pain is unclear. We sought to identify correlations between working diagnosis, physician indications, and MRI findings in a cohort of pediatric patients.

Methods
Surgeons prospectively recorded primary indications for 344 consecutive spinal MRIs between 2009-2011. MRI results were categorized as abnormal (intradural, extradural, vertebral, and/or incidental findings) or normal. Indications, diagnosis, and demographics were correlated to MRI findings.

Results
The most common diagnoses were AIS (192) and JIS (58). The primary indications were atypical curve characteristics (111), pain (68) and age at presentation (51). Radiologist report was normal in 119 (35%) and abnormal in 225 (65%). However, the reported MRI abnormality was clinically consequential in only 93 patients (27%). Fifty-two patients (15%) had their diagnosis changed due to MRI findings, including identification of spinal cord pathology in 46 of 260 patients (18%) with presumed idiopathic scoliosis. The only indication associated with the identification of cord abnormality was "curve magnitude at presentation" in patients with presumed idiopathic scoliosis. The average Cobb angle was 72° (range, 48-107°) in the 16 patients where "curve magnitude" was recorded as the primary indication, compared to 37° (range, 8-88°) in the 244 patients where it was not.

Conclusion
While radiologists reported a relatively high frequency of abnormalities on spinal MRI, the findings were deemed clinically inconsequential in nearly 60% of cases. The only positive predictor of spinal cord abnormality on MRI was curve magnitude at presentation in presumed idiopathic scoliosis patients. One-hundred and two of 143 patients (71%) who complained of back pain without an associated neurological finding had a normal or clinically inconsequential MRI.

Take Home Message
The only predictor of spinal cord abnormality in this cohort was curve magnitude at presentation. Fifteen percent had their diagnosis changed or a spinal cord abnormality detected by spinal MRI.

Overall Cohort Review (344 patients with spinal MRI)					
Variables	Levels	Overall	Response in MRI? Yes	Response in MRI? No	pValue
Abnormal vs Normal	Abnormal	225(65.4%)	93(41.3%)	132(58.7%)	—
	Normal	119(34.6%)	—	—	
Indication (all diagnoses)	Abnormal Abdominal Reflex	9(2.62%)	3(3.38%)	4(1.50%)	0.1507
	Abnormal Deep Tendon Reflexes	14(4.07%)	4(4.3%)	10(3.98%)	
	Associated Diagnosis	33(9.59%)	12(12.9%)	21(8.37%)	
	Age at Presentation	51(14.83%)	11(11.83%)	40(15.94%)	
	Congenital Scoliosis	2(0.58%)	1(1.08%)	1(0.4%)	
	Coronal Curve Characteristics	61(17.73%)	17(18.28%)	44(17.53%)	
	Curve Magnitude at Presentation	16(4.65%)	7(7.53%)	9(3.59%)	
	Pain	68(19.77%)	16(17.2%)	52(20.72%)	
	Parent Anxiety	2(0.58%)	0(0%)	2(0.8%)	
	Pre-Op	18(5.23%)	3(3.23%)	15(5.98%)	
	Rapid Curve Progression	10(2.91%)	0(0%)	10(3.98%)	
	Sacral Dimple	1(0.29%)	1(1.08%)	0(0%)	
	Sagittal Curve Characteristics	50(14.53%)	13(13.98%)	37(14.74%)	
	Other Indication	9(2.62%)	3(3.23%)	6(2.39%)	
Gender	Female	247(71.8%)	65(26.32%)	182(73.68%)	0.6318
	Male	97(28.2%)	28(28.87%)	69(71.13%)	
Back Pain as Primary Indication	No	276(80.23%)	77(27.9%)	199(72.1%)	0.4875
	Yes	68(19.77%)	16(23.53%)	52(76.47%)	
Idiopathic Scoliosis vs. Other Diagnoses	1	84(24.42%)	29(34.52%)	55(65.48%)	0.0755
	2	260(75.58%)	64(24.62%)	196(75.38%)	
Any Patient Reported Back Pain	No	155(45.19%)	40(25.81%)	115(74.19%)	0.6998
	Yes	188(54.81%)	52(27.66%)	136(72.34%)	
		Overall	Cord Abnormalities No	Cord Abnormalities Yes	pValue
Curve Magnitude at Presentation as Primary Indication in Idiopathic Scoliosis	No	244(93.85%)	204(83.61%)	40(16.39%)	0.0015
	Yes	16(6.15%)	10(62.5%)	6(37.5%)	

Table 1: Overview of Clinical and MRI Indication Data

208. Depiction of Presenting Comorbidity Profiles in Adolescent Idiopathic Scoliosis Patients with and without Syringomyelia Using Cluster Analytics

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Summary
Adolescent idiopathic scoliosis (AIS) affects nearly 4% of patients between 10 and 20 years of age. It is categorized by an abnormal curvature of the spine that is typically associated with trunk rotation. AIS can be associated with other conditions, including

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syringomyelia (AIS-SM). This study assessed clusters of diagnoses in a population of AIS patients with concordant syringomyelia. Our analyses identified neurological and pulmonary anomalies as significant risk for the unique diagnosis profile of AIS-SM patients.

Hypothesis

AIS patients with concordant syringomyelia have unique comorbidity and diagnosis profiles

Design

Retrospective cohort study

Introduction

The rarity of AIS-SM has resulted in a paucity of adequately powered studies investigating diagnoses unique to the concomitant diagnoses population.

Methods

The database was queried for ICD-9 codes pertaining to adolescent idiopathic scoliosis(737.1-3, 737.39, 737.8, 737.85, 756.1) patients aged 10-20yrs with concordant syringomyelia (AIS-SM) (336.0) from 2003-2012. Descriptive analyses assessed overall cohort demographics, comorbidities and diagnoses. Cross-tabulations assessed frequencies of concomitant diagnoses.

Results

77,183 AIS patients included(15.2yrs, 64%F). 0.9% of the AIS patients had additional spine diagnoses including: herniated disc(0.32%), spondylosis(0.23%), disc degeneration(0.21%) and stenosis(0.16%). 821(1.2%) of the AIS patients had concurrent SM, significantly greater incidence then non-AIS patients with SM(0.032%, p<0.001). Age of SM presentation: 10-13(40.5%), 14-17(42.4%) 18-20(17.1%) years. AIS-SM patients were significantly younger(13.7±2.3 years, p<0.001) with fewer females(58%, p<0.001). By organ system, AIS-SM patients presented with 74.1% pulmonary, 5.4% cardiovascular, 5.0% musculoskeletal, and 2.1% renal comorbidities. Pulmonary was the most frequent comorbidity between AIS (45.3%) and AIS-SM(74.1%),p<0.001. Amongst AIS patients, the following diagnoses had the strongest clusters with syringomyelia from greatest incidence to least: Arnold Chiari Malformation, Asthma, Tethered Cord, Hydrocephaly, Epilepsy, Hemiplegia, Quadriplegia, Pulmonary Failure, Malignancy, Restrictive Lung Disease, Spina Bifida. These top diagnoses were compared to the AIS-only population and are reported in Table 1.

Conclusion

Within the isolated AIS cohort, concordant rates of syringomyelia amounted to 1.2% from 2003-2012. Co-occurrences of other diagnoses included Arnold Chiari malformation, asthma, tethered cord, hydrocephaly, epilepsy, hemi- and quadriplegia, pulmonary failure.

Take Home Message

This study brings to light that physicians must be cognizant of concomitantly occurring diagnoses in this patient population, thereby increasing understanding and treatment of this condition.

Strongest Diagnoses Clusters For AIS-SM Patients

	Clusters with AIS-SM	Clusters with AIS	p-value
Arnold Chiari Malformation	52.2%	0.7%	<0.001
Asthma	11.9%	15.8%	<0.001
Tethered cord	9.2%	1.1%	<0.001
Hydrocephaly	6.2%	2.6%	<0.001
Epilepsy	2.5%	0.5%	<0.001
Hemiplegia	2.2%	0.5%	<0.001
Quadriplegia	1.9%	9.9%	<0.001
Pulmonary Failure	1.9%	5.4%	<0.001
Malignancy	1.7%	1.1%	<0.125
Restrictive Lung Disease	1.7%	4.4%	<0.001
Spina Bifida	1.5%	1.5%	0.992
Cerebral Palsy	1.3%	10.5%	<0.001

Table 1. Strongest diagnoses clusters for Adolescent Idiopathic Scoliosis patients with Syringomyelia (AIS-SM) compared to the clusters of same diagnoses in AIS patients without SM (AIS).

209. A Positive (+ve) Postoperative Upper Instrumented Vertebra (UIV) Tilt Angle (≥ 0°) Significantly Increases the Risk of Medial Shoulder Imbalance in Lenke 1 and 2 Adolescent Idiopathic Scoliosis (AIS) Patients†

Chris Yin Wei Chan, MD, MS; Sin Ying Lee, MBBS; Pei Ying Ch'ng, MBBS; Weng Hong Chung, MD, MS; Chee Kidd Chiu, MBBS, MS; Mun Keong Kwan, MBBS, MS

Summary

We recruited 136 Lenke 1 and 2 AIS patients (minimum 2 years follow up) to identify predictors for shoulder/neck imbalance and estimate the odds of developing shoulder/neck imbalance in patients with +ve postoperative UIV tilt angle. +ve postoperative UIV tilt angle was predictive of medial shoulder/ neck imbalance but not lateral shoulder imbalance. Patients with +ve postoperative UIV tilt angle had 15 times and 3 times increased odds of developing +ve medial shoulder and neck imbalance respectively.

Hypothesis

A positive (+ve) postoperative UIV tilt angle increases the risk of postoperative shoulder and neck imbalance.

Design

Retrospective study of a prospective database.

Introduction

Current UIV selection strategy has poor correlation with postoperative shoulder balance. Postoperative UIV tilt angle was identified

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as an important radiological parameter that correlated with medial shoulder and neck imbalance.

Methods

136 Lenke 1 and 2 AIS patients with minimum 2 years follow up were recruited. For medial shoulder and neck balance, patients were categorized into positive (+ve) imbalance (≥ +4°), balanced or negative (-ve) imbalance (≤ -4°) groups based on T1 tilt/Cervical Axis (CA) measurements. For lateral shoulder balance, patients were classified into +ve imbalance (≥ +3°), balanced and -ve imbalance (≤ -3°) groups based on Clavicle Angle (Cla-A) measurements. Linear regression analysis identified the predictive factors for shoulder and neck imbalance. Logistic regression analysis calculated the odds ratio of shoulder and neck imbalance for patient with +ve postoperative UIV tilt angle.

Results

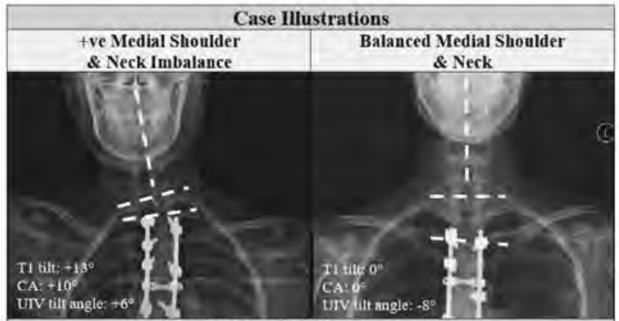
Postoperative UIV tilt angle and preoperative T1 tilt were predictive of +ve medial shoulder imbalance while postoperative UIV tilt angle and postoperative PT correction were predictive of +ve neck imbalance. 51.6% of patients with +ve medial shoulder imbalance had a +ve postoperative UIV tilt angle as compared to 3.4% of patients with balanced medial shoulder. Patients with +ve postoperative UIV tilt angle had 14.9 times increased odds of developing +ve medial shoulder imbalance and 3.3 times increased odds of developing +ve neck imbalance. Postoperative UIV tilt angle did not predict lateral shoulder imbalance.

Conclusion

Patients with +ve postoperative UIV tilt angle had 15 times increased odds of developing +ve medial shoulder imbalance (T1 tilt ≥ +4°) and 3 times increased odds of developing +ve neck imbalance (CA ≥ +4°).

Take Home Message

Patients with +ve postoperative UIV tilt angle had 15 times increased odds of developing +ve medial shoulder imbalance and 3 times increased odds of developing +ve neck imbalance.



Multinomial Logistic Regression Analysis

	+ve Medial Shoulder Imbalance		p value	+ve Neck Imbalance		p value
	n (%)	OR (95% CI)		n (%)	OR (95% CI)	
Postoperative UIV tilt angle			**0.002**			**0.027**
Positive	16 (84.2)	**14.9** (2.73-81.70)		8 (42.1)	**3.3** (1.14-9.75)	
Negative	15 (12.8)	Reference		19 (16.2)	Reference	

Case illustration

210. Ponte Osteotomies (PCOS) Increase the Risk of Intraoperative Neuromonitoring (IOM) Alerts in Adolescent Idiopathic Scoliosis (AIS) Surgery

ElAmir Bachar Harfouch, MD; Mona A. Al Faraidy, MD, MBBS

Summary

While PCOs improve kyphosis in AIS surgeries, PCOs increase the risk of IOM alerts in 12.5% of cases. IONM alerts are associated with lower Kyphosis than those without IOM alerts.

Hypothesis

PCOs improve thoracic kyphosis of the AIS surgeries but may increase the risk of IOM alerts.

Design

This is a Retrospective comparative study in a single academic institution.

Introduction

PCOs are commonly used in AIS surgeries to improve the sagittal kyphosis of the spine. But this is not without risk. We noticed more IOM alerts after we started routine PCOs in AIS surgery.

Methods

This a retrospective review of 80 AIS patients, half of them had PCOs (Schwab type 2 osteotomy). Coronal and sagittal Cobb's were measured for the Main thoracic curve and thoracic kyphosis (T5-T12) before and after surgery. Lenke type 5 cases were excluded. All cases were done by one surgeon in posterior approach only. In all Patients CoCr 5.5 mm rods and titanium screws were used. Rod was over bent on the concave side and under bent on the convex side. IONM data were reviewed. Association between

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signal loss and above parameters was checked. Statistical analysis was performed using SPSS version 25.

Results

40 patients had scoliosis correction without PCOs and 40 patients had scoliosis correction with PCOs. There were no significant difference between the two groups in patients' age; the Preop, and the postop coronal Cobb's angle for the main thoracic curve (p>0.05). Both groups had similar lenke curve subtypes (p=0.88). 90% of patients had a major thoracic curve(Lenke type1,2,3,4) and 10% were lenke Type 6. Preop Kyphosis (T5-T12) was higher in no-PCOs group (36.2deg) vs. (29deg) for PCOs group (p 0.026). Postop Kyphosis (T5-T12) was significantly lower in the no-PCOs group (17.5deg) vs. (25deg) for PCOs group (p 0.00). Rate of IOM alerts was significantly higher in the PCOs group (12.5%) vs. (0%) in the no-PCOs group (p=0.021). signal loss was associated with lower thoracic kyphosis (18deg) vs (33deg) for patients without signal loss (p=0.01). All patients fortunately had normal neurologic exam in postoperative assessment.

Conclusion

While PCOs improve postop Kyphosis, they increase the risk of IOM alerts. Lower kyphosis is associated with IOM alerts.

Take Home Message

PCOS and Low Kyphosis increase IOM alerts

		Preop (D12-D5) Cobb	Postop (D12-D5) Cobb	Age	Preop Cobb of Main Thoracic (MT) curve	MT Cobb angle on bending view	Postop. cobb for MT
No	Mean	33.59	21.23	16.41	68.15	47.53	23.20
	N	75	75	74	75	75	75
	Std. Deviation	14.359	8.996	3.036	17.584	17.307	12.180
	Median	33.00	21.00	16.00	64.00	43.00	22.00
Yes	Mean	18.00	24.00	17.80	63.20	43.80	16.00
	N	5	5	5	5	5	5
	Std. Deviation	6.595	3.000	4.301	12.276	4.764	8.031
	Median	20.00	24.00	17.00	59.00	43.00	20.00
Total	Mean	32.61	21.40	16.44	67.84	47.45	22.75
	N	80	80	79	80	80	80
	Std. Deviation	14.483	8.759	3.100	17.284	16.812	12.054
	Median	32.00	21.00	16.00	63.00	43.00	22.00
	P	0.013	0.497	0.621	0.538	0.613	0.[illegible]

Parameters	Groups	means	STD	P
Preop. (D12-D5) Cobb	without	36.20	14.999	0.026
	with	29.03	13.172	
postop (D12-D5) Cobb	without	17.58	9.449	0.00
	with	25.23	6.011	
Age	without	16.10	2.664	0.34
	with	16.78	3.475	
Preop. cobb angle for Main Thoracic (MT) curve	without	68.15	14.923	0.87
	with	67.53	19.550	
MT Cobb angle on bending view	without	47.60	14.985	0.93
	with	47.30	18.652	
Postop. cobb for MT	without	25.03	11.187	0.92
	with	20.48	12.592	

		Group: without	with	Total
IOM	no	40	35	75
		100.0%	87.5%	93.8%
	yes	0	5	5
		0.0%	12.5%	6.3%
Total		40	40	80
		100.0%	100.0%	100.0%

Chi-square=5.33, p=0.021

statistical analysis of data of the two groups

211. Halo-gravity Traction VS Halo-pelvic Traction: Which is Better for Severe Scoliosis with Malnutrition?

Zhi Zhao, MD, PhD; Jingming Xie, MD; Yingsong Wang, MD; Quan Li, MD; Qiuan Lu, MD; Zhiyue Shi, MD; Tao Li, MD; Ni Bi, MD; Ying Zhang, MD

Summary

Poor nutrition increases the risk and difficulty to perform surgical correction of severe scoliosis. Preoperative (preop) traction is often used to improve the severe deformity, the terrible respiratory function, the poor nutritional status, etc.. However, different tractions can make different effects on the preop nutritional improvement: halo-gravity traction (HGT) is a more powerful way.

Hypothesis

HGT is more effective to improve preop malnutrition in patients of severe scoliosis.

Design

A retrospective comparative analysis.

Introduction

Terrible respiratory function and poor nutritional status are the two main sources of perioperative non-neurological complications in the patients of severe scoliosis. For them, preop HGT and halo-pelvic traction (HPT) are commonly used to improve spinal deformity, increase respiratory reserve, etc., but which is more effective to improve the poor nutritional status?

Methods

According to different ways of preop tractions, 21 patients of severe scoliosis with malnutrition were divided into 2 groups: HGT (n=12) and HPT (n =9). During the traction process, added nutritional supplements were provided by nasointestinal tube or oral administration; meanwhile, non-invasive positive pressure ventilation, respiratory and physical exercises were also done daily. Before and after traction, body mass index (BMI, height being corrected by arm span length), serum albumin and prealbumin levels were reviewed for assessing nutritional changes. The changes of respiratory function (FVC%, FEV1%) and spinal deformity were also evaluated.

Results

Before traction, there were no differences in age, scoliosis, kyphosis, BMI, serum albumin and prealbumin levels, FVC% and FEV1% between the patients treated by HGT and HPT (P>0.05). After traction, the scoliotic improvement by HPT was superior to HGT (44.1% vs 25.3%). However, after HGT, the BMI, albumin and prealbumin levels were increased significantly (P<0.01), which were different from the patients treated by HPT. And there was no observed change of FVC% or FEV1% in the both groups.

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Conclusion
For the patient of severe scoliosis with malnutrition, HPT can decrease scoliosis more effectively, but which is not so conducive to increase the preop nutritional reserve; however, HGT is more effective to improve nutritional status even with less corrective power of scoliosis. A combined use of different tractions should be considered to balance the relationship between improving scoliosis and maximizing nutritional, respiratory, and physical reserves.

Take Home Message
HGT is more effective to improve nutritional status even with less corrective power of scoliosis.

212. LIV Rotation on Bending Film is not a Contraindication in Determining the LIV in Lenke 5C Patients

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Summary
This retrospective study revealed that lowest instrumented vertebra (LIV) derotation on side-bending (SB) films could predict less risk of distal decompensation in Lenke 5C patients. Nevertheless, horizontalization of LIV and minimizing LIV translation during correction would reduce risk of distal decompensation despite the presence of baseline LIV rotation.

Hypothesis
The presumed LIV rotation on baseline convex SB films may be a contraindication in determining the LIV in Lenke 5C patients.

Design
A retrospective study

Introduction
In Lenke 1A patients, derotation of the presumed LIV on baseline bending films is important due to the close relationship between LIV rotation and distal decompensation. However, the relationship between decompensation and derotation of presumed LIV in Lenke 5C patients remains unknown.

Methods
This retrospective study included 67 Lenke 5C adolescent idiopathic scoliosis (AIS) patients with a minimum of 2 years follow-up for posterior fusion. L3 was selected as LIV in all patients. Patients were divided into presumed LIV derotation group (DR group) and non-derotation group (NDR group) according to the derotation of the presumed LIV on convex SB films. Radiographic parameters were measured pre- and post-operatively including Cobb angle, coronal balance, lower disc angle of LIV, LIV tilt, LIV translation on full-spine film.

Results
Distal decompensation occurred in 15 patients (22.4%) at the final follow-up. 1 patient (1/7, 14.3%) was in the DR group and 14 patients (14/60, 23.3%) in NDR group. No difference was found in the baseline radiographic parameters between subgroups. It was suggested that the incidence of decompensation is greatly reduced with derotation of the presumed LIV on the SB film at baseline. In NDR group, the immediately postoperative lower disc angle of LIV, LIV tilt and LIV translation of patients without decompensation were significantly smaller than those of patients with decompensation ($p<0.05$), indicating that horizontalization of LIV would reduce the risk of decompensation even if the LIV was not derotated on SB films. Multivariate regression revealed that presumed LIV derotation on SB film and postoperative LIV tilt were significant predictors of distal decompensation.

Conclusion
Derotation of presumed LIV on SB films could predict less risk of distal decompensation in Lenke 5C patients. Nevertheless, horizontalization of LIV and minimizing LIV translation during correction would reduce risk of distal decompensation despite the presence of baseline LIV rotation.

Take Home Message
Disc wedging below LIV should be emphasized in Lenke 5C patients when LIV cannot be derotated on SB films.

213. High Preoperative T1 Slope is a Marker for Global Sagittal Malalignment

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Summary
T1 slope(T1S) is a parameter typically discussed in the context of cervical deformity and is correlated with health-related quality of life outcomes. Although prior research has suggested that T1S is related to global alignment, a definition for “high” T1S has not been established. Using decision-tree analysis in a cohort of adult spinal deformity (ASD) patients, this study found that a T1S>30° corresponds to high thoracic kyphosis(TK), sagittal vertical axis(S-VA), T1 pelvic-angle(TPA) and pelvic tilt(PT).

Hypothesis
High T1S is associated with worse global alignment

Design
Retrospective review of a prospective ASD database

Introduction
A database of preoperative ASD patients was analyzed. Patients

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without preoperative full-spine images were excluded. Measures obtained from standing lateral radiographs included: T1S, TK, SVA, TPA, PT, and pelvic incidence-lumbar lordosis mismatch(-PI-LL). T1S was correlated to each of these parameters. Decision tree analysis was then used to determine the T1S corresponding to published thresholds for high TK(40°), SVA(40mm), TPA(25°), and PT(25°). Alignment between high and normal T1S patients was compared via t-tests and X2 tests.

Methods

A database of preoperative ASD patients was analyzed. Patients without preoperative full-spine images were excluded. Measures obtained from standing lateral radiographs included: T1S, TK, SVA, TPA, PT, and pelvic incidence-lumbar lordosis mismatch(-PI-LL). T1S was correlated to each of these parameters. Decision tree analysis was then used to determine the T1S corresponding to published thresholds for high TK(40°), SVA(40mm), TPA(25°), and PT(25°). Alignment between high and normal T1S patients was compared via t-tests and X2 tests.

Results

211 preoperative ASD patients were included(mean 58±16y 62%F). At baseline, 30% had high TK, 54% had high SVA, 46% had high TPA, and 46% had high PT. Larger T1S was significantly correlated with greater SVA(R=.365) TPA(R=.302), TK(R=.606), and PT(R=.230)(all p<.001). Decision tree analysis yielded a threshold of 30° for high T1S, which 50% of patients had. Patients with T1S>30° had significantly higher TK, SVA, TPA, and PT, and PI-LL(Table). 79% of patients with high T1S had high TK(T1S<30= 13%), 69% had high SVA (T1S<30=38%), 66% had high TPA (T1S<30= 37%), and 60% had PT>25°(T1S<30= 42%)(all p<.05). T1S was not associated with PI.

Conclusion

Similar to previous studies higher T1S was associated with worse global alignment. T1S was most strongly associated with TK. A T1S=30° corresponds to thresholds for high TK, SVA, TPA, and PT. Therefore, surgeons should consider obtaining full-spine radiographs if a high T1S is present on cervical imaging.

Take Home Message

High T1S is associated with global malalignment. Surgeons should consider obtaining full-spine imaging if a T1S>30° is present on cervical radiographs.

	T1S ≥ 30° (n=114)	T1S<30° (n= 112)	p-value
SVA (mm)	78.7 (62.4)	33.7 (57.2)	<0.001
TPA (°)	27.6 (13.7)	18.3 (14.1)	<0.001
PT (°)	26.3 (11.6)	20.8 (13.0)	<0.001
TK (°)	41.5 (17.9)	25.8 (15.4)	<0.001
PI-LL (°)	18.2 (21.5)	11.7 (20.7)	0.021
LL (°)	35.2 (22.1)	40.8 (21.4)	0.05
PI (°)	53.9 (13.6)	52.5 (14.0)	0.453

214. Differences in Functional Treadmill Tests in Patients with Adult Symptomatic Lumbar Scoliosis Treated Operatively and Non-operatively

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Summary

Functional Treadmill Testing (FTT) has been previously described as an objective tool to evaluate patients suffering from neurogenic claudication. At baseline, patients treated operatively report symptom onset sooner on FTT than those treated non-operatively. In operatively treated patients, the difference in pre-treadmill and post-treadmill back pain and leg pain significantly improved at 2 years post-operatively. FTT is useful for determining the need for operative treatment and evaluating outcomes in patients with ASLS.

Hypothesis

Functional Treadmill Testing (FTT) demonstrates objective significant differences between patients treated surgically and non-surgically for Adult Symptomatic Lumbar Scoliosis (ASLS).

Design

Prospective Longitudinal Cohort

Introduction

ASLS has become increasingly prevalent as the population ages. ASLS can be accompanied by neurogenic claudication, leading to difficulty walking. FTT may provide an objective tool to evaluate patients with ASLS and identify patients that may benefit from surgical treatment.

Methods

One hundred and eighty seven patients who underwent non-surgical (n=88) or surgical treatment (n=99) of ASLS with complete baseline and two-year post-treatment FTTs identified. FTT parameters included maximum speed, time to onset of symptoms,

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distance ambulated, time ambulated, and the difference in back and leg pain before and after testing.

Results
At baseline, patients treated operatively reported an onset of symptoms on FTT significantly sooner than those treated non-operatively (5.5min vs 7.7min, p=0.025). When compared to baseline, operatively treated patients experienced significant improvement at 2 years in time ambulated (26.5min vs 24.4 min, p=0.001). Additionally, in the operative group, the post-treadmill minus pre-treadmill BP scores (0.5 vs. 1.6 p=0.001) and the post-treadmill minus pre-treadmill leg pain scores (0.4 vs 1.4, p<0.001) significantly improved at 2 years compared to baseline.

Conclusion
FTT is a useful adjunct to assess treatment outcomes in patient with ASLS. FTT results were different at baseline between patients treated operatively and non-operatively. Patients who had surgery had improvements in their post-treadmill minus pre-treadmill back and leg pain scores at two year follow-up.

Take Home Message
FTT is a useful adjunct to assess treatment outcomes in patient with ASLS. FTT results were different at baseline between patients treated operatively and non-operatively.

215. Utilization of Telemedicine Virtual Visits in Pediatric Spine Deformity Patients: A Comparison of Feasibility and Patient Satisfaction at a Large Academic Center

Assem A. Sultan, MD; Jacob M. Rabin; Daniel Grits, BS; Linsen T. Samuel, MD, MBA; David P. Gurd, MD; Thomas Kuivila, MD; Ryan C. Goodwin, MD

Summary
At our institution, telemedicine virtual visits (VV) have been utilized successfully for a wide spectrum of conditions among pediatric orthopaedic patients. However, it was unclear whether it can be used with similar feasibility and patient satisfaction among pediatric spine deformity patients given their unique characteristics. It was demonstrated that it can have a complimentary role to follow patients receiving operative and no-operative treatment with high patient satisfaction.

Hypothesis
Telemedicine virtual visits may be utilized to monitoring pediatric spine deformity patients that receives non-operative treatment, as well as provide postoperative surveillance of those treated surgically

Design
Retrospective cohort study

Introduction
Telemedicine platforms have evolved and healthcare systems have used the new technology to support convenient delivery of healthcare services to their patients while maintaining the quality of care. However, it is unclear whether they can be utilized effectively in patients with pediatric spinal deformity (PSD).Therefore, this study aimed to evaluate the feasibility and patient satisfaction associated with VV utilization in PSD patients in comparison to general pediatric orthopaedic indications.

Methods
Out of 482 virtual visits offered to pediatric orthopaedic patients at a large academic healthcare system between January 1st, 2017 and December 31st, 2018, a total of 189 VVs conducted by board certified orthopaedic surgeons were included in the final analysis . Patient satisfaction scores were collected at end of each VV by patient and parent rankings of the surgeon and the telemedicine service. Data on patients, visits, and connectivity sessions characteristics were collected and statistically compared between PSD visits (n=33) vs. those conducted for general pediatric orthopaedic indications (n=156) (Table 1).

Results
Although PSD patients were older (15±3.7 vs. 12±4.7 yrs, p<0.01), mostly female (76% vs. 47%, p=0.003), and had longer VVs (8±4.6, vs. 5±3.6 min, p=0.003) vs. their general pediatric orthopaedic counterparts, they demonstrated similarly high satisfaction scores for surgeon performance (5 vs. 4.8±0.1 points, p=0.08) and overall satisfaction (3±2.4 vs. 3.5±2.1, p=0.23). Approximately 80% of all VVs were conducted over mobile devices. Wait time was substantially less for PSD VVs relative to subsequent office visits (13±10 vs. 41±30 min, p<0.001)

Conclusion
Despite their unique characteristics, PSD patients had high satisfaction with surgeon's performance and their virtual experience similar to those conducted for more standard indications

Take Home Message
Telemedicine VVs can provide convenient, high quality, and satisfactory care to PDS patients.

Pediatric spine deformity visits (n=33)	General pediatric orthopaedic visits (n=156)
• Follow-up after deformity correction: 27 (82%) • Non-operative monitoring of deformity 6 (18%)	• Closed fracture reduction follow-up: 78 (50%) • Operative fracture fixation follow-up: 15 (9,6%) • Benign bony tumor resection follow-up: 10 (6,4%) • Joint pain non-operative management: 10 (6,4%) • Arthroscopic procedure follow-up: 12 (7,6%) • Monitoring after lower extremity deformity correction: 10 (6,4%) • Foot pain follow-up: 4 (2,5%) • Pediatric hand procedure follow-up: 7 (4,4%) • Pediatric hip procedure follow-up:5 (3,2%) • Follow-up after implant removal: 4 (2,5%) • Congenital hip dislocation closed reduction: 1 (0,6%)

Table 1: Virtual visits indications

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216. Understanding the Details Behind Overcorrection in Vertebral Body Tethering

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Summary

Overcorrection is a well-recognized complication of Anterior Vertebral Body Tethering (VBT). Predicting procedural success is often difficult but may be improved through a better understanding of skeletal maturity. Patients that overcorrected their deformity exhibited minimal epiphyseal capping (early Sanders 3) and delayed carpal development pre-surgically, followed by a prolonged period of maturational stasis when compared with matched controls. We recommend VBT patients exhibit at least a late Sanders 3 in order to maximize correction while limiting the risk of overcorrection.

Hypothesis

Patients that exhibit pre-surgical delayed skeletal maturity will be at a higher risk for overcorrection following VBT.

Design

This study is a retrospective study of patients who underwent VBT with a minimum two-year follow up.

Introduction

Anterior Vertebral Body Tethering (VBT) is a surgical procedure allowing for continued spinal growth while correcting the deformity and maintaining flexibility. Overcorrection is a recognized complication of VBT. Predicting these outcomes is difficult but may be improved through understanding overcorrection etiology, particularly related to skeletal maturity. Limited data are available on the relationship between skeletal maturity, procedural success (Cobb < 30° with no additional surgery), and the risk of overcorrection following VBT.

Methods

We assessed semi-longitudinal left hand-wrist radiographs of 31 VBT patients. Skeletal maturity was assessed using the Triradiate Cartilage, Sanders Staging System, and Fels Method. Four females (13%) overcorrected and were included in additional analyses (Mean Cobb 51.5°; Open Triradiate). Four matched controls were identified (Mean Cobb 51.3°; 3 Open, 1 Closed Triradiate) with identical pre-surgical Sanders Scores and Fels Skeletal Ages (± 5 months). Relative Skeletal Age (RSA; Fels Skeletal Age – Chronological Age) determined advanced (RSA ≥ 1.0 yrs.) or delayed (RSA ≤ -1.0 yrs.) skeletal maturity.

Results

Patients who overcorrected following VBT often had minimal epiphyseal capping (early Sanders 3) and underdeveloped carpals prior to surgical correction, whereas matched controls exhibited more significant epiphyseal capping (late Sanders 3) or had fully developed carpals. Patients who overcorrected also exhibited a decrease in RSA corresponding to multiple visits spent at a Sanders 3 and a Fels Skeletal Age that changed by less than 4 months over one year (Fig 1).

Conclusion

To avoid overcorrection, additional skeletal maturity details need to be obtained. We believe that patients exhibiting an early Sanders 3 with immature carpals are at higher risk for overcorrection. We recommend VBT patients exhibit at least a late Sanders 3 in order to maximize correction while limiting the risk of overcorrection.

Take Home Message

To limit the risk of overcorrection, patients undergoing VBT should exhibit substantial epiphyseal capping (late Sanders 3) and/or mature carpals prior to surgical intervention.

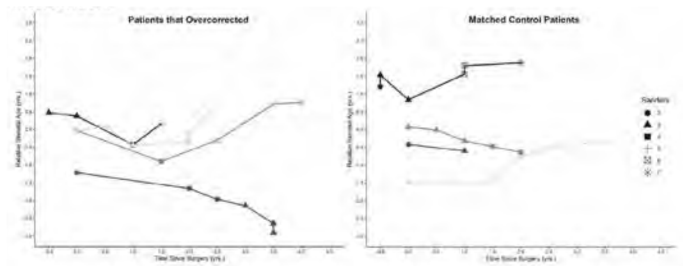

Fig 1. A comparison of time since surgery (yrs.) and relative skeletal age (yrs.) for patients that overcorrected their deformity and their matched controls, where shape indicate Sanders Scores and colors indicate matched controls.

217. Comparison between Augmented Reality-based Navigation and Free-hand Posterior Spinal Surgery for Pedicle Screw Placement. A Matched-control Study and Review of the Literature

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Summary

Twenty patients who underwent posterior screw placement using augmented reality-based (AR) navigation with intraoperative 3D imaging were compared to an equal sample size of patients who underwent free-hand (FH) surgery after matching for primary diagnosis and instrumented spinal levels. AR navigation demonstrated a statistically superior clinical accuracy for screw placement compared to FH. The difference in clinical accuracy between both groups is within the range of reported studies comparing state-of-the-art navigation and FH.

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Hypothesis

We hypothesize that AR navigation provides superior screw placement accuracy compared to FH, similarly to state-of-the-art navigation (i.e. infrared camera-based navigation with automatic registration with intraoperative 3D imaging) compared to FH.

Design

Prospective case series with retrospective matched-control.

Introduction

Several studies reported a higher screw placement accuracy for various generations of navigation systems compared to FH. AR navigation is a novel video-camera-based system integrated in a robotic C-arm for non-invasive patient tracking and instruments navigation. This study is the first accuracy comparison between AR and FH.

Methods

In the AR group, 20 patients underwent screw placement with 65% of complex deformities. The FH group was composed of 20 patients matched to the AR group based on primary diagnosis and anatomical region with screws. Screw breach was assessed by independent observers not involved in the treatments. Intra-operative cone-beam CT and postoperative CT of the AR and FH subjects respectively, were used to assess breach: grade-0 no cortical violation, grade-1 breach <2 mm, grade-2 2-4 mm breach, grade-3 >4 mm breach. Grades 0 & 1 defined accuracy. Literature comparing accuracy between state-of-the-art navigation and FH were identified to put our results in perspective.

Results

262 vs 288 screws were placed in the AR vs FH group, respectively; with comparable proportions in the thoracic spine (AR-FH: 63.4-62.5%, p=0.86). The accuracy in the AR vs FH group was 93.9% vs 89.6%; yielding a significant 4.3% increase. Eleven studies in literature comparing accuracy between state-of-the-art navigation and FH reported differences ranging from -0.6 to 12.4%. Collectively and including this current study corresponding to a total of 1016 subjects with 7715 placed screws, an overall significant 5% increase was obtained favoring navigation.

Conclusion

AR navigation demonstrated a significant increase in accuracy compared with matched-control FH, and is comparable to the average difference reported in literature for other state-of-the-art navigation system vs FH.

Take Home Message

Augmented reality navigation has a significantly increased clinical accuracy compared to free-hand technique after matching for primary diagnosis of spinal pathology and instrumented anatomical regions.

218. Safe and Effective Performance of Pediatric Spinal Deformity Surgery in Patients Unwilling to Accept Blood Transfusion

Subaraman Ramchandran, MD; Nicole Orozco, RN; Alexander Mihas, BS; Harry L. Shufflebarger, MD; Jahangir K. Asghar, MD; Stephen G. George Jr., MD

Summary

Patients requiring spinal deformity correction and who refuse blood transfusion need meticulos pre-operative evaluation and constructive use of blood salvage techniques. We report a series of 20 adolescent patients who refused blood transfusion and who underwent posterior spinal fusion (mean levels- 11.4. with 5.6 levels Ponte's osteotomies). The mean blood loss was 300cc and the drop in Hb was 2.6mg/dl post-operatively. There were no major peri-operative complications. Excellent maintenance of correction was observed at 1 year follow-up.

Hypothesis

Surgical correction of spinal deformity can be safely and effectively performed in adolescent patients who refuse blood transfusion.

Design

Retrospective single center study

Introduction

Significant blood loss is a risk often associated with the surgical treatment of spinal deformities. Patients refusing blood transfusion who require spinal deformity correction are challenging to manage. The medicolegal consequences, religious beliefs, and moral responsibility in dealing with these patients mandates effective blood conservation and salvage techniques.

Methods

The radiographic and medical records of patients whom refused blood transfusion prior to undergoing spinal deformity surgery from 2014-2018 were reviewed. All patients underwent posterior spinal instrumented fusion with all pedicle screw constructs. Patients were assessed for blood loss (EBL), deformity correction, operative time, perioperative complications, and hospital stay. At latest follow-up (mean, 16.4 months; range, 8–36) the patients were examined for radiographic fusion, progression and complications. Similarities in surgical techniques and practices were examined.

Results

20 patients were included (mean age- 14.1 yrs, 13 females, 15 AIS, 2 congenital and 3 neuromuscular). The major coronal Cobb was corrected from 55.4 to 11.2 deg (80% correction, p< 0.001) at the latest follow up. A mean of 11.4 levels were fused, 5.6 levels of Pontes osteotomies and 4 levels of thoracoplasty performed. 1 patient underwent L1 VCR and 3 patients had fusion to pelvis.

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EBL and cell saver returned averaged 307.9ml and 80ml, respectively, with a mean surgical time of 214 min. The average drop in Hb was 2.6mg/dl and length of hospital stay was 5.1 days. One patient had a late infection and 1 patient developed symptomatic proximal junctional kyphosis, both of whom required revision

Conclusion

With the utilization of hypotensive anesthesia, hemodilution, tranexemic acid, cell-saver and ultrasonic bone cutting tools, spinal deformity corrective procedures can be safely performed in adolescent patients refusing blood transfusion with excellent deformity correction and minimal complications.

Take Home Message

Spinal deformity corrective procedures can be safely and effectively performed in patients refusing blood transfusion with the utilization of hypotensive anesthesia, hemodilution, tranexemic acid, cellsaver and ultrasonic bone cutting tools

219. Conservative Treatment of Main Thoracic Adolescent Idiopathic Scoliosis: Full-time or Night-time Bracing?

Soren Ohrt-Nissen, MD, PhD; Markus Lastikka, MD; Thomas Andersen, MD, PhD; Ilkka J. Helenius, MD, PhD; Martin Gehrchen, MD, PhD

Summary

Randomized by center study comparing full-time and night-time bracing in the treatment of thoracic AIS including 77 patients. Initial curve size was slightly larger in the night-time bracing group, but progression of more than 5 degrees or to surgical indication was similar to the full-time bracing group.

Hypothesis

Treatment efficacy is comparable between the Boston full-time brace and the Providence night-time brace in main thoracic adolescent idiopathic scoliosis.

Design

Prospective comparison of two cohorts randomized by center to full-time bracing (Finnish cohort) or night-time bracing (Danish cohort).

Introduction

Full-time bracing is a proven treatment in thoracic AIS. Nigh-time bracing have been advocated in lumbar and thoracolumbar curves. Little is known of the efficacy of night-time bracing in the treatment of thoracic idiopatic curves.

Methods

Patients were treated with either the Boston brace (n=37) or the Providence brace (n=40). Inclusion criteria were Risser grade ≤2, major curve between 25-40° with the apex of the curve between T7 and T11 vertebrae. Two-year follow-up was available in all patients unless brace treatment had reached endpoint. The primary outcome measure was main curve progression to ≥45°.

Results

Median age was 12.6 years and median treatment length at follow-up was 25 months (IQR:18-32) with no difference between the groups (p ≥ 0.116). Initial median main Cobb angle was 29° (IQR:27-33) and 36° (IQR:33-38) in the Boston and Providence group, respectively (p=0.548). At follow-up, 13 patients (35%) had progressed to ≥45° in the Boston group vs. 16 patients (40%) in the Providence group (p = 0.838). Twenty-three patients (62%) had progressed by more than five degrees in the Boston group vs. 22 patients (55%) in the Providence group (p=0.685). The secondary thoracolumbar/lumbar curve progressed by more than five degrees in 14 (38%) and 18 (45%) in the Boston and Providence groups, respectively (p=0.548).

Conclusion

Despite a larger initial curve size in the Providence group, progression of more than 5 degrees or to surgical indication was similar in the Boston group. Our results indicate that night-time bracing is a viable alternative to fulltime bracing also in main thoracic AIS.

Take Home Message

There is no significant difference in progression rate to a surgical indication range (≥45°) in main thoracic AIS curves treated with Boston fulltime brace or Providence nighttime Brace

220. Variation in Thoracic Inlet Measurements and its Correlation with Pulmonary Dysfunction in Kyphoscoliotic Deformities: A Prospective Case Control Study

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Summary

Prospective case–control study was done in 80 patients and 20 controls to analyze the correlation of thoracic inlet dimensions on pulmonary dysfunction. The patients were divided into three groups based on curve magnitude and thoracic inlet index calculated on MRI, which was correlated with spirometry values and thoracic cage changes. Inlet index > 5.6 was associated with moderate to severe pulmonary dysfunction in proximal thoracic curves greater than 80 degrees with apex proximal to T5, irrespective of etiology

Hypothesis

Thoracic cage distortion and a narrow thoracic inlet would lead to a higher thoracic inlet index and worsening pulmonary function

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Design
Prospective case control study

Introduction
Pulmonary dysfunction in early onset scoliosis is due to hampered alveolar tree growth and restrictive dysfunction in late onset curves. A less pliable rib–vertebra–sternum complex leads to volume depletion and thoracic cage changes including thoracic inlet distortion presenting with respiratory failure.

Methods
Eighty kypho-scoliotic deformity patients with curves>30 degrees presenting between august 2017 to july 2018 were included. Patients with curves<30 degrees, lumbar curves, <8 yr of age and those with congenital cardiopulmonary disease were excluded. The included patients were divided into groups based on Cobb's angle 31–50,51–80 and >80 degrees. Thoracic inlet index (TII) was measured on MRI, anatomical at manubrium level (TII A), compared with 20 age matched controls. Correlation analysis of TII with pulmonary function (FEV1/FVC) and thoracic cage parameters was done

Results
Mean age of patients was14.91 years with a mean Cobb's angle was 69.8 +14.96 degrees. Mean TII A was 3.72+ 0.91, maximum 7.35 in group 3 and minimum 1.84 in group 1. In age matched controls, mean TII A was 3.23+0.43. Mean FEV1 was 70.5+11.1, mean FEV1/FVC of 1.05 + 0.03 with moderate to severe restrictive pattern in group 3 congenital curves (p < 0.001) as compared to mild impairment in group 2. TII A > 7.11 was associated with thoracic insufficiency syndrome and moderate to severe respiratory dysfunction was observed in TII A >5.6 in group 3 curves with proximal thoracic hypokyphosis and apex between T1-T4 had a significant correlation with worsening PFT and curve angle. Transverse thoracic diameter, hemithorax height, rib–apex distance were insignificant predictors

Conclusion
TII > 5.6 compared to age matched controls is strongly associated with pulmonary impairment in proximal thoracic, hypokyphotic curves > 80 degrees. The association of pulmonary impairment was weak with height of hemithorax, rib apex distance on convex side and thoracic diameter

Take Home Message
A higher thoracic inlet index > 5.6 correlates with worsening pulmonary function in severe kyphoscoliotic deformities and can aid in anticipating respiratory failure, irrespective of etiology

221. The Role of Blood Loss, Surgical Time, and Antibiotics in Spinal Surgery Infection within 90 Days

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Summary
In this large group, we find that EBL, fusion loss and neuromuscular diagnoses put patients at a higher risk for surgical spine infection after surgery. While surgeons have been able to modify other aspects of surgery like choice of antibiotics and wound closure, a greater challenge lies in addressing these issues which are difficult to modify.

Hypothesis
Surgical time, blood loss and choice of antibiotics determine risk of infection in scoliosis surgery

Design
Ambispective

Introduction
Spinal surgery infection is devastating. Multiple factors have been implicated. While choice and timing of antibiotics, nutritional status, etc. can be controlled, surgical time, blood loss and fusion levels are difficult to modify. This study inspects the role of blood loss and surgical time in postop spinal infection.

Methods
Ped scoliosis patients undergoing PSF with pedicle screws from 2005-2018 were reviewed. XR and demo data were collected. EBL, levels fused, transfusion, infection, and surgical time were collected. Surgical duration greater than 4, 5 or 6 hours were used to determine the influence of surgical duration on infection. Similarly, an EBL greater than or less than 500 cc was analyzed. All patients received IV Cefazolin for 48 hours. Those allergic to penicillin were given clindamycin. All had chlorhexadine wipes preop. No preop urine cultures or MRSA swab. Fisher's exact test, Spearman correlation and Wilcoxon tests were used.

Results
705 patients(AIS:526,NM:179) were included. 28 had infection. 266 had more than 500 cc EBL. 16 had infection(p=0.04). Number of levels fused was also significant(13vs13.5,p=0.002). 12(6.7%) NM had infection, significantly higher compared to 3% AIS(p =0.03). Surgical time greater than 4, 5 or 6 hours was not found to be significant (p =0.09,0.33,0.09).

Conclusion
Our data suggests that a lower rate of surgical spine infection in scoliosis patients is achievable by controlling variables like nutrition, type and timing of antibiotic, chlorohexidine baths and local vancomycin in the wound. Our infection rate in the NM population is much lower than previously reported. This is with a single

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drug antibiotic prophylaxis and without use of MRSA swabs or urine cultures.

Take Home Message
This study found that the risk of surgical infection is associated with number of fusion levels, blood loss and neuromuscular etiology, which are difficult to modify.

222. Comparing Cobalt Chrome, Titanium Alloy and Pure Titanium Rods for Adolescent Idiopathic Scoliosis Surgical Treatment*

Konstantinos Martikos, MD; Tiziana Greggi, MD; Cesare Faldini, MD; Francesco Vommaro, MD; Luca Boriani, MD, PhD; Antonio Scarale, MD

Summary
This is a retrospective study that confronts corrective outcomes between cobalt chrome, titanium alloy and pure titanium rods for treating adolescent idiopathic scoliosis. Amongst these three materials, cobalt chrome rods showed better frontal and sagittal plane correction and an inferior rate of proximal junctional kyphosis than the other two materials. Nevertheless, cobalt chrome rods may require high density pedicle screw constructs in order to reduce mechanical complications.

Hypothesis
Cobalt chrome rods provide better correction than titanium alloy and pure titanium in adolescent idiopathic scoliosis

Design
Retrospective study

Introduction
Adolescent idiopathic scoliosis may be surgically corrected with cobalt chrome (CC), titanium alloy (TA) and pure titanium (PT) rods. This is a retrospective study that confronts outcomes between these three type of rods, focusing on deformity correction and mechanical complications.

Methods
Inclusion criteria: adolescent idiopathic scoliosis, major curve cobb angle between 40° and 85°. Minimum follow up of 2 years. Rods other than 5.5mm diameter were excluded, patients treated with a combinations of different rods were excluded as well. A total of 136 patients were selected as appropriate for the study, divided in 46 CC patients, 49 TA patients and 41 PT patients. Groups were statistically similar in demographics, scoliosis type and curve entity. Radiographic evaluation was performed on standing x-rays, calculating scoliosis, thoracic kyphosis (from T2 to T12), apical vertebral translation (AVT) of major curve towards CSVL.

Results
In the frontal plane, CC group showed statically significant superior deformity correction (Cobb 68,4° pre-op, 11,7° post-op; AVT pre-op 74.3mm, post-op 7mm). TA group (Cobb 66,1° pre-op, 28,4° post-op; AVT pre-op 75.3mm, post-op 26,9mm) showed superior correction than PT group (Cobb 65,6° pre-op, 33,4° post-op; AVT pre-op 72.3mm, post-op 28,6mm) without achieving statistically significant difference. Thoracic kyphosis restoration was significantly superior with CC rods (pre-op 16.2°, post-op 32.6°) than with TA (pre-op 17.9°, post-op 19.3°) and PT rods (pre-op 18.3°, post-op 18.6°). Proximal junctional kyphosis was encountered in all three groups, and was asymptomatic in all patients, more frequent with TA and PT rods than CC rods. Instrumentation related mechanical complications that required revision surgery were encountered in one CC patient and in 1 PT patient.

Conclusion
CC rods provide better scoliosis correction both in frontal and sagittal plane than PT and TA rods, without having a higher rate of mechanical complications.

Take Home Message
5.5 mm cobalt chrome rods offer superior frontal and sagittal plane correction when compared to same diameter titanium alloy and pure titanium, without having a higher rate of mechanical complications.

223. Should all Non-ambulatory Children with Neuromuscular Scoliosis be Fused to Pelvis?

Niklas Tøndevold, MD; Markus Lastikka, MD; Thomas Andersen, MD, PhD; Martin Gehrchen, MD, PhD; Ilkka J. Helenius, MD, PhD

Summary
The need for pelvic instrumentation in neuromuscular scoliosis remains under debate. This retrospective study compared non-ambulatory patients from two centers, one that routinely fixed to the ilium and the other to the L5. In seventy patients with two years follow up we identified radiographic parameters where pelvic fixation could prove advantageous.

Hypothesis
Pelvic fixation is not needed as a standard procedure in all non-ambulatory patients with neuromuscular scoliosis.

Design
A two center retrospective cohort study in seventy patients with full radiographs and two year follow up.

Introduction
Pelvic fixation has been shown to be associated with up to thirty percent complication rates. Still its being regarded as the golden standard in deformity surgery in neuromusculuar scoliosis. To

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our knowledge no comparative studies have been made in L5 and Pelvic fixation in patients with the same radiographic parameters.

Methods

This retrospective study included 70 non ambulatory patients (GMFCS 4 or above) with neuromuscular scoliosis operated using bilateral segmental pedicle screw instrumentation. 35 (mean age 15) underwent fusion to L5 and 35 (mean age 15) to pelvis. Main outcome parametres included major curve (MC), pelvic obliquity (PO), thoracic kyphosis, lumbar lordosis, sagittal balance and coronal balance.

Results

MC averaged preoperatively 90 (40-141) and 46 (15-82) at FFU in the L5 and similarly 81 (33-116) and 19 (1-60) in the pelvic group ($p<0.005$ for preoperative and FFU). MC and PO correction were statistically better in the pelvic group ($p<0.005$) at FFU. There were not statistically significant differences in the OR time, BL or complications. Loss of major curve correction(>10deg) was more common in the plevic group (8 vs 1 patients), while loss of pelvic obliquity correction was more in the L5 group during FU (9 patients) . Risk factors for loss of correction included coronal imbalance >50 mm ($p=0.019$), postoperative sagittal imbalance >25 mm($p=0.037$) and diagnosis of spinal muscular atrophy ($p=0.057$).

Conclusion

Pelvic instrumentation improves radiographic correction of major curve and pelvic obliquity, but does not increase risk of complications in non-ambulatory children with neuromuscular scoliosis. Preoperative coronal imbalance (>50mm) and patients with SMA present with more loss of correction and may especially benefit from routine pelvic instrumentation.

224. Economic Trends in Spinal Deformity Surgery in the United States between 2012 and 2015

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Summary

We studied national economic data surrounding long level fusions involving 9 or more levels in the United States. An 18% decrease in hospital charge and a corresponding 11% decrease in hospital cost for spinal fusion surgery > 9 levels were observed between 2012 and 2015. This was accompanied by a 32% increase in incidence of long level fusions over the same period.

Hypothesis

Reduction in hospital charges and costs associated with spinal deformity surgery between 2012 and 2015.

Design

Retrospective Study

Introduction

Innovation in spinal instrumentation and imaging have improved long level fusions, allowing powerful corrections in spinal deformity surgery. With increasing focus on health care utilization and value-based care, it is essential to understand the economic data impacting spinal deformity surgery.

Methods

The National patient Sample (NIS) database from 2012 to 2015 was queried for patients who underwent spinal deformity surgery, defined as primary or revision fusion of ≥ 9 vertebrae (ICD-9 CM 81.64). Data on incidence per 100,000, patient income (defined as low or not low), hospital ownership, hospital charge per surgery, hospital cost per surgery, and patient insurance were collected.

Results

The incidence of spinal deformity surgery increased 23% from 4.0 in 2012 to 4.9 in 2015. Hospital charges decreased 18% from $335,142 in 2012 to $275,616 in 2015. Costs for the procedure decreased by 11% from $77,802 in 2012 to $69.546 in 2015. The cost-charge difference, defined as the difference between hospital cost and charge per procedure decreased by 20%, from $257,340 to $206,070. Between 2012 and 2015, Medicare and Medicaid beneficiaries increased as a percentage of this patient population, from 19.20% to 21.64% and 22.62% to 24.45% respectively, while the percent with private insurance decreased from 50.86% to 48.24%. Between 2012 and 2015, the percent of surgeries performed at government hospitals increased from 9.6% to 11.07% while those at private non-profit hospitals decreased from 83.57% to 82.27%.

Conclusion

In recent years in United States, spinal deformity surgery has become increasingly economical as evidenced by a marked decrease in the associated costs, charges, and cost-charge difference. There is also a concomitant increase noted in utilization of spinal deformity surgery in Medicare and Medicaid beneficiaries, indicating our health system may be adapting to an aging population.

Take Home Message

While spinal deformity surgery becomes more common, costs are declining.

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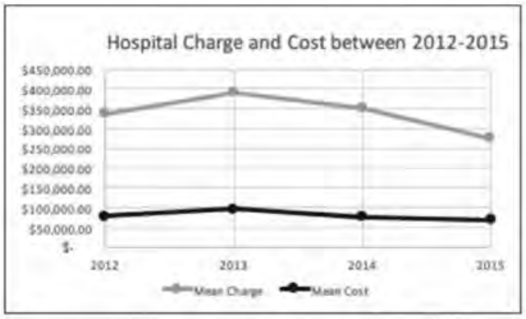

Figure1: Hospital Charge and Cost Trends between 2012 and 2015

225. Longitudinal Changes of the Sagittal Plane after Posterior Spinal Fusion of Adolescent Idiopathic Scoliosis in Lenke 5 and 6 from Baseline to 2 Year Follow Up†

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Summary

Sagittal plane assessment of lumbar lordosis (LL), pelvic tilt (PT) and pelvic incidence (PI) in AIS Lenke 5 & 6 has not been fully delineated. We studied the spinopelvic parameters over 2 yrs. Lenke 5 & 6 pts were stratified into 3 groups (low LL<40, normal LL 40-60 and pts with high LL>60) An inverse relationship between LL and PT was found, PI remains unchanged and the lordosis increases up to 2yrs.

Hypothesis

There is an inverse relationship between LL and PT in AIS Lenke 5 and 6 pts while LL changes over 2 yrs.

Design

Retrospective review of a prospectively collected multicenter database

Introduction

Coronal plane in AIS has been extensively studied, however, there is a paucity of studies investigating the changes in sagittal parameters before and after surgery in Lenke types 5 and 6 after PSF.

Methods

Baseline, 6 wks, 6 mos, 1 yr and 2-yr f/u radiographs were analyzed for sagittal plane parameters (LL, PI, PT and TL kyphosis). Lenke 5 & 6 pts were stratified according to LL into 3 groups; low LL<40, normal LL 40-60 and high LL>60. Pts within each LL group were followed from pre-op to 2 yrs after PSF for changes in TL kyphosis, LL, PI and PT.

Results

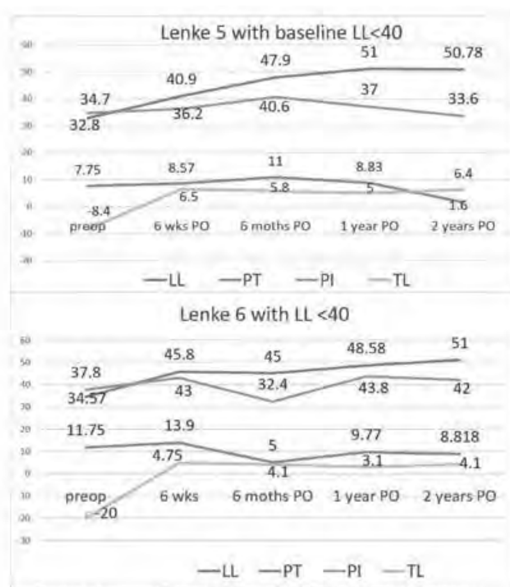
242 Lenke 5(L5) and 223 Lenke 6(L6) pts were studied. In the L5 pts the avg. preop LL =-56 (-24 to-93), avg. pre-op PT =9.3(-10-26). In L5 pts with pre-op LL<40 (n=17), LL steadily increased to 1 year then plateaued at 2 yrs. Avg. PT remained similar until 1 year then sharply declined from 1-2 yrs. In L5 pts with pre-op LL 40-60 (n=131) LL values increased from 6 wks to 6 mos then was unchanged at 2 yrs while PT gradually decreased from 6 wks to 2 yrs. In L5 pts with high preop LL>60 (n=94), postop LL increased to 6 mos then plateaued while PT trended down from 6 wks to 2 yrs. L6 pts. had an avg. preop LL of-55 (-21 to -91), avg. preop PT 10(-6 to 52). L6 pts with pre-op LL<40 (n=21) increased from pre-op to 6wks then increased up to 2 yrs. PT increased at 6 wks then trended down. L6 with pre-op LL 40-60 (n=131) LL values trended up from 6 wks to 2 yrs. PT trended down from 6 wks to 2 year. L6 with high pre-op LL>60 (n= 71) LL increased from 6 wks to 6 mos back to preop value and remained unchanged at 2 yrs. PI did not change over time but lumbar lordosis increased over the 2 yrs.

Conclusion

There is an inverse relationship between LL and PT in pts with Lenke types 5&6 when longitudinally tracked over 2 yrs postoperatively. PI did not change but lordosis increased over 2yrs.

Take Home Message

There is an inverse relationship between LL and PT in longitudinal sagittal plane changes in Lenke 5&6. Lumbar Lordosis increases, sagittal plane adapts to PSF and improves over time.



Longitudinal Changes of the Sagittal Plane after PSF for AIS Lenke 5 and 6 with baseline LL<40° up to 2 yrs. f/u showing relationship between LL , PI, PT and TL kyphosis.

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226. Significant Variation Exists Between Surgeon's Surgical Time and the Specific Steps When Performing a Posterior Spinal Fusion for Lenke 1A AIS

Daniel J. Sucato, MD, MS; Kiley Frazier Poppino, BS

Summary
A consecutive series of AIS Lenke 1A curve patients undergoing PSFI surgery by 6 surgeons at a single institution demonstrated no difference in the anesthesia prep time but a significant variation in the total surgical time (188-272 mins). Differences for each surgical step and surgeon specific areas of improvement were noted. Implementation of best practices will improve the value of AIS surgery by decreasing cost.

Hypothesis
Significant variation in operative time exists in PSFI for Lenke 1A AIS

Design
Retrospective

Introduction
Value-based medicine seeks to improve outcomes while containing costs. Since the outcome of posterior spinal fusion and instrumentation (PSFI) for AIS is generally good, its value can be improved by decreasing the 2 biggest drivers of cost: surgical time and implants. The purpose of this study was to identify variation in operative time and to identify opportunity for improvement.

Methods
A prospectively-collected series of consecutive AIS patients, who underwent a PSFI for Lenke 1A curves were reviewed. Surgery was divided into seven steps. Data was analyzed as a percentage difference between the longest and shortest duration for each step.

Results
There were 83 patients at an average age of 14.0 years, major Cobb of 57.6°, 10.5 levels fused, without significant differences in age, gender, BMI, Cobb, or thoracic kyphosis between the 6 surgeons. There were no differences in anesthesiologists' prep time (p=0.56). There was a 30.9% difference in the operative time (skin-to-skin) between surgeons (188-272 mins, p<0.001). Surgical step differences between-surgeons (greatest to least variation) were: set screw tightening/decortication/graft (88.3%, p<0.001), facetectomies/screws (65.7%, p=0.001), closure (60.3%, p<0.001), positioning/prep (52.4%, p=0.036), final x-rays (50.8%, p=0.003), exposure (48.3%, p<0.001) and rod placement/correction (38.3%, p=0.007). Time distribution for each step was conducted to identify areas where surgical efficiency could be increased. Most notably, two surgeons spent significantly more of their case time on facetectomies/screws compared to the other four surgeons (42.6% v 35.7%, p<0.001).

Conclusion
In a consecutive series of Lenke 1A AIS curves, anesthesia prep time was constant but significant variation amongst surgeons (188-272 mins), with greatest variation occurring during set screw tightening/decortication/graft and facetectomies/screw placement. Adopting best practices and surgical standardization may improve surgical time, decrease cost, and improve the value of AIS surgery.

Take Home Message
Significant variation in the operative time exists in PSFI for Lenke 1A AIS. Identifying variation and adopting surgical standardization can improve surgical time and value of AIS surgery.

227. A Risk Benefit Analysis of Increasing Surgical Invasiveness Relative to Frailty Status in Adult Spinal Deformity Surgery

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Summary
The adult spinal deformity (ASD) Invasiveness Index incorporates deformity-specific components to assess magnitude of correction. This study assessed relationships between invasiveness and experiencing major complication/reoperation within frailty subgroups. Thresholds for invasiveness risk/benefit cutoff point were determined, above which increasing invasiveness was associated with major complications/reoperations and not meeting 3Y MCID.

Hypothesis
Increasing invasiveness correlates with incidence of major complications/reoperations in ASD surgery in each frailty state

Design
Retrospective review

Introduction
How invasiveness relates to outcomes in each frailty state is unknown.

Methods
ASD patients (scoliosis≥20°,SVA≥5cm,PT≥25° or TK ≥60°) with preop frailty and invasiveness scores (Table 1). Invasiveness scores calculated within different frailty states: not frail(NF,<0.3), frail(F,0.3-0.5), severely frail(SF,>0.5). Logistic regression assessed the relationship between increasing invasiveness and major complications/reoperations and meeting MCID for 3Y HRQLs. Decision tree analysis assessed thresholds for invasiveness risk/

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benefit cutoff point, above which odds higher of experiencing complications/reoperations and not reaching MCID.

Results

195/322 patients (60±14yrs, 75%F) were included. Surgical overview:61% osteotomy,52% decompression,11±4 levels fused. Breakdown by frailty category: 98 NF, 65 F, 30 SF. Overall, regression analysis found relationships between increasing invasiveness and experiencing major complication/reoperation(1.01[1.00-1.02]). Within each frailty subgroup, NF:1.01([1.00-1.03]),F:1.01([1.01-1.02]),SF:1.01([1.00-1.01]). When defining no major complications/reoperation and meeting MCID in any 3Y HRQL as favorable outcomes, decision tree analysis established an invasiveness risk/benefit cutoff of 63.9. Patients below this threshold were 1.8[1.38-2.35] times more likely to not have major complication/reoperation and meet 3Y MCID. Invasiveness above this a negative predictor(0.55[0.401-0.754]). Factoring in frailty, risk benefit cutoff for NF:79.3(2.11[1.39-3.20]),F:111(2.62[1.70-4.06]),SF:53.3(2.35[0.78-7.13]).

Conclusion

Invasiveness directly associated with odds of major complications/reoperations. Risk/benefit cutoff for decreasing major complications/reoperations and meeting MCID 79.3 for NF patients, 111 for F, 53.3 for SF. Above these thresholds, increasing invasiveness associated with increased risk of major complications/reoperations and not meeting 3Y MCID.

Take Home Message

Invasiveness directly correlated with complications/reoperations. Risk/benefit cutoffs for major complications/reoperations and meeting MCID determined for frailty states. Above thresholds, increasing invasiveness associated with major complications/reoperations and not meeting 3Y MCID.

Table 1. Invasiveness Index

Surgical component	Points
Posterior	
Decompression	1 per vertebra
Fusion	2 per vertebra
Instrumentation	1 per vertebra
Osteotomies	
3-column	14 per osteotomy
Smith-Petersen	1 per osteotomy
Interbody fusion	
Anterior lumbar	8 per interbody fusion
Transforaminal/posterior lumbar	2 per interbody fusion
Iliac fixation	2
Revision surgery	3

228. Impact of Radiologic Variables On Item Responses Of ODI and SRS22 in Adult Spinal Deformity Patients: Differential Item Functioning (DIF) Analysis Results From A Multi-center Database

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Summary

To analyze whether responses given to ODI and SRS22 items are influenced by radiological parameters (RP) such as Global Tilt, Sagittal SVA, RSA, Sagittal PT, RPV, PI-LL, RLL, Coronal Balance, Major curve cobb angle, we conducted a DIF study and found that some questions of SRS22 and ODI are sensitive to radiological parameters. These items sensitive to RP may be more functional in establishing a connection between changes in RP and HRQoL.

Hypothesis

Few items from ODI and SRS22 are directly affected by radiologic changes.

Design

A prospectively collected multicenter ASD database.

Introduction

Evaluating whether the responses given to the items in a scale differ by external variables is a method used to evaluate the internal construct validity of the scale. Statistically, items being affected by external factors (e.g., radiological) are deemed biased and this bias is referred to as differential item functioning (DIF). On the other hand, this bias may be useful for clinical purposes and denote a sensitivity of the item to the factors (e.g., radiological) analyzed.

Methods

Patients enrolled in a multicentric ASD database who had complete SRS22 and ODI data at baseline and the 1st year (n=923; 774F, 149M; 500 surgical, 423 non-S; average age: 51.97+/-19.5) were analyzed retrospectively. DIF of items in relation to radiological parameters (RP) was analyzed using Mixed Rasch Model to define latent classes derived from personal factors; which yielded results on the presence of DIF and if so, the threshold value(s) associated with it.

Results

Overall DIF results can be seen in Fig 1. In summary, for ODI; questions (Q) 3, 6, 9 and 10 were found not to be sensitive to any RP whereas Q4 was sensitive to 6, and Q5 to 4. For SRS22; Q3, 5, and 18 were sensitive to almost all RP. More importantly, 12

SRS22 Q were found to be sensitive to MCCA, which attests to its origin as a scale for scoliosis.

Conclusion
The results of this study demonstrate that both ODI and SRS22 are moderately sensitive to radiological parameters in ASD patients, through certain questions. These items, analyzed separately or assembled as a specific ASD HRQoL scale may be functional in establishing a connection between changes in RP and HRQoL.

Take Home Message
Few items from HRQLs are directly responsive to radiologic changes. These items might be taken special attention when evaluating ASD.

229. Spino-pelvic Mismatch (PI-LL) is the Key Determinant of Patient Outcome at Average 46 Years after Instrumented Fusion

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Summary
An AIS patient cohort with 46-year follow-up after PSIF with Harrington instrumentation underwent sagittal plane radiographic analysis which was correlated with PROMIS, EQ-5D, Oswestry, SRS-7 scores and surgical details. Spinopelvic imbalance PI(pelvic incidence)- LL(lumbar lordosis) greater than 9 had higher pain interference, fatigue, higher rates of additional spinal surgery and higher prevalence of LIV at L4 and below. Sagittal plane measurements, including sagittal vertical axis(SVA), pelvic tilt(PT), and thoracic kyphosis(TK) were not correlated with patient outcomes at mean 46-year follow-up.

Hypothesis
AIS patients with favorable PROMs at long term follow-up will demonstrate more desirable sagittal plane radiographic measures.

Design
Long term follow-up

Introduction
Sagittal plane reconstruction has been shown to be an important in spinal deformity surgery. Numerous radiographic measures and parameters have been utilized to assess sagittal plane balance. Which radiographic measure is most important to reconstruct for the best long term outcome is unknown.

Methods
314 patients treated by Louis Goldstein with Harrington instrumentation between 1961 and 1977 were identified to assess overall health and function. 35 patients returned for follow-up radiographs and were analyzed for TK, LL, PI, SVA, pelvic tilt, sacral slope and PI-LL. Health and function were assessed with EQ-5D, Oswestry, SRS-7, and PROMIS. Bivariate analyses were conducted for cohorts meeting and failing to meet sagittal alignment thresholds (PI-LL< or =9, SVA<50mm, PT< 22). Multivariate analyses using linear regressions were performed for radiographic analysis, PROMIS scores, SRS, Oswestry and EQ-5D.

Results
We identified 91 patients with follow-up from 38.7 to 54.2 years and age from 51 to 70 years. 76 completed outcome questionnaires and 35 returned for scoliosis radiographs. The mean age was 60.5years, 94% female, and mean follow-up 46 years. In the bivariate analysis PI-LL>9 was the only radiographic parameter which significantly discriminated between patients "doing well" and those "not doing well" by Oswestry, PROMIS-Pain Interference(PI) and PROMIS-Fatigue(Table 1) In multivariate analysis, PI-LL>9 had statistically worse scores in PROMIS-Pain Interference, Physical Function, Anxiety, Depression, Fatigue, Social Function and Oswestry scores. In the PROMIS Anxiety and Depression, and SRS-7 models, SVA>50 mm was associated with worse scores(Table 2) LIV at L4 and below was correlated with less desirable PROMIS-PI.

Conclusion
In a cohort of patients treated with PSIF for AIS at average 46 year follow-up, desirable long-term PRO scores are most predictably associated with achieving and maintaining PI-LL< or =9, as opposed to the other well publicized sagittal plane measures.

Take Home Message
In a cohort of patients treated with PSIF for AIS at average 46 year follow-up, desirable long-term PRO scores are most predictably associated with achieving and maintaining PI-LL< or =9.

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Table 1: Sagittal Plane Radiographic Alignment and HRQoL Outcomes

	PI-LL <=9	PI-LL >9	P-value
EQ-5D	0.90	0.83	0.05
ODI	4.69	13.61	0.02*
SRS-7	24.50	22.61	0.11
PROMIS-PI	44.63	51.84	0.04*
PROMIS-Fatigue	39.22	49.94	0.01*
PROMIS- Anxiety	43.57	46.65	0.62
PROMIS-Depression	42.60	46.06	0.38

* Statistical significance at P-value <0.05

Table 2: Multivariate Analysis of Sagittal Alignment and PROMs in Beta Estimates [95% CI]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
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Sagittal Plane Radiographic Alignment and HRQoL Outcomes and Multivariate Analysis

230. Rates of Hospital Acquired Conditions Increase with Frailty Severity: A Modified Frailty Analysis Surgical Spine Patients

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Summary

Hospital acquired conditions(HACs), established in the Affordable Care Act, are defined as reasonably preventable complications(i.e. never events). HAC rates are elevated in surgical spine patients, and previous studies have not assessed the impact of frailty on frequencies. This study evaluated the rates of HACs, specifically superficial or deep surgical site infection(SSI), deep venous thromboembolism(VTE) and urinary tract infection(UTI), across frailty states, categorized by the modified NSQIP 5-factor frailty index(mFI-5: no frailty[NF]:<0.3, mild frailty[MF] 0.3-0.5, severe frailty[SF]>0.5).

Hypothesis

Increase in frailty status is associated with rise in HACs in surgical spine patients

Design

Retrospective review

Introduction

In high risk populations, such as severely frail surgical spine patients, elevated HAC rates call for the identification of potential risk factors.

Methods

Patients>18yrs identified in ACS-NSQIP database from 2005-2016. HACs identified: SSI, VTE, UTI. Descriptive analysis quantified rates of patient characteristics, operative details, and HAC prevalence. Patients were stratified via frailty status, and chi-square analysis elucidated significant annual trends and HAC rate among varying frailty groups. Multiple binary logistic regression assessed the effect of patient and operative characteristics on HAC occurrence amongst frailty sub-stratified populations.

Results

231,951 patients(57yrs, 48%F, 30.3kg/m²). From 2005 to 2016, rates of "Never events" decreased(22% to 3%, p<0.001). 7567(3%) of patients developed HACs, the most common was SSI(1.4%), followed by UTI(1.2%) and VTE(0.8%). According to frailty categories, 83.3% were NF, 15.2% MF and 1.5% SF. Prevalence of NF patients decreased(2005:89.4% to 2016:82.2%, P<0.001), while MF patients increased(9% to 16%, P<0.001), and SF remained constant(1.6% to 1.6%). After stratification by mFI-5, the prevalence of HACs increased from scores of 0 to 1(P<0.001). The individual prevalence of SSI, UTI, and VTE also increased significantly in frailty score(P<0.001). Regression analysis determined CCI(OR: 1.23[1.17-1.30], P<0.001), op time(P<0.001), BMI(P<0.001), frailty(p<0.001), and history of diabetes mellitus(P<0.001) as significant predictors on acquiring HACs. Increased frailty severity also predicted increased total HACs(OR:1.66[1.59-1.74], P<0.001), SSI(1.62[1.51-1.73], P<0.001), UTI (1.92[1.79-2.05], P<0.001), and VTE occurrences(1.42[1.29-1.55], P<0.001). Increased frailty severity predicted increased total length of stay(p<0.001), readmission(p<0.001), and total number of complications(p<0.001).

Conclusion

Frailty severity is associated with increased risk of acquiring HACs(SSIs, UTIs, and VTEs).

Take Home Message

Frailty impacts postop complications, especially the development of never events following spine surgery. This information can ultimately be utilized in an evidence based approach to preoperative optimization.

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

231. Identifying Predictors of Extended Intensive Care Unit Stay Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

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Summary

Among adolescent idiopathic scoliosis (AIS) patients undergoing posterior spinal fusion (PSF) in the NSQIP-Pediatric Procedure Targeted database, patients' demographics and number of levels fused did not impact postop intensive care unit length of stay (ICU LOS). However, baseline (BL) comorbidities were associated with extended ICU LOS. Specifically, asthma and cognitive impairment/developmental delay increased odds of >1-day ICU LOS. Additionally, hematological disorders and structural airway abnormalities predicted extended ICU LOS (>3-day). These findings may improve preoperative optimization and postoperative risk stratifications.

Hypothesis

BL pt factors will impact ICU LOS in pts undergoing PSF for AIS.

Design

Retrospective review of prospectively-collected data from 93 centers

Introduction

Previous studies have examined postop procedures to expedite discharge after PSF for AIS to improve outcomes & reduce complications/readmissions. Little predictive data exists for ICU LOS for AIS pts following PSF, thus we sought to identify any BL factors associated with lengthier postop ICU LOS.

Methods

We identified all AIS pts undergoing elective PSF (CPT-22800-4) by ortho/neurosurgeons in 2016 in the ACS NSQIP-Pediatric Procedure Targeted database & grouped pts by ICU LOS (days): G1,0-1; G2,2-3; & G3,>3 days. BL demographics, comorbidities, & periop factors were compared via univariate analysis with post-hoc Bonferroni. Multivariate regression identified predictors of G2 & G3.

Results

Included: 2346 AIS pts undergoing PSF (G1: 81.8%; G2: 16.5%, G3: 1.7%). Age, sex, or race were comparable across cohorts. G3 & G2 had higher asthma rates compared to G1: (19.5, 10.1 vs 5.5%). G3 also had higher structural airway abnormalities (19.5 vs 1.6, 1.1%) & hematologic disorders (9.8 vs 1.0, 0.8%), all $p<0.05$, though these were comparable between G2 & G1. Cognitive impairment/developmental delay rates were highest for G3 (26.8 vs 10.9, 6.2%), all $p \leq 0.032$. OR time was highest for G3 vs G2 & G1 (346.1 vs 292.6 vs 259.5mins). G3 group had the highest % of pts with ≥13-level fused (51.2%) vs G2 & G1 (20.7, 26.5%), all $p<0.05$. Groups had comparable % pts with ≤6-level PSF. BL hematol disorders & structural airway abnorms increased odds of >3D ICU LOS (OR=9.0, 6.5; $p<0.005$). Asthma & cognitive impairment both increased odds of >3 & 2-3d ICU LOS (OR=2.7, 1.7; OR=2.7, 1.9), respectively, all $p<0.05$.

Conclusion

Longer OR time & increased BL comorbidities were associated with increased ICU LOS in AIS pts. Hematologic disorders, structural airway abnormalities, asthma & cognitive impairment increased the odds of >3d ICU LOS by 9.0, 6.5, 2.7 & 2.7-fold, respectively. These results may help improve preop optimization & postop risk-stratification, potentially curbing costs & postop complications.

Take Home Message

Counseling/screening may benefit AIS pts undergoing PSF to identify baseline risk-factors of prolonged postop ICU LOS. Hematologic disorders and pulmonary structural abnormalities, among others, were associated with >3-day ICU LOS.

Baseline Comorbidities	0-1 Day	2-3 Days	>3 Days	p-value
History of asthma	5.5%	10.1%	19.5%	<0.001
Bronchopulmonary dysplasia/chronic lung disease	2.0%[a,b]	1.3%[b]	7.3%[a]	0.032
Structural pulmonary/airway abnormalities	1.1%	1.6%	19.5%	<0.001
Esophageal/gastric/intestinal disease	2.6%	4.1%	7.3%	0.066
Previous cardiac surgery	1.6%	2.5%	7.3%	0.008
Developmental delay/impaired cognitive status	6.2%	10.9%	26.8%	<0.001
Seizure disorder	1.1%	2.3%	2.4%	0.159
Cerebral palsy	0.4%	0.8%	0.0%	0.483
Structural CNS abnormality	4.7%	5.4%	9.8%	0.305
Neuromuscular disorder	5.4%	6.7%	9.8%	0.321
Hematologic disorder	1.0%	1.8%	9.8%	<0.001
Past or current cancer	0.4%	0.8%	2.4%	0.145
Posterior Spinal Fusion, Levels Fused	**0-1 Day**	**2-3 Days**	**>3 Days**	**p-value**
≤6	7.8%	9.3%	9.8%	
7-12	65.6%	70.0%	39.0%	<0.001
≥13	26.5%	20.7%	51.2%	

Table. Comparison of baseline comorbidities and levels fused during PSF across ICU LOS groups: 0-1, 2-3, and >3 days. Superscript letters indicate inter-group differences following post-hoc Bonferroni. Differences in superscript letters indicate $p<0.05$.

232. Intraoperative Ketamine May Increase Risk of Post-Operative Delirium After Complex Spinal Fusion for Adult Deformity Correction

Aladine A. Elsamadicy, MD; Isaac O. Karikari, MD

Summary

Aim of study was to identify the impact that intraoperative ketamine has on post-operative outcomes after complex spinal sur-

gery involving ≥5 level fusions. The medical records of 138 adult spine deformity patients undergoing elective, primary complex spinal deformity correction. In a multivariate nominal-logistic regression analysis, intraoperative Ketamine-Use was independently associated with post-operative delirium [OR: 9.475, 95% CI (1.026, 87.508), p=0.047). Our study suggests that the intraoperative use of ketamine may increase the risk of post-operative delirium.

Hypothesis
Ketamine increases risk for post-op delirium

Design
Retrospective Cohort Study

Introduction
There have been a few studies suggesting that intraoperative ketamine may have deleterious effects and impact post-operative delirium. Therefore, we sought to identify the impact that intraoperative ketamine has on post-operative outcomes after complex spinal surgery involving ≥5 level fusions.

Methods
The medical records of 138 adult (≥18 years old) spine deformity patients undergoing elective, primary complex spinal fusion (≥5 level) for deformity correction at a major academic institution from 2010 to 2015 were reviewed. We identified 98 (71.0%) who had intraoperative ketamine administration and 40 (29%) who did not.

Results
Patient demographics and comorbidities were similar between both cohorts, including age, gender, and BMI. The median number of fusion levels operated, length of surgery, estimated blood loss, and proportion of patients requiring blood transfusions were similar between both cohorts. Postoperative complication profile was similar between the cohorts, except for the Ketamine-Use cohort having significantly higher proportion of patients experiencing delirium (Ketamine-Use: 14.3% vs. No-Ketamine: 2.6%, p=0.047). In a multivariate nominal-logistic regression analysis, intraoperative Ketamine-Use was independently associated with post-operative delirium [OR: 9.475, 95% CI (1.026, 87.508), p=0.047).

Conclusion
Our study suggests that the intraoperative use of ketamine may increase the risk of post-operative delirium. Further studies are necessary to understand the physiological effect intraoperative ketamine has on patients undergoing complex spinal fusions in order to better overall patient care and reduce healthcare resources.

Take Home Message
Intraoperative use of ketamine may increase the risk of post-operative delirium. Further studies are necessary to understand the physiological effect intraoperative ketamine has on patients on complex spine surgery.

233. Development of a Surgeon Specific Risk Stratification Model for Complex Adult Spinal Deformity Surgery

Nathan J. Lee, MD; Xudong Joshua Li, MD, PhD; Meghan Cerpa, BS, MPH; Eric Leung, BA; Zeeshan M. Sardar, MD, MS, FRCS(C); Ronald A. Lehman Jr., MD; Lawrence G. Lenke, MD

Summary
Several large multicenter database studies have investigated complications and associated risks in developing risk stratification models for adult spinal deformity surgery. However, these models often lack surgeon-specific variables that fail to account for differences that exist between care provided by surgeons at specific institutions. Using surgeon-specific perioperative factors and outcomes, a surgeon- specific risk stratification model was generated to help guide spine deformity surgeons and their own patients in their decision making.

Hypothesis
It is possible to develop risk stratification models from single-surgeon perioperative data which will intuitively be more accurate and reliable in predicting postoperative complications for those surgeon's own practice and patients.

Design
Single-surgeon cohort study

Introduction
Complex adult spinal deformity is known to be associated with significant medical and surgical complications. Numerous large databases have studied this topic; however, they lack surgery-specific variables and fail to account for the variability that exists between care provided by surgeons at different institutions. Using surgeon-specific perioperative factors and outcomes, a risk stratification model was generated to help guide spine deformity surgeons and their own patients in their decision making..

Methods
183 adult (age ≥18) patients undergoing complex spinal deformity surgery (>5 levels) by a single surgeon at a single institution between 2015 and 2018 were reviewed. Demographics, operative characteristics, medical and surgical outcomes were assessed. Stepwise multivariate logistic regression was used to identify independent risk factors to serve as a predictive model for postoperative complications.

Results
The total complication rate was 28.4% (medical 20.2%, surgical 11.5%) with an average follow-up of 5.2 months (3months-2 years). The final model was significant (x2 28.1, p=0.0009), demonstrated good fit (Hosmer-Lemeshow x2=9.2, p = 0.327),

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and was calibrated by using the area under the receiver operating characteristics curve analysis (c=0.798). The model included BMI, number of osteotomies, operative time, hypothyroidism, history of DVT/PE, 3 column osteotomies (CO), age, and revision vs. primary surgery. Having hypothyroidism and history of DVT/PE increased risks for any complication by 2.6 and 6.4-fold respectively. The strongest independent risk factors for any complications were having a 3CO, operative time, age, and revision surgery.

Conclusion

This single-surgeon model demonstrated that specific patient factors and operative characteristics can reliably predict complications after complex deformity surgery for this surgeons' own patients.

Take Home Message

Variability in care exists between surgeons and institutions. Single-surgeon data is intuitively more accurate prediction tool than multicenter data to inform surgeons and their patients in the surgical decision-making process

Patient factors, Operative characteristics, and Outcomes

	No Complication (%)	Any Complication (%)	
N	131	52	P value
Female	66.4	73.1	0.382
Age			
≤40	43.5	21.2	0.032
41 to 50	9.9	11.5	
51 to 60	22.9	23.1	
61 to 70	22.1	40.4	
≥71	3.9	1.5	
ASA >2	19.9	34.6	0.035
BMI >30	45.0	42.3	0.737
Comorbidities			
Cardiac	26.7	36.5	0.189
Pulmonary	16.8	13.5	0.578
Gastrointestinal	0	3.9	0.024
Osteoporosis/Osteopenia	17.6	28.9	0.09
Diabetes	2.3	0	0.271
Hypothyroidism	9.2	23.1	0.012
Anemia	1.9	1.5	0.849
HxPneumonia	0	1.9	0.112
HxTIA	0	1.9	0.112
HxAnxiety	15.3	19.2	0.514
HxDepression	19.1	25.0	0.374
HxDVTPE	3.1	7.7	0.166
HxCancer	3.1	7.7	0.166
Operative Characteristics			
TIL, mean (sd)	14.3 (3.6)	15.3 (3.4)	0.081
3CO	7.6	21.2	0.01
PCO	90.8	90.4	0.924
# Osteotomies, mean (sd)	5.5 (3.0)	5.7 (3.1)	0.797
Pelvic Fixation	58.8	80.8	0.005
EBL, mean (sd)	1400.4 (765.4)	1722.1 (748.6)	0.011
Postoperative Transfusion Units, mean (sd)	1.0 (1.1)	1.4 (1.1)	0.014
Operative Time, mean (sd)	402.7 (178.1)	517.1 (146.8)	<0.001
Anesthesia Time, mean (sd)	556.6 (137.2)	645.1 (115.5)	<0.001
Revision Surgery (vs Primary)	35.9	57.7	0.007
Outcomes			
	N	%	
Any Postop Medical or Surgical Complication	53	28.4%	
Any Postop Medical Complication	37	20.2%	
Any Postop Surgical Complication	21	11.5%	

Independent Risk Factors for Any Complications C=0.78, HL=0.327	OR	95 CI		P value
BMI	0.9	0.8	1.0	0.041
# of Osteotomies	1.1	1.0	1.3	0.118
Operative duration	1.0	1.0	1.0	0.010
Hypothyroidism	2.6	0.9	7.1	0.067
Hx of DVT/PE	6.4	0.8	49.1	0.073
3CO	4.9	1.3	18.3	0.019
Age at Surgery	1.0	1.0	1.1	0.006
Surgery Revision vs Primary	2.7	1.2	6.0	0.019

234. Defining Quantitative Factors Associated with Spontaneous Lumbar Curve Correction in Lenke 1 AIS

Saba Pasha, PhD; Jean-Marc Mac-Thiong, MD, PhD

Summary

The aim of this study was to identify the range of optimal versus suboptimal rates of spontaneous lumbar Cobb correction (SLCC%) and the factors predicting such outcomes in a cohort of Lenke 1 adolescent idiopathic scoliosis (AIS) after posterior spinal fusion surgery. In 71 Lenke 1 AIS, in addition to the previously determined factors, we identified that specific range of the preoperative patient parameters and surgeon modifiable factors can guide achieving a well-targeted lumbar Cobb correction.

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Hypothesis

a combination of the patient specific parameters and surgeon modifiable factors increase the chance of achieving optimal lumbar Cobb correction in Lenke 1 AIS patients.

Design

retrospective cohort

Introduction

The aim of this study was to identify the range of optimal versus suboptimal rates of spontaneous lumbar Cobb correction (SLCC%) and the factors predicting such outcomes in a cohort of Lenke 1 adolescent idiopathic scoliosis (AIS) after posterior spinal fusion surgery.

Methods

71 consecutive Lenke1 B and C AIS patients with a fusion level to L1 and higher with two-year follow-up were included. Thoracic kyphosis (T1-T4 and T4-T12 TK), lumbar lordosis (L1-S1 LL), thoracic and lumbar Cobb angles, thoracic and lumbar apical vertebral rotation and translation (AVR and AVT), pelvic incidence (PI), sacral slope (SS), and sagittal and frontal balances (SB and FB) were measured at pre-operative, early post-operative, and two-year follow-up. The SLCC% was calculated between pre-operative and two-year follow-up. A clustering analysis determined the subgroups of patients with significantly higher and lower (optimal versus suboptimal) rate of SLCC% in the cohort. The cutoff values of the pre-operative and early post-operative radiographic parameters that significantly predicted the optimal and suboptimal SLCC% were determined using a decision tree.

Results

The averages of the optimal versus suboptimal range of SLCC% in the cohort were 72% [55%, 105%] versus 39% [-7%, 42%]. Pre-operative and early post-operative spinal parameters predicted the optimal versus suboptimal SLCC% with an accuracy of 82%, 95%CI [0.73-0.94]. Pre-operative AVTLumbar<10mm or in patients with a pre-operative AVTLumbar>10mm, early post-operative T4-T12 TK<24° accompanied by -5°<AVRThoracic<5° were the main predictors of optimal SLCC% in our cohort.

Conclusion

Quantitative clustering of the SLCC% into optimal and suboptimal groups allowed identifying the cutoff values of pre-operative (AVTLumbar) and early post-operative (T4-T12 TK and AVRThoracic) spinal parameters that can predict the optimal range of SLCC% at two-year post-operative in our cohort of Lenke 1 AIS.

Take Home Message

Selecting patient specific parameters (lumbar apical translation) and combination of surgeon modifiable factors (thoracic derotation and imparted kyphosis) can predict a well targeted rate of SLCC in Lenke 1 AIS.

235. An Analysis of Two Distinct Types of Lenke 5 Curves in Adolescent Idiopathic Scoliosis (AIS) Patients Planned for Posterior Spinal Fusion

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Summary

80 Adolescent Idiopathic Scoliosis patients were recruited in this study to define Lenke 5 curves into two subtypes: Lenke 5-ve (flexible) and 5+ve (stiff) based on the Main Thoracic (MT) flexibility on supine side bending radiographs. Lenke 5+ve (stiff) curves had significantly larger preoperative MT Cobb angle and MT side bending Cobb angle with a more proximal UIV level. Therefore, a more proximal UIV selection might be required for Lenke 5+ve (stiff) curves to attain good coronal balance.

Hypothesis

Lenke 5 curve has two subtypes (flexible vs. stiff) based on the Main Thoracic (MT) curve characteristics and Upper Instrumented Vertebra (UIV) selection.

Design

Retrospective study of a prospective database.

Introduction

UIV selection in Lenke 5 curves is controversial. Incorrect UIV selection could result in coronal decompensation. The non-structural MT curves might demonstrate a wide range of flexibility and this could determine the feasibility of selective thoracolumbar/lumbar fusion.

Methods

80 Lenke 5 AIS patients who underwent posterior spinal fusion (PSF) with minimum 2 years follow up were recruited. Patients who had preoperative MT side bending (SB) Cobb angle <15° were classified as Lenke 5-ve (flexible) curves whereas patients with MT SB Cobb angle of 15° – 24.9° were classified as Lenke 5+ve (stiff) curves. Each subgroup had 40 patients. The statistical differences for preoperative radiological parameters, UIV selection and postoperative outcome were analyzed using independent sample t test and chi-squared test.

Results

Preoperative MT Cobb angle was 30.4 ± 9.6° and 41.5 ± 8.4° in Lenke 5-ve and 5+ve curves respectively (p<0.001). Preoperative MT SB Cobb angle (6.8 ± 4.7° vs. 18.7 ± 4.3°) and MT flexibility (77.9 ± 13.9° vs. 54.1 ± 10.6°) comparing Lenke 5-ve and Lenke 5+ve curves also showed significant differences. The commonest UIV selected in Lenke 5-ve curves was T9 (n=10, 25%), T10 (n=10, 25.0%), followed by T11 (n=9, 22.5%). In Lenke 5+ve, T6 was the UIV selected in 12 patients (30.0%) and T7 was selected in 10 patients (25.0%). The difference in distribution of

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UIV selection was statistically significant. Lenke 5+ve curves had more levels fused, 9.6 ± 1.7 levels vs. 7.9 ± 2.0 levels in Lenke 5-ve curves (p<0.001). Both groups had comparable preoperative and postoperative shoulder and coronal balance.

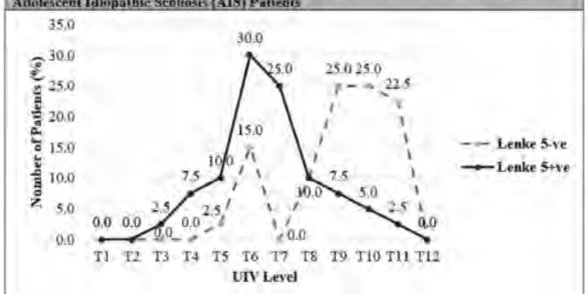
Conclusion

Patients with Lenke 5+ve (stiff) curves had significantly larger preoperative MT Cobb and MT SB Cobb angle and might require a more proximal UIV selection to achieve ideal coronal balance.

Take Home Message

There were two subtypes of Lenke 5 curves. Lenke 5+ve (stiff) curves had larger preoperative MT Cobb as well as SB Cobb angle and required a more proximal UIV selection.

Distribution of Upper Instrumented Vertebra (UIV) Level between Lenke 5-ve and 5+ve Adolescent Idiopathic Scoliosis (AIS) Patients



Parameters	Lenke 5-ve (n = 40)	Lenke 5+ve (n = 40)	p value
Preoperative			
MT Cobb Angle (°)	30.4 ± 9.6	41.5 ± 8.4	<0.001*
MT SB Cobb Angle (°)	6.8 ± 4.7	18.7 ± 4.3	<0.001*
MT Flexibility (%)	77.9 ± 13.9	54.1 ± 10.6	<0.001*
Coronal Balance (mm)	-7.5 ± 16.3	-6.1 ± 16.0	0.707
Postoperative			
Coronal Balance (mm)	-5.7 ± 7.7	-5.3 ± 10.5	0.875
Number of fusion level (n)	7.9 ± 2.0	9.6 ± 1.7	<0.001*

MT: Main Thoracic; SB: side bending
*significant

236. Large Deformity and Post-Operative PI-LL Matching Predict Improvements in Pain for Patients with AIS: Results from the PORSCHE Study

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Summary

The PORSCHE study, which is a prospective multicenter cohort of AIS patients, demonstrated that the majority of patients had moderate to severe pre-op pain (mean "worst" NRS 4.8) that improved post-operatively (mean "worst" NRS 1.6). Pre-operative scoliosis >80 degrees and pre-operative thoracic kyphosis >40 degrees were each associated with significant post-operative improvement in pain. Post-operative PI-LL mismatch was associated with significant post-operative pain.

Hypothesis

There are radiographic predictors of post-op pain following surgery for AIS

Design

Prospective multicenter

Introduction

It is well documented that there is wide variability in the treatment of post-op pain in children at home following minor surgery. To date, there has been very little systematic, prospective research examining the severity, trajectory, and treatment of children's pain at home following major surgery. The purpose of this research was to examine the radiographic predictors of post-op pain following surgery for AIS.

Methods

The Post-Operative Recovery after Scoliosis Correction: Home Experience (PORSCHE) study evaluated pre-op and min. 2 yr f/u scoliosis and sagittal spinopelvic parameters (thoracic kyphosis–TK, lordosis–LL, pelvic tilt-PT, sacral slope-SS, pelvic incidence-PI). These variables were compared to "average" and "worst" numeric rating scale for pain (NRS). NRS 0-3=mild, 4-6=moderate, 7-10=severe. Continuous and categorical variables were assessed using logistic regression and binomial variables were compared to binomial outcomes using chi square.

Results

190 (163 female) patients with mean age 14.6yr (11-19yr) from 8 Canadian centers met inclusion criteria. Mean pre-op vs final: Scoliosis 61±16 vs 18±8deg*; TK 21±17 vs 20±10deg; LL 60±12 vs 57±12deg*; PT 10±11 vs 11±13deg; SS 41±9 vs 41±9deg; PI 51±13 vs 51±15deg; SVA -7±30mm vs -11±31mm. Mean "worst" NRS 4.8 pre-op vs 1.6 final*. Number of patients with "worst" NRS pre-op vs final: Mild 72 vs 102; Mod 48 vs 15; Severe 65 vs 4. Significant findings: Pre-op scoliosis >80deg odd's ratio 6.4 (1.1-35.6) for having pre-op "average" NRS moderate or severe improve to mild at final f/u*; pre-op TK>40deg has OR 4.7 (1.1-19.3) for having pre-op "worst" NRS severe improve to mild or moderate at final f/u*; post-op PI-LL>10deg has OR=4.7 (1.3-17.7) for having final f/u "worst" NRS moderate or severe*. *p<0.05.

Conclusion

AIS patients with large pre-operative scoliosis or large pre-operative thoracic kyphosis should be counselled that their pain may improve post-operatively. Surgeons should ensure PI-LL matching post-operatively to minimize post-operative pain.

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Take Home Message
AIS patients with large pre-operative scoliosis or large pre-operative thoracic kyphosis should be counselled that their pain may improve post-operatively. Surgeons should ensure PI-LL matching post-operatively to minimize post-operative pain.

237. Changes in Pain and Physical Function Best Predict Patient Satisfaction with ASD Management After Fusion Surgery

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Summary
In this longitudinal study of ASD fusion patients, 520 PROMIS and SRS questionnaires were completed by 177 patients, and logistic regression was utilized to predict a SRS satisfaction score of 5/5 given a 5-point improvement in PROMIS domains. Our analysis determined that improvements in pain are the most important factor for patients at 6 weeks and 3 and 6 months postoperatively, and that physical function is the best predictor of patient satisfaction at 12 months.

Hypothesis
Improvement in certain PROMIS domains will best predict ASD surgery patients' satisfaction with their spine management as measured by the SRS questionnaire

Design
Longitudinal study

Introduction
Understanding how improvements in troublesome symptoms affect patient satisfaction is of great clinical use, particularly in setting appropriate expectations with patients prior to surgery. PROMIS is a multi-dimensional assessment that measures spine patients' pain interference, physical function, fatigue, anxiety, depression, sleep disturbance, and social participation with a population mean of 50 (SD 10). The SRS patient questionnaire measures satisfaction on a 5 point scale. The objective of this study is to investigate the potential relationship between PROMIS domain changes and the SRS satisfaction score.

Methods
Patients undergoing surgery for adult spinal deformity completed PROMIS and SRS questionnaires preoperatively and 6 weeks and 3, 6 and 12 months postoperatively. Between Feb. 2015 and Jan. 2018, PROMIS and SRS satisfaction data was collected for 520 visits of 177 unique patients. Stepwise logistic regression (forward selection) was used to model the likelihood of being satisfied (i.e., SRS satisfaction score 5/5) given each 5-point improvement in PROMIS health domains.

Results
At 6 weeks and 3 and 6 months after surgery, each 5-point improvement in pain was associated with increased odds of being satisfied (6 weeks, OR 1.35, p=.040; 3 months, OR 1.78, p=.006; 6 months, OR 1.44, p=.005). At 12 months after surgery, each 5-point improvement in physical function was associated with 60% increased odds of being satisfied (OR 1.60, p=.020).

Conclusion
The results suggest that the primary influence on patient satisfaction with ASD fusion surgery was improvements in pain and physical function. More specifically, pain reduction was the most important factor for patients at the 6 week and 3 and 6 months assessment, while gains in physical function was the most important factor for patients 12 months after surgery.

Take Home Message
Improvements in pain best predict patient satisfaction with ASD management at 6 weeks, 3 months, and 6 months follow-up. At 12 months follow-up, physical function best predicts satisfaction.

238. Comparison of Generic vs Spine-Specific Pain Surveys Administered before Surgery and Fulfillment of Expectations Measured after Surgery for Lumbar Degenerative Spondylolisthesis

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Summary
Compared to generic pain surveys such as PROMIS Pain Intensity and PROMIS Pain Interference, preop pain measured by spine-specific pain surveys (ODI and Global pain (VAS)) were more closely associated with spine specific patient reported outcomes of fulfillment of expectations of lumbar surgery. Whether generic pain surveys, such as PROMIS, are sufficiently sensitive to explain other outcomes of Lumbar Degenerative Spondylolisthesis needs to be assessed further.

Hypothesis
Spine-specific surveys correlates better with spine specific outcomes of surgery

Design
Prospective 2-year longitudinal study, tertiary spine center

Introduction
Generic and spine-specific surveys are used before surgery to measure pain. While both types can discern various aspects of pain,

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such as pain intensity and pain-associated disability, their ability to capture how pain impacts other outcomes, such as fulfillment of expectations, is not known.

Methods

Patients were interviewed preop surgery with the valid 20-item Expectations Survey addressing symptoms, physical function, and psychological well-being, with response options of complete to no improvement. To measure pain, patients completed global pain (VAS), modified ODI, and generic PROMIS measures of Pain Intensity and Pain Interference. Medical records were reviewed for surgeon-reported pain on flexion/extension on clinical exam and surgical complexity according to the Invasiveness Index. Two years postop patients completed same surveys. Statistics by multivariable linear regression was performed.

Results

Mean age 68, 61% women, 82% had LDS at only one level (69% L4/5), mean PI was 61o (30-84), mean PI-LL was 10o ((-16)-50), and the median surgical complexity was 7 (1-22). With respect to pain, 60% of patients had pain with extension, 25% with flexion. The median global (VAS) back pain was 6 (0-10), and mean values were: ODI 50 (6-88), PROMIS Intensity 55 (31-72), and PROMIS Interference 63 (3-100). The mean time to follow-up was 2.1 years. The mean Expectations Survey proportion of expectations fulfilled was .99 (0-3.53) Controlling for surgical complexity, higher proportions were associated with less ODI pain (1.1, CI 0.5-1.6, p=.0001), less global back pain (4.5, CI 1.6-7.3, p=002) and, to lesser extents, less generic PROMIS Pain Intensity (1.5, 0.3-2.6, p=.01) and Pain Interference (0.8, -0.1-1.6, p=.08).

Conclusion

Compared to generic pain surveys, preop pain measured by spine-specific pain surveys were more closely associated with the outcome of fulfillment of expectations.

Take Home Message

Spine specific pain scales correlates better with spine specific outcomes measures such as fulfillment of expectation compared to generic scales.

239. Insight into How to Use Multiple Skeletal Maturity Indices for Growth Assessment: Correlation Between Olecranon, Sanders and DRU Classification Systems

Prudence Wing Hang Cheung, BDSc (Hons); Federico Canavese, MD, PhD; Keith D. K. Luk, FRCS; Jason Pui Yin Cheung, MBBS, FRCS, MS

Summary

This was a radiographic analysis of 114 pediatric patients with hand and wrist, and elbow radiographs to study the relationships between olecranon, digital and wrist maturity indices. Olecranon stage 1 coincided with R3, R4, U3, SS1 and olecranon stage 5 occurring as early as R7, U6, SS4. All three indices used together can provide the best prediction for the peak height velocity (PHV) while the hand and wrist classifications provides better assessment of the post-PHV period until skeletal maturity.

Hypothesis

Combination of multiple maturity parameters provide better prediction of key maturity milestones.

Design

Cross-sectional radiographic study.

Introduction

No single maturity index provides perfect prediction of pubertal growth. Very often multiple parameters are used and their interaction can aid in more precise maturity assessment.

Methods

Left hand and wrist (Sanders staging; SS and Distal Radius and Ulna classification; DRU), and lateral elbow (olecranon staging) radiographs of paediatric patients were assessed by nine raters of different levels of experience. Their reproducibility and reliability were assessed using intra-class correlation and Goodman and Kruskal's gamma with Bonferroni correction. Inter-index associations, central tendency and dispersion of each maturity parameter were studied. Mapping of individual grades of each classification based on chronological age was performed.

Results

A total of 114 patients (63.2% girls) were studied. The reproducibility and reliability of the three maturity parameters were satisfactory, with significant correlations and associations (p<0.001) between them. All three indices overlapped across 10.2-15.1 years for girls and 12.6-16.1 years for boys. DRU grades depicted the highest and the lowest mean age for both genders. Mapping reveals uneven spans and coverage of different period by each maturity parameter, with olecranon stage 1 coincided with R3, R4, U3, SS1 and olecranon stage 5 occurring as early as R7, U6, SS4.

Conclusion

The simplified olecranon method and DRU classification can be used in conjunction at pre-pubertal and growth acceleration phases of pubertal growth spurt. All three parameters can provide precise PHV prediction, whereas only DRU and Sanders staging provides assessment of the post-PHV period until skeletal maturity.

Take Home Message

Using multiple maturity parameters improve growth prediction. Olecranon and DRU are useful for pre-pubertal phase, while all

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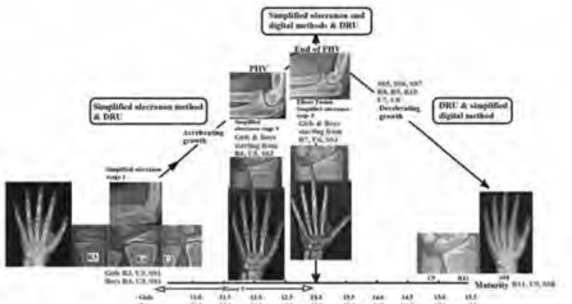
parameters predict PHV, and the DRU and Sanders stages assesses the post-PHV period.



Mapping of maturity indices

240. Extensive Corrective Fixation Surgery Improves Gait Posture in Elderly Patients with Spinal Deformities: A Comparison of Gait Analysis by Age Group

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Summary

In this study, we investigated the preoperative and postoperative gait status of 56 patients who underwent extensive corrective fusion from the thoracic spine to the pelvis between 2011 and 2016. Extensive corrective fusion surgery improved the postoperative walking posture of patients with adult spinal deformity. The effects of corrective fixation surgery on gait were similar among age groups. This suggests that the degree of gait improvement after corrective fusion surgery is the same between elderly patients and middle-aged patients.

Hypothesis

Elderly patients with adult spinal deformity may show different improvements in postoperative walking function owing to differences in muscular strength and bone quality between those in their 60s and those older than 75 years.

Design

Longitudinal cohort

Introduction

Extensive corrective fusion surgery was performed in patients with adult spinal deformity (ASD) to improve their abnormal posture. This study sought to compare the preoperative and postoperative gait posture and ability by age.

Methods

Among 224 patients with ASD, we included 56 patients (42 women; mean age, 68.8 years) who underwent extensive corrective fusion from the thoracic spine to the pelvis between 2011 and 2016. The results of a 4-m walk test were recorded preoperatively and 2 years postoperatively. The gait-trunk tilt angle and walking speed (m/min) were measured. We examined the patients after dividing them into 3 groups by age at the time of surgery: middle-age group, 40–64 years (n = 13); elderly group, 65–74 years (n = 28); and extremely elderly group, >75 years (n = 15).

Results

The mean preoperative gait-trunk tilt angle was significantly improved 2 years postoperatively (12.9° vs. 5.2°, $P < 0.01$). The mean preoperative walking speed also improved 2 years postoperatively (41.2 m/min vs. 45.7 m/min). In the analysis by age group (middle-aged, elderly, extremely elderly), the mean preoperative gait-trunk tilt angles of 11.9°, 10.0°, and 19.3° improved to 4.5°, 4.5°, and 7.2° at 2 years postoperatively, whereas the mean preoperative walking speeds of 47.9, 40.0, and 37.7 m/min improved to 52.4, 44.8, and 41.5 m/min at 2 years postoperatively, respectively. There were no statistically significant differences in the degree of improvement in the gait-trunk tilt angle and walking speed among the 3 age groups.

Conclusion

Extensive corrective fusion surgery improved the postoperative walking posture of patients with ASD. The effects of corrective fixation surgery on gait were similar among the groups. This suggests that the degree of gait improvement after corrective fusion surgery is the same between elderly patients and middle-aged patients.

Take Home Message

The degree of gait improvement after corrective fusion surgery is the same between elderly patients and middle-aged patients.

241. Risk of Curve Progression and Initial Curve Magnitude of Idiopathic Scoliosis in U.S. Children Based on Patient Age, Sex, Race, and BMI

Jeffrey Kessler, MD; Jasmine Vatani, BS; Annie Tram Anh N. Nguyen; Kevin Bondar

Summary

In a closed population of 4.5 million patients, moderately obese patients, females, Blacks and Whites tended to have the largest initial curve magnitude in childhood idiopathic scoliosis(IS). However, only younger age and larger initial Cobb angle significantly correlated with a higher risk of progression to a severe magnitude.

Hypothesis

Hypothesis: It currently is not clearly known from large self-con-

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tained populations of IS how ethnicity, sex, age, or body mass index correlate with 1) magnitude of initial curve presentation and 2) frequency of progression into a severe range(>40 degrees). Establishing the risk of presenting with larger magnitude curves, or of higher progression risk of IS based on these variables is an important step in understanding IS.

Design
Retrospective, cross-sectional analysis of a population of nearly 1 million children

Introduction
Most assessments of curve magnitude at presentation of IS and risk of progression are based on small populations. This study's purpose is to assess the effect of all patient demographics on these variables in a massive, self-contained population.

Methods
A prior retrospective chart review was done on all pts with IS < 18yo in the year 2013 assessing demographics & IS incidence. The same patient database was used to assess initial curve magnitude and final curve magnitude(with or without surgery) at minimum 2 year followup. Multivariable logistic regression analysis determined associations between age, sex, race, BMI & initial curve magnitude and odds ratio(OR) of progression to >40'.

Results
Blacks and Whites had a larger initial Cobb angle which was statistically significant (p<.004). Females had a 1.58 degrees higher initial Cobb angle(p<.001) and moderately obese patients had a 2.5 degrees higher initial magnitude vs normal weight (p<.004). In terms of risk of progression, pts with initial Cobb angle >25' had a 21x increased OR of progression to >40', as did those under age 10(OR 3.4). There was no statistically significant difference found in risk of progression based on sex, weight or ethnicity.

Conclusion
This represents the largest study on the demographics of IS, in a closed population of 4.5 million pts. It demonstrates that moderately obese patients, females, Blacks and Whites tend to have the largest curve presentation in childhood IS. However, only younger age and larger initial Cobb angle significantly correlated with a higher risk of progression to a severe magnitude.

Take Home Message
Females, obese patients, Blacks and Whites tend to have higher initial scoliosis magnitudes, though only younger patient age and higher initial curve magnitude correlated with risk of scoliosis progression.

242. Severe Pediatric Deformity Surgery had Frequent IOM Alerts but a Low Rate of Permanent Deficits at 2 Years

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Summary
Surgical treatment of severe pediatric spinal deformity is challenging and can have a high risk of neurologic injury. We investigated the incidence of IOM alerts during surgery and the development of new neurologic deficits in a prospective multicenter cohort. There was a 43% incidence of IOM alerts. However, after addressing the alerts intraop, only 2 pts had a new neurologic deficit at 2 yrs. Sagittal DAR is associated with IOM alerts and new neurologic deficits

Hypothesis
Severe pediatric deformity cases have frequent IOM alerts but few permanent deficits.

Design
Prospective observational multi-center cohort of severe pediatric deformity patients treated surgically for minimum curves of 100° or planned VCR.

Introduction
Severe pediatric deformity correction can be challenging. This study analyzed the safety, efficacy and durability of surgery at minimum of 2 yrs.

Methods
Pts with severe spinal deformity with minimum curves of 100° or planned VCR were followed for a min. 2 yrs postop. We studied x-ray parameters, IOM changes, postop deficits and recovery at min. 2 yrs.

Results
228/312 pts enrolled had a minimum 2 yrs f/u (QOLs and x-rays). 110/228 pts had a VCR and 1 a PSO. 212 had a post-only approach and 16 a combined ant/post. 228 pts had a total of 272 procedures including all stages; IOM alerts occurred in 102/272 procedures (38%). 98 pts (43%) had a total of 147 IOM alerts. An analysis was completed between a VCR, ant/post, C–DAR, S–DAR, and any IOM alert, SSEP, TCeMEP, or both. Only S-DAR was predictive for any IOM alert (p<.0001). The common triggering events were 3 column osteotomies (N=34), correction maneuvers (N=30), hypotension (N=25), implant and instru-

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mentation placement (N=20 and 19 respectively). Some alerts had multiple triggering events. 209 pts had a normal preop exam. 190 patients remained neurologically normal postop; 19 had new deficits. At 2 yrs postop, 16/19 with new deficits returned to normal, 2 continued to have a deficit, and 1 was lost to f/u. Analysis between ant/post, VCR, C-DAR and S-DAR indicated that S-DAR was associated (p=0.0035) with a new post-op deficit. 19 pts had a neurologic deficit preop; postop 6 improved to normal, 12 continued to have a deficit and 1 had a partial recovery. At 2 yrs, 13/19 with deficits preop totally recovered, 3 partially, 2 were the same, and 1 was lost to follow-up.

Conclusion

Pediatric pts with severe deformity had a 43% incidence of IOM alerts but after addressing the alerts intraop, only 2 pts had new deficits at 2 yrs. 16/19 pts with preop deficits improved or recovered.

Take Home Message

Neural monitoring should be mandatory in these cases. Sagittal DAR is associated with IOM alerts and new neurologic deficits.

Associations with neurological alerts during surgery.

Count		Response	Effect	Bivariable Odds Ratio, 95% CI and P-value				Multivariable Odds Ratio, 95% CI and P-value			
N 0	N 1	Variable		Odds Ratio	LCL	UCL	P-val	Odds Ratio	LCL	UCL	P-val
152	120	any_alert	A_P	0.402	0.110	1.190	0.1233	0.466	0.123	1.447	0.2128
152	120		C_DAR	1.022	0.982	1.064	0.2836	1.027	0.983	1.073	0.2420
151	120		S_DAR	1.068	1.037	1.101	<.0001	1.073	1.040	1.108	<.0001
152	120		VCR	1.009	0.620	1.640	0.9709	0.752	0.423	1.323	0.3256
108	12	SSEP_alert	A_P	3.184	0.150	27.398	0.3334	7.100	0.302	78.752	0.1302
108	12		C_DAR	1.068	0.957	1.175	0.2790	1.069	0.973	1.184	0.1717
108	12		S_DAR	1.026	0.963	1.090	0.4107	1.014	0.950	1.081	0.6734
108	12		VCR	2.116	0.635	7.559	0.2249	2.705	0.704	11.610	0.1540
44	76	TCeMEP_alert	A_P	0.568	0.066	4.868	0.5781	0.364	0.040	3.259	0.3351
44	76		C_DAR	0.972	0.911	1.034	0.3643	0.961	0.900	1.025	0.2331
44	76		S_DAR	0.972	0.933	1.012	0.1721	0.976	0.933	1.018	0.2586
44	76		VCR	0.676	0.318	1.434	0.3065	0.650	0.282	1.488	0.3074
88	32	Both_alert	A_P	0.914	0.044	7.440	0.9389	1.078	0.051	9.308	0.9501
88	32		C_DAR	1.009	0.943	1.080	0.7999	1.010	0.942	1.082	0.7856
88	32		S_DAR	1.021	0.978	1.066	0.3467	1.020	0.976	1.069	0.3789
88	32		VCR	1.123	0.491	2.541	0.7802	1.033	0.417	2.511	0.9435

All alert types are categorized as ever vs. never for each patient (across surgeries if in stages).

Associations with development of new neurological deficits among patients with normal neurological status preop.

Count		Response	Effect	Bivariable Odds Ratio, 95% CI and P-value				Multivariable Odds Ratio, 95% CI and P-value			
N 0	N 1	Variable		Odds Ratio	LCL	UCL	P-val	Odds Ratio	LCL	UCL	P-val
21	227	Neurological	A_P								
21	227	Neurological	C_D	0.969	0.898	1.043	0.4074	0.969	0.900	1.044	0.3945
21	227	Neurological	S_D	0.935	0.892	0.978	0.0035	0.935	0.890	0.980	0.0055
21	227	Neurological	VCR	0.860	0.350	2.186	0.7436	1.157	0.424	3.352	0.7794

Associations with neurological alerts during surgery and associations with development of new neurological deficits among patients with normal neurological status preop.

243. Medical Malpractice Litigation in Pediatric Scoliosis: A Comprehensive, Nationwide, Analysis for the Last Three Decades

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Summary

Among all cases of malpractice litigation in our analysis, Neurological complications were the most common reason for of malpractice litigation in pediatric scoliosis patients, followed by delay in diagnosis or treatment. The most likely outcome of these lawsuits was a jury verdict in favor of the surgeon

Hypothesis

With increasing number of pediatric patients undergoing surgical correction for scoliosis, malpractice litigation is expected to rise

Design

retrospective review of medico-legal database

Introduction

Reducing rates of litigation is imperative as it imposes an economic and psychological toll on all parties involved. Hence the purpose of this study was to characterize the most common reasons pediatric orthopedic surgeons are sued after performing surgical scoliosis correction, and also to report on the most likely outcomes of such lawsuits

Methods

The Westlaw legal research database and the Lexis Advance legal research database queried for jury verdicts and settlements completed between 1988 and 2018 for cases related to pediatric scoliosis in the United States. Cases were included if the patient was under 25 years old and had surgical correction of scoliosis. Causes of the lawsuit, patient characteristics and demographics, state/outcome of verdict or settlement, and indemnity payments were noted.

Results

A total of 72 records (47 females (65%), 24 males (35%)) with a mean age of 14 years (range, 2 to 25) were included in the final analysis. For all patients, massive neurological injury or paralysis was the leading cause for malpractice litigation (36%) followed by delay in diagnosis or surgery (35%), partial neurological injury (32%), and medical complications (15%). The jury ruled in the defense favor 43% of the time, and 30% in plaintiff's favor. Parties settled in 27%. Average indemnity was $2,778,703, ranging from $ 16,500 to $45,625,000.

Conclusion

Neurological complications were the most common reason for of malpractice litigation in pediatric scoliosis patients. Followed by

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delay in diagnosis or treatment. The most likely outcome of these lawsuits was a jury verdict in favor of the surgeon. However, the majority of cases resulted in some amount of payment, unlike what is currently reported in other orthopedic specialties. Average indemnity payment was also among the highest relative to that reported for other orthopedics specialties.

Take Home Message

Knowledge of malpractice litigation in pediatric scoliosis is relevant to surgeons and may help clear some of the ambiguity surrounding this possible scenario for any surgeon

244. Caudally Directed Upper-instrumented Vertebra Pedicle Screws Minimize the Risk of Proximal Junctional Failure in Patients with Long Posterior Spinal Fusion for Adult Spinal Deformity

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Summary

Adult Spinal Deformity patients undergoing long posterior fusion from the lower thoracic spine to the pelvis were investigated. Patients with upper instrumented vertebral (UIV) pedicle screws directed more than 3° cranially have 2.7 times greater odds of developing proximal junctional kyphosis and 3.9 times greater odds of developing proximal junctional failure at 2-years. UIV screws should be directed caudally in these patients to avoid the development of proximal junctional failure.

Hypothesis

Upper instrumented vertebral (UIV) pedicle screws directed caudally in Adult Spinal Deformity (ASD) patients with lower thoracic fusion will have lower incidence of Proximal Junctional Kyphosis (PJK) and Proximal Junctional Failure (PJF).

Design

Retrospective case series.

Introduction

PJK and PJF remain significant complications following ASD surgery. Orientation of UIV pedicle screws has not been studied as a potential risk factor.

Methods

ASD patients (>5 levels fused) were identified from a multi-provider academic institution with fusion from T8-T12 to pelvis. We defined a novel measurement of the UIV Screw Angle (UIVSA) as the mean of the angles between the UIV superior endplate and each UIV pedicle screw using intraoperative sagittal radiographs. A screw pointed cranially was measured as (+)UIVSA and a screw pointed caudally was measured as (-)UIVSA. PJK was defined as a proximal junction sagittal Cobb angle ≥10° and proximal junction sagittal Cobb angle ≥10° higher than preoperative measurement. PJF was defined as patients who had revision surgery for PJK. We examined the development of PJK and PJF in patients with UIVSA above and below +3° (maximum likelihood using an ROC curve), controlling for preoperative TK, osteoporosis and age.

Results

96 patients were studied with 2-year follow up. Mean age was 62 ± 11 years, 68% female. Mean follow-up was 4.6 ± 2.3 years. Patients had the following mean preoperative radiographic parameters: SVA: 10.7 ± 8.7 cm; TK: 33 ± 16°; Coronal Cobb 31 ± 17°. Mean UIVSA was -0.9° ± 6.0° (range -12.99° to 11.93°). 38 (40%) of patients had PJK at any timepoint and 28 (29%) went on to develop PJF. Patients with UIVSA greater than +3° had significantly greater odds of developing both PJK (OR 2.7 95% CI: 1.3, 7.0) and PJF (OR 3.6 95% CI: 1.3, 10.0). Screw-rod angle was not significantly associated with development of PJK/PJF, p>0.05.

Conclusion

In surgically treated ASD patients with lower thoracic fusion to the sacrum, a UIVSA greater than +3° is associated with 2.7 times greater odds of PJK and 3.9 times greater odds of PJF.

Take Home Message

Pedicle screws at the upper instrumented vertebra (UIV) should be directed caudally in ASD patients with thoracolumbar fusion to the pelvis to minimize the risk of proximal junctional failure.

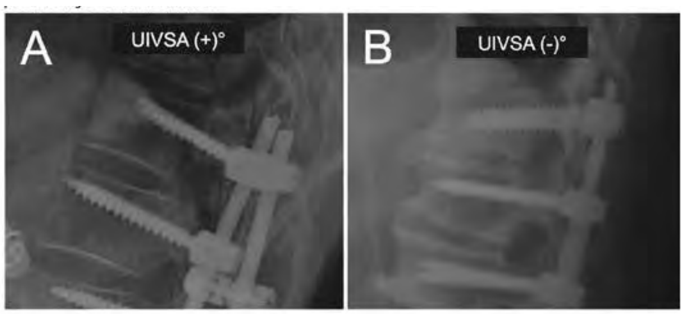

Figure 1. Sagittal Intraoperative Radiographs Demonstrating Positive (A) and Negative (B) UIVSA. Patients with UIVSA ≥+3° are at significantly greater odds of developing PJK and PJF.

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245. Preoperative Cervical Axis Deviation Increases the Risk of Postoperative Distal Adding-on Phenomenon in Lenke 1 and 2 Adolescent Idiopathic Scoliosis (AIS) Patients (Non-AR Curves)

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Summary
We studied 100 Lenke 1 and 2 (non-AR curves) patients to analyze the correlation between shoulder/neck imbalance and postoperative distal adding-on phenomenon. Distal adding-on phenomenon occurred in 19 patients. Risser grade, pre¬operative Cervical Axis (CA) and final follow up lumbar Cobb angle were the independent predictive factors. Positive preoperative CA deviation increased odds of distal adding-on by 5.4 times. There were significant differences in mean preoperative CA between patients with (3.0 ± 3.0°) and without adding-on (-0.1 ± 3.3°).

Hypothesis
Shoulder and neck imbalance before/ immediately after Posterior Spinal Fusion (PSF) could increase the risk of postoperative distal adding-on phenomenon.

Design
Retrospective study of a prospective database

Introduction
Distal adding-on phenomenon was proposed as a compensatory mechanism for postoperative shoulder imbalance.

Methods
We recruited 100 Lenke 1 and 2 AIS patients (non-AR curves) who underwent PSF. LIV was selected at the substantially touched vertebra by the CSVL in all cases. Medial shoulder and neck balance was represented by T1 tilt and Cervical Axis (CA). Lateral shoulder balance was represented by Clavicle angle (Cla-A) and Radiographic Shoulder Height (RSH). T1 tilt and CA > 0° were defined as positive (+ve). We diagnosed distal adding-on phenomenon when the disc below the LIV wedged > 5° or the end vertebra distalized. Predictive factors and odds ratio were derived from logistic regression analysis.

Results
Mean follow up duration was 30.9 ± 9.6 months. Distal adding-on phenomenon occurred in 19 patients (19.0%). Risser grade, preoperative CA and final follow up lumbar Cobb angle were the only independent predictive factors. Immediate postoperative shoulder and neck balance was insignificant. 15/19 (78.9%) patients with distal adding-on had +ve preoperative CA (p=0.001). This contrasted with 30/81 (37.0%) patients without adding-on phenomenon who had +ve preoperative CA. Positive preoperative CA deviation increased the odds of distal adding-on by 5.4 times (95% CI 1.34 – 21.51, p=0.018). There were significant differences in mean preoperative CA between patients with (3.0 ± 3.0°) and without adding-on (-0.1 ± 3.3°).

Conclusion
Distal adding-on phenomenon occurred in 19.0% of patients. Preoperative CA deviation increased the risk of distal adding-on phenomenon by 5.4 times. Other significant factors were Risser grade and final follow up lumbar Cobb angle. Immediate postoperative shoulder and neck imbalance was not a significant factor for distal adding-on phenomenon.

Take Home Message
Risser grade, preoperative CA and postoperative lumbar Cobb angle were independent predictive factors for distal adding-on phenomenon. Positive preoperative CA had 5.4 times increased odds of distal adding-on phenomenon.

Multivariate Binary Logistic Regression		
Factors	OR (95% CI)	*p*-value
Positive Preop Cervical Axis	5.36 (1.34, 21.51)	0.018
Risser 0	45.07 (2.91, 697.23)	0.006
Final Follow Up Lumbar Cobb	0.86 (0.78, 0.95)	0.004

Case illustration and outcome of logistic regression analysis in 100 Lenke 1/2 (non AR curve) AIS patients

246. Complications Related to Implants in the Management of Spinal Pathology in the Elderly Patient

Cristina Sacramento Dominguez, MD, PhD; Rocio Rodríguez-López, MD; Juan Ramón Prieto-Martínez, MD; Javier Tejada-Gallego, MD; Jose M. Silberberg Muiño, MD, PhD

Summary
Implant related complications is one of the challenge in the surgical management of elderly patients with spinal disorders. Our goal was to determine the rate and type of associated complications

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using fenestrated cemented pedicle screws. Our results show FPS improve the correction loss and decrease the rate of pseudoarthrosis. 34% of patients had cement leakage, 30% asymptomatic. Fenestrated cemented pedicle screws seem not deacrase the rate of proximal junctional failure.

Hypothesis

Fenestrated cemented pedicle screws decrease implant related complications

Design

Historical cohort study

Introduction

The management of deformity in the elderly population has associated greater number of comorbidities and risk of complications. Implant related complications is one of the challenge in the surgical management of these patients. The goal of our study was to classify and determine the rate and type of associated complications related to implants(CRI) using fenestrated cemented pedicle screws(FPS).

Methods

53 patients consecutively intervened between 2013 and 2017 were analyzed using FPS as fixation system. The inclusion criteria were ≥5 fusion level, ≥55 years. Demographic data, UIV,distal(DIV), proximal fixation type(PF) and radiological measurements(Cobb angles, pelvic parameters, proximal junctional kyphosis(PJK), proximal junctional failure(PJF) and sagittal alignment), were analyzed preop, postop and at the end of follow-up. Complications were classified as early and late (according to <or> 3 months). For the statistical analysis, the chi-square, Mann-Whitney test and Pearson correlation coefficient were performed.

Results

The mean age was 68.31±9.22, BMI 21.74±4.13, fused vertebrae 7.5±2. Early complications: compressive fractures(14):1 adjacent vertebra, 13 UIV with PF(cemented screws), failure of distal implant(2), leakage of local cement: venous or paravertebral plexus(11), intradiscal(2), epidural4) 7.5%;pulmonary embolism(1) asymptomatic. Late Complications: implant loosening: proximal screws(2), distal screws(5), broken rod(1). Thoracic kyphosis and PJK increased significantly at the end of follow-up (48.84±20.48,p0.004) and (16.38±16.7,p0.009), respectively (Rho0.517,p0.014). Patients with bad sagittal alignment (LL+PI +TK >45) developed proximal junctional failure (PJF)p0.002.

Conclusion

FPS improve the correction loss, decrease the rate of pseudoarthrosis. In our serie, the risk of pulmonary embolism and epidural cement leakage was low. 75% of the patients presented some CRI, 64% occurred before 3 months and 30% with cement leakage were asymptomatic. 28% of symptomatic patients(45%) required revision surgery; 21% related to PJF.

Take Home Message

The rate of complications related to implants is high in elderly patients Fenestrated cemented pedicle screws improve bone fixation and decrease implant loss Most of cement leakage are asymptomatic

247. Zero PCA is an Achievable Target for Postoperative Rapid Recovery Management of AIS Patients

Vishal Sarwahi, MD; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD

Summary

RRP pathway that incorporates micro-dose duramorph injection at the time of surgery allows for optimum pain control and periop management with better outcomes than the traditional PCA approach

Hypothesis

Use of intrathecal single micro-dose duramoprh can replace the need for PCA in a rapid recovery pathway protocol after scoliosis surgery

Design

Ambispective

Introduction

Narcotic substance addiction has been on a rise across all patient populations. Narcotics are often given in the form of patient controlled analgesic (PCA) during postop hospital stay as well as take home medication. The objective of this study was to report on one institution's use of intrathecal single micro-dose duramorph during surgery and its comparison to patients that had undergone traditional PCA.

Methods

In 2018, we instituted RRP for scoliosis patients undergoing PSF utilizing intrathecal micro dose duramorph. PCA used to be the mainstay for postop pain management. In the duramorph protocol, patients receive 1mcg/kg intraspinal morphine diluted in 1 cc saline administered preop by anesthesiologists or intraop by surgeon. AIS patients undergoing PSF from 2011 – 2018 were reviewed. PCA patients were included in Group 1(G1) and Duramorph in Group 2(G2). Periop data were analyzed. Fisher's exact test and Wilcoxon tests were utilized

Results

270 patients(PCA: 209;Duramorph:61). Median Cobb in G1 was 54° and 50° in G2(p <0.001). Levels fused were similar in both groups(12,p = 0.511). G2 did not require PCA, while G1 had a median of 3 days of PCA. G1 were more likely to have their first regular meal on POD 0 compared to G2(76.4% vs 54.5%,p < 0.001). Both groups had similar days until ambulation. Maximum

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VA pain scores were similar for G1 and 2(9 vs8,p=0.104).G1 had longer length of stay(5 vs 3,p <0.001) than G2. Narcotic refills were similar between groups(p = 0.963). EBL in G1 was higher (p <0.001) at 500 compared to G2 at 350. However, transfusion rates were similar(15.8%,8.1%,p = 0.15). Surgical time was significantly higher for G1 than G2, (p <0.001). Anesthesia time was also higher for G1 than G2(p <0.001). No patient had respiratory depression, needed oxygenation or had complains of itching in Group 2 nor were there any impacts on signal change

Conclusion

Using single use micro-dose Duramorph can eliminate the need for PCA with similar postoperative outcomes in a RRP.

Take Home Message

Using single use micro-dose Duramorph can eliminate the need for PCA with similar postoperative outcomes in a RRP.

248. Responding to Intra-operative Neuromonitoring (IONM) Changes During Pediatric Coronal Spinal Deformity Surgery

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Summary

The IONM of 97 pediatric patients undergoing spinal deformity surgery were reviewed. There were 39 alerts in 27 patients. Alerts were divided into bilateral (perfusion-related) and unilateral (direct trauma to the spinal cord). Addressing the causes of the spinal cord hypoperfusion (i.e. rod, blood pressure, anemia) reversed the bilateral changes. For changes related to direct trauma, removing the offending cause and time reversed or partially reversed the changes. Understanding the cause of the IONM alerts helps to direct appropriate treatment.

Hypothesis

Perfusion related produce different IONM changes than changes produced from direct trauma to the spinal cord

Design

Retrospective case review of prospectively collected data

Introduction

Despite the universal acceptance of intra-operative multi-modality neuromonitoring (IONM), significant controversy exists into what constitutes a neuromonitoring change, what significance does it represent, what actions should be taken in response, and which factors led to the changes.

Methods

A retrospective review of prospectively collected neuromonitoring data in pre-established forms on consecutive pediatric patients undergoing coronal spinal deformity surgery at a single center was performed. Pediatric patients with idiopathic or syndromic coromnal curves >80°, or patients treated with osteotomies or intra-operative traction were included. Real-time data was collected on IONM alerts with >50% loss in signal. Patients with alerts were divided into 2 groups: unilateral changes (direct cord trauma), bilateral MEP changes (cord perfusion deficits).

Results

A total of 97 consecutive paediatric patients involving 71 females and 26 males with a mean age of 14.9 (11-18) years were included in this study. There were 39 alerts in 27 patients (27.8% overall incidence). All bilateral changes responded to a combination of transfusion, increasing blood pressure, and rod removal. Unilateral changes as a result of direct trauma, mainly during decompressions, improved with removal of the causative agent. Following corrective actions in response to the alerts, all cases were completed as planned. Signal returned to near baseline in 20/27 patients at closure, with no new neurological deficits in this series.

Conclusion

A high incidence of alerts occurred in our series of cases. Dividing IONM changes into perfusion-based vs direct trauma directed treatment to the offending cause, allowing for safe corrections of the deformities. Patients did not need to recover signal to baseline to have a normal neurological examination.

Take Home Message

In paediatric spinal deformity corrections, dividing IONM changes into perfusion-based vs direct trauma directed treatment to the offending cause, allowing for safe corrections of the deformities.

Motor Evoked Potential (MEP) Changes (n = 39)

Type of MEP Change	Unilateral (n = 16)	Bilateral (n = 23)	P
Partial MEP Loss n(%)	13 (81.2%)	13 (56.5%)	0.17
Complete MEP Loss n(%)	3 (18.8%)	10 (43.5%)	0.17
Associated SSEP Loss n(%)	2 (12.5%)	2 (8.7%)	1
Mean time from start of surgery (min)	219.1 ± 87.1	254.5 ± 133.3	0.33
Action Preceding Alert			
Traction Related	0	6	0.06
Pre-incision	0	2	0.5
Pre-implant placement	0	2	0.5
Post-rod insertion	0	2	0.5
Implant Insertion	3	0	0.06
Pedicle Screw	2	0	0.16
Sublaminar Hook	1	0	0.41
Decompression for Osteotomy	6	0	0.003
Post Rod Insertion	4	17	0.004
Osteotomy Closure	1	0	0.41
Correction maneuver	1	0	0.41
Bone Graft Placement	1	0	0.41
Hemodynamics			
Mean Arterial Pressure	77.1 ± 9.8	67.6 ± 11.6	0.009

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

249. Neuroanesthesia Guidelines for Optimizing Transcranial Motor Evoked Potentials Neuromonitoring during Deformity and Complex Spinal Surgery: A Delphi Consensus Study

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Summary
We used a modified Delphi approach to obtain consensus amongst leading spinal deformity surgeons and their neuroanesthesiology teams regarding the optimal practices for obtaining consistent and reliable motor evoked potential (MEP) signals. Heterogeneous neuroanesthesia regimens were reported across the expert teams, however, agreement regarding specific principles and anesthetic agents was obtained. A set of consensus statements was created from these results to guide deformity and complex spinal neuroanesthesia care.

Hypothesis
Consensus can be obtained regarding neuroanesthesia principles for deformity surgery requiring the MEP neuromonitoring.

Design
Delphi Consensus Study

Introduction
Intra-operative monitoring of transcranial motor evoked potentials (MEPs) provides the most reliable method for assessing spinal cord integrity during deformity and complex spinal surgeries. It is the duty of the surgeon and neuroanesthesia team to understand how they can best maintain high quality MEP signals during surgery. Nevertheless, varying approaches to neuroanesthesia are seen in clinical practice. We sought to identify agreed upon neuroanesthetic principles from high volume deformity spinal surgery teams.

Methods
We identified 18 international spinal deformity experts for our study. A modified Delphi process with 2 rounds of surveying was performed. Greater than 50% and 75% agreement on the statements was considered achieving “agreement” and “consensus,” respectively.

Results
Anesthesia regimens were obtained from the expert centers. A large variation in protocols was witnessed. Two rounds of surveying were performed. Consensus was obtained in 11 of 14 statements and agreement in 3. Total intravenous anesthesia (TIVA) was identified as the optimal maintenance with few centers allowing for low MAC concentrations of inhaled anesthetic. While no strict cutoff values of propofol or opioid doses were identified, most centers advocate for <150mcg/kg/min of propofol and avoid elevated opioid concentrations. Utilization of adjuvant intravenous agents, including ketamine, dexmedetomidine and lidocaine, may help to reduce propofol and opioid requirements without negatively impacting MEPs. Maintenance of blood pressure near the patient’s preoperative baseline or mean arterial pressure greater than 80mmHg ensures appropriate spinal cord perfusion and prevents loss of MEPs.

Conclusion
Spine surgeons and their neuroanesthesia teams should be familiar with methods for optimizing MEPs during deformity and complex spinal cases. While variability in practices exist, consensus exists amongst international deformity leaders regarding best practices.

Take Home Message
We were able to utilize a modified Delphi approach to obtain consensus regarding optimal neuroanesthesia principles for deformity and complex spinal surgeries requiring optimal motor evoked potential intraoperative monitoring.

E-Poster Abstracts

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	Level of Agreement	Recommendation
Pre-Induction	Consensus	Dexamethasone, acetaminophen and pregabalin/gabapentin are all surgical adjuncts to the anesthesia regimen that can be given safely pre-operatively to decrease pain and narcotic requirements without compromising MEPs.
	Consensus	While midazolam (or other benzodiazepine) have been shown to decrease MEP signals, a dose prior to induction can be used safely for sedation without significant effect on MEPs. They should be avoided for the remainder of the case.
During induction	Consensus	Neuromuscular blockade should be avoided for cases requiring MEPs. During intubation, particularly in instances where pre-positioning baselines are required, if neuromuscular blockade is required, a short-acting or quickly reversible agent, such as succinylcholine or rocuronium, can be utilized to prevent suppression of MEPs.
After Induction	Agreement	Total intravenous anesthesia (TIVA) provides the most consistent and reliable MEP signals. Halogenated inhaled anesthetics and nitrous oxide should be avoided due to their dose-dependent suppressive effects on MEP signals.
	Consensus	Bispectral index (BIS) or electroencephalography (EEG) can be used as adjuncts during surgical cases to perform awareness monitoring in cases where minimizing anesthetic is required to enhance MEP signals.
	Consensus	While a dose-dependent suppression of MEP signals occurs with propofol use; there does not appear to be a single agreed upon maximum infusion dose. Limiting the propofol dose to less than 150 mcg/kg/min appears to be the most agreed upon cut-off, though higher doses may be tolerated in specific situations.
	Consensus	Elevated levels of propofol infusion can significantly decrease the value of MEP signals. Maintaining lower propofol infusion rates by adding other types of intravenous anesthetics (which do not adversely affect MEP signals) can be beneficial.
	Consensus	Ketamine can be used as an adjunctive medication with TIVA regimens to reduce the required dose of other MEP suppressing medications and improve post-operative pain control, particularly in chronic pain patients.
	Consensus	Lidocaine can be used as an adjunctive medication with TIVA regimens to reduce the required dose of other MEP suppressing medications and improve post-operative pain control.
	Agreement	While low doses of dexmedetomidine are generally considered safe, high doses and boluses can be suppressive of MEP signals, and therefore, are generally not recommended.
	Agreement	Ketamine can be used as an adjunctive medication with TIVA regimens to reduce the required dose of other MEP suppressing medications and improve post-operative pain control.
	Consensus	Variable opioid regimens can be safely employed with continual infusion to provide steady dosing and minimal variability throughout the case. Large boluses should be avoided until the end of the case when MEP monitoring is no longer required by the surgical team.
	None	There was no consensus regarding the specific opioid medication derivative to use during cases requiring MEPs. Methadone can considered as part of the opioid regimen, particularly in chronic pain patients.
	Consensus	To ensure appropriate spinal cord perfusion and optimize MEPs, maintenance of blood pressure close to the patient's pre-op baseline and with Mean Arterial Pressure (MAP) >80 should be performed.
During MEP Signal Loss	Consensus	In cases where unexplained decreases of MEP signals occur (after ruling out technical causes), the most important consideration is to ensure that all inhaled anesthetic agents are discontinued completely. If there are no inhaled anesthetic agents on board, blood pressure augmentation and assessment of patient's body temperature should performed. Propofol doses should then be reduced as much as possible.
Consensus = >75% of voting experts support this statement. Agreement = >50% of voting experts support this statement		

Table of Consensus Statements

250. Utility of Preoperative Bend Radiographs to 'Break the Rules' and Stop at L3

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Summary

In adolescent idiopathic scoliosis (AIS), various strategies have been proposed to determine the lower instrumented vertebrae (LIV) between L3 or L4. However, some have questioned the utility of preoperative L3-4 disc flexibility on bend radiographs. This study demonstrated that with an LIV of L3 and an end vertebrae (EV) of L4, the preoperative flexibility of L3-4 disc on bend studies can predict angulation of L3-4 disc for Lenke 3C-6C curves at 2-year follow up.

Hypothesis

For structural lumbar curves in AIS (Lenke 3C-6C), with an EV of L4, a flexible L3-4 disc on preoperative bend radiographs can predict improved alignment of the postoperative L3-4 disc space when LIV is L3.

Design

Retrospective review of prospectively collected, multicenter, AIS database.

Introduction

Multiple strategies have been proposed to guide decision-making with regards to choice of LIV between L3 and L4 for AIS in structural lumbar curves. Dubousset proposed preoperative L3-4 disc flexibility criteria, but this has not been universally applied to decision-making.

Methods

Patients with Lenke 3C-6C curves with an EV of L4 and LIV of L3 with minimum 2-year follow up were identified. Preoperative and 2-year follow up radiographs were analyzed for L3-4 disc angulation (>3° open to convexity) on neutral and bend x-rays, LIV translation and angulation. Scoliosis Research Society (SRS) questionnaire scores were also assessed. Chi-Square tests and regression modeling assessed postoperative alignment of L3-4 disc with EV of L4 as a function of preoperative disc flexibility on bend radiographs (open discs close on bend films).

Results

64 AIS cases met inclusion criteria of which 23 (36%) had flexible L3-4 disc spaces that closed on convex side on bend x-rays. The flexible L3-4 disc cohort was not associated with disc wedging at 2-year follow up (p<0.001, OR 48.1 (95% CI 10.4-222.2). Linear regression demonstrated that the in-flexible L3-4 disc cohort was associated increased postoperative L3-4 disc space angulation (3.2° (95% CI (2.2 – 4.2), p<0.001) but not LIV translation (0.26 (95% CI (-0.2 – 0.7)), p=0.26) nor LIV angulation (0.28° (95% CI (-2.3 – 1.8), p=0.79). There were no differences in SRS scores based on L3-4 disc flexibility.

Conclusion

In Lenke 3C-6C AIS, with an EV of L4, the preoperative flexibility of L3-4 disc on bend studies predicted angulation of L3-4 disc at 2-year follow up with LIV of L3. Extended follow up is needed correlate this to acceptable clinical outcomes and revision rates at long term follow up.

Take Home Message

In AIS, L3-4 disc flexibility appears to be an important factor in selecting the LIV in structural lumbar curves.

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LIV of L3 with EV of L4: Chi-Square Analysis of L3-4 Disc Flexibility				
	2 Year No Wedging	2 Year Wedging	p-value (95%)	Odds Ratio (95% CI)
Preoperative Disc Wedging on Neutral X-Ray & Closed on Bend (Flexible) (n=23)	20	3	p<0.001	48.1 (10.4-222.2)
Preoperative Disc Wedging on Neutral X-Ray & Open on Bend (Inflexible) (n=41)	5	36		

Simple Linear Regression Analysis of Postoperative Radiographic Findings As A Function Of Stiff Preoperative L3-4 Disc				
	B (95% CI)	t	p-value (95%)	Adjusted R^2
Postoperative Mean LIV (L3) Angulation (°)	0.28 (-2.3 – 1.8)	0.28	0.79	-0.15
Postoperative Mean LIV (L3) Translation (mm)	0.26 (-0.2 – 0.7)	1.14	0.26	0.01
Postoperative Mean L3-4 Disc Angulation (°)	3.2 (2.2 – 4.2)	6.4	**<0.001**	0.39

LIV of L3 with EV of L4: Comparison of L3-4 Disc Wedging				
	Preoperative (°)	2-Year Postoperative (°)	p-value (95%)	95% CI
Flexible L3-4 Disc Space	4.96 ± 2.7 (R 3-11)	0.74 ± 1.2 (R 0-2)	<0.001	3.1-5.3
Inflexible L3-4 Disc Space	4.66 ± 2.0 (R 3-11)	3.93 ± 2.2 (R 0-9)	0.12	-0.2-1.7

LIV = Lower Instrumented Vertebra; SD = Standard Deviation; ° = Degrees; mm = millimeters; ° = Degrees; ± = Standard Deviation; R = Range

Statistical Analysis of L3-4 Disc Flexibility with LIV of L3 with EV of L4

251. To Brace or Not to Brace: Development of an AIS Patient Decision Aid

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Summary

Structured interviews were performed to elicit patient and family decision support needs regarding the decision to start and maintain bracing for AIS. Information gathered focused on the decision-making process, goals, general scoliosis knowledge and treatment information needs, bracing-specific information needs and how best to depict risks and benefits of AIS bracing. The information garnered will be used to help design a user-centered web-based Patient Decision Aid (PtDA).

Hypothesis

Patients and families lack critical knowledge to make an informed decision regarding bracing.

Design

Structured interview to elicit decision support needs.

Introduction

The treatment of AIS is comprised of a number of different modalities. BrAIST demonstrated the efficacy of bracing to prevent progression to surgery but the decision to initiate and maintain bracing is still difficult for patients and families. Whilst there is a plethora of information regarding AIS bracing, there is no specific PtDA available to help in the shared decision-making process.

Methods

104 patients were assessed at five separate US sites by means of in-person interview, focus group or online survey. The interviews were structured to elicit decision support needs. Patient and family inputs were transcribed and reviewed centrally to identify common needs, concerns and desires. Specifically, we elicited comments on the decision-making process, goals, general scoliosis knowledge and treatment information needs, bracing-specific information needs and how best to depict risks and benefits of AIS bracing.

Results

Common threads were identified in each domain: 1. Parents did not feel they had a choice about treatment and requested more options and comparisons. 2. Every family's goal was to avoid surgery and to prevent progression. 3. Many families felt they lacked adequate knowledge of AIS natural history, the impact of AIS on other health issues, and the risks of frequent x-ray exposure. 4. Families wanted more specific information with respect to all aspects of brace and surgical treatments. They also desired information about yoga, scoliosis-specific exercises, and chiropractic care. 5. Families were frustrated with the lack of practical information pertaining to bracing. 6. Most families preferred pie charts to summarize the potential risks and benefits of bracing, while preferring a line graph to depict the dose-response relationship.

Conclusion

Based upon these results a user-centered designed web-based PtDA will be developed. This PtDA will be presented to a different cohort of families to evaluate its usability and its impact on patients' knowledge, treatment decisions and decisional conflict.

Take Home Message

The development of a web-based user-centered PtDA will likely enhance the shared decision-making process with respect to the initiation and maintenance of brace wear in AIS treatment.

252. Risk Factors for Surgical Site Infection in Adult Spinal Deformity: An In-Depth Analysis in 1190 Surgical Cases with Floral Distribution

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Summary

The incidence of infection was 4.6% (deep 3%, superficial 2%) in a study of 1190 Adult Spinal Deformity (ASD) operative patients. High BMI and Stainless-Steel rod material were significant risk factors. Long fusions >15 levels and >8hrs had an incidence of 10.7% vs. 0% in Fusions <5 Levels and <4hrs (p=0.01) vs. 3.8% in fusions 5-15 levels and 4-8hrs (p<0.01, OR 3.0). 53% were gram positive, 32% gram negative and 15% were mixed flora infections.

Hypothesis

Infection risk is associated with significant identifiable risk factors in ASD Surgery

Design

Retrospective Study

Introduction

Infections in ASD have the potential to result in catastrophic complications, compromising outcomes and resulting in morbidity and mortality. We report the incidence and risk factors for infection in a large cohort of ASD pts.

Methods

Database of ASD pts were analyzed from 2008-2018 for surgical site infections with at least 3 months follow up (f/u). We compared to non-infection cases to identify risk factors including patient demographics, operative details and radiographic variables. Bacterial flora info was also collected. X2 and Fisher's Exact T-test was utilized for statistical analysis

Results

1190 total cases were included and 63 infections in 55 pts were identified [incidence 4.6% (deep 3.0%, superficial 2.0%)]. Of these, 89.1% occurred in the first 60 days and an overall median day occurrence of 22 days. No association was seen with age, gender, CCI, Diabetes, Smoking or ASA scores, however, BMI was associated with infections (p<0.01) with a BMI>30 having a 3X higher risk for infection (2.8% vs 9.1%, p<0.01). There were no associations with revisions or prior infections (4.3% vs 12.0%, p=0.09). Surgical approach, staged surgery, screw material, osteotomy, interbody use (of all types) were not associated with infections but higher rates of infection with stainless steel (8.6%) vs CoCr (3.7%) vs Ti (4.2%) (p=0.03) rod material was seen. There was an association between longer fusions, higher EBL and longer OR time with infections (p<0.01). Long fusions >15 levels, >8hrs had a rate of infection of 10.7% vs 0% in Fusion <5 Levels, <4hrs (p=0.01) vs. 3.8% in fusion 5-15 levels between 4-8hrs (p<0.01, OR 3.0). Of the 63, bacterial species were known in 47 (75%) of cases with Gram+ most common (n=25, 53.2%) and Gram- (n=15) and 7 cases of mixed flora. Staph species were the most common and present in 31 cases total cases, with MRSA in 12 cases

Conclusion

High BMI, Stainless Steel rod material, longer OR times, longer fusion length and high EBL were significantly associated with infections.

Take Home Message

Our data demonstrates that low BMI, faster OR times and a lower # of fusion levels will decrease the risk for infection in ASD surgery.

253. Risk Factors for Pseudarthrosis in Adult Spinal Deformity (ASD) Surgery

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Summary

Independent risk factors for pseudarthrosis were identified in a retrospective review of 525 patients undergoing multilevel lumbar fusion for ASD. Anterior procedures confer the lowest risk, while long fusions, osteotomies and pelvic fixation increases the rate. Sagittal radiographic parameters (RP) are not predictors for pseudarthrosis. When pseudarthrosis is treated patients do as well as the no complication group.

Hypothesis

Pseudarthrosis is a multifactorial entity associated with both mechanics and biological causes.

Design

A retrospective multicenter study

Introduction

Pseudarthrosis in ASD is the most common cause of late revision. Despite its frequency, there remains no consensus on the risk factors for this complication. Some authors propose a mechanical origin while others suggest a biologic cause. The purpose of this study was to highlight independent risks factors for pseudarthrosis.

Methods

Adult patients undergoing lumbar deformity correction with a minimum of 4 instrumented vertebra and 2 years follow-up (FU) were reviewed (n=525; mean age=65 years, median FU=2.9 years). Baseline, 6 weeks and latest FU quality of life scores (HRQL), RP and reoperations for pseudarthrosis were recorded. Univariate and multivariate analysis were performed to identify risks factors for pseudarthrosis.

Results

65 patients (12.4%) developed a pseudarthrosis. Multiple de-

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mographic, surgical and RP appeared significant with univariate analysis. Notably, 88% of cases can be explained by fusion length, osteotomy requirement, pelvic fixation and combined approaches. Sagittal alignment does not influence the rate of pseudarthrosis. At latest FU, HRQL scores were comparable between patients revised for pseudarthrosis and those never revised (ODI=28% no revision and 30% revision group).

Conclusion

This study demonstrates that malalignment does not influence the rate of pseudarthrosis in multilevel lumbar fusion for ASD. Anterior approaches with anterior support decrease the rate by 30%, while long fusions, osteotomies and pelvic fixation increases the rate. After revision for pseudarthrosis, patients do as well as those that never required a reoperation.

Take Home Message

Anterior procedures reduce the rate of pseudarthrosis while long fusions, osteotomies and pelvic fixation increases the rate. Sagittal malalignment does not influence the rate.

254. Comprehensive Complication Classification for Adult Spinal Deformity: Intervention Severity and Impact on Length of Stay

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Summary

Determining the impact of complications is difficult without understating the magnitude of intervention needed to treat that complication. A system that encompasses the intervention severity and is able to predict the impact on length of stay (LOS) is needed. This study demonstrates that ASD patients with in-hospital complications have a longer LOS compared to those without. We have identified intervention severity as the only non-surgical independent predictor of increased LOS.

Hypothesis

Complications that occur during the initial hospitalization can predict LOS using a treatment severity complication classification

Design

Retrospective review prospective multicenter observational ASD database

Introduction

The current method of classification of complications as simply minor or major lacks granularity to predict outcome metrics and impact. Grading complications by treatment severity may allow for more granular information, with less bias and could be more impactful for the surgeon

Methods

Inclusion criteria were age >18yrs and ASD. To prevent outlier bias from patients that had excessive LOS (stem-leaf plot) were removed. Complications were categorized by intervention severity (0=none, 1=minor, 2=moderate, 3=severe). Poisson regression analysis was conducted to investigate the impact of intervention on LOS by controlling for the type of surgery. ANOVA with post hoc analysis was used to determine the difference between interventions and surgical type on LOS

Results

660/708 patients had no in-hospital complication after removal of outliers. LOS was significantly affected by length of fusion, use of a major osteotomy, staged surgery, revision surgery or use of interbody fusion. 436/482 patients had an in-hospital complication after removal of outliers (mean age 61, 73% female, mean BMI 27). These 436 pts required the following magnitude of intervention: 15% none, 69% minor, 9% moderate and 8% severe. Median LOS increased with increasing intervention (no complication=6d, no intervention=7d, minor=7d, moderate=9.5d, severe=11.5d). Kruskal-Wallis analysis, controlling for surgical procedure, found that intervention severity was significant in each instance.(Fig) Multivariate analysis also found intervention severity as a significant predictor of LOS compared to no-complication when controlling for surgery. Surgical factors that also affected the median LOS included length of fusion, major osteotomy, staged surgery all $p<0.01$

Conclusion

LOS is correlated to in-hospital complications and to the complication intervention severity. Surgical factors that affect LOS included length of fusion, major osteotomy or need for staged surgery

Take Home Message

Increased invasiveness of complication treatment was identified by a novel complication severity assessment scale as the only non-surgical factor that independently predicted increased hospital LOS following ASD surgery.

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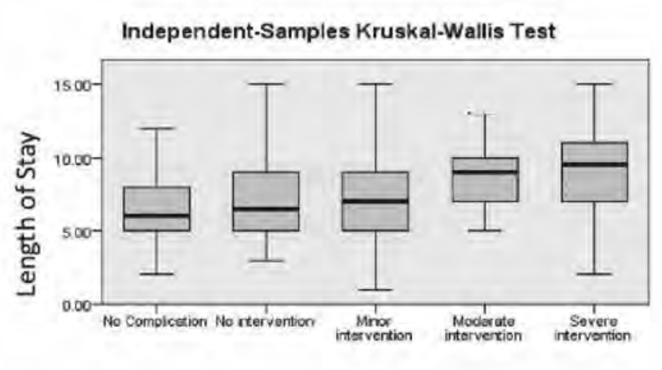

255. Severe Persistent Coronal Imbalance following Instrumented Posterior Spinal Fusion (PSF) for Adolescent Idiopathic Scoliosis (AIS)

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Summary

Severe coronal imbalance (> 4 cm) following PSF for AIS is rare but of great concern to surgeons and patients alike. In an analysis of risk factors, as well as subjective and functional outcome scores, we found that thoracic curve stiffness was a risk factor for severe post-operative coronal imbalance, which was associated with poor patient-reported-outcome measure (PROM) scores.

Hypothesis

There are specific, identifiable pre-operative, intra-operative, or post-operative risk factors for severe coronal imbalance that can be used to help guide surgical decision-making.

Design

Retrospective Case-Control

Introduction

Coronal imbalance is an unfavorable outcome following PSF for AIS, though the degree of imbalance in such patients is typically mild. However, there is a small subset of patients who become severely (> 4 cm) imbalanced following surgery. The risk factors and functional outcomes for this phenomenon have not been well studied.

Methods

Prospectively-collected data from a large multicenter registry was reviewed. Patients with severe coronal imbalance (> 4 cm) two years after PSF were included. Matched controls—who were either balanced at two years or mildly unbalanced (2-3cm)—were included at a 3:1 ratio. Comparisons were made between patient demographics, pre-operative radiographic measures, surgical factors, and residual post-operative radiographic measures. Health-related quality of life outcomes at two years were compared using SRS22 scores.

Results

Nine of 954 (0.9%) patients (88.9% females; mean age 14.8+/-2.3 years) were found to be severely imbalanced at two years. Twenty-seven matched controls were identified. There were statistically significant differences between cases and controls with respect to pre-operative bending thoracic curve magnitude (45 vs. 33 deg; p=0.013) and curve correction upon bending (22.9% vs. 63.3%; p=0.004). Pre-operative curve correction of < 40% on bending was associated with a 25.3 times greater risk for severe coronal imbalance (95% CI: 2.6–246; p=0.001). With respect to SRS scores, median pain (4.1 vs. 4.8; p=0.041), self-image (3.9 vs. 4.6; p=0.013), general function (4.5 vs. 5; p=0.022), and total (4.1 vs. 4.7; p=0.012) scores at two years were significantly lower in cases compared to controls.

Conclusion

Patients with stiff thoracic curves pre-operatively were significantly more likely to experience severe coronal imbalance at two years. In addition, the functional outcomes of these patients are significantly worse than their balanced counterparts.

Take Home Message

Increased pre-operative thoracic curve stiffness should raise surgeon awareness for altering surgical approach to minimize risk of severe post-operative coronal imbalance.

A

B

Variable	Cases n=9	Controls n=27	P-value
Thoracic Curve (°)	56 (47 – 64.5)	49 (41 – 59)	0.218
Thoracic Bend (°)	45 (37.5 – 60)	33 (21.8 – 40.8)	0.013
Thoracic Bend (% Correction)	22.9 (2.2 – 39.6)	63.3 (44.7 – 78.5)	0.004
Coronal Balance (cm)*	3.3 (0.7 – 4.9)	3.2 (1.5 – 3.9)	0.720
EIV Angulation (°)	24 (17 – 38)	23 (16.3 – 26.3)	0.323
Sagittal T2 to T12 Cobb (°)	41 (30 – 46)	26.5 (22.8 – 40.3)	0.034
Sagittal Balance (cm)	2.2 (1.2 – 4.1)	2.2 (1 – 4.0)	0.908

*Indicates variable(s) by which patients were matched
*Data expressed as absolute values
All values are expressed as medians and interquartile ranges

Figure 1. (A) Pre- and post-operative radiographs for patient with severe coronal imbalance at two-years and (B) comparison of pre-operative radiographic factors in cases versus controls.

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256. Radiation Exposure during Posterior Spinal Fusion with Freehand Technique in AIS and Literature Review on Navigation Data†

Clara Berlin, MD; Uwe Platz, MD; Björn Thomsen; Henry F.H. Halm, MD, PhD

Summary

Patients with idiopathic scoliosis are often young patients. The surgical standard is a posterior transpedicular spinal fusion. There are various surgical procedures, whereby freehanded setting of pedicle screws has proven itself. Novel techniques substitute the freehand technique with x-ray or CT-based navigation systems. These are especially advertised by industry as being less risky and more accurate. The study illuminates the aspect of radiation exposure for idiopathic scoliosis patients during surgery and the complication due to misplacement of pedicle screws.

Hypothesis

Computed tomography (CT) based navigation during posterior spinal fusion results in higher radiation dose in adolescent idiopathic scoliosis (AIS) patients compared to freehand technique.

Design

Retrospective analysis of prospective collected data

Introduction

Standard procedure in AIS is a posterior spinal fusion. Compared to freehand technique, fluoroscopy- and CT-based navigation are presumed to be safer and more accurate. A disregarded aspect of navigated procedures is the radiation exposure in young patients (pat.).

Methods

Data of 73 consecutive pat. (2016-18) were evaluated including age, fused segments, time of operation, blood loss, time of fluoroscopy, effective radiation dose (ED), correction and complications. Two standardized groups were compared. Group A with single-curve scoliosis (n=39, T=61.7±14° Cobb angle (CA)) and group B with double-curve scoliosis (n=34, T=69.2±14° CA, L=64.3±11° CA). Age of pat. was 18.7±6 (A) and 23.6±12 yrs. (B). Group-specific parameters were statistically analysed and compared by means of students t-test. ED was compared with values from literature (online database).

Results

ED per pat. was 0.17±0.1 mSv, time of fluoroscopy was 24.1±18.6 sec. with 9.5 fused segments, 222.5±72.1 min. operating time, 529±410 ml blood loss. Group A: 0.12±0.07 mSv ED per patient, 7.8 fused segments, 75.7% correction (T=46°±10); Group B: 0.24±0.14 mSv ED, 11.5 fused segments, 69.9% thoracic correction (T=47.5°±11) and 76.2% lumbar correction (L=48.7°±11). Statistically significant difference for ED ($p<0.001$), time of fluoroscopy ($p<0.05$), blood loss ($p<0.05$). No clinical or radiological evidence of screw misplacement in any case. Comparison with data from literature showed a 8.7 times higher ED for navigated procedure vs. freehand technique in scoliosis surgery.

Conclusion

Radiation exposure in freehand technique by experienced surgeons is considerably lower compared to navigated procedures. There is also a dependency on fusion length. The long-term risk of radiation-related malignant diseases shouldn't be neglected among young pat. The partially required preoperative planning CT contributes to total dose.

Take Home Message

Intraoperative computed tomography navigated procedures in scoliosis surgery are resulting in increased radiation exposure compared to freehand technique and may lead to an avoidable increased risk for radiation-related malignant diseases.

	Total	Single Curve	Double Curve	Single vs. Double Curve
Amount	73	39	34	
Age of Patient [years]	20.96	18.67	23.59	
SD Age of Patient [years]	9.7	6.0	12.1	
Time of Operation [min.]	222.49	183.54	267.18	
SD Time of Operation [min.]	72.1	54.2	64.1	
Effektive Dose [mSv]	0.17	0.12	0.24	p<0.001
SD Effektive Dose [mSv]	0.12	0.07	0.14	
Time of Fluoroscopy [sec.]	24.05	17.41	31.60	p<0.05
SD Time of Fluoroscopy [sec.]	18.6	8.6	23.5	
Blood Loss [ml]	528.97	379.49	700.44	p<0.05
SD Blood Loss [ml]	410.7	183.1	522.9	
Fused Segments [amount]	9.5	7.8	11.5	
SD Fused Segments [amount]	1.8	0.9	0.5	

*SD = Standard Deviation

Table of Results.

257. Enhanced Correction and Postoperative Shoulder Imbalance in Lenke Type 5C Adolescent Idiopathic Scoliosis†

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Summary

144 cases who underwent correction surgery for type5C curve were evaluated the risk factor of postoperative shoulder imbalance (PSI). Preoperative parameters were similar between balanced group and imbalanced group. The correction rate in the imbalanced group was significantly higher than that in the balanced group (82.1±16.2βvs 67.1±13.5%, p=0.001). Excessive correction of the lumbar curve can be a risk factor of PSI in type 5C curve.

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Hypothesis

Enhanced correction is the risk factor of postoperative shoulder imbalance in Lenke Type 5C adolescent idiopathic scoliosis.

Design

Retrospective multi-center study

Introduction

Postoperative shoulder imbalance (PSI) has negative impact on surgical results of patients with adolescent idiopathic scoliosis (AIS). However, there is few study about PSI in patients with AIS type 5C curves. The purpose of this study was to evaluate the risk factor of PSI in patients with type 5C curves.

Methods

144 cases (male 2, female 142) who underwent correction surgery for type5C curve was included in this study. The mean age at surgery was 15.8±2.9 years and the mean follow-up period was 65.5±46.7 (24-165) months. Anterior surgeries were performed in 35 patients and posterior in 109. Postoperative shoulder elevation over 2 cm on radiograph was regard as PSI in this study. The subjects were classified into the two groups of balanced shoulder group and imbalanced shoulder group. Radiographic parameters including coronal profiles and sagittal profiles before surgery and 2 years after surgery were compared between the two groups.

Results

10 patients (6.7%) presented PSI. Excepted 2 cases, the right shoulders were elevated in all PSIs. The mean preoperative Cobb angles in the balanced group were 48.8±8.9° and 48.9±4.7° in the imbalanced group. Cobb angle at final follow-up was significantly larger than that in the balanced group (15.9±6.6° vs 8.5±6.7°, p=0.001). The mean correction rate in the imbalanced group was also significantly higher than that in the balanced group (82.1±16.2βvs 67.1±13.5%, p=0.001). Surgical procedures, the mean upper thoracic and main thoracic Cobb angles of major curve, T1 angle, sagittal balance, coronal balance, thoracic kyphosis angle (T2-5,T5-12), and lumbar lordosis angle were equivalent between the two groups.

Conclusion

6.7 % of type 5C curve presented PSI. Since the mean correction rate in the imbalanced group was significantly higher than that in the balanced group, excessive correction of the lumbar curve can be the risk factors of PSI in type 5C curve.

Take Home Message

To avoid postoperative shoulder imbalance, excessive correction of the lumbar curve is not recommended for the surgical treatment of type 5C curve.

258. Evaluating the Impact of Asymptomatic HIV-Positive Disease Status on Adverse Outcomes in Surgically-managed Adult Spinal Deformity Patients: A Propensity Score-matched Analysis

Neil V. Shah, MD, MS; *Matthew J. Lettieri, BA; Madhu Oad, BS; Saad Tarabichi, BS; Vijaykumar R. Shah, MD; George A. Beyer, MS; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Bassel G. Diebo, MD; Carl B. Paulino, MD*

Summary

The literature is lacking in objective data evaluating the impact of asymptomatic, well-controlled HIV-positive status on post-operative course following ≥4-level spinal fusion (SF) for adult spinal deformity (ASD). We found asymptomatic HIV+ (AHIV) patients to have comparable complications compared to patients without HIV. Though Caucasian race predicted medical complications, AHIV status did not predict adverse outcomes. This data may improve preoperative risk stratification and planning for patients that may be wrongly presumed to be at increased risk for poorer outcomes.

Hypothesis

AHIV pts undergoing ≥4-lvl SF for ASD would have comparable outcomes to pts without HIV.

Design

Retrospective cohort

Introduction

1.3 million people currently live with HIV in the US, and with a peak prevalence of ASD of 65%, surgery for ASD is increasing. The impacts of symptomatic HIV and HIV-related diseases on postop outcomes are well-reported; HIV pts are at increased risk of postop wound and neuro complics and inpatient mortality following SF; yet, no study has evaluated the impact of AHIV status on outcomes following ≥4-lvl SF for ASD.

Methods

National Inpatient Sample (NIS) was reviewed from 2005-13 to identify all ≥18y pts who underwent a ≥4-lvl SF for treatment of ASD. Those diagnosed with AHIV status (ICD V08) were then identified and 1:1 propensity score-matched to pts without any HIV disease by age, sex, race, and insurance status. All other HIV diagnoses were excluded, as were surgical indications for other reasons. Univariate comparison of postop medical/surgical/total complications was performed. Multivariate binary logistic regressions identified independent predictors of these outcomes.

Results

Included: 86 pts (AHIV=43, no-HIV=43). Pts in both cohorts had comparable age, sex, and race, with comparable LOS (7vs4. 5days) and associated hospital charges (152,376vs$137,630),

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p>0.05. In-hospital mortality was comparable between AHIV & no-HIV pts (2.3vs0%,p=0.32). AHIV pts experienced comparable rates of individual med/surg complics to no-HIV pts, including wound & implant infections (2.3vs0% each), as well as overall medical (34.9vs20.9%), surgical (7vs7%), and overall complics (39.5vs27.9%). Regression revealed AHIV status did not increase odds of any medical, surgical, or total complics.

Conclusion
AHIV status did not adversely impact the overall postop course following ≥4-lvl SF for ASD. This study contributed data that may warrant improving preop risk stratification & planning for these pts that may be wrongly presumed to be at increased risk for poorer outcomes.

Take Home Message
Asymptomatic HIV+ patients undergoing ≥4-level fusion for ASD have overall similar complication rates as patients without HIV, with Caucasian race being a predictor of overall medical complications.

259. Indirect Decompression with Oblique Lateral Interbody Fusion Nearly Eliminates Need for Laminectomy

Alan W. McGee, Jr., MD; Zachary Wuthrich, BS; David Calabrese, MS; Andriy Noshchenko, PhD; Christopher J. Kleck, MD; Vikas V. Patel, MD, BS, MA

Summary
In this study, we assess preoperative and postoperative imaging and clinical outcome scores to assess improvement in symptoms of central canal stenosis and radiculopathy after oblique lateral interbody fusion (OLIF) without laminectomy. The purpose is to examine whether indirect decompression by OLIF is an effective method to alleviate these symptoms.

Hypothesis
Indirect decompression obtained with OLIF when used with posterior instrumentation will reduce the need for direct laminectomy based decompression in deformity patients.

Design
Retrospective case series.

Introduction
Traditional treatment for symptomatic lumbar spinal stenosis associated with spinal deformity has been by direct posterior decompression. OLIF is an indirect method that allows for distraction and placement of interbody cages which increase intervertebral height and distract at desired spinal levels.

Methods
25 patients who underwent OLIF and pedicle screw fixation without posterior laminectomy were reviewed. Cross sections of the spinal canal, disk height, cross-sectional areas of intervertebral foramina, and degree of upper vertebral slip were evaluated with MRI. Clinical symptoms and function including low back pain, leg pain, and lower extremity numbness were evaluated using a Visual Analog Scale and the Oswestry Disability Index before surgery, 6 weeks, 6 months, 1 year and 2 years after surgery.

Results
Of the 25 patients in the study the mean age was 61.1 years, there were 9 males and 16 females. Fourteen patients had at least grade I spondylolisthesis. The average number of levels using interbody fusion was 1.8 (maximum of 4 levels). Average preoperative cross sectional area (CSA) of the canal at the level of the disc was 1.43 cm2 and CSA of the foramina was 0.9 cm^2. CSA of the spinal canal was as low as 0.622 cm^2 and foraminal area was as a little as 0.266 cm^2 had complete resolution in symptoms of radiculopathy and spinal stenosis. VAS for leg pain intensity improved from 6.4 preoperatively to 3.1 at 2 years post-operatively ($p < 0.05$). The Oswestry Disability Index improved from 48.88 preoperatively to 26.67 at 2 years post-operatively ($p < 0.05$).

Conclusion
OLIF provides the necessary decompression for the treatment of central and/or lateral stenosis in a minimally disruptive way, avoiding the need for direct resection of the posterior elements. Further studies are needed to optimize criteria for which stenosis patients undergoing deformity surgery are most appropriate for indirect decompression alone.

Take Home Message
Oblique lateral interbody fusion may be a valid option for indirect decompression in patients with canal stenosis and radiculopathy.

E-Poster Abstracts

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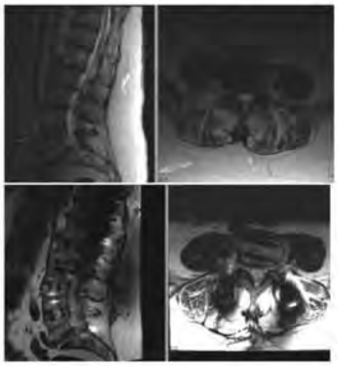
1a. Evidence of L4-5 spondylolisthesis and disc height loss
1b. Status post L4-5 OLIF with posterior instrumentation



2a/b. T2 MRI sagittal and axial image demonstrating central canal stenosis
2c/d. Improvement in central canal stenosis status post L4-5 OLIF

260. Establishment of Minor Curve Structural Criteria Using Preoperative Supine Radiographs instead of Side Bending Images for the Lenke Classification of Adolescent Idiopathic Scoliosis

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Summary
Supine side bending radiographs are used to determine minor curve structural criteria in the Lenke classification of AIS, yet inherent variability in radiographic technique and patient positioning make them difficult to reproduce. A standard supine full spine radiograph is proposed as an alternate method of determining structural criteria. A threshold of ≥35° residual Cobb angle AND ≤ 30% supine percent correction (SPC) on a single long cassette supine AP radiograph proved to be reliable minor curve structural criteria.

Hypothesis
A threshold of ≥35° residual Cobb angle AND ≤ 30% SPC on a full spine supine AP radiograph will reliably identify minor structural curves in AIS.

Design
Multi-center cohort study

Introduction
Multiple radiographic techniques are used to assess spinal flexibility in adolescent idiopathic scoliosis (AIS). Bending radiographs are currently used to identify structural minor curves in AIS, but this requires numerous radiographs which are subject to variability in patient effort and radiographic technique.

Methods
Radiographs of 70 surgically treated AIS patients were evaluated and divided into two groups: Lenke Types 1-4 (group 1) and Lenke Types 5-6 (group 2). Coronal Cobb angle and the supine percent correction (SPC) was measured for the proximal thoracic (PT), main thoracic (MT), and thoracolumbar/lumbar (TL/L) curves on each patient's standing, side bending, and supine AP radiographs. Sensitivity and specificity for our proposed supine structural criteria was calculated as well as Pearson's correlation coefficient between the supine and side-bending films.

Results
Average supine percent correction for PT, MT, and TL/L curves was 32%, 20%, and 28% respectively. For group 1 (n=57) supine films had a statistically significant high positive correlation with the side-bending films for the PT (r=0.86, p<.0001), MT (r=0.83, p<.0001), and TL/L (r=0.70, p<.0001) regions. For group 2 (n=13) supine films also demonstrated a statistically significant high positive correlation with the side-bending films for the PT (r=0.84, p=0.0003), MT (r=0.90, p<.0001), and TL/L (r=0.85, p=.0002) regions. Overall, the new criteria show a sensitivity of 76.5% and specificity of 100% for identifying structural PT curves compared to side bending X-rays. The sensitivity for MT and TL/L curves was 72.9% and 73.9% respectively, whereas, the specificity for MT and TL/L curves was 81.8% and 91.5%.

Conclusion
A threshold of ≥35° of residual Cobb angle for each region (PT, MT, TL/L) AND ≤ 30% SPC on a preop supine AP radiograph can be used as a substitute for bending films to determine minor structural curves in AIS.

Take Home Message
Supine AP radiographs are a reliable substitute to bending films for determining structural criteria of minor curves in the Lenke classification of AIS

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261. Surgeon Directed Spinal Cord Monitoring: Waveform Disappearance Superior to Amplitude Threshold for Predicting Neurological Dysfunction

Andrea Chan; Purnajyoti Banerjee, MBBS, FRCS, MS, DorthDIP-SICOT; Nasiur Rehman, FRCS; Cristina Lupu, PA-C; Tim Bishop, MBBS, FRCS; Jason Bernard, MD, FRCS; Darren F. Lui, MBBS, FRCS

Summary

Surgeon-directed MEP monitoring was utilised in 142 paediatric scoliosis correction surgeries (2012-2017). Waveform disappearance criteria was used as warning criteria in these surgeries. Absence of waveform disappearance, or maintenance of visual LL waveform is a safe method of MEP monitoring superior to amplitude reduction as a surgeon-directed method.

Hypothesis

MEP Waveform disappearance is reliable in warning of post-operative neurological deficit in paediatric scoliosis surgery.

Design

Case series of 142 scoliosis surgeries (2012-2017)

Introduction

Surgeon-directed monitoring (SDM) of Transcranial Motor Evoked Potentials (TcMEP) is valuable in spinal cord monitoring. This paper advocates that maintenance of visually observed lower-limb (LL) waveforms indicate intact spinal cord function, while waveform disappearance predicts potential motor deficit.

Methods

Surgeon-directed NIM-Eclipse MEP monitoring equipment was utilised in 142 scoliosis correction surgeries. The surgeon recognized a potential deficit warning as the persistent disappearance of LL waveforms from the monitoring screen. Amplitude data was analyzed retrospectively in attempt to numerically quantify LL-MEP amplitude reduction equivalent to observed signal disappearance.

Results

Types of deformity included 120 cases of AIS, 9 syndromic scoliosis, 9 neuromuscular scoliosis, 2 Scheuermann's kyphosis and 2 high-grade lumbar spondylolisthesis. Mean age 13.9 years (5-17 years) and M:F = 28:114. Mean duration of neuromonitoring was 302.5 minutes (SD 105.7 minutes) with an average of 20 stimulations per case. Three cases (2.11%) had complete visual loss of LL signals that did not resolve with re-stimulation, anesthetic stabilization, or reversed surgical manoeuvre. Correction was staged following axial scanning to check screw position and exclude hematoma. No cases with permanent neurological dysfunction were recorded. On analysis, all staged cases with persistent signal loss had up to >95% reduction in LL MEP amplitude.

Conclusion

MEP disappearance as an interpretation method is safe and reliable in deformity correction, with no false negative results. 'Disappearance' of signals was quantitively up to 95% amplitude reduction, likely due to background electrical noise. SDM of visual LL waveform maintenance is a safe method of MEP monitoring and superior to literature standard, 80% amplitude reduction as a surgeon-directed method. It is a cost effective alternative to traditional neurophysiology directed neuromonitoring.

Take Home Message

262. Characterizing Neurologic Injury within 90 days of Adult Spinal Deformity Surgery: Incidence, Risk Factors, Rate of Reoperation

Igor Dolgalev, MS; Peter L. Zhou, MD; Christopher G. Varlotta, BS; Tina Raman, MD

Summary

Complications after adult spinal deformity (ASD) range from minor complications to severe neurologic sequelae. We sought to better understand the incidence of neurologic injury within 90 days after ASD surgery using a large single-institution database, and found that the overall incidence was 3.1%, with predictors of neurologic complication including smoking, frailty, undergoing revision surgery, and transforaminal lumbar interbody fusion (TLIF). The rate of unplanned reoperation for neurologic injury was 2.5%.

Hypothesis

Patient demographics and operative details may have a significant effect on rate of neurologic injury within the 90-day postoperative period after ASD surgery.

Design

Retrospective review of prospectively collected single center database.

Introduction

New onset postoperative neurologic deficit represents a significant event for the patient undergoing ASD surgery. Identifying predictors of neurologic deficit may aid in preoperative patient counseling and risk assessment.

Methods

We performed a retrospective review of patients undergoing ASD surgery from 2011-2018. We investigated neurologic complications occurring after surgery, including incidence, risk factors, and rate of unplanned reoperation.

Results

1040 ASD patients (Age: 46 ± 23; BMI 25 ± 7, ASA 2.5 ± 0.6, Levels fused 10 ± 4, Revision procedure: 9%, 3-column osteoto-

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my: 13%) were included in the analysis. There were 50 neurologic complications in 32 patients (3.1%): 53% were detected pre-discharge, and 47% were detected post-discharge. 22 (2.1%) patients required unplanned reoperation. The most common neurologic complications were radiculopathy (n=28, 56%), and motor/sensory deficit (n=22, 44%). The most common cause of postoperative radiculopathy was residual stenosis after 3CO or SPO (n=20, 61%), followed by screw/implant mispositioning or migration into the foramen (n=6, 21%). LOS was longer in patients who developed a neurologic complication (10.1 ± 8.4 vs. 6.5 ± 4.3 days, p<0.0001). Patients with a neurologic complication were not more likely to sustain a wound or medical complication but had a higher rate of readmission (50% vs. 5.7% p<0.0001) and unplanned reoperation (72% vs. 6%, p<0.0001). Predictors of neurologic complication were smoking (OR: 3.0, 95% CI: 1.1-7.0), frailty (OR: 1.7, 95% CI: 1.1-2.5), revision surgery (OR: 2.5, 95% CI: 1-5.8), and TLIF procedure (OR: 2.4, 95% CI: 1.2-4.8).

Conclusion
The incidence of neurologic complications within 90 days of ASD surgery was 3.1%, the rate of unplanned reoperation, 2.1%. Smoking, frailty, revision surgery, and TLIF conferred greater risk for incurring a neurologic complication.

Take Home Message
The incidence of neurologic complications after ASD surgery was 3.1%, most commonly new onset radiculopathy. Modifiable factors including smoking and frailty predict complication risk.

263. Variation in Sagittal Spinopelvic Parameters in Korean and American Population

Woojin Cho, MD, PhD; Sandip P. Tarpada, MD; Dongyoung Kim, BS; Brittany A. Oster, BS; Hyun Jin Lim; Matthew T. Morris, MD; Hyoungmin Kim, MD, PhD

Summary
Spino-pelvic (SP) parameters have been investigated previously within 2 isolated ethnic populations. Here, we present an analysis of these measurements within a diverse urban population. We (1) found that SP measurements could be distinguished on the basis of ethnicity, and (2) established baseline measurements for each population. A significant difference was found in pelvic incidence, sacral slope, lumbar lordosis, T1-pelvic angle, and PI/LL offset between American and Korean population.

Hypothesis
SP parameters differ significantly among urban American and Korean populations

Design
Retrospective cohort study

Introduction
SP alignment is influenced by a variety of factors, including, gender, age, and ethnicity. Recent literature has reported on the influence of ethnicity on pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS), in a number of isolated populations. Here we present a retrospective chart review of SP parameters among an ethnically diverse urban population

Methods
Data from healthy American and Korean subjects from two major urban institutions were retrospectively obtained. Patient ethnicity was obtained in accordance with both institutional review boards. The following measurements were made from standing PA and lateral films from both populations, and compared using two sample T-tests: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), T1-Pelvic angle (TPA), sagittal balance (SB), coronal balance (CB), lumbar lordosis (LL) ,and PI/LL offset (PI-LL).

Results
A total of 341 patients (131 American, 210 Korean) were included. Mean PI was significantly larger in Americans (60.6 ± 13.7° vs. 44.2 ± 11.8°; p< 0.001), as were mean SS (46.56 ± 12.50° vs. 30.25 ± 8.05° ; p<0.001), mean TPA (15.56 ± 10.00° vs. 12.35 ± 8.52°; p=0.002), mean LL (56.61 ± 15.1° vs. 44.21± 9.04°; p < 0.001) and PI/LL offset (4.02 ± 18.8° vs. 0.03± 10.20°; p=0.012). PT, SB, and CB did not differ between the 2 groups(p=0.943, 0.765, and 0.129 respectively).

Conclusion
Pelvic incidence, sacral slope, lumbar lordosis, T1-pelvic angle, and PI/LL offset differ significantly in American and Korean patients. Accurate assessment of SP parameters is crucial to achieving surgical success.

Take Home Message
Spino-pelvic parameters such as pelvic incidence, sacral slope, lumbar lordosis, T1-pelvic angle, and PI/LL offset were significantly different in American and Korean patients

264. Patients' Perception and Satisfaction on Neck and Shoulder Imbalance in Adolescent Idiopathic Scoliosis

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Summary
This was a prospective study aimed to evaluate the perception and satisfaction among AIS patients with regards to Lateral Shoulder Imbalance (LSI) and Neck Tilt/Medial Shoulder Imbalance (NT). AIS patients with these deformities were aware, concerned and

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unsatisfied with their clinical appearance. LSI group had statistically significant larger Cla-A and RSH whereas the NT group had statistically significant larger T1 tilt and CA.

Hypothesis
Patients' self-image and satisfaction correlated with clinical Lateral Shoulder Imbalance and Neck Tilt/Medial Shoulder Imbalance.

Design
Prospective cross-sectional study

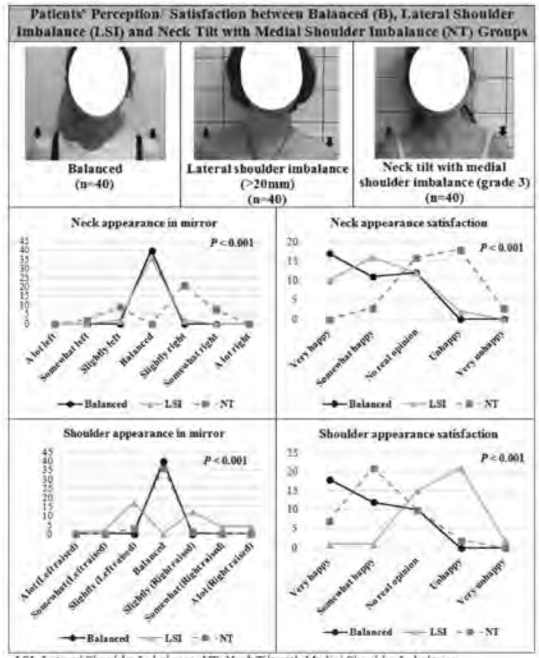
Introduction
Neck/ shoulder imbalance is a major concern among AIS patients. However, patients' perception and satisfaction on their clinical neck and shoulder imbalance are not known.

Methods
120 Lenke 1/2 AIS patients were stratified into 3 groups (40 each group): Balanced (B), Lateral Shoulder Imbalance (LSI) (>20mm), and Neck Tilt/Medial Shoulder Imbalance (NT) (grade 3). Each group was further divided into 20 preoperative and 20 postoperative patients. Patients were interviewed using Modified Neck/ Shoulder Appearance (Kuklo et al., 2002) and SRS-22r questionnaire. Radiological parameters (T1 tilt, Cervical Axis (CA), Clavicle angle (Cla-A), Radiographic Shoulder Height (RSH)) were measured and analyzed.

Results
The NT patients were aware of their abnormal neck/medial shoulder appearances and were significantly unhappy with their neck/medial shoulder appearances (p<0.001) as compared to the B and LSI groups. Similarly, the LSI patients were aware of their abnormal lateral shoulder appearances and were significantly unhappy with the lateral shoulder appearances (p<0.001) as compared to the B and NT groups. The NT group had higher T1 tilt (preop 9.2±5.0°, postop 9.5±5.3°) and CA (preop 4.6±3.1°, postop 7.0±2.0°) (p<0.01). LSI group had larger Cla-A (preop 4.8±2.8°, postop 4.0±1.3°) and RSH (preop 20.1±9.4mm, postop 17.0±6.6mm) (p<0.001). Postop B had higher scores in overall (4.2 ± 0.3, p=0.001), self-image (4.0 ± 0.5, p<0.001) and satisfaction (4.4 ± 0.5, p=0.003) domains compared to preoperative patients while preop LSI scored lowest in these three domains compared to other groups (3.5 ± 0.4, 2.4 ± 0.5 and 3.3 ± 0.5).

Conclusion
LSI and NT groups were aware and unhappy with their appearances. NT group had a larger T1 tilt and CA whereas LSI group had larger Cla-A and RSH respectively. Preop B group had higher overall SRS 22r scores, self image and satisfaction domain whereas preop LSI scored lowest in these three domains.

Take Home Message
Lateral Shoulder Imbalance (>20mm) and Neck Tilt/Medial Shoulder Imbalance (grade 3) were major concerns among the preoperative as well as postoperative AIS patients.



LSI: Lateral Shoulder Imbalance; NT: Neck Tilt with Medial Shoulder Imbalance

265. Inpatient versus Outpatient Halo-gravity Traction in Children with Severe Spinal Deformity

<u>Nestor Ricardo Davies, MD;</u> Victor Vasquez Rodriguez, MD; Mariano A. Noel, MD; Rodrigo G. Remondino, MD; Eduardo Galaretto, MD; Ida Alejandra Francheri Wilson, MD; Lucas Piantoni, MD; Ernesto S. Bersusky, MD; Carlos A. Tello, MD, PhD

Summary
Preoperative halo-gravity traction results in a decreased need for aggressive surgical techniques. The aim of this study was to compare the results, complications, and costs of preoperative halo-gravity traction in in- and outpatient. Coronal correction was 24º in in- and 28º in outpatients, sagittal correction was 27º and 29º, respectively. In each group 1 patient developed local and neurological complications. Treatment cost per patient was 2.8-fold higher in inpatients.

Hypothesis
preoperative halo-gravity traction in an outpatient setting is an effective option.

Design
A retrospective, comparative study.

Introduction
Surgical management of severe spinal deformities remains complex and controversial. Preoperative halo-gravity traction results in a decreased need for aggressive surgical techniques, lower incidence

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of intraoperative neurologic complications, and improvement of nutritional parameters and preoperative cardiopulmonary function

Methods
Twenty-nine patients younger than 18 years with kyphoscoliosis undergoing preoperative halo-gravity traction were divided into two groups: inpatients (n:15) and outpatients (n:14, home care or care at the Foundation). Traction time (weeks), traction weight (kg), radiographic curve correction, complications, and costs were compared. For statistical analysis, t-test and odds ratio were calculated with a significance of $p < 0.05$.

Results
Mean traction time was 6 weeks for in- and 4 weeks for outpatients (p=0.038). Initial traction weight was 6 kg in both groups, while final traction weight was 13 kg for in- and 15 kg for outpatients (p=0.50). At the end of the traction period, coronal correction was 24º in in- and 28º in outpatients (p=0.5), while sagittal correction was 27º and 29º, respectively (p=0.80). Pin loosening was observed in 2 patients in each group, of whom 1 outpatient developed pin-site infection. In each group, one patient developed transient neurologic complications (odds ratio=1.091). Mean treatment cost per patient was 2.8-fold higher in inpatients.

Conclusion
Considering complications and costs, our results show that preoperative halo-gravity traction in an outpatient setting is an option to be taken into account.

Take Home Message
In certain cases, preoperative halo-gravity traction in an outpatient setting is an effective with an acceptable incidence of complications

266. Accelerated Discharge Pathway Resulted in 50% Decrease in Length of Stay, Lower Pain at Discharge, and Earlier Return to School than a Traditional Discharge Pathway Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Prospective Study

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Summary
Patients treated with an AD pathway following PSF for AIS were found to have 50% lower VAS scores at discharge and returned to school 4 days earlier than those managed with a traditional discharge pathway. Parents were also able to return to work a week earlier. No difference in HRQOL scores were seen at initial follow up visit as measured by the QOR9 instrument. The AD pathway does not appear to result in worse pain at discharge.

Hypothesis
Patients with AIS managed with an AD pathway would have a similar return to school and resolution of pain compared to those with a traditional discharge pathway.

Design
Prospective cohort

Introduction
Accelerated discharge (AD) pathways have been shown to decrease length of stay after posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS). Little is known about the impact on early return to normalcy and pain at discharge

Methods
A prospective dual-center study of patients treated using an AD pathway (203 patients) or a traditional discharge (TD) pathway (86 patients) was performed with focus on pain at discharge, quality of life at one month, and return to school.

Results
Length of stay was 54% less in the AD group (2.1 days vs 5.0 days, p<0.001). Curve magnitude was larger in the TD group (64.0° TD vs 54.0° AD, p<0.001). Length of surgery (4.8 hours TD vs 2.8 hours , p<0.001), EBL (500cc vs 240cc, p<0.001), percentage of patients undergoing osteotomies (90% vs 45%, p<0.001) and a higher screw density (1.99 vs 1.60, p<0.001) were seen in the TD cohort. VAS score within 2 hours of discharge was 50% lower in the AD group (2.0 vs 4.0, p<0.001). Quality of recovery using the QOR9 instrument (maximum score 18) was no different at the first follow up (16.0 AD vs 16.0 TD, p=0.33) however patients in the AD pathway who were operated on while school was in session returned to school sooner (20.0 days vs 24.5 days p<0.001) and parents returned to work one week earlier (10.0 days vs 17.0 days, p<0.001) than those in the TD group. Negative binomial regression analysis showed no difference in QOR9 scores between groups at follow up when accounting for EBL, major curve, and length of surgery (-0.351, 95% CI -1.057 to 0.355, P-value = 0.33).

Conclusion
Patients managed with an AD pathway had lower pain scores at discharge and returned to school four days earlier than those managed with a TD pathway although both groups showed evidence of rapid return to normalcy by the first follow up visit at 4-6 weeks.

Take Home Message
This is the first study suggesting that patients managed using the AD pathway have lower pain at discharge and return to school earlier earlier than a TD pathway.

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267. Breast Asymmetry in Adolescent Idiopathic Scoliosis (AIS) Patients with Structural Thoracic Curve: A Computed Tomography (CT) Analysis and Assessment of Patients' Perception Using the BREAST-Q Questionnaire

Chris Yin Wei Chan, MD, MS; Heng Keat Tan, MBBS; Weng Hong Chung, MD, MS; Chee Kidd Chiu, MBBS, MS; Mun Keong Kwan, MBBS, MS

Summary

50 AIS patients with structural thoracic curves were analysed for prevalence of breast asymmetry and their perception of it. Correlation between Breast Asymmetry (BA)/ thoracic cage deformation with breast morphology was also investigated. BA occurred in 66.0% of patients. BA correlated significantly with Coverage Angle (CA) and Axial Breast Height but not Cobb angle. Inclination Angle also had significant correlation with Extraversion Angle, CA and Nipple-Sternum Distance. Patients with BA had significant improvement in satisfaction and psychosocial wellbeing scores postoperatively.

Hypothesis

Breast asymmetry (BA) is prevalent in Adolescent Idiopathic Scoliosis (AIS) patients with structural thoracic curves. This affects patients' satisfaction and psychosocial wellbeing.

Design

Prospective study

Introduction

Scoliosis results in BA and thoracic cage deformation. The severity of BA and its effect on patients' satisfaction has not been reported.

Methods

50 AIS patients who was scheduled for Posterior Spinal Fusion (PSF) and had preoperative CT scans were recruited. CT parameters measured for concave (CC) and convex (CV) side were Breast volume (BV), extraversion angle (EA), coverage angle (CA), axial breast height (ABH), nipple-sternum distance (NSD), Vertebral Rotation angle (VRA), Vertebral-Sternal angle (VSA) and inclination angle (IA). BA (volume difference) was calculated using the formula: 100*{(CC BV – CV BV)/ [(CC BV + CV BV)/2]}. Thoracic cage deformation was reflected by IA. External breast morphology parameters included EA, CA, ABH and NSD. Preoperative and postoperative BREAST-Q questionnaires were completed by patients.

Results

Mean age was 17.0 ± 5.5 years. Mean Cobb angle was 70.0 ± 17.7°. 33 (66.0%) patients had BA with the mean of 6.0 ± 9.9%. BA had significant correlation with CA and ABH (r=0.412 and 0.348). IA had significant correlation with EA (r=0.630), CA (r=0.326) and NSD (0.390). There was no significant correlation between BA and Cobb angle, VRA and VSA. Preoperative satisfaction domain correlated with CA (r=-0.284) whereas psychosocial score correlated with apical vertebral level (r=-0.364). Postoperative satisfaction domain improved from 31.1 ± 16.3% to 54.2 ± 15.0% while psychosocial wellbeing domain improved from 32.8 ± 18.7% to 56.4 ± 15.9% (p<0.001).

Conclusion

BA occurred in 66.0% of AIS patients. BA had weak correlation with CA and ABH but no correlation with Cobb angle. IA had moderate correlation with EA but weak correlation with CA and NSD. Patients with BA had significant improvement in satisfaction and psychosocial wellbeing scores after surgery.

Take Home Message

BA occurred in 66.0% of AIS patients. BA/ thoracic cage deformation had significant correlation with breast morphology. Patients with BA had significant improvement in satisfaction and psychosocial wellbeing scores postoperatively.

Parameters	Convex	Concave	*p*-value
Extraversion Angle (°)	20.52 ± 9.37	27.55 ± 11.99	<0.001
Coverage Angle (°)	110.79 ± 11.21	98.29 ± 11.44	<0.001
Axial Breast Height (mm)	29.29 ± 9.37	30.45 ± 10.52	0.078
Nipple-Sternum Distance (mm)	83.03 ± 12.52	84.64 ± 13.59	0.200
Breast Volume (mL)	324.36 ± 181.66	341.04 ± 187.34	<0.01
Inclination Angle (°)	65.86 ± 9.29	58.74 ± 9.71	<0.001

Clinical parameters comparing convex and concave sides

268. Grip Strength Associated with Sagittal Spinopelvic Alignment, IADL and Frailty in Male Elderly Patients with Degenerative Lumbar Diseases

Tae Woo Kim, MD; Zhimin Pan, MD, MS; Jong Joo Lee, MD; Yoon Ha, MD

Summary

Grip strength is representative and easy-to-measure muscular strengths. The aim of this study was to explore association between sagittal spinopelvic alignment and grip strength in elderly patients with degenerative lumbar diseases. Thirty-six male patients over the age of 75 years were retrospectively reviewed. Their radiographic parameters, activities of daily living(ADL), instrumental ADL and functional cross sectional area of psoas were included in

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analysis. The grip strength is related more with sagittal spinopelvic alignments compared with psoas muscle

Hypothesis

Grip strength represents sagittal spinopelvic alignment, IADL and frailty in patients with degenerative lumbar spinal disease in the elderl

Design

A cross-sectional study

Introduction

Few spinal studies have investigated the influence of muscular strength on spinal sagittal alignment. Grip strength is one of the most representative and easy-to-measure muscular strengths. The aim of this study was to explore potential association between sagittal spinopelvic alignment and grip strength in elderly patients with degenerative lumbar diseases.

Methods

Thirty-six male patients over the age of 75 years were retrospectively reviewed. Their radiographic parameters including C7 sagittal vertical axis (SVA), T1 pelvic angle (T1 PA), pelvic tilt (PT), pelvic incidence and lumbar lordosis (PI-LL), as well as FRAIL scale, activities of daily living (ADL), instrumental ADL (IADL) and functional cross sectional area (f-CSA) of psoas at the L3-4 disc level were documented. Functional CSA (f-CSA) was calculated from the formula; CSA x (1-Fatty degeneration ratio/100). The associations between aforementioned data and grip strength were analyzed through Pearson correlation coefficient and multiple linear regression.

Results

An average age of 78±2.88 years and a mean body mass index (BMI) of 23.80±2.86 were recorded. Pearson correlation analysis demonstrated that grip strength adjusted by BMI was related to age (r=-0.475, p=0.003), hypertension (r=0.338, p=0.044), T1PA (r=-0.365, p=0.029), PT (r=-0.596, p=0), PI-LL (r=-0.474, p=0.004), FRAIL scale (r=-0.466, p=0.004) and IADL (r=-0.339, p=0.043). f-CSA of psoas adjusted by BMI associated with T1PA (r=-0.338, p=0.044) and PI-LL (r=-0.373, p=0.025). FRAIL scale was relative to PT (r=0.439, p=0.007) and PI-LL (r=0.40, p=0.015). Multiple regression analysis confirmed the associations between grip strength and T1PA, PT, as well as PI-LL (β=-0.503, p=0.037; β=-0.638, p=0.002; β=-0.467, p=0.038, respectively).

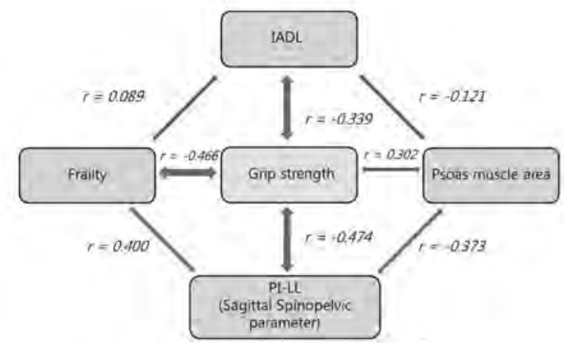
Conclusion

Grip strength is an easy-to-measure parameter associated with sagittal spinopelvic alignment. Compare to psoas area, grip strength is more associated with sagittal spinopelvic alignment

Take Home Message

The grip strength is more associated with sagittal spinopelvic alignments than psoas muscle area to sagittal spinopelvic alignments.

Also, hand grip strength represents sagittal spinopelvic alignment, IADL and frailty.



Association between grip strength and relevant variables. Red line means that it is statistically sgnificant(p<0.05). The thicker, the more association. IADL is instrumental activities of daily living, PI-LL is pelvic incidence - lumbar lordosis value

269. Changing Hand Position on EOS Spinal X-rays Does Not Impact Sagittal and Coronal Parameters

Vishal Sarwahi, MD; Jesse Galina, BS; Sayyida Hasan, BS; Melanie A. Smith, cPNP; Terry D. Amaral, MD

Summary

New protocols for spinal x-rays including new hand positioning does not affect coronal or sagittal parameters in non-operative patients. Without compromising radiographic parameters, additional prognostic data can be obtained without increasing radiation.

Hypothesis

Using a new a new spinal x-ray protocol with modified hand position does not affect radiographic parameters in non-operative patients.

Design

Retrospective review

Introduction

Our institution has implemented a new spinal XR protocol utilizing a change in hand position to examine bone age films concurrently. This is to decrease the amount of radiation used on this sensitive group of patients. The purpose of this study was to determine if the new spinal x-ray protocol affects radiographic measurements in non-operative patients

Methods

96 non-operative patients who received spinal x-rays with the old and the new protocol from 2015-2018 were included in the study. Radiographic measurements such as Cobb angle, kyphosis, lordosis, sagittal and coronal balance, Pelvic obliquity, Risser stage,

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sacral slope, pelvic incidence measured with both protocols. Median (IQR) and kruskal-wallis test was used.

Results

The average time between new and old protocol x-rays was 1.2 years. The median age for old protocol was 13.3 (11.7 – 14.8) and 14.6 years (13.6 – 15.9) for new (p<0.001). Risser signs were similar (Old: 4 (3 – 4) vs. New: 4 (4 – 4), p = 0.182). Kyphosis and lordosis were 26° (18 – 34) vs. 24° (17 – 33) and 54 (46.8 – 61.3) vs. 55 (44.8 – 63) for the old and new protocol, respectively. Pelvic incidence – lumbar lordosis (PI:LL) was similar (-6 (-15–5) vs. -6 (-14.3–6), p=0.51). Pelvic obliquity (2° (1–3) vs. 2° (1–3), p=0.36), pelvic tilt (10° (1°–17°) vs. 11° (2°–20°), p=0.51), and sacral slope (40° (34–44) vs. 37 (31–44), p=0.18). Median Cobb angle was 18° (12°–27.5°) for old protocol and 17° (10.8°–28.3°) for new (p =0.90). Coronal balance (12.2 (7.7 – 21.6) vs. 11.4 (7.4 – 13.4), p = 0.21) and sagittal balance (17.6 (9.25 – 28.4) vs. 20.7 (10.4 – 35.9), p = 0.35) were similar.

Conclusion

Modifying the hand positioning on patients undergoing low-dose spinal x-rays does not significantly impact the radiographic parameters of non-operative patients. Given these findings, it only further argues for the implementation of these protocols to use unnecessary x-rays. Further studies will be needed to see the effect of these positioning changes in surgical patients.

Take Home Message

Spinal x-rays with new hand positioning do not significantly affect radiographic parameters in non-AIS patients and can be used effectively in a clinical setting.

270. Preoperative PROMIS Satisfaction with Participation in Social Roles can Predict Patient Satisfaction in Adult Spinal Deformity

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Summary

This study examines whether preoperative PROMIS scores can predict postoperative satisfaction with treatment in patients undergoing surgery for ASD. 73 ASD patients were included. Logistic regression analysis showed that high preoperative PROMIS Satisfaction with Participation in Social Roles led to increased SRS Patient Satisfaction and NASS PSI. Thus, by assessing preoperative PROMIS scores, clinicians can identify patients likely to be satisfied with surgery.

Hypothesis

Preoperative PROMIS scores can predict patient satisfaction following surgery for ASD (Adult Spinal Deformity).

Design

Retrospective review

Introduction

Early identification of patients likely to be satisfied with treatment can help inform the potential benefits of surgery, and help set appropriate patient expectations. This study examines whether preoperative PROMIS scores can predict postoperative satisfaction with treatment in patients undergoing surgery for ASD.

Methods

Surgical ASD patients from 2015-2018 with minimum 1-year follow-up were evaluated. PROMIS questionnaires were obtained preoperatively and at 1 year postoperatively. SRS Patient Satisfaction and NASS Patient Satisfaction Index (PSI) scores were obtained at the postoperative encounter. To determine whether preoperative data could be used to predict patient satisfaction at 1-year postoperatively, we performed logistic regression analyses for both satisfaction scores, including all preoperative PROMIS scores, as well as age, gender and race. PROMIS domains assessed were pain interference, physical function, anxiety, depression, fatigue, sleep disturbance and satisfaction with participation in social roles.

Results

73 ASD patients (mean age 61.7 years) were included. At 12 months, 74% (54/73) reported high SRS Patient Satisfaction scores (4/5 or higher), and 64% (47/73) reported high NASS PSI scores. Logistic regression analysis showed that high preoperative PROMIS Satisfaction with Participation in Social Roles led to increased SRS Patient Satisfaction (OR= 1.07, CI=[1.02, 1.13], p=0.005) and NASS PSI (OR= 1.05, CI=[1.01, 1.1], p=0.04) scores. No relationship was found between preoperative PROMIS Pain Interference, Physical Function, Anxiety, Depression or Sleep Disturbance, age or gender, and patient satisfaction after 1 year.

Conclusion

High preoperative scores in PROMIS Satisfaction with Participation in Social Roles can predict patient satisfaction with treatment following surgery for ASD, as measured by both NASS PSI and SRS Patient Satisfaction.

Take Home Message

Preoperative PROMIS Satisfaction with Participation in Social Roles can predict patient satisfaction with treatment following surgery for ASD.

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271. Microdose Protocol Stereoradiography Has Similar Reliability to Standard Low-dose Protocol When Performing Concurrent Sanders Skeletal Maturity Staging

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Summary
Concurrent Sanders staging using standard low-dose spine stereoradiography has previously been shown to be as reliable as bone age radiographs. We compared the reliability between standard low-dose and microdose protocol images. The reliability of staging utilizing microdose images was similar to standard low-dose protocol images, while using much less radiation.

Hypothesis
Sanders staging on microdose protocol spinal stereoradiography is as reliable as standard low-dose images.

Design
Prospective Survey

Introduction
Decreasing patient radiation exposure is important for scoliosis patients who require serial imaging. Microdose protocol stereoradiography is now increasingly utilized. Previous studies have reported similar reliability of concurrent Sanders skeletal maturity staging based on standard low-dose stereoradiography and standard hand radiographs. To date this has not been assessed for the microdose protocol.

Methods
A randomized survey of 30 cropped and magnified hand images from standard protocol spinal stereoradiography and an equal number from microdose protocol was distributed to 6 pediatric orthopaedic spine surgeons. Each image was graded by each surgeon according to the Sanders skeletal maturity grading system. Items were randomized and graded again after a 3 week interval. Fleiss' weighted kappa for inter and intraobserver reliability were calculated and unpaired t-test was used to test for significance.

Results
The interobserver reliability for all modalities was in the strong to almost perfect agreement range. For microdose protocol, κ was 0.82 and 0.84. For standard low-dose protocol, κ was 0.83 and 0.79. The intraobserver κ was 0.86 for microdose and 0.82 for standard. Average radiation for microdose was significantly less (0.33±0.06 mGy vs. 1.89±0.42 mGy, p= 0.001).

Conclusion
Sanders staging reliability of a well-positioned hand during scoliosis stereoradiography is similarly excellent for microdose protocol and standard low-dose protocol. Microdose protocol used 82.6% less radiation than standard protocol, while still preserving the reliability of Sanders staging.

Take Home Message
When compared to the standard low-dose protocol, microdose protocol stereoradiography significantly reduces patient radiation exposure while preserving the reliability of concurrent Sanders staging.

272. The Contribution of Spinal Pseudarthrosis to the Magnitude of Surgical Correction for Thoracolumbar Kyphosis Secondary to Ankylosing Spondylitis

Bangping Qian, MD; Mu Qiao, MD; Yong Qiu, MD; Feng Zhenhua, MS; Junyin Qiu

Summary
The optimal surgical strategy for treating thoracolumbar kyphosis secondary to ankylosing spondylitis (AS) with pseudarthrosis was still controversial. In comparison with performing pedicle subtraction osteotomy (PSO) through pseudarthrosis, PSO above/below pseudarthrosis appears to be more appropriate and less technically demanding. However, limited studies have investigated the effectiveness of the aforementioned procedure. Besides, the causes for the mismatch between correction of PSO and global kyphosis (GK) remains unclear.

Hypothesis
Osteotomy above/below pseudarthrosis with posterior instrumentation covering it was a safe and effective method for kyphosis correction in AS patients. Meanwhile, the postoperative morphological change of pseudarthrosis may have contribution to the correction of local and global kyphotic deformity.

Design
Retrospective case series.

Introduction
To investigate the efficacy of PSO above/below pseudarthrosis with instrumentation covering it and the contribution of spinal pseudarthrosis to the correction of thoracolumbar kyphosis caused by AS.

Methods
Fifty-three consecutive AS patients were analyzed and divided into groups according to the presence of the preoperative pseudarthrosis. Patients with or without pseudarthrosis were defined as group P (n=17) and group NP (n=36). PSO outside the level of pseudarthrosis were performed for all the patients in group P. The average follow-up time were 40 months (range, 24-84 months). Radiographical assessment included GK, LL, SVA, local kyphosis (LK),

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osteotomized vertebra angle (OVA) and the sum of disc wedging within the fused region (SDW).

Results

Both groups were matched cohorts regarding the magnitude of preoperative sagittal parameters. Significant improvement in GK, LL, SVA, OVA and SDW were found postoperatively in both groups, and no obvious correction loss was identified at the final follow-up. LK improved from 24.53º preoperatively to 13.07º postoperatively with a mean correction of 11.64º in group P. The average correction of per PSO segment, GK and SDW for group P and NP were 33.07º, 49.33º, 5.28º and 38.28º, 44.06º, 6.03º, respectively. No neurovascular complication or pseudarthrosis was noted in either groups and solid fusion was achieved at final follow-up.

Conclusion

PSO away from the level of pseudarthrosis with posterior instrumentation crossing it was a feasible method for treatment of AS-related kyphosis and was able to maintain sustained surgical outcomes. The contribution of spinal pseudarthrosis was attributed to the opening of anterior column postoperatively and should be taken into consideration for surgical-decision making to prevent overcorrection.

Take Home Message

Satisfied radiological outcomes and solid bony union could be achieved in AS patients with PSO above/below the pseudarthrotic lesion with instrumentation covering it.

273. Bariatric Surgery Diminishes Spinal Symptoms in a Morbidly Obese Population: A 2-Year Survivorship Analysis of Cervical and Lumbar Pathologies

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Summary

Morbid obesity places mechanical stresses on the spine than can predispose patients to various spinal pathologies. Bariatric surgery has been shown to improve comorbidity burden in morbidly obese patients. In patients with common cervical and lumbar spinal diagnoses such as herniation, stenosis, spondylolisthesis and degeneration, bariatric surgery decreases inpatient visits for spinal diagnoses by 50% at 180 days postop, and cumulative resolution of symptoms continue to improve for all spinal symptoms over two years (720 days).

Hypothesis

Bariatric surgery diminishes spinal symptoms in morbidly obese patients.

Design

Retrospective review of a prospective database

Introduction

Bariatric surgery for morbid obesity decreases comorbidity burdens (rates of myocardial infarction and stroke). Mechanical stress on the spine caused by morbid obesity predispose patients to various spinal pathologies and are associated with poorer outcomes after spine surgery. The effect of bariatric surgery on spinal symptoms have yet to be elucidated.

Methods

Retrospective study of prospectively collected inpatient database from 2004-2013. Patient linkage codes identified multiple & return inpatient stays within 720 days. Included: bariatric pts with ≥1 visits before & after bariatric surgery for 1 of the following ICD-9 cervical/lumbar spinal diagnoses (dx): herniation, stenosis, spondylosis, disc degeneration, spondylolisthesis. Resolution was defined as time from bariatric surgery until patients' respective spinal symptoms were no longer present. Kaplan-Meier survivorship curves assessed rates of resolution for each spinal dx.

Results

4351 bariatric pts with preop spinal dx by ICD-9 were analyzed. Lumbar: 1049 stenosis, 774 spondylosis, 648 degeneration, 249 spondylolisthesis, 72 herniation. Cervical: 376 stenosis, 366 spondylosis, 236 degeneration, 581 herniation. Cumulative resolution rates at 90, 180, 360, and 720 day follow-up are summarized in Figure 1. Lumbar pts saw significantly higher 90d resolution for herniation than cervical pts ($p<.001$). Cervical vs lumbar degen resolution rates did not differ at 90d($p=0.058$), but did at 180d($p=0.034$). Cervical & lumbar stenosis were similar at 90d & 180d, but cervical showed greater 1Y resolution ($p=0.036$).

Conclusion

Over 50% of patients with a cervical or lumbar pathology before bariatric surgery no longer sought inpatient care for their spinal diagnosis by 180 days postop. Lumbar herniation had significantly higher 90-day resolution than cervical herniation, while cervical degeneration and stenosis resolved at higher rates than lumbar degeneration and stenosis by 180-day and 1-year follow-up, respectively.

Take Home Message

Over half of bariatric patients diagnosed with a cervical or lumbar pathology before weight-loss surgery no longer sought inpatient care for their respective spinal diagnosis at 180 days postop.

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Table 1: Cumulative resolution rates at 90-day, 180-day, 360-day, and 720-day follow-up. Bolded values indicate statistical significance at p<0.05.

Diagnosis		Resolution (%)			
		90 Day	180 Day	360 Day	720 Day
Lumbar Spine	Stenosis	48%	67.6%	**79%***	91%
	Herniation	**61%***	77%	86%	93%
	Spondylosis	47%	65%	80%	93%
	Spondylolisthesis	37%	58%	70%	87%
	Degeneration	37%	**56%***	72%	86%
Cervical Spine	Stenosis	48%	70%	**84%***	94%
	Herniation	**39%***	58%	74%	87%
	Spondylosis	46%	70%	83%	94%
	Degeneration	44%	**64%***	78%	89%
p-value		**<0.001**	**0.034**	**0.036**	

Table 1: Cumulative resolution rates at 90-day, 180-day, 360-day, and 720-day follow-up. Bolded values indicate statistical significance at p<0.05.

274. The Value of Preoperative Labs in Identifying "At-Risk" Patients for Developing Surgical Site Infections after Pediatric Neuromuscular Spine Deformity Surgery*

Ryan J. Furdock, BS; Scott John Luhmann, MD

Summary

A retrospective analysis of a twenty-year cohort of 111 pediatric neuromuscular scoliosis (NMS) patients that underwent posterior spinal fusion (PSF) with instrumentation was performed. Overall, 7 patients (6.3%) developed a postoperative surgical site infection (SSI). With the possible exception of transferrin, low preoperative lab values (prealbumin, Hgb/Hct, WBC, TLC, total protein, albumin) were not associated with SSI. These findings question the utility of the current methodology of preoperative laboratory evaluation in identifying patients at elevated risk for SSI following PSF.

Hypothesis

Low preoperative nutritional labs are associated with elevated risk of SSI following PSF for NMS.

Design

Retrospective cohort study via a single surgeon, two-hospital database.

Introduction

PSF in NMS patients is a high-risk surgery, with rates of SSI up to 24%. There is conflicting evidence in the literature regarding a possible association between low preoperative nutritional lab values and heightened risk of SSI after PSF.

Methods

A single-surgeon, two-hospital database was reviewed to identify all patients who underwent PSF for NMS. Diagnoses included cerebral palsy (n=82), myelomeningocele (n=13), spinal muscular atrophy (n=4), and other (n= 12). Medical records for 117 patients were examined; 6 were excluded due to missing lab values. SSI was defined as an infection necessitating a return to the operating room for irrigation and debridement of the surgical site. Demographic information, preoperative lab values, spinal deformity magnitude, and surgical procedure data were recorded.

Results

There were 50 males and 61 females with a mean age of 14y 2.5m (8-20y). 7 patients (6.3%) experienced postoperative SSI. SSI rate for PSF to pelvis was 7.7% vs. PSF to lumbar spine, 3.0% (NS; p=0.672). Length of PSF was not statistically associated with SSI (p=0.172). SSI due to gram positives and polymicrobial gram negatives occurred with equal incidence. Preoperative lab values of transferrin, prealbumin, albumin, WBC count, total lymphocyte count, and total protein were not associated with SSI. Patients with postoperative SSI had higher mean Hct compared to controls (p=.041). While 40.6% of controls had low Hgb (<13.8g/dl), all patients who developed SSI had Hgb within the normal range (p=.043). Similarly, while 37.6% of controls had low Hct (<40.7%), all patients who developed SSI had Hct within the normal range (p=.05).

Conclusion

Low preoperative nutritional labs, Hgb/Hct and TLC values were not found to be associated with increased incidence of SSI in this analysis. These findings question the utility of preoperative lab values in identifying "at-risk" populations for SSI after PSF for NMS.

Take Home Message

A twenty-year cohort produced by a high-volume orthopedic surgeon found that preoperative labs were not useful in predicting SSI following PSF for NMS.

[illegible]	No Infection	Surgical Site Infection	
	Mean		p-value
Age at Surgery (years)	14.11	13.57	[illegible]
Height (cm)	[illegible]	[illegible]	[illegible]
Weight (kg)	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
Transferrin (mg/dl)	[illegible]	[illegible]	[illegible]
Prealbumin (mg/dl)	[illegible]	[illegible]	[illegible]
Hgb (g/dl)	13.97	[illegible]	[illegible]
Hct (%)	[illegible]	[illegible]	[illegible]
WBC (K/cumm)	[illegible]	[illegible]	[illegible]
Total Lymphocyte Count (K/cumm)	[illegible]	[illegible]	[illegible]
Total Protein (g/dl)	[illegible]	[illegible]	[illegible]
Albumin (g/dl)	[illegible]	[illegible]	[illegible]
Estimated Blood Loss (ml)	[illegible]	[illegible]	[illegible]
Length of Anesthesia (min)	[illegible]	[illegible]	[illegible]
PreOp Coronal Cobb (degrees)	[illegible]	[illegible]	[illegible]
PreOp Coronal Balance (mm)	[illegible]	[illegible]	[illegible]
PreOp Sagittal Cobb angle (degrees)	[illegible]	[illegible]	[illegible]
PreOp Sagittal Balance (mm)	[illegible]	[illegible]	[illegible]

Table 2: Analysis of preoperative laboratory values and SSI following PSF	Normal/High Lab Value		Low Lab Value			
	No Infection	Surgical Site Infection	No Infection	Surgical Site Infection	P Value	Absolute Risk Increase w/95% CI*
Transferrin (<200mg/dl)	94% (47)	6% (3)	50% (1)	50% (1)	0.15	44% (-2.2% - 84.7%)
Prealbumin (<20mg/dl)	90% (36)	10% (4)	100% (11)	0% (0)	0.27	-10% (-23.1% - 8.6%)
Hgb (<13.8g/dl)	92% (83)	8% (7)	100% (18)	0% (0)	0.60	-8% (-15.2% - 10.2%)
Hct (<40.7%)	90% (64)	10% (7)	100% (38)	0% (0)	0.05	-10% (-19.2% - 0.5%)
WBC (<3.8K/cumm)	93.5% (100)	6.5% (7)	100% (1)	0% (0)	1.00	-6.5% (-12.9% - 72.0%)
Total Protein (<6.5g/dl)	93.1% (94)	6.9% (7)	100% (7)	0% (0)	1.00	-6.9% (-13.6% - 28.7%)
Albumin (<3.5g/dl)	93.5% (101)	6.5% (7)	0% (0)	0% (0)	1.00	0%
Total Lymphocyte Count (<1.5K/cumm)	99% (102)	1% (1)	80% (4)	20% (1)	0.09	19% (2.1% - 61.5%)

*Negative absolute risk increase indicates that low lab value was associated with lesser incidence of SSI in this study.

Demographics and Analysis of Preoperative Laboratory Values and SSI following PSF

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

275. Late Arising Infection Following Posterior Spinal Fusion in Adolescent Spinal Deformity: Single Stage Exchange with Titanium Implants

Subaraman Ramchandran, MD; Harry L. Shufflebarger, MD; Darian Daniel, BS

Summary
Late arising infection is a major cause of multiple revision procedures following posterior spinal fusion. A retrospective study of adolescent patients who having undergone posterior spinal instrumented fusion experienced late infection and underwent single-stage implant removal, debridement and exchange with titanium implants. At 2 years following revision, 91% had successful elimination of infection and all patients had maintenance of their coronal and sagittal alignment without decompensation.

Hypothesis
Single stage implant removal and re-instrumentation in late arising infections successfully treats the infection and maintains correction.

Design
Single-center retrospective study.

Introduction
Late arising infection (>6 months from index procedure) is a major cause of revision. Antibiotic therapy or local wound debridement is rarely successful in eliminating the drainage. Treatment by implant removal carries a significant risk of fatigue failure of the fusion.

Methods
A retrospective review of patients with late infection after deformity corrective surgery for the period 2006-16 was conducted. Patients were consecutive for the treatment method, implant removal and debridement and immediate re-instrumentation with titanium implants. Data included coronal and sagittal radiographic measurements, bacteriology, antibiotic protocols and outcomes including re-operations at minimum 2 years following the revision.

Results
33 patients (30 AIS, 3 Scheuermann's kyphosis) constitute the study group (mean age 14.5 ± 2.3 yrs, 84% F). Mean time from index procedure was 52 months. 28 had stainless steel and 5 had cobalt chrome imlants. Implant density for titanium exchange was 0.8. Intra-operative cultures were positive in 5 (at 7 days), 3 proprio Acnes, 1 staph epi, and 1 staph aures. Three patients (9%) subsequently drained and had implants removed. No patient had change in coronal or sagittal alignment at 2 years.

Conclusion
A one-stage removal of existing implants, wound debridement, and re-implantation with titanium implants is successful in treating the chronic drainage in 90% of patients, without change in spinal alignment. This is a viable alternative to complete implant removal or staged removal and later re-instrumentation.

Take Home Message
Single-stage implant removal, wound debridement and exchange with titanium implants is successful in treating late arising infections following posterior spinal fusion in pediatric spinal deformities with maintenance of spinal alignment.

†Luis A. Goldstein Best Clinical Research Poster *John H. Moe Best Basic Research Poster

Notes

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The Scoliosis Research Society gratefully acknowledges Zimmer Biomet for their support of the Annual Meeting Wireless Internet and Welcome Reception

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PRESENTATION KEY 1-171 = Paper/ Podium Presentations, 200-275 = E-Posters, PMC= Pre-Meeting Course, CASE= Case Discussion, LTS= Lunchtime Symposium, HDC= Half-Day Course, NMLS = Non-Member Lunch Session

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About SRS

MISSION STATEMENT

The purpose of the 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 minimum three 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 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 three-five years, during which time they must demonstrate their interest in spinal deformity and in the goals of the Scoliosis Research Society. Candidate Fellows may serve on SRS committees. After a minimum three 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.

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.

Senior Candidate Fellowship (membership) is limited to senior surgeons, neurosurgeons and to non-physicians members of allied specialties. This candidacy is a path to SRS Active Fellowship. Senior surgeons have the opportunity to become Active Fellows of SRS in two years and not 3-5 years like the regular Candidate Fellowship track. They must have 20 years of experience (time spent with fellowship and training does not count), be a full professor, head of spine unit or chief of spine division, clinical practice which includes 20% spinal deformity. After two years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Senior Candidate Fellowship does not include the right to vote or hold office.

Visit www.srs.org/membership for membership requirement details and the online application.

PROGRAMS AND ACTIVITIES

SRS is focused primarily on education and research that include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Courses, 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. For more information please visit the SRS website at www.srs.org.

SOCIAL MEDIA

Stay up to date with SRS during the Annual Meeting. Share and search public social media posts using the hashtag: #SRSAM19

Twitter: @srs_org
Facebook: Scoliosis Research Society
Instagram: @srs_org
LinkedIn: Scoliosis Research Society

If you need assistance finding the SRS social media or using the hashtag, please visit the registration desk.

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Meeting Outline

Monday, September 16, 2019	
8:00-16:00	Board of Directors Meeting*
Tuesday, September 17, 2019	
7:00-8:00	2019-2020 Committee Chair Breakfast & Education Session*
8:30-16:30	SRS Committee Meetings*
12:00-17:00	Registration Open
13:00-18:00	Speaker Ready Room Open
13:00-17:00	Hibbs Society Meeting*
19:00-22:30	SRS Leadership Dinner* (by invitation only)
Wednesday, September 18, 2019	
6:00-19:00	Registration Open/ E-Posters Open*
6:30-20:00	Speaker Ready Room Open
8:00-12:00	Pre-Meeting Course
12:15-13:15	Lunchtime Symposia
13:30-17:05	Scientific Program
17:15-18:15	Case Discussions
18:30-19:35	Opening Ceremonies*
19:35-21:30	Welcome Reception*
Thursday, September 19, 2019	
6:30-16:30	Registration Open/ E-Posters Open*
6:30-18:00	Speaker Ready Room Open
8:00-12:30	Scientific Program
12:30-12:50	Boxed-lunch Pick-up*
12:50-14:20	Industry Workshops*
14:35-17:35	Half-Day Courses
17:35-18:00	Membership Info Session*
Friday, September 20, 2019	
6:30-18:00	Speaker Ready Room Open
7:00-17:00	Registration Open/ E-Posters Open*
8:00-11:45	Scientific Program
12:00-13:30	Member Business Meeting & Lunch*
12:15-13:30	Non-Member Lunch Session*
13:40-17:30	Scientific Program
19:00-22:00	Farewell Reception*
Saturday, September 21, 2019	
6:30-12:30	Speaker Ready Room Open
7:30-11:00	Registration Open/ E-Posters Open*
8:00-12:30	Scientific Program
13:00-16:30	Board of Directors Meeting*

** Denotes Non-CME*

SRS-0819-322

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Network: SRS2019 Password: SCOLIOSIS

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