SCOLIOSIS RESEARCH SOCIETY 47TH ANNUAL MEETING & COURSE

September 5-8, 2012 · CHICAGO, ILLINOIS, USA · Sheraton Chicago Hotel & Towers

FINAL PROGRAM

www.srs.org

Jointly sponsored by the American Academy of Orthopaedic Surgeons (AAOS) and the Scoliosis Research Society (SRS)

AAOS
American Academy of Orthopaedic Surgeons

SCOLIOSIS RESEARCH SOCIETY · FOUNDED 1966 ·

2011 CORPORATE SUPPORTERS

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2011. Support levels are based on total contributions throughout the year and include the Annual Meeting, IMAST, Worldwide Regional Meetings, Global Outreach Scholarships, Edgar G. Dawson traveling fellowships, SRS Traveling Fellowships and the Research Fund. Their support has helped SRS to offer high-quality medical meetings and courses throughout the world, fund spinal deformity research, develop new patient materials, and provide educational opportunities for young surgeons and those from developing nations.

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SCOLIOSIS RESEARCH SOCIETY

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WELCOME LETTER

Dear Fellow SRS Members and Guests,

I enthusiastically welcome you to the Scoliosis Research Society's 47th Annual Meeting & Course in Chicago, Illinois, USA – the state's wonderful "Windy City." This promises to be a week filled with outstanding educational opportunities, renewal of friendships, fine dining and recreation. Without question, you'll be happy you're here!

I give a heartfelt thanks to our local organizing hosts Chris DeWald, MD, Kim Hammerberg, MD, Steve Mardjetko, MD, FAAD, John Sarwark, MD and SRS President-Elect Kamal Ibrahim, MD, FRCS(C), MA. Together, they put together a number of fun events and venues (described below) for all of us to enjoy with our free time.

This year's program has many outstanding educational opportunities. Wednesday's one-day Pre-Meeting Course, organized by Education Committee Co-Chairs Mark Dekutoski and John Dimar, and their hard-working committee, takes a unique look at the evolution of spine deformity management over the past ten years – what techniques have worked well, and what may have fallen short of expectations. This course promises to enlighten us on the recent history of a wide variety of spinal deformity subjects. Following this course will be several highly-educational Case Discussion sessions to choose from. Wednesday will conclude with the Opening Ceremonies and Welcome Reception. During the Opening Ceremonies, the Howard Steel Lecture will be the very interesting "Chicago: America's First City of Architecture," presented by Geoffrey Baer, Program Host and Producer, WTTW Channel 11 Chicago.

Beginning Thursday, the three-day Scientific Program will feature 129 podium presentations which were selected from approximately 1200 abstract submissions. For the first time, we'll be introducing a concurrent session on Friday morning. This will allow for an increased number of podium presentations and for members to attend those papers that may have particular interest to them. Program Committee Chair Daniel Sucato, MD, MS and his committee members deserve enormous credit for their hard work in organizing an excellent program that, as you will see, covers all aspects of spinal deformity. Being aware of our ever-expanding global presence, 26 percent of the podium presentations represent contributions from SRS international sites and nearly every program session includes an international member among the moderators. In addition, four Lunchtime Symposia, and three Half-Day Courses will compliment the free paper sessions.

I am proud to have Alvin H. Crawford, MD as my Harrington Lecturer. Dr. Crawford, the SRS' 31st President in 2001, will give the lecture titled "Journey to the Top." Without doubt, with Al's experience and wit, this lecture will be entertaining and educational. This year's Lifetime Achievement Award recipients are Vernon T. Tolo, MD and Robert B. Winter, MD. The Walter P. Blount Humanitarian Award recipient is Anthony S. Rinella, MD. My sincere congratulations go to each of these very impressive award recipients.

Friday night's Farewell Reception will be held at the inspiring Art Institute of Chicago. In addition to being a tremendous social setting, a portion of the Art Institute will be open for gallery tours, making this an exceptional evening. Thursday and Friday mornings will offer fun guest activities which include a "Picasso-for-a-Day Painting Activity" and a "Windy City Coffee and Book ("Loving Frank: A Novel") Chat". What a fun week this will prove to be.

This has been an outstanding year for me serving as your 41st President. I've had phenomenal support and guidance from our Board of Directors, council chairs, committee chairs and members and task forces. Through the work of everyone, this Society continues to thrive and truly represents the "state-of-the-art" in spinal deformity care. I especially thank my Presidential Line colleagues, Kamal Ibrahim, MD, FRCS(C), MA, Steve Glassman, MD and Larry Lenke, MD, all of whom contributed so much each week throughout this year – a remarkable trio. I also want to extend my heartfelt gratitude to Tressa Goulding and her administrative staff for their tireless work and creativity each and every day of the year. They are an exceptional collection of people whose energy and synergy help to make this extraordinary Society what it is today. Thank you for allowing me the privilege and honor of being your president.

My very best to all of you,

R. Stephens Richards, III, MD
SRS President

STATE OF ILLINOIS
OFFICE OF THE GOVERNOR
SPRINGFIELD, ILLINOIS 62706

Pat Quinn
GOVERNOR

September 5, 2012

Scoliosis Research Society
555 East Wells Street
Milwaukee, WI 53202

Dear Friends:

On behalf of the State of Illinois, it is a privilege to extend my sincere greetings to all national and international attendees who are gathered at the Sheraton Chicago Hotel & Towers for the Scoliosis Research Society Annual Meeting to realize the society's mission of improving patient care for those with spinal deformities.

This annual event is a wonderful opportunity to support a meaningful organization that supports research and education as the best defense against scoliosis. The Scoliosis Research Society has given millions of dollars towards grants for research; however, more research is always needed.

In June of this year, I officially declared Illinois to be in observance of the National Scoliosis Awareness Month. I proclaimed that Illinois stands in support of the Scoliosis Research Society and its efforts to improve the quality of life for those who are affected with the condition.

It is my hope that this year's gathering will be even more enjoyable and successful than prior years and I thank all participants for their exceptional support in the fight against scoliosis. It is a privilege to extend my words of tribute to all. Please know that you have my best wishes for an enjoyable and educational conference!

Sincerely,

Pat Quinn

Pat Quinn
Governor

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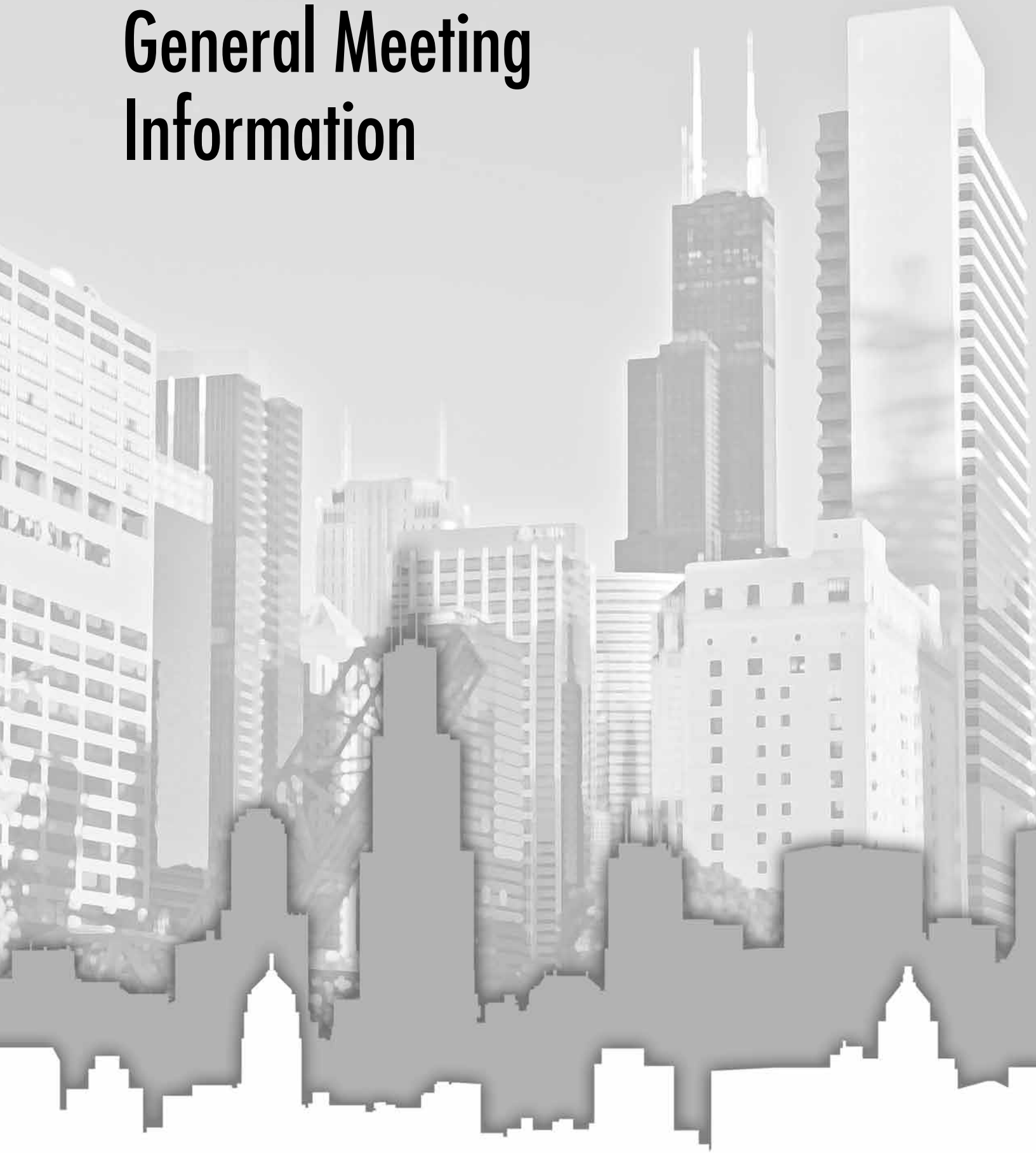
Paul D. Sponseller, MD
Daniel J. Sucato, MD, MS
Adam L. Wollowick, MD
Lukas P. Zebala, MD

General Meeting Information



The Scoliosis Research Society gratefully acknowledges
Medtronic for their support of the Pre-Meeting Course,
Welcome Reception, Farewell Reception, Beverage Breaks,
Wireless Internet, Annual Meeting E-Newsletter, Half-Day Courses,
and overall support of the 47th Annual Meeting & Course.

Medtronic

GENERAL MEETING INFORMATION

Abstract Volume
All abstracts accepted for presentation at the 47th Annual Meeting have been published in the Final Program (pages 53-155). Each attendee will receive one copy of the program along with their registration materials. Abstracts have also been posted online to the Program tab of the SRS Annual Meeting website (www.srs.org/professionals/meetings/am12/program.php)

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 times inside the Sheraton Chicago Hotel & Towers, 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
The Half-Day Courses on Thursday, September 6 require a ticket for admission. Tickets for these sessions are not included in the meeting's base registration fees, but are available for an additional $30. Tickets will be collected by ushers in exchange for lunch prior to the sessions. A limited number of tickets may be available at the Registration Desk. In addition, tickets will be required for admission to the Farewell Reception. The Farewell Reception will take place at the Art Institute of Chicago, at an additional $25 fee per ticket for registered delegates and registered guests. If you pre-registered, tickets may be found in your registration packets. A limited number of tickets may be available at the Registration Desk.

Attire
Business casual (polo or dress shirts, sport coats) is appropriate for meeting sessions and for all Annual Meeting & Course sessions and events. Business casual is also appropriate for the Farewell Reception.

Business Center
The Sheraton Chicago Hotel & Towers offers a full-service FedEx office Business Center.

FedEx Office is located on the lobby level across from the Tours Desk. Hours are Monday through Friday 6:30am – 6:00pm and 8:00am – 3:00pm on weekends. Hours are subject to change.

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

Certificates Of Attendance
Certificates of Attendance will be provided to pre-registered delegates within their registration materials. Delegates registering onsite may request a Certificate of Attendance at the Registration Desk. Registration staff may email the certificate to delegates or delegates may be asked to return to the desk to claim the certificate.

Emergency & First Aid
The Sheraton Chicago Hotel & Towers 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.

Guest Hospitality Suite & Activities
Location: Columbus Room, Lobby Level
Registered guests of Annual Meeting & Course delegates are welcome to meet and plan their days over a continental breakfast, courtesy of SRS. The Guest Hospitality Suite is open Thursday, September 6 through Saturday, September 8 from 7:30 – 10:00am in the Columbus Room on the lobby level of the Sheraton Chicago Hotel & Towers.

SRS is also pleased to announce the following activities available only to registered guests:

- Picasso-for-a-Day Painting Activity
  Thursday, September 6, 2012
  7:30 – 10:00am
  Guests are invited to explore their creativity and train their artistic eyes in preparation for Friday's Farewell Reception at the Art Institute of Chicago! Whether guests consider themselves artists or have never painted before, an instructor will guide them through recreating their choice of three featured paintings... and at the end of the morning, each will go home with a unique 11x14" masterpiece! All supplies (canvases, paint, brushes, aprons, etc.) will be provided, and there is no additional cost to guests. However this activity is limited to the first 30 guests to register. Please inquire at the SRS Registration Desk to determine availability. Guests are required to make their own arrangements for shipment/transport of paintings, if necessary.
- Windy City Coffee & Book Chat
  Friday, September 7, 2012
  9:00am
  Guests are invited to read *Loving Frank: A Novel by Nancy Horan* in advance and join in a friendly group discussion during breakfast. "I have been standing on the side of life, watching it float by. I want to swim in the river. I want to feel the current." - So writes Mamah Borthwick Cheney in her diary as she struggles to justify her clandestine love affair with Frank Lloyd Wright. In 1903, Mamah and her husband, Edwin, had commissioned the renowned architect to design a new home for them. During the construction of the house, a powerful attraction developed between Mamah and Frank, each married with children. In time, the two embarked on a course that would shock Chicago society and forever change their lives.

Guests must be registered with SRS to access the Hospitality Suite and take part in these activities.

GENERAL MEETING INFORMATION

Internet

Location: Sheraton 1-3, Level 4

Attendees can search the Internet and check email at the Internet kiosks, supported, in part, by a grant from K2M.

Wednesday, September 5 . . . . . 6:30am – 6:00pm
Thursday, September 6 . . . . . 6:30am – 4:30pm
Friday, September 7 . . . . . 6:30am – 5:30pm
Saturday, September 8 . . . . . 6:30am – 12:45pm

On meeting room levels 2 and 4, wireless internet is available, supported, in part, by a grant from Medtronic. To connect, open your computer's wireless connections, then select "SRS2012" from the list of available networks. No password is required.

Wireless internet is also available in the lobby for free of charge. The wireless code is "Sheraton Guest." The Link Café also offers computers and printers free of charge for guests of the hotel. Guests should enter their last name and room number.

Language

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

Lost & Found

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

Members Business Meetings

Location: Chicago 8-10, Level 4

All SRS members are invited to attend the Members Business Meetings, held Thursday, September 6 through Saturday, September 8 from 6:30 – 7:45am in the Chicago Ballroom 8-10 on Level 4 of the Sheraton Chicago Hotel & Towers. Agendas will include election of officers, reports from the various SRS committees, presentations by the 2012 Travelling Fellows, and updates on SRS activities and programs. A hot breakfast will be served. Breakfasts are supported, in part, by a grant from Medtronic.

Messages

A self-service message board (non-electronic) will be available in the Registration Area for attendees to post notes or leave messages for other attendees. Please remember to check for any messages that may be left for you. This message center is supported, in part, by a grant from K2M.

Non-Members Continental Breakfast

Location: Sheraton 1-3, Level 4

All non-member delegates to the SRS Annual Meeting are invited to meet with their colleagues, view posters and network over coffee and a continental breakfast served Thursday, September 6 through Saturday, September 8 from 6:30 – 7:45am in the Sheraton Ballroom 1-3 on Level 4 of the Sheraton Chicago Hotel & Towers. Breakfasts are supported, in part, by a grant from Medtronic.

An SRS Membership Information Session will be held during the continental breakfast on Friday, September 7 from 6:45-7:40am. Members of the SRS leadership and Fellowship Committee will present history of the SRS, overview of fellowship requirements and their general experiences as SRS members. All non-members are welcome to attend.

Photography Policy

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

Poster Hall

Location: Sheraton 1-3, Level 4

Tuesday, September 4 . . . . . 2:00 – 6:00pm (setup)
Wednesday, September 5 . . . . . 6:30am – 6:00pm
Thursday, September 6 . . . . . 6:30am – 4:30pm
Friday, September 7 . . . . . 6:30am – 5:30pm
Saturday, September 8 . . . . . 6:30am – 12:45pm

E-Posters may be viewed on monitors located in the Sheraton Ballroom 1-3 on Level 4, or from your own laptop using the CD-ROM provided with your registration materials, supported, in part, by a grant from K2M.

Registration Desk

Location: Sheraton/Chicago Promenade, Level 4

Tuesday, September 4 . . . . . 2:00 – 6:00pm
Wednesday, September 5 . . . . . 6:30am – 6:00pm
Thursday, September 6 . . . . . 6:30am – 4:30pm
Friday, September 7 . . . . . 6:30am – 5:30pm
Saturday, September 8 . . . . . 6:30am – 12:45pm

Smoking Policy

Smoking is not permitted during any meeting activity or event.

Speaker Upload Area

Location: Sheraton/Chicago Ballroom, Level 4

Podium presenters may upload their PowerPoint presentations in the Presentation Upload Area, located at the back of the general session room, Sheraton/Chicago Ballroom on Level 4. E-Posters may NOT be uploaded onsite.

Wednesday, September 5 . . . . . 6:30am – 6:00pm
Thursday, September 6 . . . . . 6:30am – 4:30pm
Friday, September 7 . . . . . 6:30am – 5:30pm
Saturday, September 8 . . . . . 6:30 – 11:00am

Please upload your presentation no later than 24 hours before the session begins.

GENERAL MEETING INFORMATION

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.

Tour Information

Delegates and guests, including adults and children ages 10 and up, are able to attend optional tours. Tickets are required to participate in the tours and must have been requested directly with AlliedPRA, our partners in Chicago, before August 1. AlliedPRA will distribute tour tickets and handle all tour inquiries at a Tours Desk on the lobby level of the Sheraton Chicago Hotel & Towers. Please direct all questions to the AlliedPRA Tours Desk, as the SRS Registration Desk will not have any tour-related information. A schedule of planned tours can be found in the Social Events & Tours section on page 14.

Venue Information

The Sheraton Chicago Hotel & Towers is the location for the 47th Annual Meeting & Course:

301 East North Water Street
Chicago, IL 60611
1-877-242-2558
www.sheratonchicago.com

SRS ANNUAL MEETING & COURSE MOBILE APP

A mobile and online app will be available to all delegates during the 47th Annual Meeting & Course. The app is designed to provide all the information about the Annual Meeting & Course and Chicago in one convenient location and can be accessed from any smart phone or computer with an internet connection. To download the app visit

http://eventmobi.com/srsam12

or scan the QR code below with your smart phone.

- **New this year"
  - Download all the abstracts and final program right from the app!
  - A new offline mode will allow delegates to access all static content, including the agenda, speaker listing and info booth, on the app without an internet connection.
- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule.
- An information booth featuring everything you need to know about the Annual Meeting & Course, and its host city of Chicago, including scientific and social program details, information on the Sheraton Chicago Hotel & Towers, as well as downtown Chicago dining and attractions.
- Live audience polls during the Pre-Meeting Course, Half-Day Courses and a Hibbs Award voting poll on Friday, September 7.
- Maps of the Sheraton Chicago Hotel & Towers and meeting space.
- An alert system for real-time updates from SRS - program changes, tour and social event notifications, and breaking news as it happens.
- A complete list of Annual Meeting faculty and podium presenters, including presentation titles, times, dates, and locations.

To learn more about the app or how to use the QR code, please refer to the insert in your registration bag or visit www.srs.org.

CME INFORMATION

Meeting Description

The Scoliosis Research Society Annual Meeting & Course is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Over 100 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

At the conclusion of the 47th Annual Meeting & Course, participants should be able to:

- Recognize factors that may contribute to higher complication rates or risk of reoperation and incorporate pre-and peri-operative steps that help to avoid complications in spinal deformity surgery;
- Assess clinical and radiographic factors that contribute to positive or negative outcomes in spinal deformity surgery and utilize this knowledge to prevent adverse outcomes;
- Understand new techniques for the treatment of patients with Early Onset Scoliosis;
- Understand the short and long-term effect of fusion for patients with AIS using a variety of correction strategies and implants.

Target Audience

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

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 joint sponsorship of the American Academy of Orthopaedic Surgeons (AAOS) and SRS. AAOS is accredited by the ACCME to provide continuing medical education for physicians.

Credit Designation

AAOS designates this live activity for a maximum of 25.75 (6.25 for the Pre-Meeting Course; 19.5 for the Annual Meeting) *AMA PRA Category 1 Credit(s)™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Disclosure Policy

It is the policy of AAOS and SRS to ensure balance, independence, objectivity and scientific rigor in all of their educational activities. In accordance with this policy, AAOS and SRS identify 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 AAOS and 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 on pages 15-30.

FDA Statement (United States)

Some drugs and medical devices discussed 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

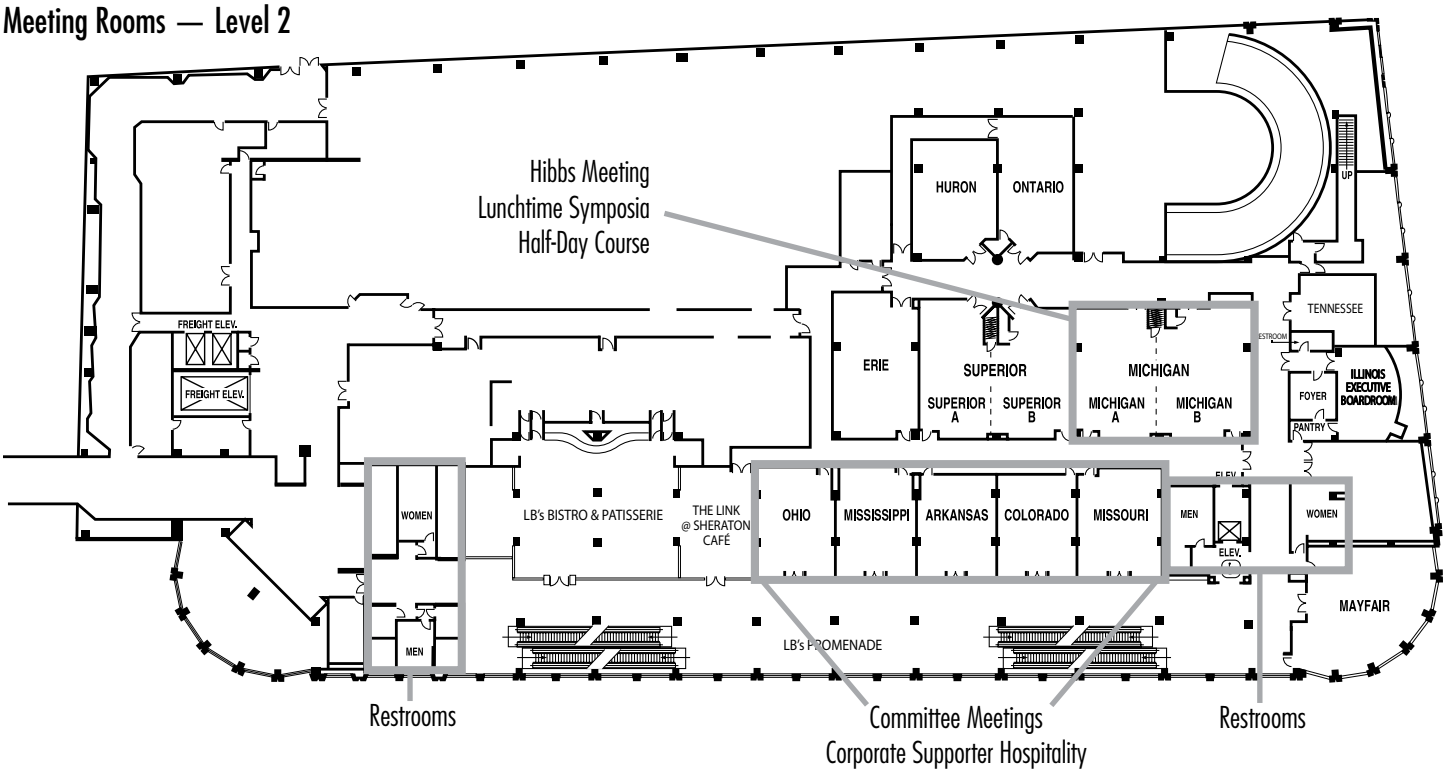
SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting or Course, including those participating in tours and social events. Participants and guests are encouraged to take out insurance to cover loss incurred in the event of cancellation, medical expenses or damage to or loss of personal effects when traveling outside of their own country.

SRS cannot be held liable for any hindrance or disruption of Annual Meeting and Course proceedings arising from natural, political, social or economic events or other unforeseen incidents beyond its control. Registration of a participant implies acceptance of this condition.

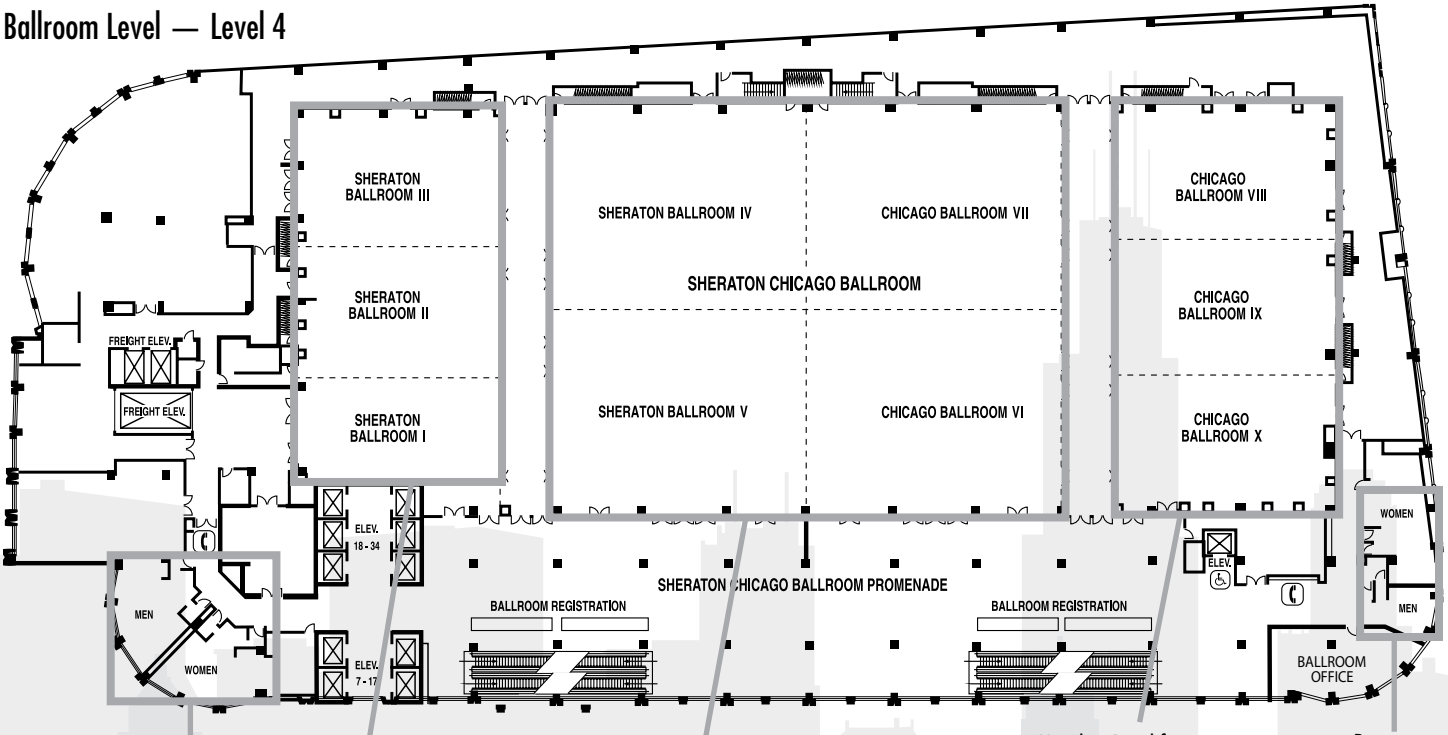
The materials presented at this continuing medical education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement, or opinion of the faculty that may be helpful to others who face similar situations.

SHERATON CHICAGO HOTEL & TOWERS FLOORPLAN

Meeting Rooms — Level 2



Ballroom Level — Level 4



MEETING OUTLINE

(subject to change)

Monday, September 3, 2012

7:00am – 5:00pm	Board of Directors Meeting	Columbus Room, Lobby Level

Tuesday, September 4, 2012

7:00am – 5:00pm	SRS Committee Meetings	Ohio, Mississippi, Arkansas, Colorado & Missouri Rooms, Level 2
1:00 – 5:00pm	Hibbs Society Meeting	Michigan Room, Level 2
2:00 – 6:00pm	Poster Set-Up	Sheraton 1-3, Level 4
2:00 – 6:00pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
7:00 – 10:00pm	SRS Leadership Dinner (by invitation only) Buses depart the Sheraton at 6:45pm.	University Club of Chicago

Wednesday, September 5, 2012

6:30am – 6:00pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 6:00pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
8:00am – 11:30am	Pre-Meeting Course – Morning Session	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
11:45am – 12:45pm	Lunchtime Symposia: Research Outcomes Global Outreach	 Michigan Room, Level 2 Chicago 8-10, Level 4
1:00 – 4:10pm	Pre-Meeting Course – Afternoon Session	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
4:30 – 5:45pm	Case Discussions	Ohio, Mississippi, Arkansas, Colorado & Missouri Rooms, Level 2
6:00 – 7:30pm	Opening Ceremonies	Sheraton/Chicago Ballroom, Level 4
7:30 – 9:00pm	Welcome Reception	Sheraton/Chicago Ballroom Promenade, Level 4

Thursday, September 6, 2012

6:30am – 4:30pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 4:30pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast	Sheraton/Chicago Ballroom Promenade, Level 4
7:30 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 12:15pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
12:15 – 1:30pm	Lunch & Networking for Half-Day Course Participants (ticket required for lunch)	Sheraton 1-3, Level 4
1:30 – 4:30pm	Half-Day Courses: Minimally Invasive Surgery Infection Sagittal Balance	 Chicago 8-10, Level 4 Michigan Room, Level 2 Sheraton/Chicago Ballroom

MEETING OUTLINE

(subject to change)

Friday, September 7, 2012

6:30am – 5:30pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 5:30pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast & Membership Information Session	Sheraton/Chicago Ballroom Promenade, Level 4
7:30 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 11:50am	Scientific Program	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
12:00 – 1:00pm	Lunchtime Symposia: Coding Non-Operative Management	 Chicago 8-10, Level 4 Michigan Room, Level 2
1:15 – 5:23pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
7:00 – 10:00pm	Farewell Reception Buses depart the Sheraton at 6:45pm. Return trips begin at 9:00pm.	Art Institute of Chicago

Saturday, September 8, 2012

6:30am – 12:45pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 12:45pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast	Sheraton/Chicago Ballroom Promenade, Level 4
7:00 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 12:39pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
12:39pm	Meeting Adjourns	
1:00 – 3:30pm	Board of Directors Meeting	Columbus Room, Lobby Level
5:30pm	Robert B. Winter, MD Endowment Fund Dinner	Chicago 8-10, Level 4

GUEST LECTURERS & AWARD RECIPIENTS

Howard Steel Lecture

Wednesday, September 5, 2012

Geoffrey Baer

Program Host and Producer, WTTW Channel 11 Chicago

"Chicago: America's First City of Architecture"

Multiple Emmy award-winning writer, producer and program host Geoffrey Baer is known for his masterful storytelling, conversational style, and contagious enthusiasm. He is best known for his popular feature-length TV specials about Chicago architecture and history, including "Biking the Boulevards," "Chicago's Lakefront," "Chicago by Boat: the New River Tour," "Chicago's Loop: a Walking Tour," and "Chicago by 'L': Touring the Neighborhoods," as well as six programs covering virtually all of Chicago's suburban areas. Programs seen nationally on Public Television include a documentary about acclaimed New York architect Robert A. M. Stern and "Saved from the Wrecking Ball," a documentary about the preservation of Mies van der Rohe's Farnsworth House. He is currently in production on a new PBS primetime special "Ten Buildings that Changed America" debuting in the spring of 2013. Mr. Baer also appears weekly on WTTW's flagship nightly public affairs program "Chicago Tonight," answering viewers' questions about Chicago architecture and history in a segment called "Ask Geoffrey." In his 22 years at WTTW, he has written and produced numerous other documentaries and cultural and entertainment specials for local and national television, and has served as the executive producer of the weekly cultural magazine show "Artbeat Chicago," and of the weekly documentary series "Chicago Stories." He has been a docent for the Chicago Architecture Foundation since 1987, is a board member of the Art Institute of Chicago's Architecture and Design Society, and an emeritus board member of Lookingglass Theatre Company. In addition to his Emmy awards, Mr. Baer has received the CPB Gold Award from the Corporation for Public Broadcasting, and awards from the National Association of Broadcasters, the New York Festivals, the US International Film and Video Festival, and the Chicago Headline Club.

Walter P. Blount Humanitarian Award Recipient

The 2012 Walter P. Blount Humanitarian Award will be presented on Wednesday, September 5, acknowledging outstanding service to those with spinal deformity, and for generosity to the profession and Society.

Anthony S. Rinella, MD

Anthony S. Rinella, MD is a board-certified, fellowship-trained spine surgeon. His practice, Illinois Spine & Scoliosis Center, is a referral center for complex adult and pediatric procedures, including scoliosis and revision procedures. He has a special interest in the cervical spine, and minimally invasive procedures.

Dr. Rinella grew up in Flossmoor, Illinois, where his parents live today. He attended Northwestern University as an undergraduate, and graduated with honors in philosophy. He later attended medical school at the University of Illinois College of Medicine. He performed his residency at Northwestern University and completed a fellowship and adult and pediatric spinal surgery at Washington University in St. Louis with Drs. Bridwell, Lenke, and Riew. Dr. Rinella was certified by the American Board of Orthopaedic Surgery (ABOS) in 2004.

Dr. Rinella is also founder of SpineHope, a nonprofit organization that performs global outreach to indigent children with complex spinal deformities in South America. Through this organization, he hopes to expand SRS' treatment sites throughout South America, and transport particularly high-risk children to the U.S. for specialized care. Dr. Rinella is the medical director of the trip, and will complete his ninth trip to Cali, Colombia in 2013.

Harrington Lecture

Thursday, September 6, 2012

Alvin H. Crawford, MD

"Journey to the Top"

In 1964, Alvin H. Crawford, MD became the first African American to graduate from the University of Tennessee College of Medicine. After medical school, he started residency at Boston Naval Hospital and completed it in the Combined Harvard University Orthopaedic Program. He was an Aufranc hip reconstruction fellow and performed subsequent pediatric orthopaedic and spine fellowships at Boston Children's Hospital and the A.I. DuPont Institute, started the San Diego Naval Pediatric and Scoliosis service.

Dr. Crawford directed the Orthopaedics Program at Cincinnati Children's Hospital for 29 years and was awarded Chairs in Pediatric Orthopaedics and Spine. In 2011, the Crawford Spine Center was named to honor his many years of dedicated service. In addition, Dr. Crawford has completed multiple visiting professorships, lectured and performed surgery in 38 countries and trained 54 fellows.

He is considered an authority on video-assisted thoracoscopic surgery as well as neurofibromatosis in children, a genetic disorder often associated with scoliosis. He has published more than 200 articles, 63 chapters and authored or co-authored six books. He was cited as one of the Top 10 Educators, and only surgeon, in the first 100 Years at Cincinnati Children's Hospital and received the Founder's Award from the Cincinnati Pediatric Society.

Dr. Crawford was the first African American president of the Scoliosis Research Society in 2001 and was senior traveling fellow in 2009. He received the Daniel Drake Medal, the highest academic award given by the University of Cincinnati, the 2007 Diversity Award from the American Academy of Orthopaedic Surgeons (AAOS), and the International Trumpet Award heralding the accomplishments of a Black American who has inspired others. Most recently, he was selected for the 2011 Laurel Wreath Award from his fraternity, Kappa Alpha Psi, the fraternity's highest award. He is currently President of the John Robert Gladden Society, a multi-cultural affiliate of AAOS.

Dr. Crawford is husband to Alva Jean, father to Alvin and Carole, grandfather to Mia and Elle, a musician and tennis enthusiast.

GUEST LECTURERS & AWARD RECIPIENTS

Lifetime Achievement Award Recipients

The 2012 Lifetime Achievement Awards will be presented on Thursday, September 6. 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.

Vernon T. Tolo, MD

Vernon T. Tolo, MD is currently chief emeritus of the Children's Orthopaedic Center at Children's Hospital Los Angeles (CHLA). He served as chief of orthopaedics at CHLA from 1987-2009. He also is the John C. Wilson, Jr., Professor of Orthopaedics at the Keck School of Medicine at the University of Southern California.

Dr. Tolo received his undergraduate degree from Concordia College in Minnesota and his medical degree from Johns Hopkins University School of Medicine. His surgical and orthopaedic training was at Johns Hopkins Hospital, where he was chief of pediatric orthopaedics for 11 years before moving to CHLA. In 2001, he was inducted into the Johns Hopkins Society of Scholars.

Dr. Tolo has been active in several orthopaedic associations. He has been president of the Pediatric Orthopaedic Society of North America (POSNA), the Scoliosis Research Society (SRS) and the Orthopaedic Section of the American Academy of Pediatrics (AAP). He was also president of the American Academy of Orthopaedic Surgeons (AAOS) from 2002-2003. His awards include the Distinguished Achievement Award from POSNA and the Tipton Leadership Award from AAOS. He currently is editor-in-chief of the Journal of Bone and Joint Surgery.

His primary clinical interests in pediatric orthopaedics are spinal deformity, orthopaedic problems associated with skeletal dysplasia and cerebral palsy, and orthopaedic injuries in children and adolescents.

Robert B. Winter, MD

Born in 1932 in Cedar Rapids, Iowa, Dr. Robert B. Winter attended Grinnell College in Grinnell, Iowa, graduating in 1954. Following college, he went to medical school at Washington University in St. Louis and graduated in 1958.

Dr. Winter interned at Minneapolis General Hospital, and completed his subsequent residency in orthopaedics at the University of Minnesota with Chief John Moe, MD. During his second year, on August 24, 1960, Dr. Moe invited Dr. Paul Harrington to show the residents and staff Harrington's new spinal rod system and perform two scoliosis surgeries at Gillette. Dr. Winter was selected as a resident for one of the two cases.

Upon completion of residency in 1963, Dr. Winter entered general orthopaedic practice in St. Paul, Minnesota, while simultaneously spending one day a week at Gillette on the scoliosis service. During this time, he wrote the classic article on congenital spine deformity, which was published in 1968. In 1966, he went to Sao Paulo, Brazil to assist Dr. Moe in the establishment two scoliosis centers, a trip that would profoundly affect his career.

In 1971, Dr. Winter accepted a full-time position with the University of Minnesota, solely focused on scoliosis and pediatric orthopaedics. He was president of SRS in 1974, as well as secretary of the Pediatric Orthopaedic Society from 1974 to1979. In 1973, Dr. Moe, Dr. John Lonstein, Dr. David Bradford and Dr. Winter formed the Twin Cities Scoliosis Center. They began their spine fellowships in 1971 and published their first textbook in 1978. Dr. Winter retired from clinical practice in 1993, but continued to be heavily involved in research and teaching until 2011.

He says his greatest accomplishment was marrying Jane in 1957 and helping her raise five wonderful children.

SOCIAL EVENTS

Opening Ceremonies & Welcome Reception

Wednesday, September 5, 2012
6:00 – 9:00pm
Sheraton/Chicago Ballroom & Promenade
Open to all registered delegates and their registered guests at no additional fee. Name badges are required.

The Annual Meeting will officially begin with Opening Ceremonies and this year's Howard Steel Lecture, "Chicago: America's First City of Architecture," presented by Geoffrey Baer, Program Host and Producer, WTTW Channel 11 Chicago. The evening will include an introduction of the SRS officers and honored presidents from other spine societies. All guests are invited and encouraged to attend the Opening Ceremonies. Following the Opening Ceremonies, guests will move to a hosted reception featuring heavy hors d'oeuvres, cocktails, and plenty of lively conversation and reunions with colleagues and friends.

The Welcome Reception is supported, in part, by grants from Medtronic and Synthes Spine.

Farewell Reception at the Art Institute of Chicago

Friday, September 7, 2012
7:00 – 10:00pm
Art Institute of Chicago
Open to all registered delegates and registered guests. Tickets are $25 each and must be purchased in advance. A limited number of tickets may be available onsite, but SRS strongly urges delegates and guests to purchase tickets at the time of registration. Name badges are required.

The 47th Annual Meeting culminates with an evening at the Art Institute of Chicago. Busses will depart the Sheraton beginning at 6:45pm, and will continue to run between the Sheraton and the Art Institute until 10:00pm. The Art Institute of Chicago, founded in 1879 as both a museum and a school, was built on the rubble of the 1871 Chicago fire. The museum originally housed a collection of plaster casts and had a visionary purpose: to acquire and exhibit art of all kinds and to conduct programs of education. The collection now encompasses more than 5,000 years of human expression from cultures around the world, including one of the world's most notable collections of Impressionist and Post-Impressionist art in its permanent collection. Notable works housed at the Art Institute include Vincent VanGogh's *Self-portrait*, *The Old Guitarist* by Pablo Picasso, Claude Monet's *Water Lillies* and *American Gothic* by Grant Wood. At one million square feet, it is the second largest art museum in the United States behind only the Metropolitan Museum of Art in New York City. Business or cocktail attire is appropriate. Cocktails and heavy hors d' oeuvres will be served.

The Farewell Reception is supported, in part, by a grant from Medtronic.

TOURS

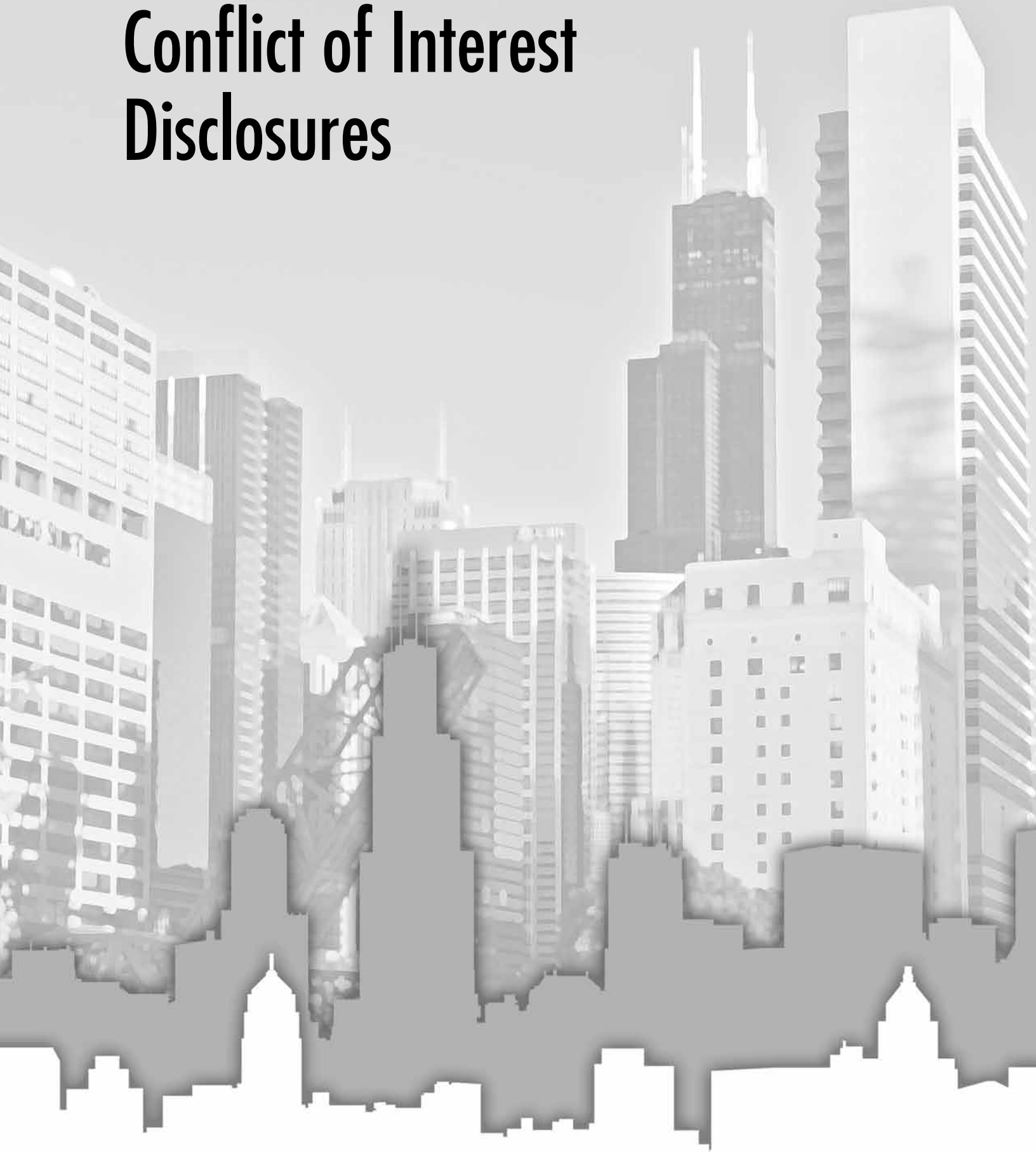
Delegates and guests, including adults and children ages 10 and up, are able to attend optional tours. Tickets are required to participate in the tours and must have been requested directed with AlliedPRA, our partners in Chicago, **before August 1**. Onsite registration is **not** available. AlliedPRA will distribute tour tickets and handle all tour inquiries at a Tours Desk on the lobby level of the Sheraton Chicago Hotel & Towers. Please direct all questions to the AlliedPRA Tours Desk, as the SRS Registration Desk will not have any tour-related information.

The following tours will depart from the lobby of the Sheraton Chicago Hotel & Towers promptly at the times listed below:

Thursday September 6, 2012

1:15pm – 3:45pm	Architectural River Cruise
1:00pm – 3:00pm	Chicago on Fire!

Conflict of Interest Disclosures



The Scoliosis Research Society gratefully acknowledges
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CONFLICT OF INTEREST DISCLOSURES

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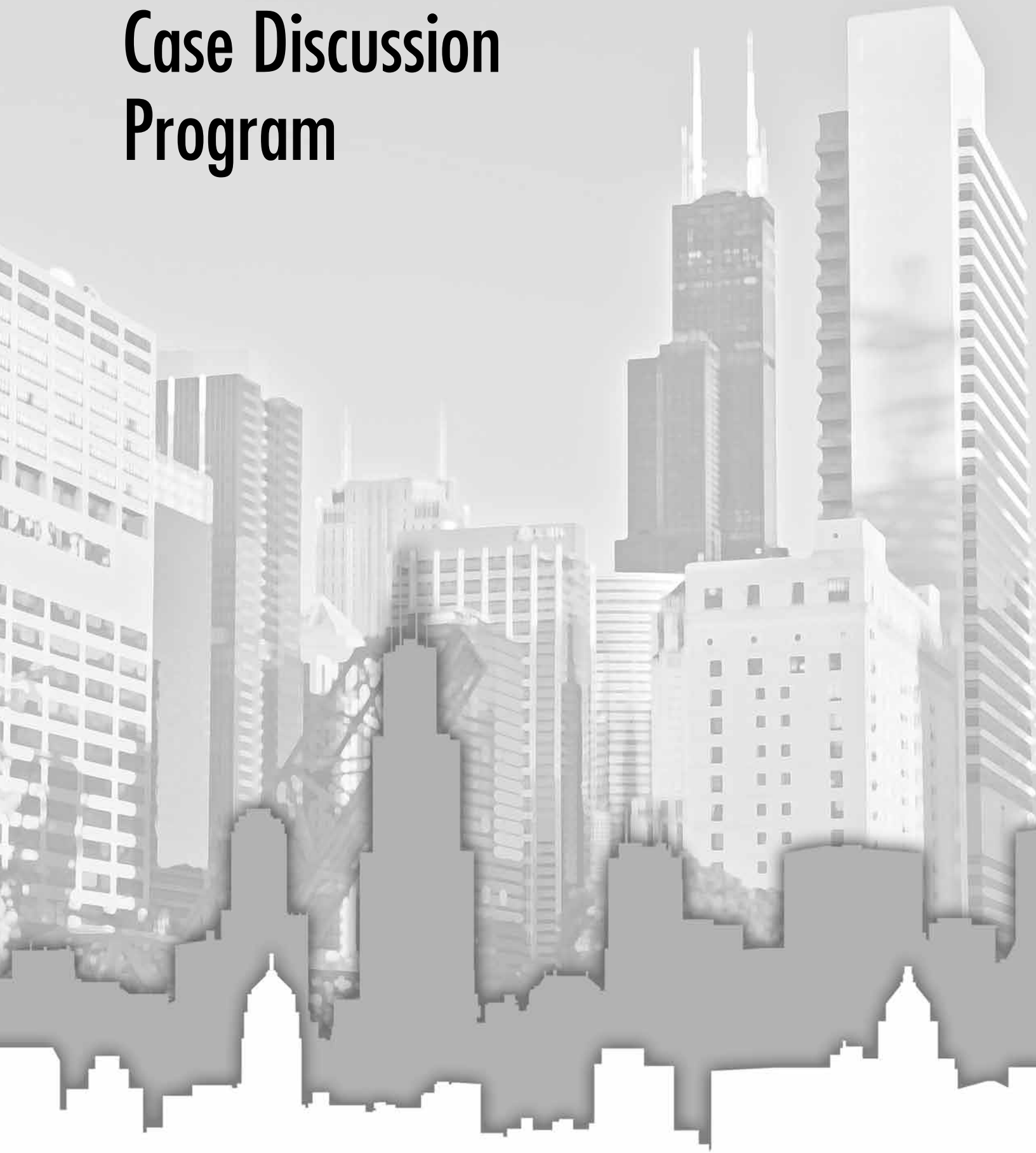
CONFLICT OF INTEREST DISCLOSURES

Kenneth Ward, MD	USA	Axial Biotech (c,f)
William C. Warner, MD	USA	No Relationships
Kota Watanabe	Japan	Medtronic (b)
Stuart L. Weinstein, MD	USA	No Relationship
Gavin White	Australia	Medtronic (b)
Brendan A. Williams, AB	USA	No Relationships
Brad Williamson	United Kingdom	No Relationships
Robert B. Winter, MD	USA	EBI (g)
Carol Wise, PhD	USA	No Relationships
Raymund Woo, MD	USA	Biomet (b); K2M (a,b,e); Mimedx (b); Seaspine (b,g)
Kirkham B. Wood, MD	USA	No Relationships
Ashley Woodbury, BS	USA	No Relationships
Chia H. Wu, MD	USA	No Relationships
Thomas A. Wâxnäs	Sweden	No Relationships
Jingming Xie	China	No Relationships
Kei Yamada, MD, PhD	Japan	No Relationships
Kent T. Yamaguchi, BA	USA	No Relationships
Haruhisa Yanagida, MD	Japan	Japanese Government (a); Medtronic (a)
Burt Yaszay, MD	USA	DePuy Spine (a,d); Ellipse (a,b); K2M (a,b); KCI (a); Orthopediatrics (g); Synthes Spine (b)
Guney Yilmaz	USA	No Relationships
Mauno Ylikoski, MD	Finland	No Relationships
Andrew Yoo	USA	No Relationships
Petya Yorgova, MS	USA	No Relationships
Timo A. Yrjonen, MD	Finland	No Relationships
Fiona WP Yu, BSc (Advanced)	Hong Kong	No Relationships
Yang Yu	China	No Relationships
Dongping Zhang, MD, MS	USA	No Relationships
Ying Zhang	China	No Relationships
Zhi Zhao	China	No Relationships
Xiaowei Zhu, MS	USA	No Relationships
Zezhang Zhu	China	No Relationships
SRS Staff (Section 11)		
Cydni Chapman	USA	No Relationships
Tressa Goulding, CAE, CMP	USA	No Relationships
Megan M. Kelley	USA	No Relationships
Courtney Kissinger	USA	No Relationships
Katy Kujala-Korpela	USA	No Relationships
Brian Lueth	USA	No Relationships
Nilda Toro	USA	No Relationships

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

Case Discussion Program



The Scoliosis Research Society gratefully acknowledges
K2M, Inc. for their support of the E-Poster CD-ROM,
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CASE DISCUSSION PROGRAM

Wednesday, September 5, 2012

4:30-5:45pm

These sessions are open to all Annual Meeting & Course delegates. Pre-registration is not required and no additional fee applies.

The Case Discussions allow an opportunity to present unique and challenging clinical cases to the SRS with a panel of experts present to review and discuss each case and the clinical issues that are highlighted, as well as answer questions from audience participants. The panels will also prepare case studies for presentation and discussion, as time allows. All of the following Case Discussion presentations were selected from those submitted through the abstract submission and review process.

Neurologic Complications

Room: Arkansas, Level 2
Moderator: Richard E. McCarthy, MD
Panelists: Hilali H. Noordeen, FRCS
Harry L. Shufflebarger, MD

Cases for Discussion:

Loss of Fixation of Upper Thoracic Pedicle Screws Causing Spinal Cord Injury
Kira F. Skaggs, Aimee Brasher, Charles E. Johnston, John Purvis, John T. Smith, Karen S. Myung, David L. Skaggs

Delayed Post-Operative Neurological Deficit after Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: Possible Association with Post-Operative Anemia
Pedro M. Fernandes, MD, Stuart L. Weinstein, MD

Delayed Postoperative Neurological Deficit Following Anterior and Posterior Surgery for Congenital Kyphoscoliosis: Resolved By Revision and Four-Rod Instrumentation Technique
Pooya Javidan, MD, Nima Kabirian, MD, Gregory Mundis, Jr., MD, Behrooz A. Akbarnia, MD

Large Symptomatic Epidural Hematoma Distal to the Instrumentation in a 25-Year-Old Patient after VCR for Scheuermann's Kyphosis
Mostafa H. El Dafrawy, MD, Michael Alapatt, MD, Khaled Kebaish, MD

Revision Surgery after Neurological Injury in Complex Congenital Kyphoscoliosis
Vishal Sarwahi, MD, Terry D. Amaral, MD, Preethi M. Kulkarni, MD, Adam L. Wollowick, MD

Miscellaneous Complications

Room: Mississippi, Level 2
Moderator: James O. Sanders, MD
Panelists: Carlos A. Tello, MD
Paul D. Sponseller, MD

Cases for Discussion:

Dystrophic Scoliosis due to NF 1and Dual Intraspinal Dislocation of Rib Heads
Krishna Kumar Ramachandran Nair, MBBS, MNAMS, DO, DNB

Ogilvie Syndrome and Arterial Hypertension Associated with Occipito-Cervical Fusion in a Patient with Torticollis and Occipito-Cervical Instability
Carlos A. Tello, MD, Eduardo Galaretto, MD, Mariano A. Noel, MD, Ida Alejandra Francheri Wilson, MD, Rodrigo G. Remondino, MD, Maria Selva Vallejos Arce, MD, Mariano O. Reynier, MD, Gaston Eljure, MD, Nicolas Coombes, MD, Romina Corrado, MD, Ernesto Bersusky, MD

Strategy for Revision Surgery for Progressive Scoliosis after Implant Removal due to Surgical Site Infection: Case Report
Taichi Tsuji, Noriaki Kawakami, MD, DMSC, Kazuyoshi MIyasaka, MD, Tetsuya Ohara, Yoshitaka Suzuki, Toshiki Saito, Ayato Nohara, Ryo Sugawara

Management of Deep Infection after Posterior Spinal Instrumentation with Prolonged Suction Drainage
Yong Min Kim, MD, PhD, Seung Myung Choi, MD

Postoperative Vision Loss Following Posterior Spinal Fusion for Scheuermann's Kyphosis with Complete Resolution of Symptoms
Monica M. Payares, MD, Terry D. Amaral, MD, Adam L. Wollowick, MD, Vishal Sarwahi, MD

CASE DISCUSSION PROGRAM

Adult Deformity

Room: Ohio, Level 2
Moderator: Oheneba Boachie-Adjei, MD
Panelists: Christopher I. Shaffrey, MD
Joseph H. Perra, MD

Cases for Discussion:

Unrecognized Intraoperative Colon Perforation During Minimally Invasive Lateral Interbody Fusion for Degenerative Scoliosis
Adam L. Wollowick, MD, Terry D. Amaral, MD, Vishal Sarwahi, MD

Three-Stage Reconstruction for Chin on Chest Deformity in a 65-Year-Old Female with Multiple Comorbidities and Post-Polio Syndrome
Mostafa H. El Dafrawy, MD, Hamid Hassanzadeh, MD, Khaled Kebaish, MD

Non-Contiguous Two Level VCR for Severe Thoracic Kyphosis in an Osteoporotic Patient
Mostafa H. El Dafrawy, MD, Philip Neubauer, MD, Khaled Kebaish, MD

An Unusual Case of Degenerative Scoliosis and Leg Pain
Sanjeev Suratwala, MD

How Can We Manage a Severe Spinal Deformity with Multiple Spinal Canal Stenoses?
Kazuhiro Hasegawa, MD, PhD, Haruka Shimoda, Kanji Sasaki

Spondylolisthesis

Room: Colorado, Level 2
Moderator: Hubert Labelle, MD
Panelists: Pierre Roussouly, MD
Douglas C. Burton, MD

Cases for Discussion:

Reverse Spondyloptosis in a 12-Year-Old Girl with a History of Tuberculosis: A Case Report
Brian J. Deignan, MD, H. R. Tuten, MD

Spondyloptosis of the Cervical Spine in a Patient with Neurofibromatosis Type 1(NF1)
Senthilnathan Thirugnanasambandam, MD, Alvin H. Crawford, MD, Francesco T. Mangano, DO

Cauda Equina Syndrome due to Iatrogenic Grade IV Spondylolisthesis s/p Posterior Spinal Fusion for Paralytic Scoliosis
Christopher DeWald, MD

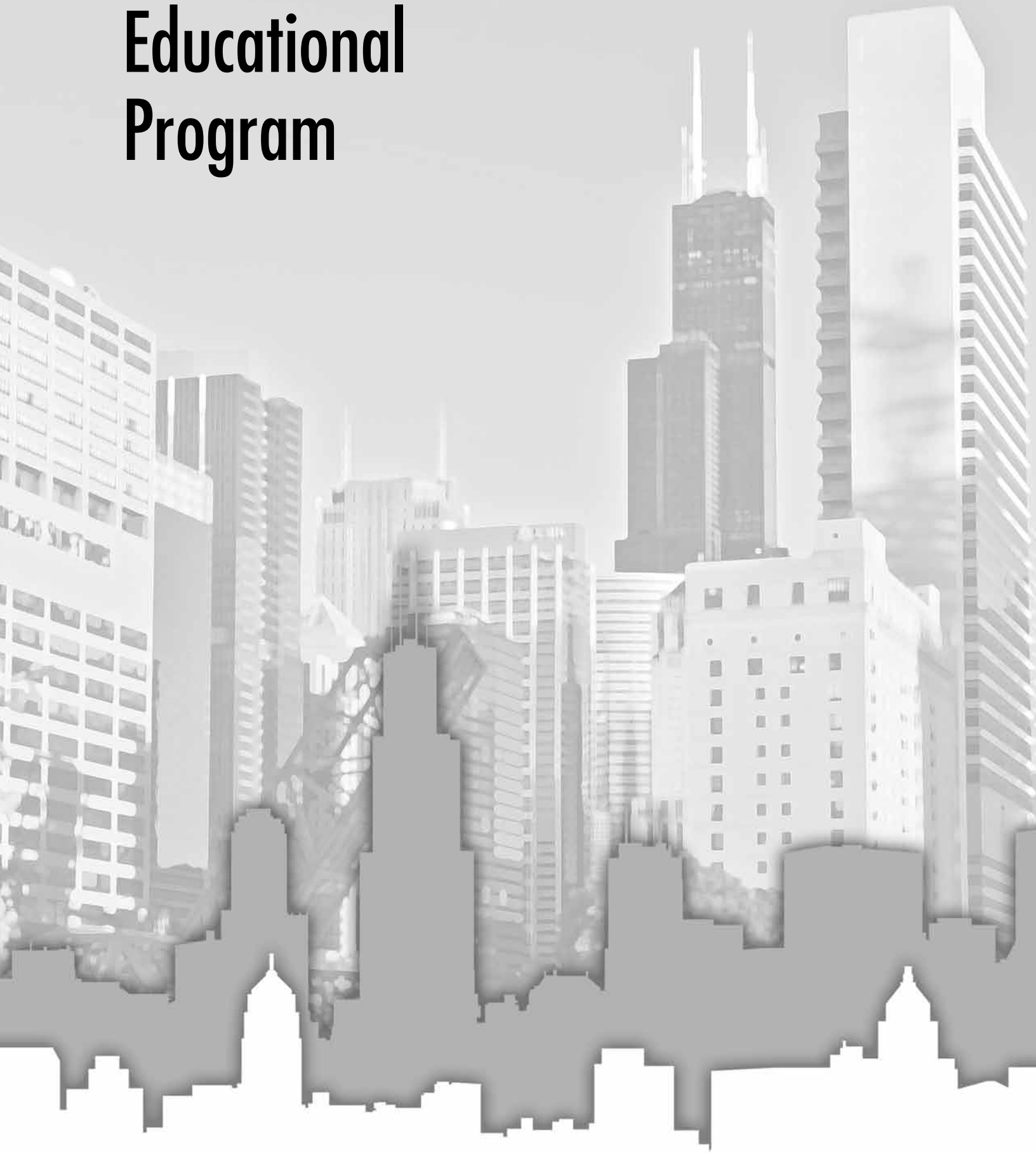
L5 Spondyloptosis Associated with Massive Dural Ectasia and Progressed Low Back Pain: Case Report
Ying-Song Wang, MD, Jing-Ming Xie, Tao Li, Ying Zhang, Zhi Zhao, Wei Zhao

Revision Spondyloptosis Resection Surgery from a Posterior-Only Approach: Review of Four Cases
Jeremy L. Fogelson, MD, Lawrence G. Lenke, MD, Brenda A. Sides, MA

Spine Deformity Ultra-Long Follow-Up: What Have We Really Learned?

Room: Missouri, Level 2
Moderator: Behrooz A. Akbarnia, MD
Panelists: Ronald DeWald, MD
Robert B. Winter, MD
Sigurd H. Berven, MD

Educational Program



The Scoliosis Research Society gratefully acknowledges
DePuy Spine for their overall support of the Post-Meeting Webcast
and overall support of the 47th Annual Meeting & Course.

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Wednesday, September 5, 2012

Lunchtime Symposia
11:45am – 12:45pm
Pre - registration is required for all of the following sessions and space is limited.

Breaking News: Initial Presentations from Recent SRS Grant Winners

Room: Michigan Room, Level 2
Chair: John M. Flynn, MD

The Research Grants Committee presents a lunchtime symposium, giving recent grant recipients an opportunity to present and discuss the fruits of their labors. After presenting their preliminary or final results, each project will be discussed in detail. There will also be an opportunity to discuss the grant funding application process with the members of the Research Grants Committee

11:45 - 11:50am	Introductory Comments *John M. Flynn, MD*
11:50 - 11:55am	The Influence of Asymmetric Loading on the Structure and Metabolism of the Human Invertebral Disc *Lisbet A. Haglund, PhD*
11:55am - 12:00pm	Improving Bone Formation in Osteoporosis through Mechanical Signaling Pathways *Frank Acosta, MD*
12:00 - 12:05pm	Patients with Adolescent Idiopathic Scoliosis and Scroth Curve Type 3c who will respond to Schroth Exercises *Eric C. Parent, PhD*
12:05 – 12:15pm	Discussion
12:15 - 12:20pm	Genetic Determinants of Vestibular Dysfunction in AIS *Shunmoogum A. Patten, MD*
12:20 - 12:25pm	Three-Dimensional Visualization of Vertebral Growth Cartilage and Disc: The Effects of Growth Modulation *Peter O. Newton, MD*
12:25 - 12:30pm	"SMART" Internal Spinal Orthosis for Gradual Correction of Spinal Deformities *Kenneth MC Cheung, MD*
12:30 – 12:40pm	Discussion
12:40 - 12:45pm	Concluding Comments *Charles E. Johnston, MD*

EDUCATIONAL PROGRAM

Reaching Around the World – Global Outreach Committee

Room: Chicago 8-10, Level 4
Chair: Kenneth J. Paonessa, MD

Meet the members of the Global Outreach Committee and representatives from the SRS Endorsed Sites at the Global Outreach Committee Lunchtime Symposium. If you have ever thought about volunteering your skills and knowledge in another country or want to learn about some of the current treatments of less common conditions, such as Pott's Disease or untreated severe scoliosis, then you will find this symposium informative. During the symposium, representatives from the SRS Endorsed Sites will report on the past year's activities at some of the sites where they have volunteered, including Western and Eastern Africa, South and Central America, the Indian Subcontinent and Asia, and Eastern Europe. If you have already been involved in the global outreach of spinal deformity care, this is an excellent opportunity to network with colleagues.

11:45 - 11:50am Introductory Comments
Kenneth J. Paonessa, MD

11:50am - 12:20pm Summary from Global Outreach Sites

- 11:50 – 11:55am Ghana (FOCOS)
  Kenneth J. Paonessa MD
- 11:55 – 11:58am Trinidad (FOCOS)
  Vincent Arlet, MD
- 11:58am – 12:02pm Columbia (Spinehope)
  Anthony S. Rinella MD
- 12:02 – 12:07pm Bulgaria (Official SRS Site)
  Steven M. Mardjetko, MD, FAAP
- 12:07 – 12:12pm Dominican Republic (Butterfly Foundation)
  Andrew W. Moulton, MD
- 12:12 – 12:17pm Indonesia
  Theodore A. Wagner, MD
- 12:17 – 12:20pm Uganda
  Isador H. Lieberman, MD, MBA, FRCSC

12:20 - 12:25pm Future Sites: Bangladesh, Iran, Jamaica, Middle East
Kenneth J. Paonessa, MD and Youssry El-Hawary, MD

12:25 - 12:35pm GOP Survey Results
Samuel K. Cho, MD and Hossein Mehdian, MD, FRCS(Ed)

12:35 – 12:45pm Discussion

Thursday, September 6, 2012

Half-Day Courses
1:30 – 4:30pm

Pre-registration is required for all sessions and space is limited. There is an additional registration fee of $30 for the Half-Day Courses, which includes a ticket for lunch, which will collected by ushers.

Minimally Invasive Surgery

Room: Chicago 8-10, Level 4
Chairs: Stephen J. Lewis, MD, MSc, FRCSC; Adam L. Wollowick, MD; Choll W. Kim, MD, PhD

This half-day course will highlight the principles of minimally invasive surgery (MIS) and their incorporation into both adult and pediatric spinal deformity surgery. A highly visual and interactive program will demonstrate key technical features and principles of MIS deformity surgery. The faculty will highlight the importance of minimizing dead space to promote a better environment for fusion. Technical aspects of tissue handling, instrumentation placement, and deformity correction and decompression techniques will be reviewed. Short term results as well as early and late pitfalls will be discussed. The latest instrumentation will be reviewed, and the speakers will address unmet needs to direct future advances. Interactive case discussions will complete the course.

Part 1: Introduction

Moderator: *Adam L. Wollowick, MD*

1:30 – 1:35pm Objectives of the Symposium and Introduction of the Speakers
Adam L. Wollowick, MD

1:35 – 1:45pm Minimally Invasive Spine Surgery 2002 - 2012: Where Have We Been and Where are We Going?

- Review Key Literature to Demonstrate what has been Shown to Work
- Review the Techniques and Results of MIS Ecompression and Fusion for Common Spinal Conditions
  - Discectomy
  - Laminectomy
  - TLIF
  - ALIF
  - Direct Lateral
  - Trauma

Choll W. Kim, MD, PhD

1:45 – 1:55pm Shortcomings of Standard Approaches to Spinal Deformity and Benefits of Minimally Invasive Approaches and their Application to Deformity

- Review Common Problems with Open Deformity Surgeon in Children and Adults
  - Pseudarthrosis
  - Adjacent Segment Degeneration
  - Infection
- Review the Principles of Tissue Handling, Deadspace, and Intermuscular Planes

Stephen J. Lewis, MD, MSc, FRCSC

EDUCATIONAL PROGRAM

Part 2: Techniques for Pediatric Spinal Deformity
Moderator: *Stephen J. Lewis, MD, MSc, FRCSC*

1:55 – 2:10pm Posterior Approaches for MIS Deformity Surgery including Screw Placement
- Percutaneous
- Multiple Incisions
- Mini-Open
- Open Wiltse Approach

Vishal Sarwahi, MD

2:10 – 2:25pm Correction and Fusion Techniques
- Rod Rotation, Translational, Distraction/Compression Techniques
- Anterior Release Techniques
- Posterior Release Techniques
- Intra-Operative Traction
- Techniques and Graft Material Used in Obtaining Facet Fusions

Firoz Miyanji, MD, FRCSC

2:25 – 2:35pm Discussion

Part 3: Pediatric Scoliosis: Case Examples
Moderator: *Adam L. Wollowick, MD*
Panel: *Kamal N. Ibrahim, MD, FRCS(C), MA; Firoz Miyanji, MD, FRCSC; Vishal Sarwahi, MD; Stephen J. Lewis, MD, MSc, FRCSC*

2:35 – 2:40pm AIS (Lenke 1 and 5)
Adam L. Wollowick, MD

2:40 – 2:45pm AIS (Lenke 2, 3, 4)
Firoz Miyanji, MD, FRCSC

2:45 – 2:50pm Neuromuscular Curve Correction
Stephen J. Lewis, MD, MSc, FRCSC

2:50 – 3:00pm Discussion

Part 4: MIS Techniques for Adult Degenerative Deformity
Moderator: *Choll W. Kim, MD, PhD*

3:00 – 3:10pm Direct Lateral Approaches in Lumbar Scoliosis
Neel Anand, MD

3:10 – 3:20pm Obtaining Fusion at L5-S1 including MIS Interbody Techniques
Choll W. Kim, MD, PhD

3:20 – 3:35pm Advanced MIS Adult Deformity

3:20 – 3:25pm MIS Pelvic Fixation Techniques
Neel Anand, MD

3:25 – 3:30pm Correction Maneuvers in Adult Lumbar Scoliosis
Stephen J. Lewis, MD, MSc, FRCSC

3:30 – 3:35pm Addressing the Kyphotic Degenerative Lumbar Curve
Ahmad Nassr, MD

3:35 – 3:45pm Discussion

Part 5: Adult Degenerative Deformity Case Examples

Moderator: *Choll W. Kim, MD, PhD*
Panel: *Stephen J. Lewis, MD, MSc, FRCSC; Neel Anand, MD; Nils Hansen-Algenstaedt, MD, PhD; Ahmad Nassr, MD; Kamal N. Ibrahim, MD, FRCS(C), MA*

3:45 – 3:50pm Degenerative Lumbar Curve Requiring Decompression and Interbody Fixation
Neel Anand, MD

3:50 – 3:55pm Thoracolumbar Curve Requiring Pelvic Fixation
Stephen J. Lewis, MD, MSc, FRCSC

3:55 – 4:00pm Kyphotic Curve Requiring Osteotomy
Nils Hansen-Algenstaedt, MD, PhD

Part 6: Complications in MIS Deformity

4:00 – 4:15pm Complications in MIS Deformity
- Lateral Complications: Paraesthesias, Neurologic Injury, Visceral Injury, Vascular Injury, Endplate Fracture, Cage Misplacement/Migration, Pseudarthrosis
- Posterior Interbody Complications: Radiculitis, Ectopic Bone, Pseudarthrosis, Cage Misplacement/Migration
- Decompression Complications: CSF Leak, Inadequate Decompression
- Deformity Complications: Flatback, Inadequate Correction, Coronal/Sagittal Imbalance, Misplaced Hardware, Neurological Injury, Vascular/Visceral Injury, Pseudarthrosis (Facet Fusion)

Adam L. Wollowick, MD

4:15 – 4:25pm Synopsis and Closing Remarks
Stephen J. Lewis, MD, MSc, FRCSC

Infection: What You Need to Know

Room: Michigan Room, Level 2
Chairs: John R. Dimar, II, MD; Sigurd H. Berven, MD

Upon the conclusion of this half-day course, the participant should be able to:
- Identify an acute post-operative infection, obtain medical consultation with infectious disease, and institute expedient medical treatment.
- Recognize a primary osteomyelitis, institute appropriate diagnostic testing, understand the changing presentation of the disease and arrange appropriate treatment, either medical management or emergent surgical treatment.
- Understand and appreciate the appropriate surgical treatment algorithms and surgical & medical techniques required to achieve an effective cure.

Moderators: *John R. Dimar, II, MD; Sigurd H. Berven, MD*

1:30 – 1:50pm What are the Long-Term Outcomes of Current Treatment & What New Aggressive Treatment Algorithms are Available to Prevent Postoperative Spinal Infections?
Sigurd H. Berven, MD

1:50 – 2:10pm Pediatric Spinal Infections: Has the Etiology, Incidence, Demographics & Treatment Modalities Changed Over the Past 10 Years?

1:50 – 2:00pm Topic 1: Neuromuscular, Myelomenigioceole
Suken A. Shah, MD

2:00 – 2:10pm Topic 2: AIS & Growing Spine
Lori Ann Karol, MD

2:10 – 2:20pm What Techniques Have Proven to be Effective in Decreasing the Rate of Iatrogenic Infections & are They Cost Effective Compared to Having a "Never Event" Infection?
Joseph H. Perra, MD

2:20 – 2:30pm What Effect Have Changes in Spinal Implant Materials Used in Interbody & Pedicle Rod/Screw Systems had on Infection Rates over the Past Decade?
Michael J. Yaszemski, MD, PhD

EDUCATIONAL PROGRAM

2:30 – 2:40pm	Have Pyogenic Spinal Infections Changed over the Past Decade, What is the Status of Medical (Non-Operative) Treatment with the Antibiotics & the Current Indications for Surgical Referral? *Manabu Ito, MD, PhD*
2:40 – 3:00pm	Pyogenic Osteomyelitis: What are the Current Recommended Surgical Techniques that are Required Following Failed Medical Management? *John R. Dimar, II, MD*
3:00 – 3:20pm	Case Presentations: Acute Postoperative & Pyogenic Osteomyelitis: Discussion of Current Treatment Options? Moderator: *Sigurd H. Berven, MD* *Panel:* *Manabu Ito, MD, PhD; Lori Ann Karol, MD; Joseph H. Perra, MD; Suken A. Shah, MD*
3:20 – 3:30pm	Discussion
3:30 – 3:40pm	The Diagnostic Dilemma of Acute Epidural Abscesses: What are the Clinical Signs & Have the Diagnostic Testing & Treatment Techniques Changed? *Brian A. O'Shaughnessy, MD*
3:40 – 3:50pm	Rare Infections of the Spine: Are Fungal and Mycobacterium Infections Increasing in Frequency in the US & has the Medical & Operative Treatment Modalities Changed over the Past Decade? *Munish Chandra Gupta, MD*
3:50 – 4:00pm	Tuberculosis of the Spine: What New Treatment Modalities & Surgical Techniques Have Been Developed to Address Acute & Chronic Infections? *Kenneth M C Cheung, MD*
4:00 – 4:20pm	Case Presentations: Acute Epidural Abscess & Chronic Granulomatous Infections: Discussion of Current Treatment Options Moderator: *Paul T. Rubery, Jr, MD* Panel: *Kenneth M C Cheung, MD; Paul M. Huddleston III, MD; Brian A. O'Shaughnessy, MD; John R. Dimar, II, MD*
4:20 – 4:30pm	Discussion
4:30 – 4:35pm	ARS Questions

Sagittal Plane Deformity: Cradle to Grave

Room: Sheraton/Chicago Ballroom, Level 4
Chairs: Frank J. Schwab, MD; Hubert Labelle, MD; Mark B. Dekutoski, MD

The half-day course on Sagittal Plane Deformity presents to the learner current concepts and evidence-based data on the management of complex high risk conditions in Sagittal Plane Spinal Deformity Surgery for the highest level of experienced learners in the spine community.

Upon the conclusion of the course, the learner should understand the breadth of approaches to evaluation, treatment, and intervention for these sagittal plane conditions so as to affect greater understanding of techniques of evaluation, natural history, outcome expectations and relative risk benefit of intervention in complex deformity. The learner will experience a breadth of approaches and in so doing enhance their awareness of the ability to enhance patient outcome by selective application of complex techniques in the proper patient. These challenging conditions are to be interactively presented and openly discussed.

Part 1: Introduction
Moderators: Hubert Labelle, MD; Mark B. Dekutoski, MD

1:30 – 1:38pm ARS Four Cases – What Would You Recommend?
Symptomatic Isthmic Spond
Gr III Compensated
Gr IV De Compensated
Gr IV Decompensated sp Fusion
Mark B. Dekutoski, MD

1:38 – 1:48pm Development of Pelvic Incidence and its Relationship to Sagittal Balance from Birth to Maturity: Cradle to Young Adult
Hubert Labelle, MD

1:48 – 1:53pm Development of Spondylolysis – Natural History, HQOL data, Indications Techniques
John F. Sarwark, MD

1:53 – 2:00pm The Balanced, Unbalanced Compensated Decompensated Spine: Critical Issues in Patient Selection for Reduction of High Grade Spondylolisthesis
Pierre Roussouly, MD

2:00 – 2:05pm Spondylo Reduction Techniques and Critical Review of Literature Outcome
Daniel J. Sucato, MD, MS

2:05 - 2:25pm Case Discussions: Reduction vs. Insitu & Patient Selection and Outcomes
Panel: Daniel J. Sucato, MD, MS; Hubert Labelle, MD; John F. Sarwark, MD; Pierre Roussouly, MD

2:25 – 2:30pm ARS Questions

Part 2: Pediatric and Young Adult Sagittal Plane Challenges
Moderators: Daniel J. Sucato, MD, MS; Mark B. Dekutoski, MD

2:30 – 2:40pm Case Discussion: Cong Bar, Scheuermans, Flatback AIS
Mark B. Dekutoski, MD

2:40 – 2:50pm Sagittal Plane Deformity in Native AIS and Iatrogenic Deformity: Ian Stokes Vs DD Aronson
Michael G. Vitale, MD, MPH

2:50 – 2:55pm Sagittal Plane in Congenital Scoliosis
Daniel J. Sucato, MD, MS

2:55 – 3:00pm Sagittal Plane in Neuromuscular Scoliosis
Lawrence G. Lenke, MD

3:00 – 3:25pm Roundback and Scheuermann's
Charles E. Johnston, MD

3:25 – 3:30pm ARS Questions

EDUCATIONAL PROGRAM

Part 3: Aging with Deformity – Sagittal Plane Deformity and Safittal Plane Deformity Associate with Adult AIS

Moderators: *Frank J. Schwab, MD; Mark B. Dekutoski, MD*

3:30 – 3:35pm Case Overviews:
Flatback: Degenerative
AIS in the Adult with Sagittal Plane Deformity
Post Traumatic Thoracic
Post Surgical Sagittal Plane Deformity
PJK
Frank J. Schwab, MD

3:35 – 3:45pm Natural History: Sagittal Plane Spino-Pelvic Concepts for the Adult: Considerations in the Previously Operated Patient, Adult AIS and De-Novo Deformity
Virginie LaFage, PhD

3:45 – 3:50pm EBM, HQOL Data, Patient Selection and Outcome Expectations
Justin S. Smith, MD, PhD

3:50 – 3:55pm Cost Utility of Sagittal Plane Re-Alighnment Procedures
Keith H. Bridwell, MD

3:55 – 4:00pm Natural History, EM HQOL Data, Cervical Kyphotic Disease, OPLL Ankylosing Spondylitis, Emphasis Cervical Deformity
Kristen E. Radcliff, MD

4:00 – 4:05pm ASD Sagittal Plane Evaluation, HQOL Considerations, Surgical Planning and Corrective Techniques
Frank J. Schwab, MD

4:05 – 4:10pm PJK: Risk Factors HQUL Data Techniques
Justin S. Smith, MD, PhD

4:10 – 4:25pm Case Discussions
Panel: Frank J. Schwab, MD; Kristen E. Radcliff, MD; Justin S. Smith, MD, PhD

4:25 – 4:30pm ARS Questions

Friday, September 7, 2012

Lunchtime Symposia
12:00 – 1:00pm
Pre - registration is required for all of the following sessions and space is limited.

ICD-10 – What Does It Mean to You and Your Practice?

Room: Chicago 8-10, Level 4
Chair: R. Dale Blaiser, MD

The SRS Coding Committee will explain how the medical infrastructure across the nation is gearing up for the conversion from ICD-9 to ICD-10. The new system will affect providers of spine and deformity care as well as all medical specialties. There will be major changes in coding specificity and documentation which will have major effects on physician practices. This symposium will provide an overview of ICD-10 to interested members. There will be an introduction to ICD-10 and an explanation as to why the change was felt to be necessary. The basic code structure and function will be explained. Members will learn about diagnosis codes relevant to spinal deformity and how to find them. New requirements for documentation will be introduced. Members will learn about strategies for incorporating ICD-10 into their own practices. There will be instruction for members about where to locate additional information and resources about ICD-10.

12:00 - 12:13pm	Introduction to ICD-10 *Patrick Cahill, MD*
12:13 - 12:25pm	Code Structure and Function *R. Dale Blasier, MD*
12:25 - 12:37pm	Introduction to Codes Relevant to Spinal Deformity Implementation *Matthew D. Hepler, MD*
12:37 - 12:50pm	Implementation *Christopher J. DeWald, MD*
12:50 – 1:00pm	Discussion

EDUCATIONAL PROGRAM

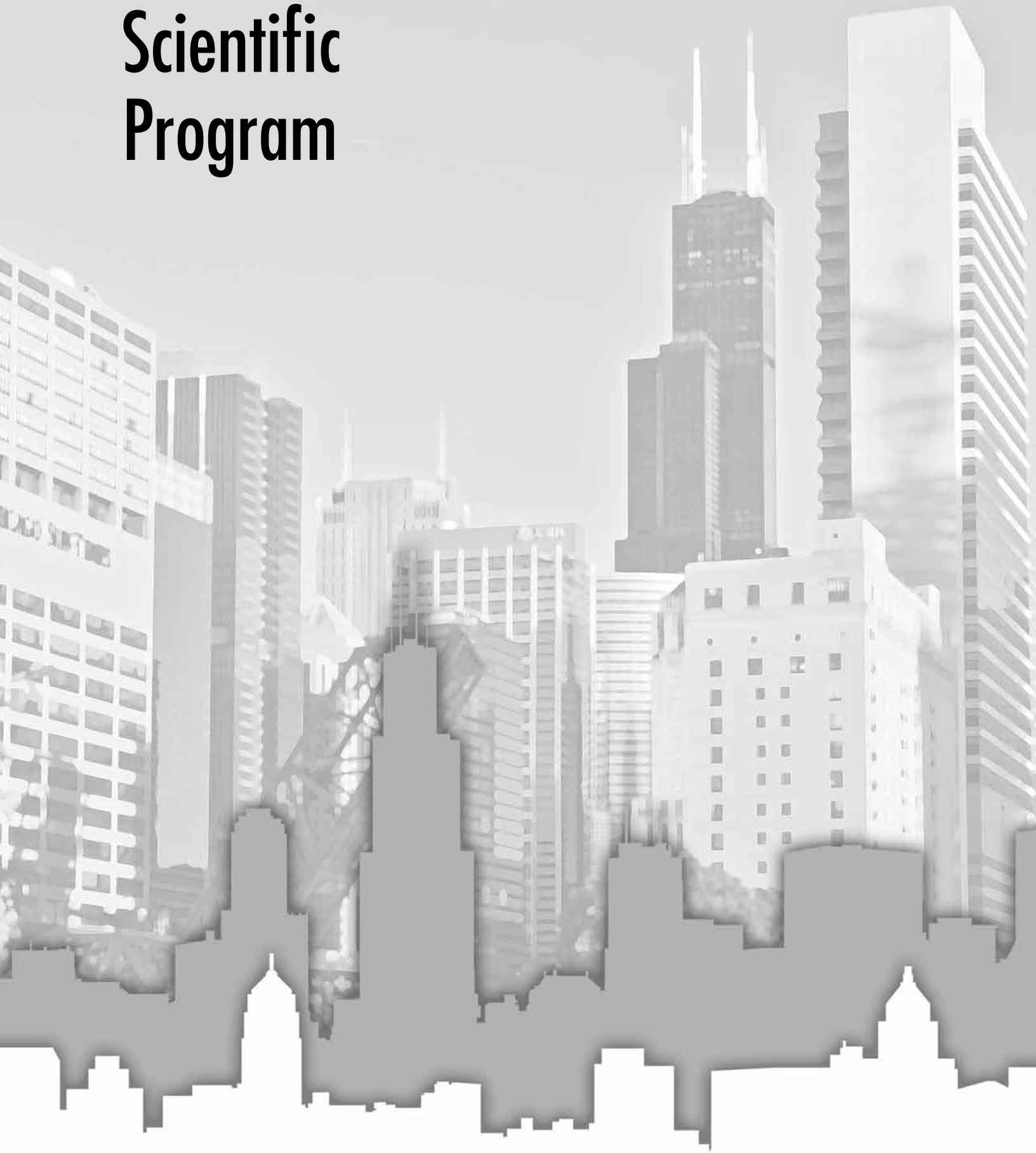
Non-Operative Treatment of Adolescent Idiopathic Scoliosis

Room: Michigan Room, Level 2
Chair: Nigel J. Price, MD

The Non-Operative Committee will give an international perspective on current non-operative techniques for AIS. Presenters will review the current status of school screening, current concepts in bracing techniques and how to achieve optimum results with bracing. The evidence for scoliosis specific exercise will be reviewed and the quality-of-life measures for non-operative treatments will be discussed, as well as the current evidence for non-operative therapies. The presentations will be given by an international panel of experts in non-operative care.

Moderators:	*Nigel J. Price, MD; John G. Thometz, MD*
12:00 - 12:02pm	Introductory Comments *Nigel J. Price, MD*
12:02 – 12:07pm	SRS International Task Force on Scoliosis Screening for AIS *Hubert Labelle, MD*
12:07 – 12:17pm	How to Optimize AIS Brace Fit and Wear - An Orthotist's Perspective *Luke Stikeleather, CO*
12:17 – 12:27pm	Optimal Brace Wear and Compliance *Michael T. Hresko, MD*
12:27 – 12:30pm	Discussion
Moderators:	*Paul D. Sponseller, MD; Joseph P. O'Brien, MBA*
12:30 – 12:40pm	Non-Operative Management of AIS - The SOSORT Approach to Brace Treatment *Theodoros Grivas, MD, PhD*
12:40 – 12:50pm	Non-Operative Treatment of AIS - What is the Level of Evidence for Exercises and Bracing *James O. Sanders, MD*
12:50 – 12:55pm	Future Directions of Non-Operative Care of AIS *Paul D. Sponseller, MD*
12:55 – 1:00pm	Discussion

Scientific Program



The Scoliosis Research Society gratefully acknowledges
Orthofix, Inc. for support of the Annual Meeting E-Newsletter.

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Thursday, September 6, 2012

SESSION 1 ADOLESCENT IDIOPATHIC SCOLIOSIS

Moderators: Lawrence G. Lenke, MD and Ahmet Alanay, MD

Room: Sheraton/Chicago Ballroom, Level 4

7:55 – 8:00am	Welcome & Announcements
8:00 – 8:04am	Paper #1: **Intervertebral Disc Degeneration During Postoperative Follow-Up More Than Ten Years after Corrective Surgery in Idiopathic Scoliosis: Comparison between Patients with and without Surgery** *Ayato Nohara; Noriaki Kawakami, MD, DMSc.; Taichi Tsuji; Tetsuya Ohara; Toshiki Saito; Yoshitaka Suzuki; Ryo Sugawara; Kyotaro Ota, MD; Kazuki Kawakami*
8:04 – 8:08am	Paper #2: **Motion of the Unfused Lumbar Segments Remains Increased up to Six Years after Fusion for AIS** *Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Maty Petcharaporn, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Baron S. Lonner; Firoz Miyanji, MD, FRCSC; Peter O. Newton, MD*
8:08 – 8:12am	Paper #3: **Surgical Outcomes in Adolescent Idiopathic Scoliosis with or without Spondylolisthesis** *Stuart Hershman, MD; Jason Hochfelder, MD; Laura E. Dean, BA; Burt Yaszay, MD; Baron S. Lonner*
8:12 – 8:21am	Discussion
8:22 – 8:26am	Paper #4: **Cost Effectiveness of Surgical Treatment for Adolescent Idiopathic Scoliosis (AIS)** *Chia H. Wu, MD; Lisa Mcleod, MD; John M. Flynn, MD*
8:26 – 8:30am	Paper #5: **Potentially Avoidable X-rays in Mild AIS Patients** *James W. Ogilvie, MD; Lesa M. Nelson, BS; Rakesh Chettier, MS; Kenneth Ward, MD*
8:30 – 8:34am	Paper #6: **ICU vs. Hospital Floor: Which is Best following Spinal Fusion for AIS?** *Le-qun Shan, MD; David L. Skaggs, MD; Christopher Lee, BS; Cathy Kissinger, RN, MN, NE-BC; Karen S. Myung, MD, PhD*
8:34 – 8:43am	Discussion
8:44 – 8:48am	Paper #7: **Does Following the Lenke Classification Treatment Algorithm Improve Outcomes?** *David H. Clements, MD; Randal R. Betz, MD; Peter O. Newton, MD; Lawrence G. Lenke, MD; Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Harms Study Group*
8:48 – 8:52am	Paper #8: **The Use of 3D Spinal Parameters to Differentiate between Progressive and Non-Progressive AIS Curves at the First Visit** *Marie-Lyne Nault, MD, MSc; Jean-Marc Mac-Thiong, MD, PhD; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon; Hubert Labelle, MD; Jacques de Guise, PhD; Stefan Parent, MD, PhD* **This presentation is the result of a project funded, in part, by an SRS Research Grant.**
8:52 – 8:56am	Paper #9: **Inclusion of the Proximal Thoracic Curve Does Not Provide Better Shoulder Balance in All Lenke 2 Curves** *Daniel J. Sucato, MD, MS; Anna M. McClung, RN*
8:56 – 9:05am	Discussion
9:06 – 9:10am	Paper #10: **Additional Risk Factors for Adding-On after Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis (AIS): Implication of LIV Angle and Lumbo-Sacral Takeoff (LSTO)** *Woojin Cho, MD, PhD; Michael Faloon, MD; David Essig, MD; Gbolabo Sokunbi; Thomas Ross, MS, RN; Matthew E. Cunningham, MD, PhD; Oheneba Boachie-Adjei, MD*
9:10 – 9:14am	Paper #11: **Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis Curves with a C lumbar Modifier: Which Rules can be Broken?** *Jacob Schulz, MD; Jahangir Asghar, MD; Tracey Bastrom, MA; Harry L. Shufflebarger, MD; Peter O. Newton, MD; Burt Yaszay, MD; Harms Study Group*
9:14 – 9:18am	Paper #12: **Surgeon Variability For Treatment of Lenke 1C Curve Patterns With Selective Thoracic Fusions** *Ronald A. Lehman, MD; Lawrence G. Lenke, MD; Daniel J. Sucato, MD, MS; B. Stephens Richards, MD; Keith H. Bridwell, MD*
9:18 – 9:27am	Discussion

SCIENTIFIC PROGRAM

9:28 – 9:32am Paper #13: **Late Implant Removal after Posterior Correction of Thoracic AIS with Pedicle Screw Instrumentation - A Matched Case Control Study with Ten-Year Follow-Up**
Mazda Farshad, MD, MPH; Christoph Sdzuy; Kan Min, MD

9:32 – 9:36am Paper #14: **Unplanned Return to the Operating Room in Patients with AIS: Are We Doing Better with Pedicle Screws than with Hybrid Constructs?**
Amer F. Samdani, MD; Eric J. Belin, MD; Joshua M. Pahys, MD; Firoz Miyanji, MD, FRCSC; Patrick J. Cahill, MD; Harry L. Shufflebarger, MD; Baron S. Lonner; Peter O. Newton, MD; Randal R. Betz, MD

9:36 – 9:40am Paper #15: **Does Higher Screw Density Result in Increased Curve Correction and Improved Clinical Outcomes in AIS?**
David W. Polly, MD; A. Noelle Larson, MD; Beverly E. Diamond, PhD; Charles Gerald T. Ledonio, MD; Daniel J. Sucato, MD, MS; Hubert Labelle, MD; John B. Emans, MD; B. Stephens Richards, MD; Charles E. Johnston, MD

9:40 – 9:49am Discussion

9:49 – 10:10am BREAK

SESSION 2 CERVICAL, TUMOR, TRAUMA, ADULT SPINE DEFORMITY

Moderators: Sean Molloy, MBBS, MSc, FRCS and Alexander R. Vaccaro, MD, PhD
Room: Sheraton/Chicago Ballroom, Level 4

10:10 – 10:14am Paper #16: **Controlled Reduction Technique for Cervical Osteotomy in Ankylosing Spondylitis**
Hossein Mehdian, MD, MS(Orth) FRCS(Ed); Ben Boreham, MB BCh FRCS(Orth); Ranganathan Arun, FRCS(Tr&Orth), DM, MRCS

10:14 – 10:18am Paper #17: **Kyphotic Deformities of the Cervical Spine - Prospective Study of 90 Patients**
Jan Stulik; Jan Kryl; Tomas Vyskocil; Michal Barna; Petr Nesnidal

10:18 – 10:22am Paper #18: **Cervical Lordosis Actually Increases with Aging and Progressive Degeneration in Spinal Deformity Patients**
Han Jo Kim, MD; Lawrence G. Lenke, MD; Addisu Mesfin, MD; Jeremy L. Fogelson, MD; Stuart Hershman, MD; K. Daniel Riew, MD

10:22 – 10:31am Discussion

10:32 – 10:36am Paper #19: **Operative vs. Nonoperative Treatment of Thoracolumbar Burst Fractures without Neurological Deficit: Fifteen to Twenty-Year Follow-Up**
Kirkham B. Wood, MD; Amir A. Mehbod, MD; Glenn R. Buttermann, MD; Christopher C. Harrod, MD

10:36 – 10:40am Paper #20: **Pediatric Cervical Fractures with Associated Spinal Cord Injury**
Amit Jain; Paul D. Sponseller, MD

10:40 – 10:44am Paper #21: **Predictors of Treatment Outcomes in Geriatric Patients with Odontoid Fractures - AO Spine North America Multi-Centre Prospective Study GOF**
Michael Fehlings, MD, PhD, FRCSC; Arun Ranganathan, DM, FRCSEd(T&O), PGDip(OrthEngin), MRCSEd; Alexander R. Vaccaro, MD, PhD; Paul Arnold; Branko Kopjar

10:44 – 10:53am Discussion

10:54 – 10:58am Paper #22: **The Effect of Surgery on Health Related Quality of Life and Functional Outcome in Patients with Metastatic Epidural Spinal Cord Compression - The AOSpine North America Prospective Multicenter Study**
Michael Fehlings, MD, PhD, FRCSC; Branko Kopjar; Charles G. Fisher, MD, MHSc, FRCSC; Alexander R. Vaccaro, MD, PhD; Paul Arnold; James Schuster, MD, PhD; Joel Finkelstein, MSc, MD, FRCSC; Laurence D. Rhines, MD; Mark B. Dekutoski, MD; Ziya L. Gokaslan, MD; John C. France, MD

10:58 – 11:02am Paper #23: **Four-Step Approach to Spinal Aneurysmal Bone Cyst in Children: Long-Term Outcomes**
Camila De Mattos, MD; Chanika Angsanuntsukh, MD; Denis Sakai, MD; Lauren Tomlinson, BS; Keith D. Baldwin, MD, MSPT, MPH; John P. Dormans, MD

11:02 – 11:06am Paper #24: **Factors Associated with the Development of Spinal Deformity after the Treatment of Childhood Spinal Tumors**
Sarah Clarke; Brad Williamson

11:06 – 11:15am Discussion

11:16 – 11:20am	Paper #25: **Clinical Improvement Through Surgery for Adult Spinal Deformity (ASD): What can be Expected and Who is Likely to Benefit Most?** *Bertrand Moal, MS; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Praveen V. Mummaneni, MD; Gregory M. Mundis, MD; Jamie S. Terran, BS; Eric Klineberg, MD; Robert A. Hart, MD; Oheneba Boachie-Adjei, MD; Christopher I. Shaffrey, MD; Frank Schwab, MD; International Spine Study Group*
11:20 – 11:24am	Paper #26: **Comparison of Outcomes of Surgery Performed in the Second Decade vs. Third and Fourth Decades for Idiopathic Scoliosis** *Meric Enercan; Emre Acaroglu, MD; Ahmet Alanay; Ferran Pellise, MD; Cagatay Ozturk, MD; Alauddin Kochai; Sinan Kahraman; Tunay Sanli, MA; Azmi Hamzaoglu, MD*
11:24 – 11:28am	Paper #27: **Operatively (OP) Treated Adult Spinal Deformity (ASD) Patients Report Worse Health Related Quality of Life (HRQOL) than Nonoperative (NON), Regardless of Age; However, Radiographic Deformity Differs Between Age Groups** *Kai-Ming Fu, MD, PhD; Shay Bess, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Frank Schwab, MD; Douglas C. Burton, MD; Behrooz A. Akbarnia, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Robert A. Hart, MD; Eric Klineberg, MD; Munish C. Gupta, MD; Praveen V. Mummaneni, MD; International Spine Study Group*
11:28 – 11:37am	Discussion
11:37 – 11:42am	Harrington Lecture Introduction *B. Stephens Richards, III, MD* *President*
11:42am – 12:05pm	Harrington Lecture "Journey to the Top" *Alvin H. Crawford, MD*
12:05 – 12:15pm	Presentation of the Lifetime Achievement Awards *Kamal N. Ibrahim, MD, FRCS(c), MA* *President-Elect* *Steven D. Glassman, MD* *Vice President*
12:15 – 1:30pm	Networking Lunch Open to all Half-Day Course participants. Pre-registration and tickets are required.
1:30 – 4:30pm	Half-Day Courses (see pages 35-40) Pre-registration and tickets are required.

SCIENTIFIC PROGRAM

Friday, September 7, 2012

*** Sessions 3A and 3B run concurrently from 7:55 to 9:49am. The combined Session 4 resumes after the break at 10:09am.***

SESSION 3A EARLY ONSET SCOLIOSIS (runs concurrently with Session 3B, see page 43)
Moderators: Suken A. Shah, MD and Francisco Sanchez Perez-Grueso, MD
Room: Sheraton/Chicago Ballroom, Level 4

7:55 – 8:00am	Welcome & Announcements
8:00 – 8:04am	Paper #28: **Five Year Follow-Up of 40 Patients with Original Shilla Procedure** *Richard E. McCarthy; Frances L. McCullough, MNSc*
8:04 – 8:08am	Paper #29: **Comparison of Growing Rod vs. Cast Treatment for Early-Onset Scoliosis** *Charles E. Johnston, MD; Anna M. McClung, RN; George H. Thompson, MD; Connie Poe-Kochert, BSN; James O. Sanders, MD; Growing Spine Study Group*
8:08 – 8:12am	Paper #30: **Comparison of Surgical Treatments for Infantile and Juvenile Scoliosis** *Joshua M. Pahys, MD; Lukas P. Zebala, MD; Patrick J. Cahill, MD; Michael P. Kelly, MD; Jahangir Asghar, MD; Lawrence G. Lenke, MD; Randal R. Betz, MD; Amer F. Samdani, MD*
8:12 – 8:21am	Discussion
8:22 – 8:26am	Paper #31: **Segmental Self Growing Rod Constructs in the Management of Early Onset Neuromuscular Scoliosis** *Hossein Mehdian, MD, MS(Orth) FRCS(Ed); Ben Boreham, MB BCh FRCS(Orth); Tim Hammett, MRCS; Jonathan A. Clamp, FRCS(Tr&Orth); Nasir A. Quraishi, FRCS*
8:26 – 8:30am	Paper #32: **Surgical Results of Magnet-Driven Growth Rods(MdGR) in Early-Onset Scoliosis(EOS)** *Nanjundappa S. Harshavardhana, MS(Orth), Dip. SICOT; Farhaan Altaf, MBBS, BSc, MRCS; Fady S. Sedra; Hazem B. Elsebaie, FRCS, MD; Hilali H. Noordeen, FRCS*
8:30 – 8:34am	Paper #33: **Next Generation of Growth-Sparing Techniques: Preliminary Clinical Results of a Magnetically Controlled Growing Rod in 14 Patients** *Behrooz A. Akbarnia, MD; Kenneth M. Cheung, MBBS(UK), FRCS(England), FHKCOS, FHKAM(ORTH); Hilali H. Noordeen, FRCS; Hazem B. Elsebaie, FRCS, MD; Muharrem Yazici, MD; Zaher Dannawi, FRCS (Tr & Orth); Nima Kabirian, MD*
8:34 – 8:43am	Discussion
8:44 – 8:48am	Paper #34: **Comparison of Two Fusionless Scoliosis Surgery Methods in the Treatment of Progressive AIS: A Preliminary Study** *John T. Braun, MD*
8:48 – 8:52am	Paper #35: **A New Gliding Spinal Anchor for Self-Growing Rods: Trolley Screw** *Jean A. Ouellet, MD; Karina Klein; Thomas Steffen; Brigitte von Rechenberg*
8:52 – 8:56am	Paper #36: **Safety and Efficacy of Instrumented Convex Growth Arrest in Treatment of Congenital Scoliosis** *Gokhan H. Demirkiran; Guney Yilmaz; Ibrahim Akel, MD; Emre Acaroglu, MD; Ahmet Alanay; Muharrem Yazici, MD*
8:56 – 9:05am	Discussion
9:06 – 9:10am	Paper #37: **Proximal Segmental Kyphosis and Proximal Junctional Kyphosis after Growing Polysegmental Instrumentation in EOS Patients** *Andriy Mezentsev, MD; Dmytro Petrenko*
9:10 – 9:14am	Paper #38: **What is the Effect of Serial Growing Rod Lengthening on the Sagittal Profile and Pelvic Parameters in Early Onset Scoliosis?** *Suken A. Shah, MD; Ali F. Karatas; Arjun A. Dhawale, MD; Ozgur Dede, MD; Laurens Holmes, PhD, DrPH; Petya Yorgova, MS; Geraldine I. Neiss, PhD; Gregory M. Mundis, MD; Jeff Pawelek; Behrooz A. Akbarnia, MD; Growing Spine Study Group*
9:14 – 9:18am	Paper #39: **The Early-Onset Scoliosis Questionnaire (EOSQ) Reflects Improvement in Quality of Life After Growth Rod Surgery** *Hiroko Matsumoto, MA; Daren J. McCalla, BS; Kumar Nair, BA; Brendan A. Williams, AB; Jacqueline Corona, MD; Behrooz A. Akbarnia, MD; John T. Smith, MD; John B. Emans, MD; David L. Skaggs, MD; Michael G. Vitale, MD, MPH*
9:18 – 9:27am	Discussion

9:28 – 9:32am Paper #40: **Management of Thoracic Insufficiency Syndrome (TIS) in Jarcho-Levin Syndrome Using Vertical Expandable Prosthetic Titanium Rib (VEPTR)**
Joshua G. Karlin, BS; Ajeya Joshi; Hope Trevino, AA; Davin Cordell, MD; James W. Simmons, DO, PhD

9:32 – 9:36am Paper #41: **Management of Thoracic Insufficiency Syndrome (TIS) in Congenital Scoliosis Patients Using Vertical Expandable Prosthetic Titanium Rib (VEPTR)**
Ajeya Joshi; Lilian Nguyen; Davin Cordell, MD; Hope Trevino, AA; James W. Simmons, DO, PhD

9:36 – 9:40am Paper #42: **Long-Term Outcomes of Early Fusion Surgery for Congenital Scoliosis at Ten Years of Age or Younger with a Minimum Ten Years Follow-Up after Surgery**
Toshiaki Kotani; Shohei Minami; Tsutomu Akazawa, MD; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Manabu Ito, MD, PhD; Morio Matsumoto, MD; Kota Watanabe; Haruhisa Yanagida, MD

9:40 – 9:49am Discussion

SESSION 3B ADULT DEFORMITY (runs concurrently with Session 3A, see page 42)
Moderators: Keith H. Bridwell, MD and Daniel Henri Chopin, MD
Room: Chicago 8-10, Level 4

7:55 – 8:00am Welcome & Announcements

8:00 – 8:04am Paper #43: **Does Return to OR Affect Long-Term Outcomes in Adult Spinal Deformity Patients Undergoing Long Fusions to the Sacrum? Minimum Five-Year Follow-Up**
Michael Faloon, MD; David Essig, MD; Woojin Cho, MD, PhD; Thomas Ross, MS, RN; Matthew E. Cunningham, MD, PhD; Bernard A. Rawlins, MD; Oheneba Boachie-Adjei, MD

8:04 – 8:08am Paper #44: **Primary vs. Revision Surgery: Multi-Center Analysis of Clinical and Functional Outcomes Following Surgery for Adult Spinal Deformity**
Khaled Kebaish, MD; Eric Klineberg, MD; Mostafa H. El Dafrawy, MD; Christopher P. Ames, MD; Shay Bess, MD; Vedat Deviren, MD; Justin S. Smith, MD, PhD; Robert A. Hart, MD; Munish C. Gupta, MD; International Spine Study Group

8:08 – 8:12am Paper #45: **Factors Predicting Cost-Effectiveness of Adult Spinal Deformity Surgery at Two Years Follow-Up**
Charla R. Fischer, MD; Baron S. Lonner; Jamie S. Terran, BS; Brian McHugh, MD; Steven D. Glassman, MD; Keith H. Bridwell, MD; Frank Schwab, MD; Virginie Lafage, PhD

8:12 – 8:21am Discussion

8:22 – 8:26am Paper #46: **Proximal Junctional Failure (PJF) Classification and Severity Scale: Development and Validation of a Standardized System**
Robert A. Hart, MD; Shay Bess, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Themistocles Protopsaltis, MD; Oheneba Boachie-Adjei, MD; Christopher P. Ames, MD; Vedat Deviren, MD; Richard Hostin, MD; Eric Klineberg, MD; Praveen V. Mummaneni, MD; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Frank Schwab, MD; International Spine Study Group

8:26 – 8:30am Paper #47: **Proximal Junctional Kyphosis after Posterior Fusion for Adult Scoliosis: Is There a Correlation with Pelvic Incidence**
Mario Di Silvestre, MD; Francesco Lolli; Francesco Vommaro; Konstantinos Martikos, MD; Tiziana Greggi, Head; Angelo Toscano

8:30 – 8:34am Paper #48: **Proximal Junctional Kyphosis Results in Inferior SRS Pain Sub-Scores in Adult Deformity Patients**
Han Jo Kim, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Kwang-Sup Song, MD; Tapanut Chuntarapas, MD; Stuart Hershman, MD; Chaiwat Piyaskulkaew, MD.; Jeremy L. Fogelson, MD; Addisu Mesfin, MD; Moon Soo Park, PhD

8:34 – 8:43am Discussion

8:44 – 8:48am Paper #49: **Health Impact Comparison of Different Disease States and Population Norms to Adult Spinal Deformity (ASD): A Call for Medical Attention**
Kai-Ming Fu, MD, PhD; Shay Bess, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Eric Klineberg, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Praveen V. Mummaneni, MD; International Spine Study Group

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8:48 – 8:52am Paper #50: **Modeling of Cost-Effectiveness of Adult Spinal Deformity Surgery at Five Years Follow-Up**
Brian McHugh, MD; Jamie S. Terran, BS; Charla R. Fischer, MD; Steven D. Glassman, MD; Keith H. Bridwell, MD; Frank Schwab, MD; Virginie Lafage, PhD

8:52 – 8:56am Paper #51: **Analysis of the Cost-Effectiveness of Surgical Treatment for Adult Spinal Deformity**
Richard Hostin, MD; Michael F. Obrien, MD; Ian McCarthy, PhD; Neil Fleming, Ph.D; Gerald Ogola; Rustam Kudyakov, MD, MPH; Kathleen M. Richter, MS, MFA, ELS; Rajiv Saigal, MD, PhD; Sigurd H. Berven, MD; Vedat Deviren, MD; Christopher P. Ames, MD; International Spine Study Group

8:56 – 9:05am Discussion

9:06 – 9:10am Paper #52: **Outcomes Following Three-Column Spinal Osteotomies: Impact of HRQOL and Age on Two-Year Follow-Up**
Christopher P. Ames, MD; Justin K. Scheer, BS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD; Eric Klineberg, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Richard Hostin, MD; Michael F. Obrien, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Frank Schwab, MD; Vedat Deviren, MD; Khaled Kebaish, MD; International Spine Study Group

9:10 – 9:14am Paper #53: **Prevalence and Risk Factors for Pseudarthrosis following Lumbar Pedicle Subtraction Osteotomy (PSO) in Adult Spinal Deformity**
Douglas D. Dickson, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Brenda A. Sides, MA

9:14 – 9:18am Paper #54: **Outcome and Complications of Sacro-Pelvic Fixation Using S2 Alar-Iliac (S2AI) Fixation in Adult Deformity Patients Fused to the Sacrum: A Prospective Study with Minimum Five-Year Follow-Up**
Khaled Kebaish, MD; Mostafa H. El Dafrawy, M.D; Hamid Hassanzadeh, MD; Paul D. Sponseller, MD

9:18 – 9:27am Discussion

9:28 – 9:32am Paper #55: **The Schwab-SRS Adult Spinal Deformity Classification: Assessment and Clinical Correlations Based on a Prospective Operative and Non-Operative Cohort**
Frank Schwab, MD; Virginie Lafage, PhD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Bertrand Moal, MS; Christopher P. Ames, MD; Kai-Ming Fu, MD, PhD; Praveen V. Mummaneni, MD; Douglas C. Burton, MD; Munish C. Gupta, MD; Vedat Deviren, MD; Gregory M. Mundis, MD; Robert A. Hart, MD; Shay Bess, MD; International Spine Study Group

9:32 – 9:36am Paper #56: **Ninety-Day Readmission Rate after Spine Fusion for Adult Deformity**
William Schairer; Alexandra Carrer, MD; Vedat Deviren, MD; Serena S. Hu, MD; Praveen V. Mummaneni, MD; Christopher P. Ames, MD; Dean Chou, MD; Aenor J. Sawyer, MD; Steven Takemoto, PhD; Sigurd H. Berven, MD

9:36 – 9:40am Paper #57: **Preventing Spinal Cord Deficits in Adult Spinal Surgery with Intraoperative Monitoring: A Single Institution Experience**
Jeremy L. Fogelson, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Michael Roth, BS; Linda Koester, BS; Han Jo Kim, MD; Stuart Hershman, MD; Addisu Mesfin, MD

9:40 – 9:49am Discussion

9:49 – 10:09am BREAK

SESSION 4 SPINAL CORD MONITORING, INNOVATIVE TECHNIQUES

Moderators: John M. (Jack) Flynn, MD and Keith D. K. Luk, MD
Room: Sheraton/Chicago Ballroom, Level 4

10:09 – 10:13am Paper #58: **Responding to Neuromonitoring Changes in Three-Column Posterior Spinal Osteotomies for Rigid Pediatric Spinal Deformities**
James G. Jarvis, MD; Samuel Strantzas, MSc., D.ABNM; Laura M. Holmes, BScH, CNIM; David E. Lebel, MD, Ph.D; Stephen J. Lewis

10:13 – 10:17am Paper #59: **Alarm Point of Transcranial Electrical Stimulation Motor Evoked Potentials for Intraoperative Spinal Cord Monitoring: A Prospective Multicenter Study**
Sho Kobayashi, PhD; Yukihiro Matsuyama, MD; Kinichi Shinomiya; Shigenori Kawabata, PhD; Muneharu Ando; Zenya Ito; Saito Takanori; Yasushi Fujiwara; Kazunobu Kida; Kei Yamada, MD, PhD; Tukasa Kanchiku; Kazuhiko Satomi; Toshikazu Tani

10:17 – 10:21am	Paper #60: **The Ability to Obtain and Maintain Transcranial Motor Evoked Potentials During Spinal Deformity Surgery in Patients with Neural Axis Abnormalities** *Daniel J. Sucato, MD, MS; Ryan D. Muchow, MD; Anna M. McClung, RN; Steven Sparagana, MD; Patricia Rampy, MS, REPT, CNIM; Elizabeth M. Van Allen, MS*
10:21 – 10:30am	Discussion
10:31 – 10:35am	Paper #61: **Feasibility of Passive Correction in Congenital Scoliosis** *Choon Sung Lee, MD, PhD; Chang Ju Hwang, MD, PhD; Dong-Ho Lee, MD, PhD; Yung-Tae Kim, MD; Nam Heun Kim, MD; Hyougmin Kim; Hyounmin Noh; HeeSang Lee, MD*
10:35 – 10:39am	Paper #62: **Analysis of Maternal Risk Factors Associated with Congenital Vertebral Malformations(CVM)** *Phillip F. Giampietro, MD, PhD; Jens Eickhoff, PhD; Ken Noonan, MD; Blaise Nemeth; Cathy McCarty, PhD, MPH; Cathleen L. Raggio, MD*
10:39 – 10:43am	Paper #63: **Lumbosacral Hemivertebra Resection with Transpedicular Instrumentation by a Posterior Only Approach in Young Children** *Yong Qiu; Jing Guo; Zhen Liu; Zezhang Zhu; Bangping Qian; Bin Wang; Yang Yu*
10:43 – 10:52am	Discussion
10:53 – 10:57am	Paper #64: **Sacral-Alar-Iliac Fixation in Pediatric Deformity: Two to Five-Year Follow-Up** *Rohan Joshi; Khaled Kebaish, MD; Paul D. Sponseller, MD*
10:57 – 11:01am	Paper #65: **Pedicle Screw Hubbing in the Adult and Immature Thoracic Spine: A Biomechanical and Micro-Computed Tomography Evaluation** *Daniel G. Kang, MD; Ronald A. Lehman, MD; Anton E. Dmitriev, PhD; Adam J. Bevevino, MD; Rachel E. Gaume, BS; Haines Paik, MD; Lawrence G. Lenke, MD*
11:01 – 11:05am	Paper #66: **A Minimum Two-Year Follow-Up Study of Simultaneous Double Rod Rotation Technique for Adolescent Idiopathic Scoliosis** *Manabu Ito, MD, PhD; Yuichiro Hisada; Yuichiro Abe, MD, PhD; Kuniyoshi Abumi, MD*
11:05 – 11:14am	Discussion
11:15 – 11:18am	20th IMAST (2013) Preview *Christopher I. Shaffrey, MD* *IMAST Committee Chair*
11:18 – 11:21am	48th Annual Meeting (2013) Preview *Pierre Roussouly, MD & Daniel Chopin, MD* *2013 Local Hosts*
11:21 – 11:24am	Worldwide Conferences Preview *Ahmet Alanay, MD* *Worldwide Conference Committee Chair*
11:24 – 11:30am	Introduction of the President *Kamal N. Ibrahim, MD, FRCS(c), MA* *President-Elect*
11:30 – 11:50am	Presidential Address *"State of the Art in 2012"* *B. Stephens Richards, III, MD* *President*
11:50am – 12:00pm	Walking Break
12:00 – 1:00pm	Lunch & Lunchtime Symposia (see pages 43-??)
1:00 – 1:15pm	Walking Break

SCIENTIFIC PROGRAM

SESSION 5 HIBBS CLINICAL AND BASIC SCIENCE AWARD NOMINEES

Moderators: Brian D. Snyder, MD, PhD and Marinus DeKleuver, MD, PhD
Room: Sheraton/Chicago Ballroom, Level 4

1:15 – 1:19pm †Paper #67: **A Genome-Wide Association Study Identified a New Susceptibility Locus for Adolescent Idiopathic Scoliosis**
Yohei Takahashi; Morio Matsumoto, MD; Katsuki Kono; Noriaki Kawakami, MD, DMSc.; Manabu Ito, MD, PhD; Koki Uno, MD, PhD; Shohei Minami; Haruhisa Yanagida, MD; Hiroshi Taneichi, MD; Kota Watanabe; Taichi Tsuji, MD; Hideki Sudo; Teppei Suzuki; Yoshiaki Toyama; Shiro Ikegawa, MD, PhD

1:19 – 1:23pm †Paper #68: **Comparing Apples and Oranges: Molecular Pathogenesis of Adolescent Idiopathic Scoliosis Varies by Patient Ancestry**
Kenneth Ward, MD

1:23 – 1:27pm †Paper #69: **Idiopathic Scoliosis Mutations in VANGL1, an Axial Development Gene**
Carol Wise, PhD; John A. Herring, MD; Xiaochong Gao; Dongping Zhang, MD, MS; Swarkar Sharma, PhD

This presentation is the result of a project funded, in part, by an SRS Research Grant.

1:27 – 1:36pm Discussion

1:37 – 1:41pm †Paper #70: **The Effect of Prophylactic Local Epidural Steroid Delivery in a Spinal Cord Injury Model**
Martin Quirno, MD; Kirk A. Campbell, MD; Andrew Yoo; Jason M. Cuellar, MD, PhD; Christian Hoelscher, BS; Pedro A. Ricart Hoffiz, MD, MS; Tate M. Andres, BS; Thorsten Kirsch, PhD; Thomas Errico

1:41 – 1:45pm †Paper #71: **Are Volumetric Bone Mineral Density and Bone Micro-Architecture in Adolescent Idiopathic Scoliosis Associated with Leptin and Soluble Leptin Receptor?**
Elisa MS Tam, MSc; Fiona WP Yu, BSc (Advanced); Vivian WY Hung; Zhen Liu; Tsz-ping Lam, MB, BS; King Lok Liu; Bobby KW Ng, MD; Kwong Man Lee, Ph.D; Yong Qiu; Jack C. Cheng, MD

1:45 – 1:51pm Discussion
Moderators: David S. Marks, FRCS and B. Stephens Richards, III, MD

1:52 – 1:56pm *Paper #72: **Scoliosis Research Society-22 Results in 3,052 Healthy Adolescents Age Ten to 19 Years**
Michael D. Daubs, MD; Brandon Lawrence, MD; Man Hung, PhD; Alpesh A. Patel, MD; Prokopis Annis, MD; John T. Smith, MD; Ashley Woodbury, BS; Darrel S. Brodke, MD

1:56 – 2:00pm *Paper #73: **The Natural History of Scheuermann's Kyphosis - A Comparative Study after 37-Year Follow-Up**
Leena Ristolainen, MSc, PT; Jyrki A. Kettunen, PhD; Markku Heliovaara, MD; Urho M. Kujala; Ari O. Heinonen, PhD; Dietrich Schlenzka, MD, PhD

2:00 – 2:04pm *Paper #74: **Deep Surgical Site Infection Following Growing Rod Surgery in Early Onset Scoliosis: How Does It Change the Course of Treatment?**
Nima Kabirian, MD; Behrooz A. Akbarnia, MD; Jeff Pawelek; Milad Alam, BS; Gregory M. Mundis, MD; Ricardo Acacio, MD; George H. Thompson, MD; David S. Marks, FRCS; Adrian Gardner, BM MRCS FRCS (T&O); Paul D. Sponseller, MD; David L. Skaggs, MD; Growing Spine Study Group

2:04 – 2:08pm *Paper #75: **Major Perioperative Complications after Surgery for Cerebral Palsy: Assessment of Risk Factors**
Amer F. Samdani, MD; Eric J. Belin, MD; Firoz Miyanji, MD, FRCSC; Joshua M. Pahys, MD; Suken A. Shah, MD; Peter O. Newton, MD; Randal R. Betz, MD; Paul D. Sponseller, MD

2:08 – 2:20pm Discussion

2:21 – 2:25pm *Paper #76: **Rates and Causes of Mortality Associated with Spine Surgery Based on 108,419 Procedures: A Review of the Scoliosis Research Society Morbidity and Mortality Database**
Justin S. Smith, MD, PhD; Dwight Saulle, MD; Ching-Jen Chen, BA; Lawrence G. Lenke, MD; David W. Polly, MD; Manish K. Kasliwal, MD; Paul A. Broadstone, MD; Steven D. Glassman, MD; Alexander R. Vaccaro, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD

*Hibbs Award Nominee for Best Clinical Presentation †Hibbs Award Nominee for Best Basic Science Presentation
The Russell A. Hibbs Awards are presented to both the best Clinical and Basic Science papers presented at the SRS Annual Meeting. The top podium presentations accepted in each category are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

2:25 – 2:29pm *Paper #77: **Thromboembolic Complications in Children with Spinal Fusion Surgery**
Amit Jain; Paul D. Sponseller, MD

2:29 – 2:33pm *Paper #78: **Reduced Rate of Late Infection after Posterior Spine Instrumentation with Titanium-Alloy vs. Stainless Steel Implants**
Thomas A. Wåxnäs

2:33 – 2:42pm Discussion

2:43 – 2:47pm *Paper #79: **High Dose BMP-2 in Adults: Major and Minor Complications in 502 Cases**
Addisu Mesfin, MD; Jacob M. Buchowski, MD, MS; Adam B. Aronson, BS; Wajeeh R. Bakhsh, BA; Jeremy L. Fogelson, MD; Stuart Hershman, MD; Han Jo Kim, MD; Lukas P. Zebala, MD; Azeem AHMAD, BA; Keith H. Bridwell, MD

2:47 – 2:51pm *Paper #80: **Operative Time and Patient Age, Rather Than Recombinant Human Bone Morphogenetic Protein-2 (BMP) Use, Increase Major Complications in Adult Spinal Deformity (ASD) Surgery**
Shay Bess, MD; Breton Line, BSME; Oheneba Boachie-Adjei, MD; Robert A. Hart, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Frank Schwab, MD; Behrooz A. Akbarnia, MD; Douglas C. Burton, MD; Richard Hostin, MD; Eric Klineberg, MD; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; International Spine Study Group

2:51 – 2:55pm *Paper #81: **Change in Classification Grade by the Schwab-SRS Adult Spinal Deformity (ASD) Classification Predicts Impact on Health Related Quality of Life (HRQOL) Measures: Prospective Analysis of Operative and Nonoperative Treatment**
Justin S. Smith, MD, PhD; Eric Klineberg, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Bertrand Moal, MS; Christopher P. Ames, MD; Richard Hostin, MD; Kai-Ming Fu, MD, PhD; Douglas C. Burton, MD; Behrooz A. Akbarnia, MD; Munish C. Gupta, MD; Robert A. Hart, MD; Shay Bess, MD; Virginie Lafage, PhD; International Spine Study Group

2:55 – 3:04pm Discussion

3:05 – 3:10pm *Spine Deformity* - Journal Introduction
John E. Lonstein, MD
Editor

3:10 – 3:30pm BREAK

SESSION 6 ADOLESCENT IDIOPATHIC SCOLIOSIS II

Moderators: Laurel C. Blakemore, MD and Peter O. Newton, MD
Room: Sheraton/Chicago Ballroom, Level 4

3:30 – 3:34pm Paper #82: **Criteria for Determining LIV in Lenke 6C Curves: Suk Criteria vs. the End Vertebrate**
Jahangir Asghar, MD; Harry L. Shufflebarger, MD; Robert P. Norton, MD; Rafaela Solano, RN

3:34 – 3:38pm Paper #83: **Lowest Instrumented Vertebra Selection for Lenke 5C Scoliosis: A Minimum Two-Year Radiographic Follow-Up**
Yu Wang, MD, PhD; Cody E. Bunger

3:38 – 3:42pm Paper #84: **The Treatment of Thoracolumbar / Lumbar Adolescent Idiopathic Curves (Lenke 5C): Anterior vs. Posterior Approach with Modern Instrumentation**
Darren R. Lebl, MD; Oheneba Boachie-Adjei, MD; Behrooz A. Akbarnia, MD; Jaspaul Gogia, MD; Joseph I. Krajbich, MD; Raymund Woo, MD; Akilah B. King, BA; Matthew E. Cunningham, MD, PhD; Mark D. Rahm, MD; Complex Spine Study Group

3:42 – 3:51pm Discussion

3:52 – 3:56pm Paper #85: **The Clinical Value of an Intermediate Risk Score with AIS Prognostic Testing**
Kenneth Ward, MD; Lesa M. Nelson, BS; Rakesh Chettier, MS; James W. Ogilvie, MD

3:56 – 4:00pm Paper #86: **Amicar vs. Tranexamic Acid: A Prospective Randomized Double-Blinded Study**
Matthew A. Halanski, MD; Jeffrey Cassidy; Nabil Hassan, MD

*Hibbs Award Nominee for Best Clinical Presentation †Hibbs Award Nominee for Best Basic Science Presentation
The Russell A. Hibbs Awards are presented to both the best Clinical and Basic Science papers presented at the SRS Annual Meeting. The top podium presentations accepted in each category are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

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4:00 – 4:04pm Paper #87: **What Would Be the Annual Cost Savings if Fewer Screws Were Used in AIS Treatment in the US?**
A. Noelle Larson, MD; David W. Polly, MD; Stacey J. Ackerman, MSE, PhD; Charles Gerald T. Ledonio, MD; Baron S. Lonner; Suken A. Shah, MD; Paul D. Sponseller, MD; John B. Emans, MD; B. Stephens Richards, MD; Minimize Implants Maximize Outcomes Study Group

4:04 – 4:13pm Discussion

4:14 – 4:18pm Paper #88: **Surgical Treatment of Main Thoracic Adolescent Idiopathic Scoliosis: A Prospective Ten-Year Follow-Up Study**
Krishna Cidambi, MD; Tracey Bastrom, MA; Carrie E. Bartley, MA; David H. Clements, MD; Randal R. Betz, MD; Lawrence G. Lenke, MD; Peter O. Newton, MD; Harms Study Group

4:18 – 4:22pm Paper #89: **Surgical Correction of Lenke 1A Curves: What are the Changes Taking Place in 3D?**
Stefan Parent, MD, PhD; Marjolaine Roy-Beaudry, MSc; Jihane Rouissi; Jean-Marc Mac-Thiong, MD, PhD; Carl-Éric Aubin, PhD, PEng.; Peter O. Newton, MD; Suken A. Shah, MD; Hubert Labelle, MD

4:22 – 4:26pm Paper #90: **Postoperative Shoulder Imbalance in Lenke Type 1A Curve and Related Factors**
Morio Matsumoto, MD; Kota Watanabe; Noriaki Kawakami, MD, DMSc; Taichi Tsuji; Koki Uno, MD, PhD; Teppei Suzuki; Manabu Ito, MD, PhD; Haruhisa Yanagida, MD; Shohei Minami; Tsutomu Akazawa, MD

4:26 – 4:35pm Discussion

4:36 – 4:40pm Paper #91: **Do Findings on Post-Operative Radiographs Result in the Need for Additional Surgery after Posterior Spinal Fusion?**
Grant H. Garcia, BA; Min Jung Park, MD, MMSc.; Keith D. Baldwin, MD, MSPT, MPH; Denis S. Drummond, MD; David A. Spiegel, MD

4:40 – 4:44pm Paper #92: **Recurrence of Rib Prominence Following AIS Surgery with Pedicle Screws and Direct Vertebral Body Derotation**
Amer F. Samdani, MD; Jahangir Asghar, MD; Firoz Miyanji, MD, FRCSC; Michelle C. Marks, PT, MA; Jane S. Hoashi, MD, MPH; Baron S. Lonner; Patrick J. Cahill, MD; Joshua M. Pahys, MD; Peter O. Newton, MD; Randal R. Betz, MD

4:44 – 4:48pm Paper #93: **Vertebral Body Stapling in the Treatment of Moderate Thoracic Adolescent Idiopathic Scoliosis in Immature Patients**
Acke Ohlin, MD, PhD

4:48 – 4:57pm Discussion

4:57 – 5:01pm Paper #94: **The Prevalence of Postoperative Pain in Adolescent Idiopathic Scoliosis and the Association with Preoperative Pain**
Tracey Bastrom, MA; Michelle C. Marks, PT, MA; Burt Yaszay, MD; Peter O. Newton, MD; Harms Study Group

5:01 – 5:05pm Paper #95: **Perioperative Use of Gabapentin in Patients with AIS Improves Outcomes in Pain Management after Posterior Spinal Fusion**
Curtis D. VandenBerg, MD; Suken A. Shah, MD; Peter G. Gabos, MD; J. Richard Bowen, Medical Doctor; Kenneth J. Rogers, PhD; Karen Sacks, MSN; Dinesh K. Choudhry, MD

5:05 – 5:09pm Paper #96: **Ioniizing Radiation Exposure in Early Onset Scoliosis IEOS) Patients Treated with Rib-Based Distraction**
Nelson Astur, MD; Tyler A. Cannon, MD; Derek M. Kelly, MD; William C. Warner, MD; Jeffrey R. Sawyer, MD

5:09 – 5:18pm Discussion

Saturday, September 8, 2012

SESSION 7 NEUROMUSCULAR, KYPHOSIS, SPONDYLOLISTHESIS, INNOVATIVE METHODS, ETIOLOGY

Moderators: Lori A. Karol, MD and Steven M. Mardjetko, MD, FAAP
Room: Sheraton/Chicago Ballroom, Level 4

7:55 – 8:00am Welcome & Announcements

8:00 – 8:04am Paper #97: **Wound Infections after Spine Deformity Correction Cerebral Palsy: Risk Factors**
Paul D. Sponseller, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Peter O. Newton, MD; Leslie M. Thaxton, MS, MBA; Tracey Bastrom, MA; Michelle C. Marks, PT, MA

8:04 – 8:08am Paper #98: **Hip Subluxation, Pelvic Obliquity, and Scoliosis in the CP Population: A Random Triad or a Predictable Relationship?**
Firoz Miyanji, MD, FRCSC; Amer F. Samdani, MD; Peter Sturm, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Peter O. Newton, MD

8:08 – 8:12am Paper #99: **Comparison of Life Expectancy between Surgical Treatment and Conservative Treatment Group in Flaccid Neuromuscular Scoliosis**
Hyon Su Chong; Hak-Sun Kim, MD

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8:12 – 8:21am Discussion

8:22 – 8:26am Paper #100: **Hybrid vs. Total Pedicle Screw Instrumentation in Patients Undergoing Surgery for Neuromuscular Scoliosis: A Comparative Study with Matched Cohorts**
Ilkka Helenius, MD, PhD; Mikko Mattila; Tuomas Jalanko, MD; Ville Puisto, MD, PhD; Olli T. Pajulo, MD, PhD

8:26 – 8:30am Paper #101: **The Usefulness of Noninvasive Positive Pressure Ventilation in Surgery of Flaccid Neuromuscular Scoliosis Patients**
Hyon Su Chong; Hak-Sun Kim, MD; Hyoung Bok Kim; Do-yeon Kim; Jea-Woo Lim; Mary Ruth A. Padua, MD; Dong-Eun Shin, PhD

8:30 – 8:34am Paper #102: **Functional Effects of Cervical Spine Disease in Adults with Down Syndrome**
Martin J. Herman, MD; Peter D. Pizzutillo, MD

8:34 – 8:43am Discussion

8:44 – 8:48am Paper #103: **Minimum Five-Year Follow-Up of Posterior -Only Surgery for Thoracic and Thoracolumbar Kyphosis**
Stuart Hershman, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Han Jo Kim, MD; Jeremy L. Fogelson, MD; Addisu Mesfin, MD; Brenda A. Sides, MA

8:48 – 8:52am Paper #104: **Comparison of Different X-Ray Methods to Evaluate the Flexibility of Kyphosis in Scheuermann's Disease**
Meric Enercan; Cagatay Ozturk, MD; Sinan Kahraman; Levent Ulusoy; Ramazan Soydan; Alauddin Kochai; Ahmet Alanay; Azmi Hamzaoglu, MD

8:52 – 8:56am Paper #105: **The Prevalence of Abnormal Preoperative Neurologic Exam in Scheuermann's Kyphosis: Correlation with X-Ray, MRI, and Surgical Outcome**
Woojin Cho, MD, PhD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Guangxun Hu; Jacob M. Buchowski, MD, MS; Ian G. Dorward, MD; Joshua M. Pahys, MD; Samuel K. Cho, MD; Matthew Kang, MD; Lukas P. Zebala, MD; Linda Koester, BS

8:56 – 9:05am Discussion

9:06 – 9:10am Paper #106: **Demographics and Outcomes Based on Spondylolisthesis Slip Grade**
John R. Dimar, MD; Hubert Labelle, MD; Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Michael T. Hresko, MD; Mark Weidenbaum, MD

9:10 – 9:14am Paper #107: **Isthmic Spondylolisthesis with Concomitant Scoliosis. A Retrospective Report on 21 Operated Patients with Mean Follow-Up over Ten Years**
Dietrich Schlenzka, MD PhD; Mauno Ylikoski, MD; Timo A. Yrjonen, MD; Teija Lund, MD, PhD; Heikki Österman; Timo Laine; Mikko S. Poussa

9:14 – 9:18am Paper #108: **Prevalence of Spondylolisthesis and Concomitant Adolescent Idiopathic Scoliosis**
Ronald A. Lehman, MD; Lawrence G. Lenke, MD; Kathy Blanke, RN; Daniel G. Kang, MD; Ensor E. Transfeldt, MD; Hubert Labelle, MD; Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD

9:18 – 9:27am Discussion

9:28 – 9:32am Paper #109: **Treatment of Low Grade L5-S1 Developmental Spondylolisthesis: Predictors of Operative and Non-Operative Treatment**
Michael T. Hresko, MD; Hubert Labelle, MD; John R. Dimar, MD; Mark Weidenbaum, MD; Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Courtney W. Brown, MD

9:32 – 9:36am Paper #110: **Compensatory Mechanisms and the Effect of Age on Sagittal Balance in Spondylolisthesis**
Sabarul Mokhtar, MD(UKM), MS(Orth); Ioannis Sergides; Davor Saravanja, B Med FRACS; Peter McCombe; Gavin White; William R. Sears, MB BS FRACS

9:36 – 9:40am Paper #111: **A Line of Zebrafish with Progressive Spinal Curvature**
Henry G. Tomasiewicz, PhD; Channing Tassone; John G. Thometz, MD; XueCheng Liu, MD, PhD

9:40 – 9:49am Discussion

9:50 – 9:54am Paper #112: **Ghrelin Levels in Adolescent Idiopathic Scoliosis**
Jerome Sales de Gauzy, PhD; Isabelle Gennero; Franck Accadbled, MD, PhD; Jean-Pierre Salles

9:54 – 9:58am Paper #113: **The Relationship of Symptomatic Thoracolumbar Disc Herniation and Scheuermann's Disease**
Zhongqiang Chen, MD

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9:58 – 10:02am Paper #114: **Relationship between Syringomyelia Size and Scoliosis in Patients with Chiari I Malformation**
David H. Kim, BS, MS; Michael P. Kelly, MD; Tae S. Park, MD; Lawrence G. Lenke, MD; David D. Limbrick, MD, PhD

10:02 – 10:11am Discussion

10:12 – 10:20am Transfer of Presidency
B. Stephens Richards, III, MD and Kamal N. Ibrahim, MD, FRCS(c), MA

10:20 – 10:30am Awards Presentation
Daniel J. Sucato, MD, MS
Program Committee Chair
- Russell A. Hibbs Awards for Best Clinical Presentation and Best Basic Science Presentation
- Louis A. Goldstein Award for Best Clinical Poster or E-Poster
- John H. Moe Award for Best Basic Science Poster or E-Poster

10:30 – 10:50am BREAK

SESSION 8 COMPLICATIONS, OSTEOTOMY

Moderators: Steven D. Glassman, MD and Reinhard D. Zeller, MD, FRCSC
Room: Sheraton/Chicago Ballroom, Level 4

10:50 – 10:54am Paper #115: **Management of Delayed (Greater than One Year) Deep Infection after Spinal Fusion**
Jaren LaGreca; Mark Hotchkiss, BA; Sumeet Garg, MD; Mark A. Erickson, MD

10:54 – 10:58am Paper #116: **Prevalence of Intra-Operative Tissue Bacterial Contamination in Posterior Pediatric Spinal Deformity Surgery**
Sreeharsha V. Nandyala, BA; Richard M. Schwend, MD

10:58 – 11:02am Paper #117: **Intravenous Vancomycin to Prevent Surgical Site Infections: Impact and Complications of a New Prophylaxis Protocol at a Large Pediatric Spine Center**
Wajdi Kanj, BS; Melissa Gunderson, BA; Keith D. Baldwin, MD, MSPT, MPH; John M. Flynn, MD

11:02 – 11:11am Discussion

11:12 – 11:16am Paper #118: **Postoperative Drains and the Risk of Surgical Site Infection Following Spinal Surgery**
Tate M. Andres, BS; Richelle C. Takemoto, MD; Pedro A. Ricart Hoffiz, MD, MS; Thomas Errico; Baron S. Lonner

11:16 – 11:20am Paper #119: **Outcome and Treatment of Post-Operative Spine Surgical Site Infections: Predictors of Treatment Success and Failure**
Keishi Maruo, MD; Sigurd H. Berven, MD; Serena S. Hu, MD; Shane Burch, MD; Vedat Deviren, MD; Bobby Tay, MD; Christopher P. Ames, MD; Praveen V. Mummaneni, MD; Dean Chou, MD; Amir Abdul-Jabbar; Steven Takemoto, PhD

11:20 – 11:24am Paper #120: **Plastic Surgery-Assisted Management of Spinal Surgical Site Infection Reduces Risk of Implant Removal by Half**
Karen S. Myung, MD, PhD; Kent T. Yamaguchi, BA; Jeffrey Hammoudeh, MD; Vernon T. Solo, MD; David L. Skaggs, MD

11:24 – 11:33am Discussion

11:34 – 11:38am Paper #121: **Pedicle Screw Misplacement in Apical and End Vertebrae: A CT-Based Review of 285 Pediatric Patients**
Terry D. Amaral, MD; Beverly Thornhill, MD; Adam L. Wollowick, MD; Jonathan J. Horn; Meredith Steinman; Vishal Sarwahi, MD

11:38 – 11:42am Paper #122: **The Accuracy of Pedicle Screw Placement in Scoliosis Surgery: Comparison between O-Arm-Based and Conventional Computed Tomography-Based Navigation**
Toshiaki Kotani; Tsutomu Akazawa, MD; Kayo Koyama; Masaru Sonoda; Shohei Minami

11:42 – 11:46am Paper #123: **Radiation Dose from 3D O-Arm Imaging in Adolescent Idiopathic Scoliosis (AIS) Surgery**
Xiaowei Zhu, MS; Denise Magill, MS; Marc Felice; John P. Dormans, MD

11:46 – 11:55am Discussion

11:56am – 12:00pm Paper #124: **Incidence, Diagnosis and Management of Sacral Fractures Following Multi-Level Spinal Arthrodesis**
Dennis S. Meredith, MD; Fadi Taher, MD; Frank P. Cammisa, MD; Federico P. Girardi, MD

12:00 – 12:04pm	Paper #125: **Revision Spinal Fusion in Patients Older than 75: Is it Worth the Risks?** *Michael S. Chang, MD; Jan Revella, RN; Dennis Crandall, MD*
12:04 – 12:08pm	Paper #126: **The Prevalence of Endocrine Abnormalities in Patients with Pseudarthrosis after Spinal Fusion** *Colin G. Crosby, MD; Michael D. Stockin, BS; Kevin R. O'Neill, MD, MS; Jesse E. Bible, MD; Clinton J. Devin, MD*
12:08 – 12:17pm	Discussion
12:18 – 12:22pm	Paper #127: **Results of Corrective Osteotomy in Ankylosing Spondylitis with Fixed Kyphotic Deformity** *Ki Tack Kim; Sang-Hun Lee; Dae-Hyun Park; Man-Ho Kim; Dae-Seok Huh*
12:22 – 12:26pm	Paper #128: **The Effect of PVCR on Pulmonary Function Improvement in Severe Rigid Spinal Deformity Patients with Respiratory Dysfunction** *Jing-Ming Xie; Ni Bi; Ying-Song Wang, MD; Ying Zhang; Zhi Zhao; Tao Li*
12:26 – 12:30pm	Paper #129: **Predictors of Pulmonary Improvement after Vertebral Column Resection for Severe Spinal Deformity** *David B. Bumpass, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Jeremy J. Stallbaumer, MD; Yongjung J. Kim, MD; Michael J. Wallendorf, PhD; Woo-Kie Min, MD PhD; Brenda A. Sides, MA*
12:30 – 12:39pm	Discussion
12:39pm	Adjourn

Podium Presentation Abstracts

The Scoliosis Research Society gratefully acknowledges
Synthes Spine for their support of the Welcome Reception.

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PODIUM PRESENTATION ABSTRACTS

1. Intervertebral Disc Degeneration During Postoperative Follow-Up More Than Ten Years after Corrective Surgery in Idiopathic Scoliosis: Comparison between Patients with and without Surgery

Ayato Nohara; Noriaki Kawakami, MD, DMSc; Taichi Tsuji; Tetsuya Ohara; Toshiki Saito; Yoshitaka Suzuki; Ryo Sugawara; Kyotaro Ota, MD; Kazuki Kawakami
Japan

Summary: This study was designed to investigate whether corrective surgeries in AIS improve the natural course of patients 10 years after surgery in terms of disc degeneration (DD) in distal unfused segments and lower back pain (LBP). This study compared three groups; a surgical group, non-surgical mild scoliosis group and non-surgical severe scoliosis group. There were no significant differences in DD and LBP between the surgical and mild scoliosis group, but significant differences between the surgical and severe scoliosis group.

Introduction: The purpose of this study was to investigate the effectiveness of surgical correction for patients with adolescent idiopathic scoliosis (AIS) over a postoperative course of 10 years by comparing the occurrence of disc degeneration (DD) in distal unfused segments with non-surgical patients.

Methods: This was a retrospective and comparative study analyzing X-ray, MRI, and clinical charts of patients who were diagnosed with AIS. All patients were female and divided into three groups. Group O was a surgical group and included 52 patients who underwent corrective surgery (mean age; 18.2). Evaluation was performed 10 years after surgery (mean age; 28.2). The other two were non-surgical groups. Group M included 45 patients (mean age; 27.8) with similar age and magnitude of scoliosis as those measured 10 years after the surgery in Group O. Group S included 32 patients (mean age; 28.7), who exhibited scoliosis similar to the predicted magnitude of scoliosis in patients of Group O assuming that they did not undergo surgery based on the assumption that the curvature would be aggravated by approx. 0.5 per year after maturity. DD were evaluated according to Pfirrmann's grading system. Clinical outcome was assessed with subjective symptoms of low back pain.

Results: The main preoperative curves and 10 years postop. Group O, were 59.4° and 24.4°. The lumbar curves were 40.0° and 16.9°, and L4 tilt were 12° and 7°, respectively. DD was recognized in 61.5% of patients exhibiting mainly 46.2% on L5/S. Twenty-seven patients (51.9%) had low back pain. The main curve, lumbar curve and L4 tilt in Group M were 26.8°, 18.3° and 8°, respectively. DD was confirmed in 47.7% of patients exhibiting mainly 22.7% on L4/5, 25.0% on L5/S. Twenty-nine patients (64.4%) complained of low back pain. The main curve, lumbar curve and L4 tilt in Group S were 66.9°, 45.5° and 17°, respectively. DD was recognized in 26 patients (84.4%) exhibiting 25% on L1/2, 31.3% on L2/3, 46.9% on L3/4, 53.1% on L4/5, and 31.3% on L5/S. Twenty-seven patients (84.4%) complained of low back pain.

Conclusion: The results demonstrated that corrective surgery for patients with AIS significantly decreased the incidences of DD and LBP 10 years after surgery in comparison to the non-surgery group.

2. Motion of the Unfused Lumbar Segments Remains Increased up to Six Years after Fusion for AIS

Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Maty Petcharaporn, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Baron S. Lonner; Firoz Miyanji, MD, FRCSC; Peter O. Newton, MD
USA

Summary: Inter-vertebral motion of the unfused distal segments was measured at varying post-operative time-points (up to 6 years) in 165 patients with Adolescent Idiopathic Scoliosis (AIS) who underwent posterior spinal fusion and instrumentation. Increased motion from L4 to S1 was seen with a more distal lowest instrumented vertebra. No change in motion was seen over the post-operative time periods analyzed.

Introduction: Changes in motion of the un-fused segments of the spine may relate to postop degeneration following fusion for AIS. The purpose of this study was to assess the L4-S1 motion of the spine in AIS patients following instrumented fusion as a function of the time postop.

Methods: Patients were offered inclusion into this IRB approved prospective study at their routine 2-6 year post-operative visits at one of 5 participating centers. Coronal motion was assessed by standardized radiographs acquired in maximum right and left bending positions. The intervertebral angles were measured via digital radiographic measuring software and the motion from the levels of L4 to S1 was summed. Patients were grouped by their post-operative follow-up time point: 2-3.9 years and 4-6 years. The effects of follow-up time and the lowest instrument vertebra (LIV) on L4-S1 motion were evaluated with a 2 way ANOVA.

Results: The data for 165 patients are included. The LIVs ranged from T10 to L4. The distal residual unfused motion (from L4 to S1) was greater among fusions where the LIV was lower in the spinal column compared to those where the distal segment was higher in the spinal column ($p<0.001$). There was no significant change in L4-S1 motion between patients at the 2-3.9 year post-operative time points and patients at the 4-6 year post-operative time points (Figure 1).

Conclusion: In post-operative adolescent idiopathic scoliosis patients, a more distal fusion resulted in greater L4-S1 motion. This first evaluation of motion at different post-operative time points revealed no significant changes between 2-3.9 and 4-6 years post-operatively. The increased motion in the lower lumbar spine associated with more distal levels of fusion may maintain functional motion in the near term, it is certainly concerning for risk of later degeneration. At up to 6 years, there is no evidence of deteriorating kinematics, although continued follow up is mandatory. 10 year data will continue to be collected.

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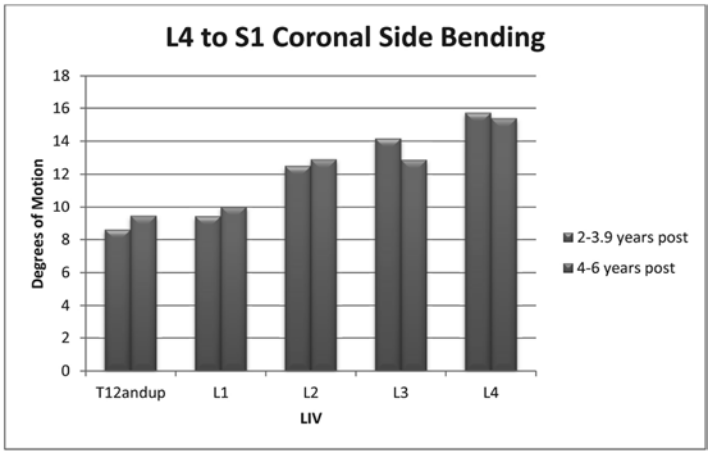
Figure 1. Coronal motion from L4 to S1 by LIV for two post-op time groups.



3. Surgical Outcomes in Adolescent Idiopathic Scoliosis with or without Spondylolisthesis

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Summary: The prevalence of spondylolisthesis (SPL) in pts with operative adolescent idiopathic scoliosis (AIS) is 4.6%. AIS and SPL can be treated independently without increasing risk of slip progression. Curve corrections are maintained regardless of a concomitant SPL. According to SRS-22 data, AIS patients with SPL who undergo spinal fusion have similar clinical outcomes as operatively treated AIS patients.

Introduction: SPL has previously been reported to occur in pts with AIS. There are no reports, however, in the literature describing the outcomes of pts with SPL and operatively treated AIS. Our study set out to compare clinical and radiographic outcomes in operative AIS pts with and without SPL.

Methods: 349 consecutive pts with operatively treated AIS were reviewed. Those with concomitant SPL comprised our study group. A set of matched controls with AIS but without SPL was assembled by pairing for age, gender, Lenke curve type, and Cobb angle. Post-op SRS-22 scores, radiographic outcomes, and slip progression (SPL group) were compared.

Results: The study group pts (N=16, 4.6%) and the set of matched controls (N=16) averaged 14.8 years of age (11-20) at the time of surgery. F/u averaged 46.9 months (24-120) for the study group, and 47.8 months (24-96) for the controls. All slips occurred at L5/S1. High grade slips (N=3, 19%) were treated before scoliosis fusion. Cobb angles averaged 58.5 degrees (40-80) in the study group and were corrected to 20.5 degrees (3-35). Cobb angles averaged 56.8 degrees (42-85) in the control group and were corrected to 20.1 degrees (6-38). Pelvic incidence (PI) was significantly higher in the study group as compared to the contols (68.3 vs 50.0; p=0.002). Slip progression did not occur in any pts. The LIV was >3 levels from the SPL in all pts. No differences were seen in the SRS-22 domains at final f/u between the 2 groups (Pain p=0.285; Activity p=0.080; Image p=0.282; Mental p=0.246; Satisfaction p=0.281; Avg p=0.579).

Conclusion: SPL occurs in 4.6% of operative AIS cases; only 0.9% were high grade slips. Good clinical outcomes at 2 years can be expected in AIS with SPL without fear of slip progression. Slip progression does not appear to be affected by a fusion mass separated by at least 3 levels. Increased PI is associated with SPL in the operative AIS population. Clinical outcomes at a minimum of two years are similar for AIS operative patients with or without SPL.

4. Cost Effectiveness of Surgical Treatment for Adolescent Idiopathic Scoliosis (AIS)

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Summary: To calculate the cost effectiveness of surgical treatment for AIS patient, we divided total direct cost by QALYs gained over remaining life span to yield $8,182 per QALY. Compared to other treatments previously studied, PSF for severe AIS is very cost effective.

Introduction: Increasingly, government and payers are scrutinizing the cost effectiveness of medical and surgical treatments of various diseases. Previous studies calculated the cost and health-related quality-of-life (HRQL) of AIS fusion separately. The aim was to evaluate the cost effectiveness of surgical treatment for AIS patients, and compare it to other common treatments (Table 1).

Methods: We conducted a literature review comparing HRQL preoperatively vs. postoperatively. The difference in HRQLs at 2 year follow up, was multiplied by remaining life span of the matching patient group, yielding the maximum QALYs gained. This estimate is very conservative, because untreated severe (>50°) AIS is known to progress and cause pulmonary decline, which we could not estimate. QALYs are then adjusted by discount rate of 3%. The hospital cost is determined by weighing variable cost of surgery by Lenke curve type prevalence. Professional fees (surgeon and anesthesiologist) were calculated using CPT code 22802 (PSF 7-12 levels), 22843 (posterior segmental instrumentation 7-12 levels), and 00670 (anesthesia for extensive spine procedure) as published by CMS. This fee source was used because it is standardized and represents cost from society's perspective. The rate a surgeon may bill a private insurer can be much higher, but it reflects local market conditions, not cost to society. Total direct cost, including hospital and professional fees, is divided by adjusted QALYs gained.

Results: PSF for severe scoliosis has been shown to increase HRQL (SRS-22) from .741 to .898. The difference between life expectancy and age at operation is 60 years, yielding a maximum of 9.42 QALYs gained. Conservatively discounted at 3%, this analysis yields 4.35 QALYs per PSF. Hospital cost, weighted by Lenke curve type, is $31,820. Surgeon's fee is $2,935 (CPT 22802, 22843). Anesthesiologist's fee is $833 (CPT 00670). The total cost of $35,593 divided by 4.35 QALYs yields $8,182 per QALY.

Conclusion: For AIS surgical candidates, surgery costs $8,182 per QALY. This compares favorably against procedures such as CABG for left main disease ($9,050) or TKA ($18,700), because the gain in HRQL is carried over a longer time period due to relatively younger age at initial operation.

5. Potentially Avoidable X-rays in Mild AIS Patients

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Summary: Prognostic DNA-based testing for risk of curve progression in skeletally immature AIS patients can potentially minimize unnecessary x-ray exposure with its attendant risk of oncogenesis.

Introduction: Previous exposure to ionizing radiation is a risk factor in oncogenesis. Diagnostic x-rays have been shown to increase the likelihood of subsequent malignancy in AIS patients. Without intervention, 80% or more of skeletally immature patients with AIS <25° will not experience clinically significant curve progression. We reviewed the medical records of patients with mild AIS who had a <1% risk of curve progression (ROP) based upon DNA testing to document the number of x-ray examinations that were potentially avoidable.

Methods: We retrospectively obtained a saliva sample to calculate a DNA-based ROP score. Consecutive medical records were surveyed of 151 Caucasian AIS patients (135 females, 16 males) who had a <1% ROP to 40° before skeletal maturity or 50° at maturity and were followed for curves <26°. The inclusion criteria were: 1. Diagnosis of AIS with initial Cobb angle <26°; 2. At least 3 years in treatment; 3. Skeletally immature at initial presentation (average age 12 yrs, range 9-15) and 4. ROP score signifying < 1% risk of progression. The subjects came from a wide geographic distribution in North America and had been evaluated by members of the SRS. Brace prescriptions and the number of diagnostic spine x-rays for each patient were recorded.

Results: The initial Cobb angle averaged 15°(range 5-25°). The Cobb angle at skeletal maturity averaged 18° (range 9-25°), with an average age of 19 yrs (range 14-27). All patients reached at least Risser 4 at final follow up. No curve had progressed beyond 25°. These low risk patients had an average of 6.9 (range 3-24) diagnostic spine x-rays during the period of their AIS care. Observation only was specified in 119 patients (mean initial Cobb of 14°). An orthosis was prescribed for 32 patients(mean initial Cobb of 21°). Matching the 32 braced patients with 32 unbraced patients based on initial Cobb angles, the Cobb angles were identical at maturity.

Conclusion: Without a reliable method of identifying which mild AIS patients are at risk of curve progression, some patients are exposed to bracing and ionizing radiation with little clinical benefit. Previous work has shown the direct and indirect costs and suggested the oncogenic risks x-rays that made be avoided with prognostic testing.

6. ICU vs. Hospital Floor: Which is Best following Spinal Fusion for AIS?

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Summary: Patients with AIS undergoing PSF had shorter hospital stays and decreased blood draws, analgesic requirements and hospital charges when postoperatively treated on the hospital floor rather than an ICU. Furthermore, when patients were sent to the ICU, surgeries were often cancelled due to a lack of an ICU bed. Since sending patients to the hospital floor, no patient in over 2 years was cancelled due to a lack of a hospital bed.

Introduction: Efforts to reduce health care costs while delivering better health care and patient satisfaction are mandated throughout the nation. Here, we report the purpose of this study is to compare postoperative management on a hospital floor vs. ICU in patients with AIS undergoing posterior spinal fusion. We hypothesized that healthy patients after spinal fusion for AIS can safely be managed on a general surgical floor post-operatively, instead of an ICU, and thereby, also, reduce costs of hospitalization.

Methods: A retrospective review of 124 consecutive cases of AIS treated with spinal fusion from August 2007 to August 2010 was performed. Inclusion criteria were diagnosis of AIS and posterior-only spinal fusion (PSF).

Results: Of 124 patients, 66 were managed postoperatively in the ICU prior to May 20, 2009 and 58 on the hospital floor after May 20, 2009. The average age at surgery was 15 years (range, 10-20 years). An average number of 11 levels were fused (6-15). The average age at surgery, weight, pre- and post-operative Cobb angle, and levels instrumented were not significantly different (p>0.05) between groups. The amount of analgesic and anti-anxiety medications (IV morphine, p=0.0001; acetaminophen-hydrocodone, p=0.0001; PO valium, p=0.0001), number of post-operative blood tests (p=0.0001), days of hospital stay (p=0.04) and number of physical therapy sessions (p=0.03) were significantly less in the floor group than the ICU group. No patient from the floor group had to be admitted to the ICU. Average charges for the floor group was $33,120.70 and for the ICU group was $39,252.26 (p=0.0001).

Conclusion: Initial post-operative management of patients with AIS following PSF on a standard hospital floor, rather than an ICU, was associated with a shorter hospital stay, fewer blood tests, less analgesic and anti-anxiety medications, and less physical therapy sessions. In addition, there was a 15% decrease in hospital charges for the group that did not go to the ICU.

7. Does Following the Lenke Classification Treatment Algorithm Improve Outcomes?

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USA

Summary: We evaluated surgical outcome of 570 AIS patients to determine the effect of breaking or following the Lenke Classification treatment algorithm rules for fusing only structural curves. The data suggest that not fusing structural curves will result in a suboptimal trunk shape outcome compared to fusing all structural curves.

Introduction: The Lenke Classification describes curve type and provides treatment algorithm guide lines by recommending fusion only of structural curves. The surgical outcome as defined by trunk shape of following these guidelines vs. breaking the Lenke rules has not been investigated.

Methods: Prospectively collected data from a multicenter AIS database were used. Surgical AIS cases for each Lenke Classification type 1-6 were judged "Rule-breakers" (more than two vertebrae of a non-structural curve fused or more than 2 vertebrae of a structural curve not fused) or "Rule-followers." Both groups were evaluated for significant pre-op and 2 year post-op shoulder height asymmetry, trunk shift and deviation from the C7-CSVL as well as rib and lumbar prominence.

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Suboptimal outcome was defined as post-op shoulder asymmetry, trunk shift or deviation from C7-CSVL more than 2 cm; also residual thoracic prominence more than 7 or lumbar prominence more than 4 by scoliometer.

Results: The data for 570 AIS patients with 2 year follow-up were eligible for inclusion; 153 patients were "Rule-breakers" and 417 were "Rule-followers" (Table 1). Lenke 3 and 6 curve types had a significantly higher percentage of suboptimal results with "Rule-breakers" than "Rule-followers." Lenke 1, 2 and 5 curve types did not have a significant difference in trunk shape outcome between "Rule-breakers" and "Rule-followers." Lenke 4 curve type had too few patients for significant analysis. Thoracic and lumbar prominence was not significantly different between "Rule-breakers" and "Rule-followers" in each Lenke group.

Conclusion: Our data suggest that not fusing structural curves ("Rule-breaker"), especially in Lenke 3 and 6 types, will result in a suboptimal trunk shape outcome compared to fusing all structural curves ("Rule-follower"). Fusing non-structural curves ("Rule-breakers") in Lenke 1, 2 and 5 curve types does not result in a suboptimal trunk shape outcome although it may result in less residual flexibility. Thoracic and lumbar rib prominence result is not affected by adherence to treatment guidelines. The Lenke Classification treatment algorithm does result in better trunk shape outcome when guidelines are followed.

8. The Use of 3D Spinal Parameters to Differentiate between Progressive and Non-Progressive AIS Curves at the First Visit

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Canada

Summary: Based on a prospective cohort of 134 patients followed for a mean of 37 months, 3D parameters of the spine calculated at the first visit were identified as being different between the evolutive and the non evolutive patients. Parameters were torsion, plane of maximal curvature orientation, hypokyphosis and apical vertebra axial rotation.

Introduction: Prediction of curve progression remains challenging in adolescent idiopathic scoliosis (AIS) at the first visit. The objective of this study was to compare 3D morphologic parameters of the spine at the first visit between a non-progressive and a progressive group of immature patients with AIS.

Methods: This is a single-center prospective series of 134 consecutive patients with a diagnosis of AIS followed from their first visit to maturity (mean 37 months). The first group was made of AIS patients with a minimum of 6° progression of the major curve between the first and last follow up (P) (n=53) and the second group was composed of non progressive patients that reached maturity with less than 6° of progression (n=81). 3D reconstructions of the spine at the initial visit were obtained using EOS™ images and 3D parameters calculated automatically. There were 6 categories of measurements: angle of plane of maximum curvature, Cobb angles (kyphosis, lordosis), 3D wedging (apical vertebra, apical disks), rotation (upper and lower junctional vertebra, apical vertebra, thoracolumbar junction), torsion and slenderness (height/width ratio).

Results: There was no statistical difference between the two groups for age and initial Cobb angle. Four distinct parameters were found to be significantly different and clinically significant by being greater than the measurement error. The significant parameters included spinal torsion, the rotation of the plane of maximal curvature, hypokyphosis and apical vertebral rotation (table).

Conclusion: This study confirms that even at the initial visit, 3D morphologic differences exist between progressive and non-progressive curves in AIS, in particular parameters linked to rotation, hypokyphosis, plane of maximal curvature and torsion of the spine. These findings underscore the importance of the torsional aspect of the deformity occurring in the junctional zone under the main curve. Wedging doesn't seem to be related to progression at this early stage. It supports the use of 3D reconstructions of the spine in the initial evaluation of AIS to help predict the outcome.

9. Inclusion of the Proximal Thoracic Curve Does Not Provide Better Shoulder Balance in All Lenke 2 Curves

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Summary: This study demonstrates greater likelihood of including the PT curve when the Lenke classification and pedicle screws are used for Lenke 2 AIS without improved shoulder balance at 2 years. This calls into question the need to instrument all PT curves with the Lenke 2 classification.

Introduction: The Lenke classification has established criteria which designate the proximal thoracic (PT) curve as structural (Lenke 2) in adolescent idiopathic scoliosis (AIS). However, this may overestimate the necessity to include the PT. The purpose of this study was to determine the incidence of including the PT curve for Lenke 2 curves based on time period, implant type and whether inclusion of the PT curve resulted in better shoulder balance.

Methods: A retrospective review of a consecutive series of patients with Lenke 2 AIS at a single institution from 1996-2000 (early group) and from 2002-2009 (late group) was performed. Patients were grouped into those who had inclusion of the PT curve (+PT fusion) vs not (-PT fusion) and whether screws (S) or hybrid constructs were used (H).

Results: There were 88 in the +PT group and 64 in the -PT group without differences in age (14.3 vs. 14.4yrs), gender, the preoperative PT magnitude (45.2 vs. 46.9), or flexibility (27.9% vs. 26.8%), the main thoracic (MT) magnitude (64.9 vs. 65.0), clavicle angle or shoulder height or T1 tilt Inclusion of the PT curve occurred more often in the late group (63.0 vs 54.6%) (p=0.04) and when all-screw constructs were used (73.0% vs 47.0%) (p=0.03). Postoperatively, the PT Cobb was less for the +PT/S group compared to the +PT/H and -PT/H groups and remained smaller (17.4) at 2 years compared to the +PT/H (24.0) but was similar to the S (19.4) and H (24.0) when the PT was not included. Metrics for shoulder balance (T1 tilt, Shoulder height, and clavicle angle) at 2 years were no different whether the PT curve was included or whether S or H constructs were used.

Conclusion: The PT curve is more commonly instrumented in Lenke curves when screws are used and with more recent surgeries. Despite instrumentation of the proximal curve and improved postoperative PT curve correction, there are no differences in shoulder height parameters. This study calls into question the need to instrument all PT curves with the Lenke 2 classification.

10. Additional Risk Factors for Adding-On after Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis (AIS): Implication of LIV Angle and Lumbo-Sacral Takeoff (LSTO)

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Summary: AIS patients treated with Posterior thoracic fusion, all pedicle screws, by one surgeon, using same LIV selection criteria, and x-ray measurement in PACS performed by, single investigator) were reviewed for additional risk factors for adding on AD and compared a control (C) group. LIV-H angle (preop) and mismatching LIV-H with LSTO (pre and postop) were found to be the additional risk factors for AD.

Introduction: Previous studies have shown that the proper selection of LIV is critical in preventing adding-on (AD) phenomenon after selective thoracic fusion (STF). However, even after selecting the correct LIV, AD can still occur.

Methods: This is a retrospective review of 380 consecutive AIS Pts who underwent corrective surgery by a single surgeon. LIV was chosen as stable vertebra (SV) or SV-1 if intersected by the CSVL. 135 Pts were identified who had complete radiographic images stored in PACS. After Lenke 5, ant. or combined surgeries, TL fusion, and hybrid construct were excluded, 78 Pts who received STF with all pedicle screw construct were selected. 2 groups were identified: Adding-on (AD) and Control (C). AD was defined as >5° angle of sup. endplate of LIV-1 to inf. endplate of LIV+1 between postop and the final f/u. All Pts were included in AD regardless of failure occurring before or after 2 yrs. In C, pts with less than 2 yrs f/u or with other complications (e.g. metal failure…) were excluded. We analyzed AD, and compared them with C to identify risk factors not previously defined.

Results: Pts with other complication and f/u less than 2yrs were excluded, and there remained 11 Pts in AD (14%), and 8 in C. First notice of AD was avg. 0.65 ± 0.86 yr. There were no Lt convex thoracic curves. There was no significant difference between the 2 groups in terms of demographic data, LIV selection, and curve types. In AD, there was significant curve progression within fused segments. Even though Lumbo-Sacral Takeoff (LSTO) (the angle between the superior endplate of L5 and the line connecting the superior most point of each ala) was not significantly different, (LIV-H)+LSTO and LIV-H showed significant difference.

Conclusion: After excluding the effect of known risk factors for AD, LIV-H angle and mismatching LIV-H with LSTO were found to be the additional risk factors for AD. In addition to consideration of other risk factors such as LIV selection or Risser stage, these risk factors should be considered for AIS surgeries to prevent adding on which may require additional surgeries and extension of fusion to distal lumbar spine, thus obviating the objective to save levels during the index procedure.

No Significant Difference				Significant Difference (bold)			
	Control (C) Avg ± SE	Adding-On (AD) Avg ± SE	P-value		Control (C) Avg ± SE	Adding-On (AD) Avg ± SE	P-value
Sex (male=1, female=0)	0.38 ± 0.52	0.18 ± 0.40	0.19	Adding-on angle preop	9.57 ± 6.95	4.27 ± 10.54	0.13
Age at Surgery	16.01 ± 1.72	15.47 ± 2.32	0.29	Adding-on angle postop	4.63 ± 5.80	-0.27 ± 6.93	0.06
Risser sign	4.14 ± 0.63	3.64 ± 1.12	0.15	**Adding-on angle Final f/u**	**3.75 ± 12.75**	**-9.64 ± 10.94**	**0.01**
Lenke Type	1.38 ± 0.52	1.60 ± 0.69	0.20	Adding on angle Postop-Preop	-3.75 ± 3.65	-5.27 ± 10.09	0.35
L-modifier (A=1, B=2, C=3)	1.50 ± 0.76	1.73 ± 0.65	0.25	**Adding on angle Final-Postop**	**-0.88 ± 8.17**	**-8.64 ± 6.65**	**0.02**
SV-LIV	-0.25 ± 0.71	-0.55 ± 0.82	0.21	Adding on angle Final-Preop	-4.63 ± 6.76	-13.91 ± 15.78	0.07
Levels Fused	9.13 ± 1.46	9.20 ± 1.14	0.45	Apex-C7 (T-AVT) Preop	38.88 ± 29.70	47.45 ± 9.54	0.19
Number of Screws	17.00 ± 3.82	18.10 ± 1.73	0.21	Apex-C7 (T-AVT) Postop	11.13 ± 10.15	11.55 ± 11.35	0.47
LSTO Preop	-5.75 ± 4.20	-6.82 ± 4.62	0.31	**Apex-C7 (T-AVT) Final f/u**	**11.63 ± 10.15**	**25.64 ± 8.37**	**0.01**
LSTO Postop	-4.18 ± 4.90	-4.73 ± 4.71	0.41	**Apex-C7 (T-AVT) Final -Postop**	**0.50 ± 3.82**	**14.09 ± 13.10**	**0.01**
LSTO Final	-4.63 ± 5.10	-3.09 ± 5.07	0.26	MT Postop	20.86 ± 6.23	21.09 ± 6.04	0.47
PT Preop	28.75 ± 14.52	30.55 ± 11.18	0.38	**MT Final f/u**	**22.29 ± 6.29**	**27.27 ± 5.35**	**0.045**
MT Preop	51.00 ± 8.72	50.82 ± 5.46	0.48	**MT Final-Postop**	**1.25 ± 2.38**	**6.18 ± 7.56**	**0.047**
TL/L Preop	28.63 ± 9.62	35.36 ± 9.91	0.08	**LIV-H Preop**	**19.38 ± 7.41**	**26.45 ± 5.18**	**0.01**
LIV-Disc Preop	8.00 ± 5.26	8.55 ± 5.28	0.41	LIV-H Postop	5.63 ± 5.85	9.09 ± 5.56	0.10
C7-CSVL (Coronal Balance) Preop	-5.38 ± 7.61	-5.27 ± 16.84	0.49	LIV-H Final f/u	8.13 ± 6.06	9.64 ± 7.41	0.32
Lumbar-CSVL (L-AVT) Preop	-8.625 ± 12.83	-12.55 ± 10.29	0.23	**(LIV-H)+LSTO Preop**	**13.63 ± 5.13**	**19.64 ± 5.18**	**0.01**
T Apex Rotation (AVR) Preop	1.69 ± 0.59	1.64 ± 0.39	0.41	**(LIV-H)+LSTO Postop**	**0.88 ± 4.29**	**4.91 ± 5.15**	**0.04**
L Apex Rotation (AVR) Preop	0.44 ± 0.50	0.86 ± 0.71	0.08	(LIV-H)+LSTO Final	3.50 ± 2.98	6.55 ± 7.15	0.14

11. Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis Curves with a C lumbar Modifier: Which Rules can be Broken?

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Summary: Several studies have provided recommendations for when selective thoracic fusion should be performed: AVT ratio >1.2, thoracic:lumbar (TH:L) curve magnitude ratio >1.2, lumbar curve magnitude <45° and lumbar curve bending <25°. When tested against the chance of attaining a set of pre-defined desired outcome parameters, only lumbar curve magnitude <45° and lumbar curve bending <25° resulted in any success.

Introduction: Several studies have provided recommendations for when selective thoracic fusion (STF) should be performed: TH:L apical vertebra translation (AVT) ratio >1.2, TH:L curve ratio >1.2, lumbar curve <45° and lumbar curve bending <25. Utilizing previously established criteria for optimal STF outcomes, we tested these rules to determine the likelihood of attaining the desired post-op outcome.

Methods: Prospectively collected cases from a multi-center database were analyzed. Lenke 1-4C AIS patients who underwent STF with minimum 2yrs f/u were included. Based on prior study, successful 2 year outcome was defined as: lumbar Cobb <26°, lumbar percent correction >37%, C7-CSVL deviation <2cm, DFQ <4, trunk shift <1.5cm, lumbar rib hump <5°. For each pre-op rule, AVT ratio >1.2, curve magnitude ratio >1.2, lumbar curve magnitude >45° and lumbar curve bending >25°, patients were divided into 2 groups based on whether they adhered to the rule. Chi-squared analysis was used to determine if implementation of the rule increased the chance of attaining the pre-defined successful outcome.

Results: 106 patients were analyzed and the percentage of successes for those that followed or broke the rules were calculated (Table). Neither AVT ratio >1.2 nor Cobb ratio >1.2 predicted greater success with regards to any of the target

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outcome parameters. Pre-op lumbar curve of <45° lead to optimal outcome with respect to DFQ (p<0.001) and lumbar curve size (p=0.06). Lumbar bend <25° was associated with increased success for DFQ (p<0.001), lumbar curve size (p<0.001) and C7-CSVL deviation (p=0.05). While the lumbar bend <25° rule was not associated with increased optimal outcome for trunk shift, patients who were more flexible (12° vs 18, p<0.005) were more likely to attain an ideal post-op trunk shift (<1.5cm).

Conclusion: Predicting which AIS curves will respond well to STF remains a challenge. Our study suggests that performing STF in patients with a pre-op lumbar curve <45° or a pre-op lumbar bend <25° will increase one's chance in attaining our pre-defined successful outcome parameters. Considering that outcomes also depend on surgeon factors, no rule is a guarantee for success. Similarly, performing a STF outside the recommended rule does not guarantee a poor outcome.

Table 1

	Selective Thoracic Fusion Rules							
	45 degree rule		25 degree bend		AVT > 1.2		Cobb ratio >1.2	
	< 45	> 45	<25	> 25	> 1.2	< 1.2	> 1.2	<1.2
DFQ < 4	66%	29%	66%	12%	48%	61%	60%	55%
Lumbar Cobb < 26	72%	42%	73%	24%	65%	65%	66%	64%
L correction > 37%	62%	67%	64%	59%	74%	59%	66%	59%
C7-CSVL < 2cm	78%	79%	81%	59%	83%	76%	73%	86%
L prominence < 5	78%	76%	77%	80%	79%	77%	83%	69%
Trunk shift < 1.5cm	64%	56%	57%	45%	72%	58%	65%	58%

*Highlighted areas indicate significant differences

12. Surgeon Variability For Treatment of Lenke 1C Curve Patterns With Selective Thoracic Fusions

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Summary: Since the establishment of the Lenke et al classification for Adolescent Idiopathic Scoliosis (AIS), selective thoracic fusion (STF) for Lenke 1C curve pattern (King II) has been suggested as the optimal treatment. However, many Lenke 1C curves are not currently being treated with STF, and surgeon variability in their approach to this curve pattern appears to be highly individualized and may be related to surgeon volume/experience in their approach to this curve.

Introduction: AIS classification systems assist surgeons to identify curve types and determine caudal fusion level. The Lenke classification purports that 1C curves ("false double major curves") should be treated with STF. Despite widespread popularity and use of this novel classification system, STF are not performed uniformly for Lenke 1Cs. We set out to determine surgeon variability in performing STF for Lenke 1C curves.

Methods: A prospective, multicenter database was reviewed, and 344 patients with Lenke 1C curves treated with posterior segmental instrumentation systems were analyzed. Patients were divided into two groups: Group 1 - STF with LIV at L1 or cephalad; and Group 2 - nonselective fusions (NSF) with LIV at or caudad to L3. Preoperative radiographs and surgeon profiles of 57 SRS members whom performed the cases were analyzed for choice of STF and volume of cases.

Results: Only 50.6% (174/344) of patients underwent a STF. The Cobb angle ratios (Thoracic:Lumbar) were significantly larger in the STF group (1.35) compared to the NSF group (1.18). For all surgeons, the performance of STF varied from 0% (6 surgeons) to 100% (4 surgeons). Eighty percent of cases were performed by surgeons doing >5 cases, and surgeons who did 12 or more cases performed STF in 64% of cases. Those who did less than 5 surgeries performed STF in 35% of cases. Of those surgeons who did >12 cases, STF varied from 25% (n=3) to 83.3% (n=2).

Conclusion: There remains a tremendous amount of variability in surgeons' decision to perform a selective thoracic fusion for Lenke 1C curve patterns (51%). Surgeon volume (>12 1C curves/yr) appears to demonstrate a positive correlation with a greater propensity to perform a STF (83.3%).

13. Late Implant Removal after Posterior Correction of Thoracic AIS with Pedicle Screw Instrumentation - A Matched Case Control Study with Ten-Year Follow-Up

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Switzerland

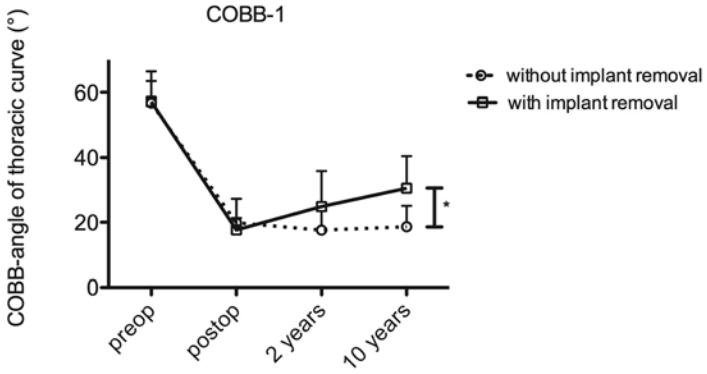
Summary: This matched case control study documents that late implant removal after posterior correction of thoracic AIS with pedicle screw instrumentation results in a significant loss of correction of 10-15° at 10 y follow-up, but without clinical relevance as measured by the SRS-24 questionnaire.

Introduction: Late implant removal is occasionally necessary after instrumented posterior correction of adolescent idiopathic scoliosis (AIS) due to late implant infection or implant associated pain. Progression of deformity after implant removal is possible and its clinical relevance is not yet known due to lack of studies with a comparable control group.

Methods: 50 patients with AIS and pedicle screw instrumentation for posterior correction that were followed for at least 10 years, of whom 7 patients needed implant removal (IR) after 3.4 (range 1.1 - 7.9) years due to late implant associated infection. These patients were matched to another 7 patients without any complications (control) by curve type (IR=control: 1 Lenke 1A, 2 Lenke 1B, 2 Lenke 2C, 1 Lenke 2B and 1 Lenke 3C), Risser stage (IR: 3.2±0.9, control: 3±1.4), age (IR =control: 15±2 years) and gender (all female). Radiological measurements were done preoperatively, at 6 weeks, 2 years and 10 years postoperatively. All patients completed the SRS-24 questionnaire at 10 year follow-up.

Results: Although the curve magnitude of the main thoracic curve was similar preoperatively (IR: 57±6°, control 57±10°) and corrected equally (IR: 18±4°, control 20±7°), the deformity progressed in the IR group by tendency at 2 years (25±11° vs control 17±6°) and became statistically different at 10 years (IR: 31±10°, control 19±6°, p<0.05). There was no significant difference in the total SRS Score between the groups (IR: 99±13, control: 90±17, p>0.05) at 10 years.

Conclusion: Late implant removal after posterior correction of thoracic AIS with pedicle screw instrumentation results in a significant loss of correction of 10-15° at 10 y follow-up, but without clinical relevance as measured by the SRS-24 questionnaire.



14. Unplanned Return to the Operating Room in Patients with AIS: Are We Doing Better with Pedicle Screws than with Hybrid Constructs?

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Summary: Few previous studies have compared rates of return to the operating room between pedicle screw and hybrid constructs. Our results suggest fewer returns to the OR with pedicle screw constructs, although long term follow-up is needed. In addition, a comprehensive analysis of pre- and intraoperative factors reveals longer operating time as an independent risk factor for return to the OR.

Introduction: Rates of return to the OR following definitive fusion for AIS vary. Pedicle screws (PS) provide improved correction over hybrid constructs (Hb); however, a paucity of data exists comparing the two with respect to unplanned returns to the OR and identifying potential risk factors for patients treated with PS.

Methods: A multicenter AIS database was retrospectively queried to identify consecutive AIS patients who underwent PSF with either a PS or Hb construct with a minimum of 2 year follow-up (mean time since surgery PS=4.7, Hb=11.2 years). All returns to the OR were identified and were stratified into 'Early' (less than 60 days) or 'Late' (≥ 60 days) and reason for return. Multivariate logistical analysis was performed to identify potential risk factors for the patients treated with PS.

Results: 627 patients met our inclusion criteria (PS= 540, Hb= 87). Demographics and pre-op radiographic parameters were similar for both groups. Rate of return for PS was 3.5% (mean 0.61 years after surgery) vs. Hb 12.6% (mean 1.62 years). Of the PS patients, the majority of returns occurred Early (12/19=63%) whereas the converse was true for the Hb group (Late 8/11=73%). Early returns to the OR occurred in 2.3% of patients with PS compared to 3.4% in Hb group. The most common reason for an early return to the OR in the PS group was malpositioned screws (1.7%) followed by infection (0.4%). In the Hb group, the most common reason was infection (2.2%) followed by malpositioned instrumentation (1.1%). Late returns to the OR occurred in 9.2% of Hb patients vs. 1.5% in the PS group. Reasons for late return were: infection (PS= 1.1%, Hb=1.2%), pseudarthrosis (PS=0.2% S, Hb=2.3%), prominent instrumentation (PS=0.2%, Hb=3.4%), and malpositioned instrumentation (PS=0, Hb=2.3%). Operating time was identified as an independent risk factor for an unplanned return to the OR.

Conclusion: Patients treated with PS constructs appear to have decreased rates of return to the OR when compared with Hb constructs (3.5% vs 12.6%). In patients treated with PS, the majority of returns occur in the Early postoperative period and are for misplaced pedicle screws (1.7%). Longer OR times increase the chance of an unplanned return to the OR.

15. Does Higher Screw Density Result in Increased Curve Correction and Improved Clinical Outcomes in AIS?

David W. Polly, MD; A. Noelle Larson, MD; Beverly E. Diamond, PhD; Charles Gerald T. Ledonio, MD; Daniel J. Sucato, MD, MS; Hubert Labelle, MD; John B. Emans, MD; B. Stephens Richards, MD; Charles E. Johnston, MD
USA

Summary: Multivariate analysis of prospective data on 1247 patients undergoing primarily pedicle screw instrumentation for scoliosis revealed that higher screw density (screws per level fused) was associated with a statistically increased % correction of the Cobb angle (69% vs. 65% correction) in Lenke 1 and 2 curves. Anchor density did not significantly contribute to total SRS score, but was associated with SRS Appearance and SAQ Appearance scores for Lenke 1 curves.

Introduction: We sought to evaluate a large prospective database of AIS patients treated with predominantly pedicle screw contructs to determine whether anchor density was associated with curve correction and patient reported outcome scores.

Methods: 1247 AIS patients met inclusion criteria (Lenke 1 and 2 curves) with predominantly screw constructs (# screws/# total implants > 80%, mean 95.8% ± 5.6% screws). Mean screw density was 1.48 ± 0.31. Thus, < 1.48 screws per level fused was considered low density, and ≥ 1.48 was considered high density. ANCOVA analysis was undertaken to determine association of screw density with % curve correction, SRS, and SAQ scores at 1- and 2-years, controlling for flexibility, fusion length, demongraphics, and surgeon.

Results: High screw density compared to low density was associated with increased % curve correction in Lenke 1 curves at 1-year (69% vs. 65% correction, p=0.0015), controlling for % pre-operative curve flexibility (p=0.0093), length of fusion (p<0.0001), and gender (p=0.078), (model, p<0.0001). For Lenke 2 curves at 1-year, high density constructs were associated with increased % major curve correction (68% vs. 63%, p=0.0073), controlling for length of fusion (model, p<0.0001). Similar findings held at 2-year follow-up.

Thoracic kyphosis at 2 years was negatively correlated with screw density (28° vs. 32°, p<0.0002) controlling for age and length of fusion in Lenke 1 curves (model, p<0.0001). A similar relationship was found for Lenke 2 curves (26° vs. 33°), controlling for length of fusion and pre-op kyphosis.

For Lenke 1 curves only, SRS Appearance Score at 2-years was positively associated with screw density (low: 4.15 vs. high: 4.3, p=0.018). Similarly, the SAQ Appearance score similarly was improved in the high implant density group (high: 14 vs. low: 15, p=0.01), with contributions from length of fusion (p=0.01), and pre-operative SAQ (p<0.0001) for Lenke 1 curves.

Conclusion: For Lenke 1 and 2 curve patterns, improved % correction of major coronal curve was noted at 1 year follow-up in the high screw density cohort. Although

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statistical significance was reached, it is unclear if screw density resulted in clinically significant differences in patient-reported outcomes.

16. Controlled Reduction Technique for Cervical Osteotomy in Ankylosing Spondylitis

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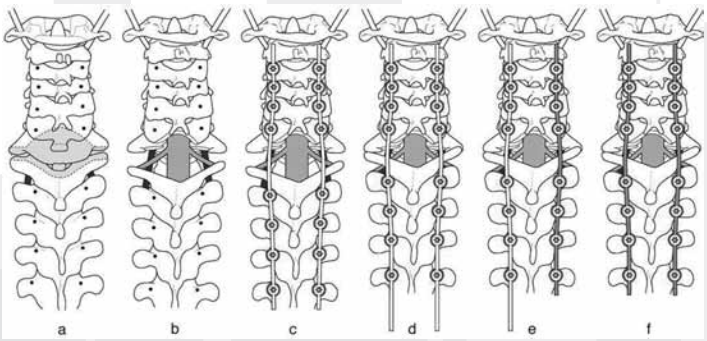
Summary: Cervical Osteotomy in Ankylosing Spondylitis can be a life-changing experience for patients but the potential risks are very serious. We report our experience of a technique which has avoided serious complications in all patients treated over an 16 year period.

Introduction: Cervical osteotomy in Ankylosing Spondylitis (AS) has been used for correction of fixed, cervico-thoracic kyphotic deformity (CTKD) but is associated with significant risks. We have previously published a novel technique to perform this procedure safely. We report further refinements to an existing technique for instrumented reduction of cervical osteotomy and assess the safety and efficacy of this procedure in 15 patients.

Methods: The senior author performed cervical osteotomy for severe CTKD in 14 AS patients from 1993-2009, There were 13 male and 2 female patients, average age 56(40-74) years. The primary surgical indication was restriction of frontal visual field. The average symptoMDuration was 2.7(1-5) years. All patients had a general anaesthetic underwent cervical osteotomy and instrumentation from C3-T5 in prone position using our described technique.

Results: The mean duration of surgery was 4.7hrs (3 to 6.5). Average blood loss was 1938ml (1000-3600). The mean follow-up period was 6.5 yrs(2-16). The mean chin-brow vertical angle (CBVA) was 54 degrees (20 to 70) preoperatively, which improved to 7 degrees (2-12) postoperatively. The mean pre-op Kyphotic angle was 19.2 degrees (14-28); post-operatively this improved to -34 degrees (-21 to -39). There were no instances of neurological deficit. No loss of correction or implant failure has occurred during follow-up.

Conclusion: This technique allows a safe, controlled reduction for cervical osteotomy correcting fixed CTKD in AS. The technique reliably achieves rigid immobilisation which reduces the risk of intra- and post-operative junctional subluxation, avoids the need for prolonged post-operative halo-vest immobilisation and provides satisfactory fusion.



Sequential demonstration of operative technique

17. Kyphotic Deformities of the Cervical Spine - Prospective Study of 90 Patients

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Summary: The aim of the study was to make the clinical and radiographic evaluation of a group of patients with kyphotic deformity treated at our department.

Introduction: The development of a cervical kyphotic deformity can be associated with a degenerative disease, trauma, tumour, developmental anomaly and also a surgical procedure. Post-operative kyphosis can develop after both the anterior and posterior surgical approaches. The deformity can also result from systemic diseases, such as ankylosing spondylitis or rheumatoid arthritis.

Methods: Retrospective analysis of 102 patients underwent correction of cervical kyphosis at our department between 5/2005 and 4/2010, 90 patients were included in this study with an average age of 56.7 years. In 6 patients kyphosis was caused by an inveterate injury, in 71 by degenerative disease, in 6 by rheumatoid arthritis, and 7 due to previous surgery. All patients were examined before surgery by radiography, CT scanning and magnetic resonance imaging. Surgery was carried out from the anterior, posterior approach, or combined approach. The surgical outcome was assessed using the Nurick score and Neck Disability Index (NDI), the Visual Analogue Scale (VAS) was used to evaluate pain intensity or paraesthesia.

Results: The average NDI value was 25.5 before surgery and 14.3 and 14.9 at one and two years after surgery. The average pre-operative Nurick score was 0.7; an average post-operative value of 0.6 and 0,6. The average VAS value for neck and radicular pain was 5.7 pre-operatively, and 2.5 and 2.7, respectively. Complete bone union was achieved at 6 months after surgery in 97.8% patients. The average pre-operative value for the cervical curvature index (Ishihara) was -13.7, postoperatively was +15.3. The average pre-operative cervical kyphosis was -14.4 degrees, postoperatively was +13.5.

Conclusion: The results showed a marked improvement in the patients' quality of life after kyphosis correction, improved neurological status and an improved posture seen on radiograms of the cervical spine. The study also revealed a higher number of potential complications associated, in particular, with corrective osteotomy. The best results were achieved with the combined surgical approach; however, the choice of a surgical method was independent on the patient's clinical status.

18. Cervical Lordosis Actually Increases with Aging and Progressive Degeneration in Spinal Deformity Patients

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Summary: We found a paradoxical increase in cervical lordosis with aging in Spinal Deformity patients. Not surprisingly, there was also an increase in cervical degeneration seen with aging. However, cervical degeneration was not significantly associated with an increase in cervical lordosis.

Introduction: It is theorized that with age and degeneration, the cervical spine loses lordosis and becomes progressively more kyphotic; however, there are no studies which support these conclusions. We performed a radiographic analysis of asymptomatic adults of varying ages, all with differing forms of spinal deformity to their

Thoracic/Lumbar spine to see how Cervical Lordosis changes with increasing age. We hypothesized that Cervical Lordosis would decrease with aging and increasing degeneration.

Methods: EOS X-rays were reviewed on Adult Spinal Deformity patients and only those which allowed for complete visualization of the occiput to the feet were used. A total 104 EOS films of patients of age >18 without documented neck pain, prior neck surgery or deformity were used for review. Cervical lordosis (CL), standard cobb measurements, sagittal balance parameters (SSVA) and cervical degeneration was quantified radiographically by the method previously described by Gore et al. Statistical Analysis was performed with one way ANOVA to see significant differences seen between age groups <40, 40-60 and >60 as well as with changes in sagittal balance. Statistical analysis was performed with one-way ANOVA with a p-value <0.05 as significant.

Results: The average CL actually increased with increasing age (CL 10.3 ±14.7, 15.4 ±15.1, 23.3 ±16.7 in age <40, 40-60 and >60 respectively $p<0.05$). Not surprisingly, the average cervical degeneration score increased at all disc space levels from C2 to C7 across age groups (0.7 ±1.2, 9.9 ±69, 16.3 ±8.9 in age <40, 40-60, >60 respectively $p<0.01$) with the highest degeneration seen at the C5-6 and C6-7 disc space (3.7 ±3.3, 3.2 ±2.9 respectively $p<0.01$). This increase in degeneration did not correlate with the increase in cervical lordosis seen with aging ($r=0.02$, $p=0.84$).

Conclusion: Cervical lordosis actually increased with aging in adult spinal deformity patients. There was no relationship between cervical degeneration and cervical lordosis despite the strong relationship seen between increasing cervical lordosis with older age groups.

19. Operative vs. Nonoperative Treatment of Thoracolumbar Burst Fractures without Neurological Deficit: Fifteen to Twenty-Year Follow-Up

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USA

Summary: Long term (fifteen to twenty year) follow-up was performed on a group of individuals with stable, neurologically intact burst fractures of the thoracolumbar junction. They were originally randomized and prospectively enrolled into one of two treatment groups: operative (instrumented fusion) vs. non-operative treatment (cast or orthosis). Long term analysis (fifteen to twenty years) reveals improved pain and function scores, general health, less medication used and more patients working in the group treated without surgery.

Introduction: Comparative studies of operative vs. non-operative treatment for neurologically intact, stable burst fractures of the thoracolumbar junction have not shown a meaningful difference at early follow-up. Longer outcome data does not exist.

Methods: From 1992 to 1997, 47 consecutive patients with stable burst fractures and no neurological deficit were prospectively randomized to one of two treatment groups: operative (posterior or anterior arthrodesis) or non-operative (body cast or orthosis). At follow-up (ave. 17 years (15 to 20 years) patients filled out VAS pain scales, Roland and Morris disability questionnaire, the Oswestry questionnaire, and the SF-36. Work and health status was obtained, as were standing radiographs.

Results: Of the original operative group of 24 patients, follow-up was obtained on 19. 1 had died and 4 could not be located. Of the original non-operative group of 23 patients, 18 were available; 2 had died and 4 could not be located. Average kyphosis was not significantly different between the two groups.(Op: 14°; Non-op: 16.5°). Average pain scores were not statistically different (Op: 4; Non-op: 2.25), but the ODI and the Roland and Morris scores were statistically better in the group treated non-operatively: (ODI OP: 17.1; Non-op:5.5 $p=0.05$, R and M OP: 8, Non-op: 2. $p=0.01$). All of the SF-36 favored non-operative treatment although only the physical, social and general health scores reached statistical significance. 30% of those operated on showed significant segmental degeneration immediately caudal to their fusion. One received extension of his fusion. Two patients treated non-operatively went on to laminectomies for distal herniated discs. More people treated non-operatively were working. Four times as many used narcotic pain medication who had received surgery.

Conclusion: While early analysis (four years) revealed few significant differences between the two groups, it appears at late follow-up (fifteen to twenty years) that those with stable burst fractures treated non-operatively report less pain and better function than those treated surgically.

20. Pediatric Cervical Fractures with Associated Spinal Cord Injury

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USA

Summary: Pediatric cervical fractures with associated cord injury have distinct characteristics depending on location: upper (C1 to C4) (30% cases) vs. lower (C5 to C7) (70% cases) vertebrae. C1-C4 fractures are more common in children ≤10 and in African Americans, while C5-C7 fractures are more common in older children and in Caucasians. Significantly more spinal fusions are performed in patients with lower cervical fractures. Mortality is highest in children ≤5 years and those with upper cervical fractures.

Introduction: Our aim is to provide national perspective on pediatric cervical fractures with associated cord injuries. We hypothesize that fractures in the upper (C1-C4) and lower (C5-C7) cervical vertebrae differ in patient characteristics and associated mortality.

Methods: Using the Nationwide Inpatient Sample database, we identified children (≤18 years) from 2000-2008 who had cervical fractures with associated cord injury. Chi-squared test, Z-test of proportions and logistic regression were used to analyze relationships between discrete variables, proportions and trends respectively.

Results: From 2000-2008, 3,963 children were hospitalized for cervical fractures with associated spinal cord injury. 30% fractures were in C1-C4 vertebrae, and 70% were in C5-C7 vertebrae.

Patients with C1-C4 fractures had a significantly lower mean age: 13.2 years vs. 15.9 years ($P<0.01$). Children ≤10 years suffered mostly from C1-C4 fractures, while children >10 experienced mostly C5-C7 fractures. For each additional year of age, the odds of developing C1-C4 fracture decreased 0.87-fold ($P<0.01$), while the odds of developing C5-C7 fracture increased 1.1-fold ($P<0.01$).

Males experienced majority of fractures in both locations. Overall, 67% fractures were in Caucasian and 13% in African American children. However, C1-C4 fractures

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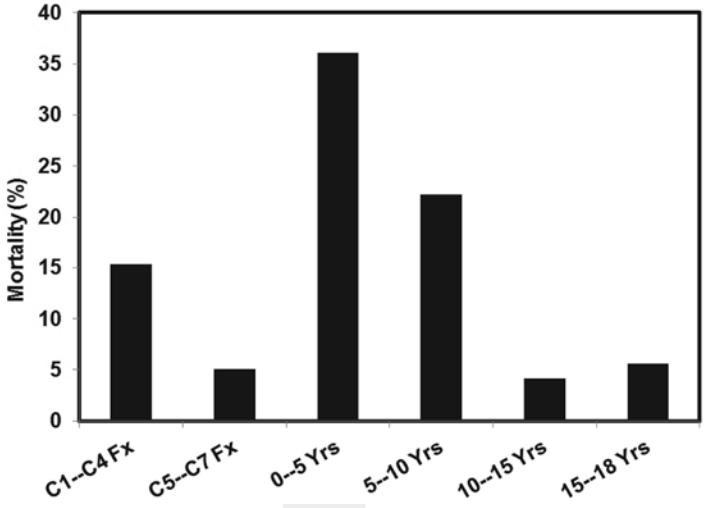
were 1.4X more likely in African Americans (P<0.01), and C5-C7 fractures were 1.2X more likely in Caucasians.

22% patients were placed in halo traction, and 52% received operative treatment. Significantly more patients with C1-C4 fractures were placed in halo traction (27% vs. 22%) (P<0.01). However, significantly more patients with C5-C7 fractures received operative treatment (62% vs. 38%) (P<0.01). Overall spinal fusion rate was 41%; fusion rate was significantly higher in patients with C5-C7 fractures (45% vs. 30%) (P<0.01).

Overall, in-hospital mortality was 8.4%. Mortality was highest in young children, with a 35% rate in children ≤5 years. Patients with C1-C4 fractures had a 3X higher mortality rate (15% vs. 5%) (P<0.01).

Conclusion: Cervical spine fractures with associated spinal cord injury in the upper vs. lower cervical vertebrae differ significantly in patient characteristics and associated mortality.



Mortality by Fracture Type and by Age

21. Predictors of Treatment Outcomes in Geriatric Patients with Odontoid Fractures - AO Spine North America Multi-Centre Prospective Study GOF

Michael Fehlings, MD, PhD, FRCSC; Arun Ranganathan, DM, FRCSEd(T&O), PGDip(OrthEngin), MRCSEd; Alexander R. Vaccaro, MD, PhD; Paul Arnold; Branko Kopjar
Canada

Summary: The purpose was to identify patient and treatment characteristics associated with treatment success or failure using rigorous pre-determined criteria.

Introduction: Odontoid fractures are common cervical spine fractures in the elderly and represent a significant management challenge with widely divergent views regarding the utility of operative vs non-operative management. 159 patients with radiographically confirmed Type II odontoid fracture were enrolled in this prospective study at 10 sites in the USA and one site in Canada between January 2006 and May 2009.Subjects were followed prospectively at 6 and 12 months post initial treatment with Neck Disability Index (NDI) and SF36v2 scores.Plain radiographs (anteroposterior, lateral and open-mouth views) were also performed to assess fracture union.Final treatment outcome was classified as Failure (F) or Success (S) by the following pre-determined criteria.Failure of the treatment was defined if any of the following was true: 1) subject died, regardless of cause of death; 2) NDI declined by more than 9.5 (literature based clinically significant difference); 3) subject experienced a major complication.

Methods: Baseline characteristics between the "F" and "S" groups were compared by t-test for the continuous variables and chi-square test for the categorical variables.The characteristics associated with treatment outcomes were identified by multiple logistic regression analysis.All analyses were performed in SAS 9.3.

Results: 101 patients were treated surgically and 58 conservatively. Seventy-three (45.9%) patients were deemed to have a successful outcome and 86 (54.1%) had a failure according the pre-determined criteria.Twenty nine patients (18.1%) expired before reaching 12 months follow-up and 3 withdrew from the study.Follow-up information was available for 103 out of 130 surviving patients (81.1%).Twelve months SF 36v2 scores were worse in the failure group compared to the successful group.The characteristics associated with treatment failure were older age (OR = 1.05 for each year of age);initial conservative treatment (OR = 2.92); and baseline neurologic system comorbidity (OR = 4.13).

Conclusion: Neurologic compromise, increasing age and non-surgical treatment are associated with failure of treatment in patients with geriatric odontoid fractures.

22. The Effect of Surgery on Health Related Quality of Life and Functional Outcome in Patients with Metastatic Epidural Spinal Cord Compression - The AOSpine North America Prospective Multicenter Study

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Canada

Summary: This prospective study shows that surgery improves pain and functional outcomes in patients with MESCC.

Introduction: Studies suggested that combined surgery and radiotherapy provides optimal neurological recovery in patients with epidural spinal cord compression (MESCC). The impact of surgery on functional and quality of life outcomes is less clear.

Methods: To date, 147 patients with solitary symptomatic MESCC were enrolled in a prospective multi-center, ongoing cohort study. Patients were followed for 12 months.

Results: The average age was 58 years (SD 11, range 30- 82) with 58% males. Common primary sites were lung (23%), breast (13%), prostate (15%), kidney (12%), other genitourinary (9%) and, unknown (14%). Baseline Visual Analog Pain (VAS) level was 7.1 (SD 2.5); the ODI was 61.6 (SD 21.5); the SF36v2 Physical Component Score (PCS) was 32.2 (SD 7.7) and, the EQ-5D was .39 (SD .26). Only 41% of the subjects had normal ASIA motor impairment grade "E"; 39% had grade "D"; 15% "C", 2% "B" and, 2% "A".

Median survival was 213 days (95% CI 133—285 days). 30% survived 12 months. Survival was strongly associated with the site of the primary neoplastic disease (P < .05). About 64% of patients with breast cancer and only 21% of

patients with lung cancer survived 12 months. Median survivals were 569 and 93 days in the breast and lung cancer groups, respectively.

Patients who survived 3 months experienced significant improvement in pain, function and health utility. At 3 months, Pain VAS improved for 1.8 (SD 3.2, P < .05) and, ODI for 16.6 (SD 28.2; P < .01) and EQ5D .16 (SD .30, P < .01). The improvement in SF36v2 PCS was 1.46 (SD 11.0) but not statistically significant (P = .36). The gains in EQ5D, ODI and VAS Pain were maintained in patients who survived 6 months.

Conclusion: Surgically treated patients with MESCC are a diverse group of patients with different prognoses. Survival prognosis is associated with type of primary cancer with lung cancer being associated with the poorest prognosis and breast cancer with the best. The surviving patients experience clinically relevant symptoms improvement and gains in function and utility. Our analysis supports use of surgery in patients with survival expectancy of 3 months or more.

23. Four-Step Approach to Spinal Aneurysmal Bone Cyst in Children: Long-Term Outcomes

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USA

Summary: The 4-step approach is an effective way to prevent recurrences when treating Aneurysmal Bone Cysts (ABC) of the spine when compared to the traditional approach consisting of curettage and bone grafting.

Introduction: ABC is a benign but locally aggressive tumor-like condition. We compared a 4-step approach, consisting of intralesional curettage, high-speed bur, electrocautery, and bone grafting to the traditional approach, consisting of curettage and bone grafting.

Methods: Twenty-one cases of spinal ABC were collected from a tertiary pediatric tumor center over a 21 year period (1990 to 2011). The data was analyzed using SPSS v16. A value of $p<0.05$ was considered statistically significant.

Results: The mean age of the patients was 11.9 years (range 3.6 to 18.6). There were 10 males (48%) and 11 females (52%). The mean follow-up time was 5.2 years (range 0.4 to 16). Fifteen patients (71%) underwent the 4-steps approach, while 6 (29%) were treated with the traditional technique. Nine of the ABCs were localized in the lumbar region (43%), 5 in the cervical region (24%), 4 in the thoracic region (19%) and 3 in the sacral region (14%). Sixteen patients had a follow-up of 2 years or more (11 with the 4-step and 5 with the traditional technique). The mean blood loss was 448mL in the 4-steps group and 400mL in the traditional group, p=0.639. There was one change in neuromonitoring in each group, p=0.45, one patient had a previous motor weakness that persisted after surgery and one patient was asymptomatic at the last follow-up. There were 4 recurrences in the traditional technique and one recurrence the 4-steps group, p=0.028, NNT=1.6. The 3 year disease free survival is 20% in the traditional group vs. over 80% in the 4 step group.

Conclusion: This is the largest series presented with pediatric only spinal ABCs. The estimated blood loss and neuromonitoring changes in both groups are similar. We suggest that a 4-step approach to a spinal ABC in pediatric patients is a safe and more effective technique in preventing recurrence.

24. Factors Associated with the Development of Spinal Deformity after the Treatment of Childhood Spinal Tumors

Sarah Clarke; Brad Williamson
United Kingdom

Summary: This study reports the aetiological factors for the development of spinal deformity after the treatment of childhood spine tumours. Cervical position of the tumour, diagnosis of astrocytoma, and the number of segments involved were positively associated with the subsequent development of deformity. Age at diagnosis was not a significant association.

Introduction: Tumours of the spinal column in childhood are rare, but often result in late deformity. This study examines the aetiological factors associated with the development of deformity.

Methods: We examined the NW Children's Cancer Registry for patients who had tumours affecting the spinal column between C1 and the sacruMDiagnosed between 1954 and 2008. The notes were examined. Data were collected and statistically analysed.

Results: 91 children fulfilled the inclusion criteria. We have found complete hospital and registry records for 46 who form the material of this study. 24 were boys. The diagnosis was made between 1958 and 2008. Age at diagnosis averaged 111 (2-178) months. Tumours most commonly affected the thoracic spine.

15 patients were treated by surgery alone, 5 radiotherapy alone and 4 had only chemotherapy. 21 patients had combined treatments, and one had none.

Four patients had insufficient length of follow up for deformity to develop, and one had a progressive scoliosis prior to diagnosis. Of the remaining 41 patients 13 (32%) developed a deformity after treatment. Deformity affected 40% of patients having surgery and 35% of those having radiotherapy. No patient having chemotherapy alone became deformed.

Age at diagnosis had little effect on the likelihood of developing deformity. Patients who developed deformity were disproportionately likely to have a diagnosis of astrocytoma, more extensive disease (5.7 v 4.9 segments), and a tumour in the cervical spine.

Of the 13 who developed deformity, 7 developed kyphosis, 3 scoliosis and 3 both. The Cobb angle ranged from 53 to 105 degrees. The median time between treatment and diagnosis of a deformity was less than 12 months. Six patients have required treatment for their deformity.

Conclusion: This is the first study to report the aetiological factors for the development of spinal deformity in children with spinal tumours. About a third of will develop a deformity. Site, extent and histological type of tumour are significant risk factors. Knowledge of the aetiological factors may allow closer follow up and earlier treatment of those at higher risk.

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25. Clinical Improvement Through Surgery for Adult Spinal Deformity (ASD): What can be Expected and Who is Likely to Benefit Most?

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USA

Summary: For 152 patients with spinal deformity and follow up of 1 year, the percentages and extent of clinical improvement was evaluated using SRS score. Normative values for the SRS scores were included and difference with patients were expressed in number of MCID at BL and 1 year. 29 % of patients did not experience improvement following surgery. Patients with severe disability were more likely to perceive improvement than patient with less disability.

Introduction: For ASD, the evaluation of the surgical treatment's success using clinical score, must take into account baseline (BL) disability/pain and the improvement defined as minimal clinical important difference (MCID). The study's aim was to evaluate percentages and extent of clinical improvement following surgery.

Methods: Prospective analysis of consecutive and operative ASD patients. Inclusion criteria included patients (age>18) with BL and 1 year SRS score. Normative values for the SRS scores were included and difference with patients (Diff Norm) were expressed in number of MCID. At BL, patients were classified by activity and pain scores based on the Diff Norm: Worst (Diff Norm> 4 MCID for both domains), Severe (2<Diff Norm<4 MCID for both domains), Poor (2MCID < Diff Ref for only one domain) and Moderate (Diff Norm<2MCID for both domains). At 1 year, patients were classified into 4 groups based on their improvement: None (Gain <1MCID for both domains), Mediocre (Gain>1MCID in only one domain), Satisfactory (Gain>1MCID for both domains) and Excellent (Gain>1MCID for both domains and Diff Norm<1MCID at 1 year). Distinction between curve types was also done.

Results: 152 patients (age = 55±15) were included. At BL, for 93% of the patients, the worst scores were in Activity or Pain. At BL, the distribution was 36% Worst, 27% Severe 24% Poor and 13% Moderate. Patient with Sagittal only and Sagittal TL curve were more likely to be 'Worst' patients (41% and 49%). The distribution by improvement was: 15% None, 14% Mediocre, 25% Satisfactory and 46% Excellent. No difference of improvement was found between curve types. 39 % of 'Moderate' patients achieved no improvement. 5% of 'Worst' patients were classified as None, 45% and 27% were classified as Satisfactory and Excellent.

Conclusion: 29% of patients did not experience improvement following surgery. Patients with severe disability were more likely to perceive improvement than patient with less disability. The clinical success of surgery seems to be independent of curve type. Further analysis will identify strategies and patient parameters associated with successful outcome.

26. Comparison of Outcomes of Surgery Performed in the Second Decade vs. Third and Fourth Decades for Idiopathic Scoliosis

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Summary: In this study, patients undergoing posterior surgery for idiopathic scoliosis (IS) in their 2nd decades compared to those in 3rd and 4th decades, demonstrated better outcome and less complication rates.

Introduction: There are no studies so far comparing the possible differences in curve characteristics such as severity and rigidity as well as correction rates and clinical outcomes after surgery between adolescent (11-18) and young adulthood (20-40) IS patients. The aim of this case control study was to compare patients undergoing posterior surgery for IS in their 2nd decades with those in 3rd and 4th decades, for curve characteristics, radiographic and clinical outcome and complications.

Methods: A group of 30 consecutive adult IS patients who had undergone surgery in their 3rd or 4th decades (Group A) were compared to a gender, curve type and severity matched group of 30 adolescents (Group B). All patients were operated by the same surgeon using posterior pedicle screw instrumentation and had >2 years follow-up. Pre, post-op and follow-up A-P, lateral and bending x-rays were evaluated for flexibility and correction. Clinical outcome was analyzed by the global rating of change scores (GOS) after intervention for improvement and deterioration measured with a 15-point scale ranging from -7 (no improvement) to +7 (improved a lot).

Results: MT and TL/L curves were significantly more flexible in group B ($p<0.05$). The correction rates after surgery was significantly higher in MT and TL/L curves ($p<0.05$) in group B. Duration of operation was longer in group A but did not reach the level of significance ($p=0.089$). Five patients in group A had extension of fusion to L5 and below compared to no patients in group B. Nine patients in group A had complications (superficial infection (3), rod dislodgement (1), pulmonary(4), GIS complications (1)) while only 3 patients in group B had complications (superficial infection (3)). GOS was significantly higher in group B.

Conclusion: IS in young adults (age 20 to 40) had different intrinsic curve characteristics than its adolescent counterpart with more rigid curves. Posterior instrumentation surgery provided lesser correction with more complications and longer fusions compared to adolesents. Clinical improvement perceived by patients was better in adolescents than the young adults.

27. Operatively (OP) Treated Adult Spinal Deformity (ASD) Patients Report Worse Health Related Quality of Life (HRQOL) than Nonoperative (NON), Regardless of Age; However, Radiographic Deformity Differs Between Age Groups

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USA

Summary: Multicenter, prospective analysis of 497 consecutive ASD patients demonstrated sagittal alignment, ODI, SF-36PCS, and leg pain worsened with

age. OP reported worse HRQOL than NON for all age groups. Radiographic analysis demonstrated OP scoliosis was worse than NON in younger age groups but sagittal alignment was similar. For oldest group, scoliosis was similar but OP sagittal alignment was worse than NON. Further research is needed to identify sources of poor HRQOL for different ASD age groups.

Introduction: ASD is a heterogeneous disease. Little prospective data exists for age related differences in ASD. Purpose: identify age related factors associated with poor HRQOL and OP vs. NON treatment.

Methods: Multicenter, prospective analysis of consecutive ASD patients. Inclusion criteria: age >18 yrs, no prior surgery, and ASD (scoliosis ≥20 degrees, sagittal vertical axis (SVA) ≥5cm, pelvic tilt (PT) ≥25 degrees, or thoracic kyphosis (TK)> 60 degrees). Demographic, radiographic and HRQOL data evaluated including: SRS-22, Oswestry Disability Index (ODI), SF-36, and numeric pain scale (NRS). Patients stratified into 3 age groups (G1=<50 yrs, G2=50-65 yrs, G3=>65 yrs) and divided into OP vs. NON.

Results: 497 ASD (mean age 50.4 years) met inclusion criteria (table). Age stratification demonstrated progressive age associated worsening of sagittal alignment (SVA, PT, pelvic incidence-lumbar lordosis (PI-LL) mismatch) and HRQOL (ODI, SF-36 PCS, SRS-22 total, SRS-22 function and pain, and NRS leg pain; $p<0.05$). Stratification by treatment demonstrated OP (n=156) was older, had larger BMI, greater deformity (except PT), and worse HRQOL scores on all measures (except mental health scores) than NON (n=341; $p<0.05$). Age/treatment stratification demonstrated OP G1 and G2 had larger maximal scoliosis than NON ($p<0.05$), but similar sagittal alignment. G3 OP had similar maximal scoliosis but larger SVA than NON ($p<0.05$). OP HRQOL values including ODI, SF-36 PCS,SRS-22 total, and SRS-22 function, pain, and self-image were worse than NON in all subgoups (G1-3: $p<0.05$). SRS-22 pain, SRS-22 activity and ODI differences between OP vs. NON reached previously reported minimal clinically important difference (MCID) for all subgoups (G1-3).

Conclusion: Age associated differences for ASD must be considered when deciding upon treatment. OP uniformly reported worse HRQOL than NON. Oldest OP patients had worst sagittal alignment, ODI and SF-36 PCS scores. However, younger OP groups also reported worse HRQOL than NON despite normal sagittal alignment. Scoliosis magnitude corresponded to poor HRQOL in younger cohorts. Further research is needed to identify sources of poor HRQOL for different ASD age groups.

28. Five Year Follow-Up of 40 Patients with Original Shilla Procedure

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Summary: The 40 pts. receiving the original Shilla growth guidance technique using the Shilla cap and having > 2 year follow-up were reviewed. These patients demonstrated spinal growth, increased SAL, required fewer surgeries than predicted with traditional distraction techniques, and had an acceptable number of complications. No patient had neurologic changes. Six pts. have reached skeletal maturity and undergone definitive fusion. One patient had removal of the implants at skeletal maturity without definitive fusion.

Introduction: 40 pts treated with Shilla were evaluated. 5 pts were accounted for but not available: 2 deaths (unrelated to their spinal surgery), 1 pt. was changed to another type of treatment due to repeated skin breakdown, 1 had implant removal prior to 6 mos , and 1 has given verbal follow-up only. Cases were reviewed retrospectively for indications and outcomes including diagnoses, procedures, clinical parameters, and complications.

Methods: A retrospective review of 40 pts who had undergone Shilla was performed. 35 had >2 yr F/U. (mean 5 yrs range 2+6 to 7+7). Diagnoses: NM-16, Synd-17, IIS-3, JIS-3, and Cong.-1. Spinal cord monitoring was accomplished where appropriate.

Results: Average F/U is 5 y. Preop curve was 68 degrees (40-115) and 44 degrees at latest F/U. SAL and spinal growth (T1-T12) increased. There were 2.7 procedures/pt. Projected number of surgeries with traditional distraction techniques would have been 9.9/pt. 6 pts had definitive fusion. 1 merely had removal of implants at maturity. 27 pts. experienced complication(s) with return to OR. 5 pts. experienced >2 complications each. Complications were divided into: Implant-43, Wound-15, and Alignment-6. Rod fracture occurred 13 times.

Conclusion: The Shilla growth guidance technique offers a method of treatment of EOS allowing spinal growth while controlling the deformity without scheduled repeated returns to the OR. The complication rate is acceptable and multiple diagnoses can safely be treated with the Shilla technique. Pts. are allowed to participate in most normal childhood activities.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

29. Comparison of Growing Rod vs. Cast Treatment for Early-Onset Scoliosis

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Summary: A direct comparison between casting and growing rods(GR) for EOS was performed,matching 25 pairs of patients according to age,diagnosis,and initial curve severity. GR patients had smaller curves and gained more T1-S1 length at last f/u,but required longer treatment period,more treatment sessions,and suffered 21 complications compared to 1 cast complication.

Introduction: Direct comparison of different treatments for the same condition is not often possible. We were able to compare 2 common treatments for EOS in a case-matched cohort.

Methods: 25 cases from 3 centers with cast experience were matched with 25 cases from a prospective multicenter database of GR patients according to age,diagnosis,and major Cobb. Outcome was determined by curve magnitude and T1-S1 length at last f/u.

Results: There was no difference in age,initial Cobb or T1-S1 length in each patient pair, confirming accuracy of matching(Table). 6 pairs had neuromuscular diagnoses,9 had IIS/JIS,10 were syndromic. GR patients were treated for mean 4.5 yr,significantly > cast patients (2.4 yr,p=.003).GR patients had much smaller curves at f/u (47.5 vs 66.1 deg),having mean 5.6 lengthenings vs 3.9 casts. However,11 GR patients suffered 21 complications compared to 1 cast complica-

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tion.T1-S1 length was the same at f/u,although GR cases gained more length than casting (p=.012). Cast patients gained more length/year of rx.

Conclusion: In this unique comparison of 2 rx's for EOS patients closely matched for age,diagnosis and curve severity,GR patients had smaller curves and gained more length at f/u,but required a longer treatment period to achieve this. 44% of GR patients suffered 21 complications, compared to 1 cast skin complication. Cast length gain/year of treatment was more efficient.

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30. Comparison of Surgical Treatments for Infantile and Juvenile Scoliosis

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USA

Summary: A retrospective review of 31 patients from two institutions evaluated VEPTR vs. GR for the treatment of infantile/juvenile scoliosis. Excellent coronal correction was initially obtained for both, however, neither achieved further correction after initial implantation. VEPTR demonstrated significantly progressive kyphosis during treatment. Although complication rates were high, both constructs enabled significant spinal growth.

Introduction: The vertical expandable prosthetic titanium rib (VEPTR) and growing rods (GR) are currently in use for the treatment of severe infantile/juvenile scoliosis refractory to conservative methods. Both constructs have demonstrated efficacy in maintaining curve correction while allowing for spinal growth via lengthening procedures. However, no study directly compares these two treatments for infantile/juvenile scoliosis.

Methods: A retrospective chart review of 31 patients (18 VEPTR/13 GR) with a minimum two year follow-up from two institutions was performed. To reduce bias, one center exclusively performed VEPTR, while the other GR, for the surgical treatment of infantile/juvenile scoliosis. Radiographic, perioperative and clinical data was analyzed.

Results: There was no difference between the two groups (age at initial surgery, sex, diagnosis, height/weight, and preop coronal/sagittal Cobb angle). Average follow-up: VEPTR 4.2 years vs. GR: 3.5 years.

GR achieved a higher coronal curve correction compared to VEPTR immediately post-op (36% vs. 20%, p=0.09). Neither group achieved significantly more coronal curve correction from initial to final follow-up. VEPTR had significantly greater kyphosis vs. GR at initial and final follow-up at T2-T12 and T5-T12 ($p<0.05$). T2-T12 and T5-T12 kyphosis increased significantly in VEPTR pts an average of 15° (p=0.002) and 10° (p=0.03), respectively.

The average number of instrumented levels was similar (13 vs. 12.5 levels, p=0.54). There were no significant differences with regards to number or duration between lengthenings . The magnitude and rate of spine growth, T1-S1, was similar for both groups at final follow-up ($p>0.4$). Complications occurred in 8/18 (44%) VEPTR and 9/13 (69%) GR patients, p=0.27. Instrumentation migration/failure (VEPTR=12 vs. GR=14) was most common, followed by wound infection (VEPTR: 5/18 vs. GR: 3/11).

Conclusion: VEPTR and GR are viable options for treatment of infantile/juvenile scoliosis. Significant spine growth was achieved for both groups, but VEPTR had significantly increased kyphosis compared to GR. Neither construct showed significant coronal curve correction from initial to final follow-up. Complication rates for VEPTR and GR were high at 44% and 69%, respectively.

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31. Segmental Self Growing Rod Constructs in the Management of Early Onset Neuromuscular Scoliosis

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United Kingdom

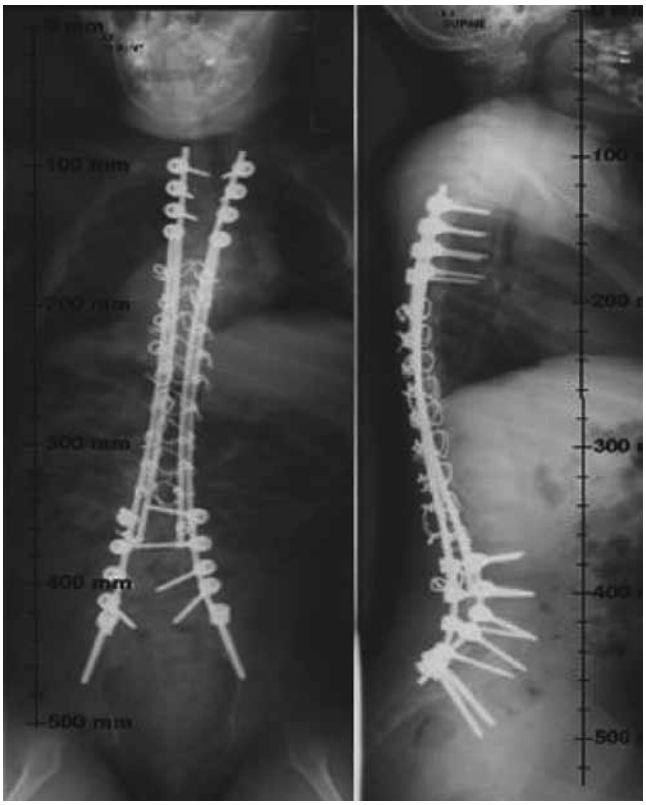
Summary: Segmental Self Growing Rod Constructs in Early Onset Neuromuscular Scoliosis provides surgeons with a means of segmental correction of the deformity in both planes, without the morbidity of multiple operations, implant adjustments or abolition of spinal growth.

Introduction: Spinal deformity occurs in children with neuromuscular disease. Constriction of the chest cavity as a result of a spinal deformity restricts lung growth and will contribute to further pulmonary complications. However, while correction of deformity is imperative, it should not be at the expense of spinal growth. Various techniques exist but are compromised by lack of segmental control or the need for multiple operations to adjust construct length. We present a method which addresses both problems and evaluate the structural effectiveness, degree of correction, spinal growth and complications with the use of SSGRC in EONMS.

Methods: 9 males and 7 females with EONMS underwent surgery. Average age 7.1 years (5-8). Mean follow-up 3.2 years (2-13). Six patients had Type 2 SMA, 3 patients Type 3, 2 patients Hypotonia, 4 patients Muscular Dystrophy and 1 patient CP. Instrumentation was extended from T2 to S1 +/- fixation to the pelvis. Hospital stay averaged 7.6 days.

Results: Pre-operative scoliosis averaged 68.9°(range 40°-92°) and post-op 9.6° (range,0°-35°). Pre-op Kyphosis averaged 62° (range, 37°-90°) and post-op Kyphosis 28.5° (range, 20°-40°). The number of vertebrae averaged 13 levels (range 9-17) and mean spinal growth was 30mm (range 10-120 mm). Complications included one superficial Infection treated with antibiotics and one loss of distal fixation requiring revision.

Conclusion: The mean scoliosis correction was 59°, kyphosis 34°; maintained at average follow up 3.2 years. The observed mean spinal growth of 3 cm over 4 years represents 79% of that expected.The SSGRC is a powerful, definitive technique for managing EONMS without the morbidity of repetitive surgery, while maximising spinal growth and thoracic development.



AP and Lateral post operative images of Segmental Self Growing Rod Construct.

32. Surgical Results of Magnet-Driven Growth Rods(MdGR) in Early-Onset Scoliosis(EOS)

Nanjundappa S. Harshavardhana, MS(Orth), Dip. SICOT; Farhaan Altaf, MBBS, BSc, MRCS; Fady S. Sedra; Hazem B. Elsebaie, FRCS, MD; Hilali H. Noordeen, FRCS
United Kingdom

Summary: Conventional growth rods(CGR) have a high complication rate attributed to frequent surgeries required for lengthening. 34 patients underwent treatment with the Magnetic Remotely Controlled Growth Rod (MRCGR), the lengthenings were performed on an out-patient basis without the need for any anesthesia / analgesia. Our results have demonstrated that the MRCGR is a safe and effective growth-sparing modality in the treatment of progressive early-onset scoliosis (EOS) significantly decreasing the rate of the overall complications and avoiding the risks encountered with CGR.

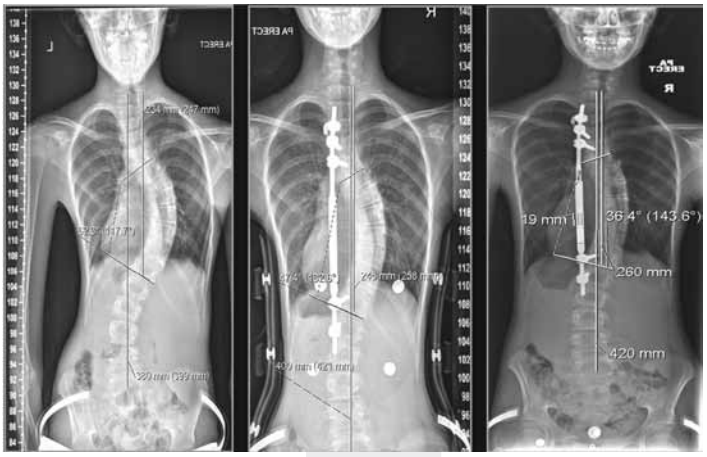
Introduction: Progressive EOS ideally requires a management regimen which arrests the progression of spinal deformity without affecting / compromising on spinal growth, chest wall development & pulmonary maturation. The CGR has a high complication rate attributed to frequent surgeries required for lengthening. We describe our experience with regards to safety and efficacy of the use of a non-invasive MRCGR in children with EOS. The lengthenings are performed on an outpatient basis with the use of an external remote controller (ERC).

Methods: A total of 34 patients (13/m21f) underwent treatment with the MRCGR. All surgeries were performed by the senior author. All patients had at least 3 lengthenings. The average age of the patients was 8 years (5-12 years). There were 12 patients with single rod constructs and 22 patients with dual rod constructs. Data analysed included preoperative, post index surgery and final follow-up Cobb angle measurements and T1-S1 heights. We also reported on the number and frequency of lengthenings as well as complications.

Results: There was an average of 4.8 distractions per patient. The mean time between distractions was 63 days(r42-98). The average pre-operative Cobb angle measured 68 degrees(r46-108) & was corrected to 46 degrees(r28-91) post-operatively and 41 degrees (r27-86) at the final f/u. The average pre-operative T1-S1 length measured 304mm (r243-380) which increased to 335mm(r253-400) postoperatively and increased to 348mm(255-420) at final f/u.

In the single rod group one patient developed a superficial wound infection, two patients had temporary loss of distraction and one patients had a rod breakage. In the dual rod group one patient experienced hook pullout and one patient had prominent metalwork. There were no neurological complications in any of the patients related to the index surgeries or distractions.

Conclusion: Our early results have demonstrated that the MRCGR is a safe and effective growth-sparing modality in the treatment of progressive EOS significantly decreasing the rate of the overall complications and avoiding the risks related to repeated surgical lengthening procedures required with the conventional growing rods.



Idiopathic scoliosis treated with MdGR: Pre-op, Immediate post-op and Final xray after 3 lengthenings

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33. Next Generation of Growth-Sparing Techniques: Preliminary Clinical Results of a Magnetically Controlled Growing Rod in 14 Patients

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USA

Summary: Growth-sparing techniques are commonly used for the treatment of progressive EOS. The standard growing rod (GR) technique requires multiple surgeries for lengthening. The preliminary results of MCGR has shown the comparable

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outcomes to standard GR without the need for repeated surgery which can be expected to reduce the overall complication rate in GR surgery.

Introduction: The growing rod (GR) technique for management of progressive Early-Onset Scoliosis (EOS) is a viable alternative but with a high complication rate attributed to frequent surgical lengthenings. The safety and efficacy of a non-invasive Magnetically Controlled Growing Rod (MCGR) has been previously reported in a porcine model. We are reporting the preliminary results of this technique in EOS.

Methods: Retrospective review of prospectively collected multi-center data. Only patients who underwent MCGR surgery and at least 3 subsequent spinal distractions were included in this preliminary review. Distractions were performed in clinic without anesthesia or analgesics. T1-T12 and T1-S1 height and the distraction distance inside the actuator were analyzed in addition to conventional clinical and radiographic data.

Results: Patients (N=14; 7 F and 7 M) had a mean age of 8y+10m (3y+6m to 12y+7m) and underwent a total of 14 index surgeries (SR: index single rod in 5 and DR: dual rod in 9) and 91 distractions. There were 5 idiopathic, 4 neuromuscular, 2 congenital, 2 syndromic and one NF. Mean follow-up (FU) was 10 months (5.8-18.2). Mean Cobb changed from 57° pre-op to 35° post-op and correction was maintained (35°) at latest FU. T1-T12 increased by 4 mm for SR and 10 mm for DR with mean monthly gain of 0.5 and 1.39, respectively. T1-S1 gain was 4 mm for SR and 17 mm for DR with mean monthly gain of 0.5 mm for SR and 2.35 mm for DR. The mean interval between index surgery and the first distraction was 66 days and thereafter was 43 days. Complications included one superficial infection in (SR), one prominent implant (DR) and minimal loss of initial distraction in three after index MCGR (all SR). Overall, partial loss of distraction was observed following 14 of the 91 distractions (one DR and 13 SR). This loss was regained in subsequent distractions. There was no neurologic deficit or implant failure.

Conclusion: MCGR appears to be safe and provided adequate distraction similar to the standard GR technique without the need for repeated surgeries. DR patients had better initial curve correction and greater spinal height. No major complications were observed during the short follow-up period.

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34. Comparison of Two Fusionless Scoliosis Surgery Methods in the Treatment of Progressive AIS: A Preliminary Study

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USA

Summary: Initial correction and subsequent control of progression were evaluated in 9 AIS patients treated with one of two methods of Fusionless Scoliosis Surgery (FSS): vertebral stapling vs ligament tethering. Ligament tethering demonstrated significantly greater initial correction and subsequent control of curve progression than stapling. Ligament tethering, unlike bracing or fusion surgery, allows significant scoliosis correction without sacrificing growth, motion and function of the spine.

Introduction: Fusionless Scoliosis Surgery (FSS) is a novel treatment option for AIS patients not amenable to brace treatment and at high risk (>90%) for progression to fusion surgery. Though two FSS methods, vertebral stapling and ligament tethering have demonstrated effectiveness in controlling AIS progression, these have never been compared clinically in well matched groups with similar indications.

Methods: Retrospective study of 9 consecutive AIS patients (average age 12+11) treated with stapling vs tethering for thoracic curves >30° (average 35.6°) in the setting of skeletal immaturity (average Risser 0-1). Risk of progression was assessed using 3 methods (Lonstein, Sanders, ScoliScore). All pts had >90% risk of progression to fusion surgery by at least 2 of the 3 methods. Cobb angles pre-op, post-op and final were compared.

Results: Nine well matched female pts with 14 curves underwent endoscopic FSS: 4 had stapling of 6 curves and 5 had tethering of 8 curves. Stapled curves were initially corrected from 34.5° pre-op to 31.3° post-op but subsequent curve control was poor with progression over 22 months to 44.5°. Tethered curves initially corrected from 36.6° pre-op to 21.4° post-op with good control over 10 months with additional correction to 18.0°. Ligament tethering demonstrated significantly greater initial correction (p=.001) and subsequent control of curve correction (p=.002) when compared to vertebral stapling. No complications were encountered, however, 1 stapled pt required fusion for a progressive curve to 55°.

Conclusion: Both initial correction and subsequent control of curve progression are important in the fusionless treatment of AIS. In this preliminary study, it appears that ligament tethering provides greater initial correction and subsequent control of AIS curve progression than vertebral stapling.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

35. A New Gliding Spinal Anchor for Self-Growing Rods: Trolley Screw

Jean A. Ouellet, MD; Karina Klein; Thomas Steffen; Brigitte von Rechenberg
Canada

Summary: A new pedicle base gliding spinal implant was tested in a free rooming sheep model. With no additional surgery, the instrumented spines grew 95% as compared to its match control group. A 30% screw loosening was noted with no evidence of granulomatous reaction. Heterotopic ossification occurred along the growing rods. These new implant may be used in growth guidance constructs such as Shilla or Modern Luque Trolley construct for the management of early onset scoliosis.

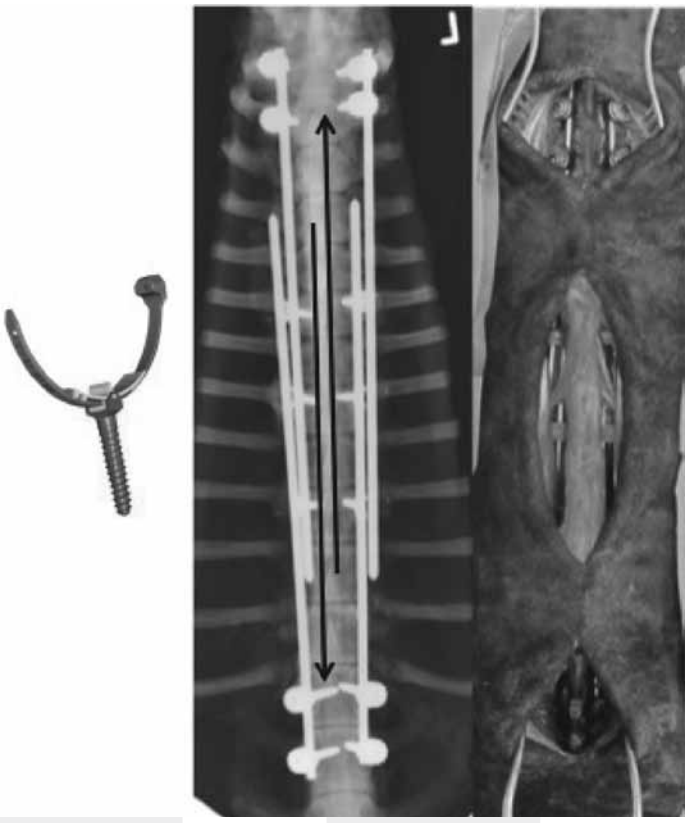
Introduction: The challenge when managing early-onset scoliosis (EOS) is to prevent curve progression while maintaining spinal growth. Current surgical treatments (growing rods, VEPTR) require repetitive interventions to lengthen the implants. Prior growth guidance system such as Luque trolley have had a high rate of implant failure, spontaneous fusion, and particle debris. The purposes of the study was to test, in an animal model, a new posteriorly based pedicle screw self growing rod system.

Methods: Six match pairs of immature male sheep (3m old) were randomized to an observation or surgical group and were F/U for 9 m. The surgical group under a GA had implantation of Modern Luque Trolley construct. It comprises of two pairs of 5-mm titanium rods tunneled in a subfascial/intramuscular fashions. Each rods were rigidly anchored to the spine at one end. In the intercalated segments, a series of new gliding spinal anchors inserted in a minimal invasive technique captured

the spine & the 2 overlapping rods. As the spines grew, the rigidly proximal-fixed rods move away from the distally fixed rods (Fig. 4). At fixed intervals, the animals were brought back from pasture for plain radiographs, regular CT, physical exams. At necropsy, micro CT and histology including microscopic wear analysis were done.

Results: Successful implantation & instrumentation of all sheep was achieved. There was: no implant failure, with no additional lengthening procedure 95% spinal growth was achieved as compared to control group. 30% (16 of 46) fixed prox/dist anchors were loose, 33% (7/36) gliding screws were loose. Histology found no granulomas locally nor systemically with little evidence of particle debris around gliding screws. 50% of the animals had one or more site of spontaneous heterotopic bone formation tracking along rods.

Conclusion: The findings of loosing are in keeping with free ranging animal rather than tissue reaction of implant. Self lengthening growing rod maintains spinal growth in a non scoliotic model. Heterotopic ossification remains a challenge in transmuscular growing rod construct.



Luque Trolley construct with overlapping gliding rods. Intra operative picture showing transmuscular approach.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

36. Safety and Efficacy of Instrumented Convex Growth Arrest in Treatment of Congenital Scoliosis

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Summary: The study was designed to retrospectively evaluate safety and efficacy of instrumented posterior convex growth arrest(CGA) in congenital scoliosis. Our purpose was to evaluate the improvement of the curves radiologically.

Introduction: Anterior and posterior convex hemiepiphysiodesis is a widely used surgical alternative in the treatment of congenital scoliosis. This procedure has the advantage a single surgery and the disadvantage of the need for both anterior and posterior approach. Furthermore, outcome may be unpredictable. Posterior CGA with pedicle screws at each segment on the convex side may obviate the need of anterior surgery and make outcomes more predictable.

Methods: Patients who had posterior CGA with convex cobb to cobb pedicle screw instrumentation for congenital scoliosis were evaluated with preoperative, early postoperative and latest follow-up standing anteroposterior and lateral radiograms, clinical records.

Results: Twelve patients with congenital scoliosis (6 M, 6 F) were included. Average follow-up was 56 mo(36-74) and average age at the time of operation was 64 mo(15-108). Average curve magnitude was 48 deg(34-68) preoperatively, 37.6 deg(28-58) early postoperatively, and 32.8 deg (16-52) at latest follow-up. There were no wound infections or instrumentation failures during follow-up. Instrumented immediate correction effect was obtained in all curves. In 3 patients significant curve control and fusion effect was obtained at the latest follow up. Eight patients revealed significant growth modulation which resulted in curve regression during follow up (p=0.012). Whereas curve progression was observed in 1 patient due to a technical error.

Conclusion: Pedicle screw instrumented CGA for congenital scoliosis has the advantages to obviate the anterior procedure and postoperative immobilization. This technique can be safely applied at an early age like 15 months. Acute curve correction can be obtained with this technique. Growth modulation affect can add more improvement in curve control. Our results imply that this technique is a safe and reliable procedure for the stabilization of the curve as well as classical convex growth hemiepiphysiodesis technique.

37. Proximal Segmental Kyphosis and Proximal Junctional Kyphosis after Growing Polysegmental Instrumentation in EOS Patients

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Summary: The purpose of this study is to define if polysegmental growing instrumentation and derotation for the spinal correction result in PSK and PJK.There were 26 patients with EOS treated with convex growth arrest and growing polysegmental instrumentation. It is found that postoperative spinal kyphosis does not affect PJK and PSK rate in our study. The type of thoracic spine anchoring is important for avoiding junctional zone problems.

Introduction: Utilization of growth sparing techniques has potentional risk for proximal segmental kyphosis (PSK) and proximal junctional kyphosis (PJK) develop-

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ment. The purpose of this study is to define if polysegmental growing instrumentation and derotation for the spinal correction result in PSK and PJK.

Methods: A comparative retrospective study was performed. There were 26 patients with EOS treated with convex growth arrest and growing polysegmental instrumentation. In all patients rod derotation has been performed. The Ist growp 13 pts underwent hybrid instrumentation (T-spine hooks ans L-spine screws) and the IInd group 13pts treated with screws only. Preoperative T2-T5 and T5-T12 angles. T-kyphosis, PSK, PJK were assessed postoperatively and after 4 years follow-up.

Results: Mean number of the instrumented vertebras was 12 vs 11,9, mean growth of the instrumented spine was 7,1 mm (I) and 7,2 mm (II) per year. Preoperative T2-T5 angles were 6,3 (I) and 10,4 (II), T5-T12 angles were 10,8 (I) and 40,6 (I). Postoperative kyphosis was 26,2 vs 30,8, PSK was 8,9 (I) and 12,8 (II), PJK was 5,6 (I) and 9,5 (II). After 4 years thoracic kyphosis was 29,8 vs 37,7, PSK angles were 11,4 (I) and 18,7(II), PJK was 7,6 and 10,7. There were 1 pt in the I group and 4 pts in the II group with PJK over 10.

Conclusion: In spite of preexisting hypo or hyperkyphosis, polysegmental fixation and spinal derotation restore normal sagittal profile. Growth sparing surgery utilizing hook fixation of the thoracic spine decreases likelihood of PSK and PJK occurence in skeletal immature EOS patients.

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38. What is the Effect of Serial Growing Rod Lengthening on the Sagittal Profile and Pelvic Parameters in Early Onset Scoliosis?

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USA

Summary: The serial lengthening of growing rods in EOS resulted in a decrease in thoracic kyphosis, increase in lumbar lordosis and improved sagittal balance to a more neutral position without an appreciable incidence of PJK. There was no independent effect of the number of lengthenings on thoracic kyphosis, lumbar lordosis or junctional problems.

Introduction: Posterior distraction-based growing rods (GR) are a growth-friendly technique for the management of early onset scoliosis (EOS). However, there are no published studies on the effect of serial GR lengthenings on sagittal balance (SB), thoracic kyphosis (TK), lumbar lordosis (LL), or pelvic parameters. The current study assessed the effect of repeated GR lengthenings on the sagittal and pelvic profile in patients with EOS.

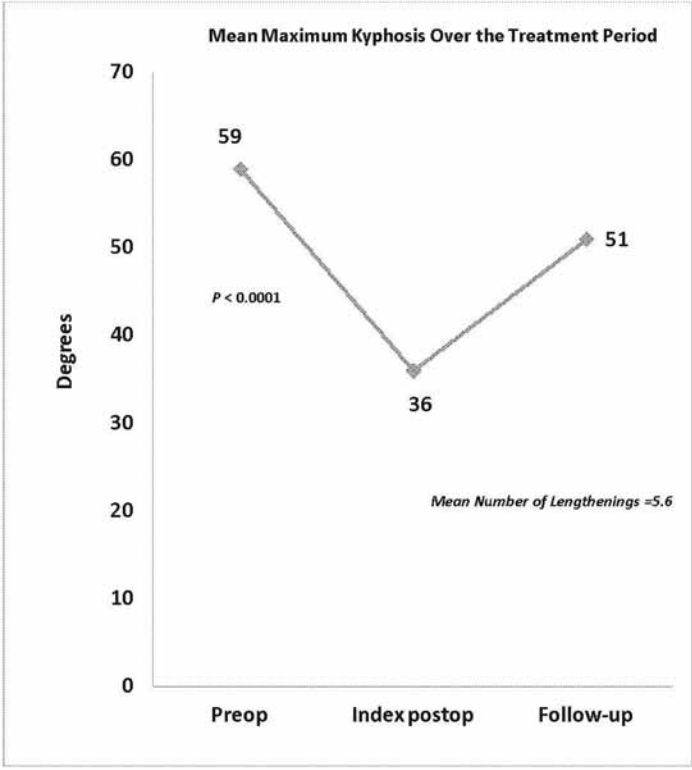
Methods: We queried retrospectively and prospectively collected data from a multicenter EOS database. Patients with minimum 2 year follow up were selected with the following inclusion criteria: 1) single or dual GR surgery; 2) ambulatory; 3) at least 3 lengthenings at latest follow up. Maximum TK, LL (measured L1-S1) and SB (measured C7 to sacrum) were assessed pre-op, after index implant surgery and at latest follow-up all by two independent observers. The independent effect of the number of lengthenings (NL) was examined by comparing patients with < 5 lengthenings and >5 lengthenings.

Results: 43 patients met the inclusion criteria. Mean NL was 6.4 (range 3-16). Mean pre-op age was 5.6 years (SD±2.4). There was a decrease in TK after index surgery, which increased over the lengthening period, and a non-significant increase in LL was observed. Pelvic parameters were unchanged over the treatment period (see table). Significant improvement was observed in SB; both for patients with positive SB (49 mm pre-op, 31 mm after index, 6 mm latest follow-up; p<0.001) and for negative SB (-28 mm pre-op, 4 mm after index, 6 mm latest follow-up; p<0.001). The effect of NL (> than or < than 5) was not significant on max TK, LL, PJK or DJK.

Conclusion: SB was significantly improved with GR surgery. TK decreased after index surgery and increased between post index surgery and latest follow-up, which was accompanied by a small increase in LL. However, there was no independent effect of NL on TK, LL or junctional problems. Although the primary aim of growing rods is improvement of the coronal plane deformity and maintenance of spinal growth, this is the first study to indicate that the sagittal plane effects are favorable as well. The number of lengthenings over time does not cause deterioration in the sagittal plane parameters.

Table 1:Mean values of sagittal profile and pelvic parameters over the treatment period

Parameter	Preop	Index Postop	Follow Up	P value
Max Kyphosis	59°±24	36°±15	51°±17	0.000*
Lum Lordosis	-40°±36	-35°±30	-50°±31	0.185
Prox Junct Angle	-4°±15	3°±10	6°±17	0.002*
Distal Junct Angle	-11°±14	-8°±11	15°±18	0.020*
Pelvic Incidence	45°±15	47°±13	50°±9	0.417
Sacral Slope	35°±18	36°±18	36°±17	0.367
Pelvic Tilt	9°±15	8°±8	10°±8	0.995



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39. The Early-Onset Scoliosis Questionnaire (EOSQ) Reflects Improvement in Quality of Life After Growth Rod Surgery

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USA

Summary: The EOSQ has been developed to reflect quality of life (QOL) and caregiver impact in children with early onset scoliosis (EOS). We sought to assess the responsiveness of the EOSQ to repetitive surgeries and to establish normal reference values through a prospective, multicenter study. EOSQ scores improved from pre- to post-operative visits, particularly in patients with neuromuscular disease. The finalized EOSQ-24 is able to reflect changes in QOL among EOS patients and is appropriate for use in children aged 0-18 years.

Introduction: The EOSQ is a 22 item questionnaire which has been previously validated to reflect disease-specific QOL in children with early onset scoliosis. The purpose of the current study is to further validate the EOSQ by examining the responsiveness this measure to surgical interventions, and to establish normative reference scores.

Methods: In this prospective, multicenter study, 64 EOS patients (age 5.7 years, 0-11) undergoing treatment with traditional growing rods (GR) (n=26), VEPTR (n=34) or Shilla (n=4) were enrolled from 5 centers. Parents of GR and VEPTR patients completed the EOSQ at 3 visits: pre-implantation and prior to first and second expansions. Total, domain, and item scores with differences and effect sizes were calculated for VEPTR, GR, and all patients. 138 healthy patients were recruited to serve as normative references.

Results: Significant improvements in EOSQ scores were noted across multiple domains in patients before and 6 months after surgery. Effect sizes were small to medium. Patients with EOS of neuromuscular etiology exhibited the largest improvements in QOL. 9 of 10 domains and 20/22 items had good distribution with no floor or ceiling effects. Norms for the EOSQ were developed across a range of ages, and normative patients showed no flooring effects and significant differences were noted between norms and patients with EOS across all ages. A 2-item 'Satisfaction' domain was added to reflect perceived treatment effectiveness.

Conclusion: The current work further validates the now finalized EOSQ-24. This measure shows differences in QOL before and after surgery and appears to be an appropriate measure of outcome in comparing treatment options in this group of patients. It is applicable to children aged 0-18 years. Psychometrics, including few ceiling or floor effects, appear excellent. Future efforts include applying the EOSQ-24 to non-surgical patients and translating into foreign languages.

40. Management of Thoracic Insufficiency Syndrome (TIS) in Jarcho-Levin Syndrome Using Vertical Expandable Prosthetic Titanium Rib (VEPTR)

Joshua G. Karlin, BS; Ajeya Joshi; Hope Trevino, AA; Davin Cordell, MD; James W. Simmons, DO, PhD
USA

Summary: Jarcho-Levin phenotypic subtypes treated with VEPTR showed intermediate-term scoliosis correction, normalized SAL, improved pulmonary performance by AVR, and continued spinal growth with height gains, all with a manageable complication profile. Sagittal profile remained stable but longer term follow-up will track potential junctional issues and outcomes at maturity. These results expand on earlier analysis of a separate SCD cohort but also demonstrate effectiveness in STD subtypes as well.

Introduction: VEPTR is an effective treatment for TIS associated with various spinal and thoracic deformities. We analyzed the effect of VEPTR treatment on patients with Jarcho-Levin Syndrome based on phenotypic subtypes.

Methods: We retrospectively reviewed 29 consecutive cases of Jarcho-Levin treated using VEPTR with minimum 2-year follow-up. Charts were reviewed for operative course, Assisted Ventilation Rate (AVR), and complications. Sitting radiographs were measured for Cobb angle, sagittal profile, thoracic and lumbar heights, hemithoracic and thoracic widths, and space available for lungs (SAL).

Results: Mean age at implant was 3.7 years with 6.9 years follow-up. Ten patients had spondylocostal dysostosis (SCD), all with scoliosis; 19 had spondylothoracic dysplasia (STD), 9 with (STD-S) and 10 without (STD-N) scoliosis. AVR significantly improved from before implant to last follow-up ($p<0.05$). Superficial (n=1) and deep (n=2) infections occurred and were successfully treated.

SCD, STD-S, and STD-N groups had significantly different pre-op Cobb angles (54.3°, 24.1°, 5.1°) ($p<0.05$). In the SCD and STD-S subgroups, Cobb angle improved to 35.8° and 19.9°, respectively, after implant ($p=0.01$), with lasting correction at last follow-up (32.3° and 19.2°).

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While SAL was 0.95 in the non-scoliotic group (STD-N) and stayed stable, it was 0.84 in the scoliotic groups (SCD + STD-S) (p=0.001 vs. STD-N), and improved during treatment (0.84 to 0.95, pre-op to last f/u, p=0.003).

Thoracic height significantly increased during implant in all groups ($p<.05$) and to last follow up (see figure 1). Thoracic and lumbar growth vs. normals (Dimeglio) was calculated (see figure 1). There was no difference between groups for % lumbar growth/year (SCD 4.5%/yr, STD-S 3.9%/yr, STD-N 4.7%/yr).

Conclusion: Three subgroups of Jarcho-Levin were classified based on diagnostic subgroups and scoliosis. VEPTR treatment improved pulmonary status in all patients, with scoliosis correction in both SCD and STD-S subgroups, though greater relative correction was attained in the SCD group. Thoracic asymmetry, as measured by SAL, improved regardless of initial scoliosis. Thoracic height increased at similar rates in all groups. Complications were manageable.

41. Management of Thoracic Insufficiency Syndrome (TIS) in Congenital Scoliosis Patients Using Vertical Expandable Prosthetic Titanium Rib (VEPTR)

Ajeya Joshi; Lilian Nguyen; Davin Cordell, MD; Hope Trevino, AA; James W. Simmons, DO, PhD
USA

Summary: Intermediate term follow-up of progressive congenital scoliosis patients treated with VEPTR with opening wedge thoracostomy demonstrated satisfactory control of spinal deformity, thoracic growth, and improved pulmonary status. A repeat opening wedge thoracostomy, performed in a subset of patients, correlated with a larger initial curve more resistant to correction. Sagittal profile was stable, but longer term follow-up will be required to assess junctional issues and decision-making at skeletal maturity.

Introduction: VEPTR is used for TIS associated with various spinal and thoracic deformities. In severe variants of congenital scoliosis, biplanar progression is likely, casting is ineffective, and early fusion has poor outcomes. We analyzed the results of VEPTR treatment on patients with progressive congenital scoliosis (PCS).

Methods: We reviewed 32 cases of PCS with TIS treated using VEPTR. Charts were reviewed for operative course, Assisted Ventilation Rate (AVR) changes, and complications. Sitting radiographs were measured for Cobb angle, sagittal profile, thoracic height and width, and space available for lungs (SAL). Opening wedge thoracostomy (OWT) usually accompanied initial device implantation and was repeated later in a subset of patients.

Results: Patients averaged 4.1±3.1 years at first VEPTR implant, with average follow-up of 3.8±1.2 years. Post-op Cobb angle improvements were maintained at last follow-up, along with SAL and thoracic height and width gains (Table 1). Sagittal profile appeared stable over time. OWT accompanied initial VEPTR surgery in 30/32 patients. Patients needing repeat OWT during treatment (6/30) had a larger initial curve (70.7±29.5°), with significant gains in thoracic height, but not in Cobb angle. AVR improved 1-3 grades in 5/31 patients needing pre-op support and remained unchanged for the other 26/31 patients needing no support pre-op. Medical and device (dislodgement 16/32 patients, infection 6/32 patients) complications were manageable.

Conclusion: VEPTR is an effective management option for children with PCS, with a manageable complication profile. Height gains were possible even through fused spinal elements; pulmonary performance improvements and gains in thoracic dimensions and SAL were noted. Stabilization of congenital scoliosis decreased the risk of interval worsening of TIS.

42. Long-Term Outcomes of Early Fusion Surgery for Congenital Scoliosis at Ten Years of Age or Younger with a Minimum Ten Years Follow-Up after Surgery

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Summary: We investigated the long-term clinical outcomes of 60 patients with congenital scoliosis who had early fusion surgery at 10 years of age or younger. The proportion of sitting height to total height was well maintained and lung space improved for over 10 years after surgery, although patients' total height was shorter than average.

Introduction: In a multicenter study, we conducted a retrospective analysis of long-term radiographic outcomes in order to investigate the long-term surgical outcomes for 60 cases of congenital scoliosis.

Methods: Between 1978 and 2000, 60 patients with congenital scoliosis underwent surgery for posterior and/or anterior fusions. There were 25 males and 35 females whose average age at the time of initial surgery was 5.5 years (range: 2-10 years). Their average follow-up was 15.6 years (range: 10-28 years). We determined changes in Cobb angles of the main and compensatory curves, revision, lung space, and total and sitting heights at pre-surgery, 1-year post-surgery, and at final follow-up.

Results: Main curve magnitudes were 58.4, 40.1, and 47.1 degrees at, respectively, pre-surgery, 1-year post-surgery, and final follow-up. Compensatory curve magnitudes were 37.0, 26.7, and 33.3 degrees at, respectively, pre-surgery, 1-year post-surgery, and final follow-up. Revision surgery was performed for 20 cases (early complications in 2 cases, deformity deteriorations in 18 cases). Average heights for females were 101.1 cm and 147.7 cm at pre-surgery and final follow-up; the average height of Japanese females aged 20 years is 158.2 cm. Average heights for males were 103.7 cm and 156.2 cm at pre-surgery and final follow-up; the average height of Japanese males aged 20 years is 170.4 cm. The proportion of sitting height to total height was 52.0% and 52.1% at pre-surgery and final follow-up; the average proportion for Japanese females aged 20 years is 53.9%. Growth rates of lung space (final follow-up/pre-surgery) were 141.5% and 143.9 % in the convex and concave thorax, respectively, while the growth rate in T1-S1 was 136.3%.

Conclusion: The proportion of sitting height to total height was well maintained and lung space improved for over 10 years after surgery, although height was shorter than average. To our knowledge, this is the largest series to have been studied for long term follow-ups after early fusion surgery for congenital scoliosis at 10 years of age or younger.

43. Does Return to OR Affect Long-Term Outcomes in Adult Spinal Deformity Patients Undergoing Long Fusions to the Sacrum? Minimum Five-Year Follow-Up

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USA

Summary: This is a long-term retrospective review of primary and revision long fusions to the sacrum for adult spinal deformity (ASD) surgery comparing the impact of reoperation (RTO) on SRS-22 & ODI scores. At 5-yrs f/u, RTO had significant detrimental effects on outcomes scores across all domains.

Introduction: Long fusions from the thoracic spine to the lumbo-sacral pelvis in patients with adult deformity are fraught with complications and the need for reoperation despite improvements in technology and techniques. Complications and RTO can significantly impact patient health related quality of life. This study aims to compare outcomes scores between ASD patient cohorts based upon their RTO.

Methods: This is a retrospective review of 132 consecutive patients that underwent anterior-posterior spinal fusion from the thoracic spine to the sacropelvis and had a minimum of 5-yrs follow up. Patients were divided into two groups: primary surgery (PS) & index revision (IR) surgery; pts were then subdivided based on whether or not they returned to OR, (RTO & NRTO). SRS-22 individual domains & Oswestry Disability Index scores were compared between groups.

Results: 91 patients had complete outcomes measures and were included in the analysis. 12 males, 79 females; mean age at surgery 54.9 yrs (30-78), mean f/u 5.8 yrs (4.8-12.8). There were 50 in the PS group 41 in the IR group. Final SRS-22 total scores were 3.74 and 3.41 (p=0.02) for the respective groups. Their ODI scores were 12.69 & 17 (p=0.02). Overall, there were 29 patients in the RTO group and 62 in the NRTO group. Final SRS-22 totals were 3.20 and 3.77 (p<0.001) for the two groups, and ODI scores were 19.40 and 12.36 (P=0.001) respectively. There were 14 PS and 15 IR who required RTO. Final SRS-22 total for the PS-RTO and IR-RTO groups were 3.29 and 3.11 (p=0.26) respectively. Final ODI scores for the PS-RTO and IR-RTO groups were 16.64 and 22.14 (p=0.71) respectively. There were 36 PS and 26 IS with no RTO. Final SRS-22 total for the PS-NRTO and IR-NRTO groups were 3.92 and 3.57 (p=0.0.03) respectively. Final ODI scores for the PS-NRTO and IR-NRTO groups were 11.06 and 14.12 (p=0.10) respectively.

Conclusion: RTO significantly effected ODI & SRS -22 outcomes scores in each of the individual domains at 5 yrs f/u regardless of PS or IR status. No difference was seen between the PS and IR patients requiring RTO. Overall, the PS group had improved outcomes when compared to the IR group.

44. Primary vs. Revision Surgery: Multi-Center Analysis of Clinical and Functional Outcomes Following Surgery for Adult Spinal Deformity

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Summary: We report and compare functional outcome and complications for patients undergoing primary and revision surgery for the treatment of adult spinal deformity. Despite being technically challenging, there were similar rates of complications in both the revision and primary surgery. Both groups improved their 1-year HRQoL scores and although there was greater improvement in the revision group, the final HQRoL scores were better both pre and post operatively in the primary group.

Introduction: Revision surgery for adult spinal deformity (ASD) is thought to be associated with a high complication rate and poor outcome. We hypothesize that revision deformity surgery may have a higher incidence of complications, but patients undergoing revision procedure experience a comparable gain in functional outcome compared to those undergoing primary surgery.

Methods: Multicenter, prospective analysis of complication rates following ASD surgery for consecutive ASD patients after primary surgery (PS) or revision Surgery (RS). Inclusion criteria: age ≥ 18 yrs, ASD surgery (ASD=scoliosis ≥20o, sagittal vertical axis (SVA) ≥5cm, pelvic tilt (PT) ≥25o, or thoracic kyphosis (TK) >60o), complete demographic, radiographic, and operative data, and min 1 yr follow up. Rates of major, minor, and complications requiring surgery were evaluated. Mulivariate analysis performed.

Results: Of 317 patients, 187 met inclusion criteria. 113 PS were younger (avg 53) than RS pts (avg 59) (p<0.005). Perioperative morbidities are reported on Table 1 Preop HRQoL scores were significantly lower for RS in all SRS domains and ODI scores (p<0.05). Both groups had significant improvements in their functional outcome across SRS domains and ODI. Although RS had greater improvement across all scores, the 1-yr SRS scores were higher in PS except activity (p=0.11) and satisfaction (p=0.07), which were similar to RS. ODI score was lower in PS compared to RS at 1 year (21.5 vs 29.9, p<0.001).

Conclusion: Although more technically challenging, revision surgery for ASD has similar rates of major and minor complications compared to primary (except deep infection). Primary patients' 1-year ODI and SRS scores were better than revision, despite greater overall improvement in revision HRQoL scores.

45. Factors Predicting Cost-Effectiveness of Adult Spinal Deformity Surgery at Two Years Follow-Up

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USA

Summary: Cost-effectiveness analysis was performed on 499 patients who underwent surgery for adult spinal deformity. Based on a policy benchmark of less than $100,000/QALY as cost-effective, analysis was performed to identify pre-operative patient and surgical factors associated with cost-effectiveness. Patient factors associated with cost-effectiveness include higher ODI, lower SRS scores and lower maximum Cobb angle. Also, shorter fusions appear to influence cost-effectiveness.

Introduction: Cost-analysis of spine surgery is important to guide health economic discussions and drive cost effective(CE) modeling. Previous studies have shown that a surgical intervention needs to have a cost/QALY of less than $100,000 to be CE for society as a whole. The aim of this study was to identify pre-operative factors that lead to cost-effectiveness at 2 yr follow up in the setting of surgical treatment for adult spinal deformity.

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Methods: This is a retrospective analysis of a prospective consecutive, multicenter database including 499 pts who underwent surgery for adult spinal deformity. Change in QALY was calculated from the 2 yr change in ODI through an established conversion to utility. Medicare coding was used to determine the direct costs of surgical intervention based upon DRG and RVU reimbursement. Analysis was performed to determine which factors were associated with a cost/QALY less than $100,000, making the procedure CE. ANOVA, Chi Square, and linear regression analysis was utilized to compared CE and non CE pts.

Results: A total of 45 pts (9%) had a cost/QALY of less than $100,000 at 2 yr follow up. Pts were 84% female, average 55.2yo and 40% adult IS, 26.7% (12) adult de novo scoliosis, 17.8% (8) degenerative scoliosis and 15.6% (7) sagittal imbalance. There was no significant differences in gender, diagnosis, and age between CE and non CE pts. Pts with a pre-op ODI score greater than 60 and an SRS Pain below reference normative values by 2 MCID, had the highest odds ratio of being CE (4.18). Higher ODI (57 vs 37.5, p=0.001), lower maximum Cobb angles (37° vs 46°, p=0.023) and lower SRS scores,(2.5 vs 2.9, p=0.001) were significant for cost effectiveness. The CE pts have fewer levels fused compared to the non CE pts, 7.96 vs 9.58, respectively (p=0.01).

Conclusion: Pts with greater pre-op disability, higher ODI and lower SRS scores, are more likely to be CE, less than $100,000/QALY. Additionally, shorter fusions appear to influence cost-effectiveness at 2 yr following surgical interventions.

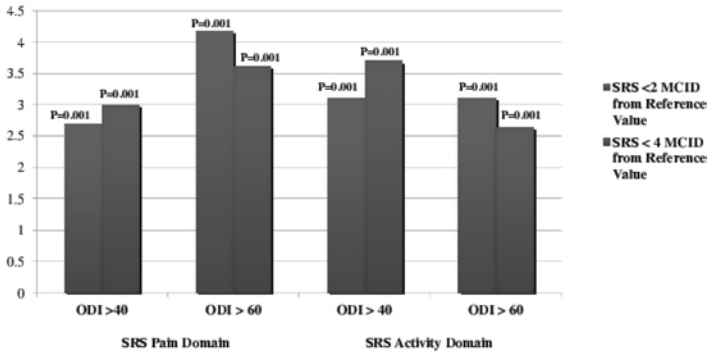

Figure 1. Odd Ratios for cost effectiveness based on preoperative HRQOL scores

46. Proximal Junctional Failure (PJF) Classification and Severity Scale: Development and Validation of a Standardized System

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USA

Summary: PJF is a potentially catastrophic complication following adult spinal deformity (ASD) surgery requiring accurate diagnosis. A PJF severity scoring scale (PJFSS) that integrated 6 distinct PJF characteristics was created using a modified Delphi technique. Intra and Inter-rater agreement was substantial for all PJF characteristics and moderate for PJFSS classification. All PJF features significantly correlated with treatment recommendation. Total PJFSS score strongly correlated with recommended treatment. The proposed PJFSS classification has good reliability and repeatability and correlates strongly with recommended treatment.

Introduction: Confusion exists regarding the consequences of postoperative proximal junctional kyphosis (PJK). PJF, defined as failure of the structures stabilizing the upper instrumented vertebra (UIV) region, is a severe form of PJK that is a potentially catastrophic complication. No validated classification exists for PJF. Purpose: develop and validate a PJF classification and severity scale.

Methods: 14 surgeons participated in a modified Delphi approach to identify clinical and radiographic features of PJF. A classification assigning severity of 6 distinct PJF characteristics was agreed upon (Neurological Deficit, Focal Pain, Instrumentation Problem, Kyphosis/PLC Integrity, UIV/UIV+1 Fracture, and Level of UIV) and a total PJF severity score (PJFSS) created. 15 case examples were graded by 14 surgeons in 2 separate grading sessions; time between grading sessions= 7 days. Intra and inter-rater reliability of 6 PJF severity features and PJFSS was calculated. Correlation with recommended treatment (observation, cement augmentation or revision surgery) was assessed.

Results: Mean kappa intra-rater (0.74) and inter-rater (0.71) agreement for severity scores of all 6 PJF characteristics was substantial (kappa intra-rater range; UIV/UIV+1 Fracture =0.43 to Neuro status=0.89; kappa inter-rater range; UIV/UIV+1 Fracture =0.31 to Neuro status=0.89). Mean PJFSS intra-rater (kappa=0.47) and inter-rater (kappa= 0.42) agreement was moderate. All 6 PJF features significantly correlated with treatment recommendation (mean R value=0.3; p<.01). Mean R values for PJF features and recommended treatment ranged from level of UIV (0.13) to Pain (0.44). Total PJFSS score strongly correlated with recommended treatment (mean R value=0.63; p<0.01). PJFSS ≥7 uniformly resulted in recommendation for revision surgery.

Conclusion: PJF requires accurate diagnosis. The proposed PJFSS classification has good reliability and repeatability and correlates strongly with recommended treatment. Pain, kyphosis, neurological status, and instrumentation failure were the strongest predictors for recommendation for surgical revision. Further validation of the PJFSS classification using a prospective cohort is needed and underway.

47. Proximal Junctional Kyphosis after Posterior Fusion for Adult Scoliosis: Is There a Correlation with Pelvic Incidence

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Summary: Adult scoliosis surgery can present high complications rate, such as Proximal Junctional Kyphois (PJK). Thirty-eight consecutive patients affected by adult scoliosis with positive sagittal imbalance and treated with posterior instrumented fusion were reviewed to assess complications incidence. PJK incidence was 23.7%, 50% in case of UIV between T10 and L1. Patients with high pelvic incidence (>55°) showed an increased loss of lumbar lordosis, of sagittal balance and an increased PJK incidence.

Introduction: Adult scoliosis posterior fusion can present high complications rate, such as proximal junctional kyphosis (PJK). Aim of the study is to evaluate the incidence of PJK and a possible correlation with Pelvic Incidence.

Methods: Thirty-eight consecutive patients (31 women and 7 men, mean age 66 years) surgically treated at our Department between 2000 and 2005 were included in the study. All patients were affected by an adult idiopathic scoliosis with positive sagittal imbalance; in 14 cases a previous arthrodesis was performed. A posterior only pedicle screw instrumentation (extended to L5 in 7 and to S1 in 31 cases) associated with a PSO in 10 cases and with multilevel SPO in 28 cases, was performed. Upper Instrumented Vertebra (UIV) ranged from T10 to L1 in 14 cases and from T1 to T5 in 24. Charts, radiographic, and outcomes analysis (Oswestry, VAS) was performed.

Results: At a mean follow up of 4.2 years (range, 3.5 to 8.1) PJK overall incidence was 23.7%: in cases of short instrumentation (upper level between T10 and L1) incidence increased to 50% ($p < 0.05$). According to Pelvic Incidence, patients were divided into 2 groups: Group A (PI < 55°: 23 cases) and Group B (PI > 55°: 15 cases). Patients of Group B showed an increased loss of lumbar lordosis (43% vs 12%, $p < 0.05$) and loss of sagittal balance (35% vs 15%, $p<0.05$) and an increased PJK incidence (40% vs 13.6%, $p<0.01$) at final follow up.

Conclusion: Adult scoliosis surgery presented an overall incidence of 23.7% of PJK. In cases of adult scoliosis with positive sagittal imbalance, a lower UIV (T10-L1) was associated with a statistically higher risk of developing PJK; moreover a higher Pelvic Incidence (> 55°) was associated with a statistically higher risk of PJK and correction loss on sagittal plane, at follow-up.

48. Proximal Junctional Kyphosis Results in Inferior SRS Pain Sub-Scores in Adult Deformity Patients

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Summary: Proximal Junctional Kyphosis (PJK) is associated with inferior SRS pain sub-scores. Other statistically significant risk factors associated with PJK were age >60, osteoporosis and the distance of the upper instrumented vertebrae (UIV) from the C7 Plumbline (C7PL).

Introduction: To date, PJK has been primarily a radiographic finding. Inferior outcomes associated with PJK have not been reported. We performed an analysis of PJK in adult deformity patients (pts) to identify risk factors for its development and to evaluate its effect on clinical outcomes.

Methods: 364 pts at a single institution from 2002-2007 with adult idiopathic/degenerative scoliosis with 2 yr minimum follow up (f/u) (avg. 3.5 yrs) were analyzed. Inclusion criteria were age > 18, fusions >5 levels from any thoracic UIV to any LIV. Radiographic assessment included standard Cobb measurements in the coronal and sagittal plane in addition to measurements of the PJK angle at post-operative time points: 1-2 months, 2 yrs, and final f/u. PJK was defined as an angle > 10°.

Results: The prevalence of PJK was 39.5% (144/364). The average age in the non-PJK group (I) was 48.9 ±15.0 vs. 53.3 ±14.5 in the PJK group (II) ($p<0.01$) and specifically, age >60 posed a higher prevalence. ($p=0.02$). The prevalence of osteoporosis was 9.8% vs. 20.4% in group I vs. II respectively ($p=0.02$). Gender, Body Mass index (BMI), revision vs. primary surgery and smoking status were not significantly different between the groups ($p=0.66$, 0.66, 0.19, 0.66 respectively).

Pain was prevalent in 0.9% vs. 29.4% in group I vs. II ($p<0.01$), which translated into a lower improvement in the SRS pain domain (mean change +1.2 vs. +0.8, $p=0.04$) despite no differences seen in the other SRS domains, total SRS score or ODI. In our stepwise multivariate regression model, the presence of pain of the upper back or neck was highly predictive of PJK (Odds Ratio 12.5, CI 2.5-63.2, $p<0.01$).

Radiographically, no differences were seen in corrections between groups. However, increasing distance of the UIV to C7PL had a higher prevalence of PJK ($p=0.01$). Instrumentation type, surgical approach and the presence of crosslinks were not significantly different between groups.

Conclusion: Often considered primarily a radiographic finding, our data suggests that PJK results in worse clinical outcomes measured by the SRS pain sub-score. In addition, our regression model suggests that pain in the upper back has a strong predictive value for PJK.

49. Health Impact Comparison of Different Disease States and Population Norms to Adult Spinal Deformity (ASD): A Call for Medical Attention

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Summary: Medical and health policy providers often underestimate ASD associated disability. Multi-center, prospective analysis of 497 consecutive ASD patients, no prior history of spine surgery demonstrated mean ASD SF-36 physical component scores (PCS) were 3 minimally important difference (MID) values (9 total points) below the mean US population norm. All ASD age generational groups had PCS minimum one MID value below US population generational means. ASD had similar PCS MID impact upon US population as cancer, diabetes and heart disease.

Introduction: ASD is a known cause of poor health related quality of life (HRQOL), however, medical and health policy providers often underestimate ASD associated disability. Comparisons of ASD HRQOL values to other disease states may increase awareness of ASD disability. Purpose: compare ASD SF-36 Standard Form Version 2 (SF-36) scores to age specific normative data and disease specific norms.

Methods: Multi-center, prospective analysis of consecutive patients, no prior history of spine surgery, treated operatively (OP) or nonoperatively for ASD (scoliosis ≥20°, sagittal vertical axis (SVA) ≥5cm, pelvic tilt (PT) ≥25°, or thoracic kyphosis (TK)> 60°). ASD demographic and SF-36 physical component scores (PCS) and mental component scores (MCS) were compared to United States (US) normative values, age generational values and disease specific norms. All ASD SF-36 data reported as norm-based score (NBS) with standard deviations (sd), compared to NBS means and reported based upon minimally important difference (MID) values for PCS and MCS (3 NBS points).

Results: 497 ASD (mean age 50.4 years) met inclusion criteria. Mean ASD PCS was 3 MID values (9 total NBS points) below the mean general population norm

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(ASD=41 sd 11; US mean=50). ASD MCS (49 sd 11) was similar to US mean MCD (50). ASD age generational PCS declined more rapidly with age than US age generational norms. The minimum one MID decline in PCS between generations occurred at an earlier age for ASD than US norms. All ASD generational PCS values were minimum one MID lower than US generational values. ASD MCS values were not MID compared to US generational norms, except for 55-64 age group. Comparing ASD PCS to disease specific PCS norms, mean ASD PCS was 4 MID values below mean PCS for healthy population (55), and had similar MID impact as cancer (41), diabetes (41), heart disease (39), and rheumatoid arthritis (40).

Conclusion: ASD can be a debilitating disease that impacts physical function to a similar clinically important degree as diabetes and heart disease. The physical impact of ASD worsens with age and warrants similar research and health policy attention as other more traditional diseases such as cancer and diabetes.

50. Modeling of Cost-Effectiveness of Adult Spinal Deformity Surgery at Five Years Follow-Up

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Summary: Cost-effectiveness analysis was performed on 499 patients who underwent surgery for adult spinal deformity using pre and 2 year post-operative ODI to model cost/QALY at 5 yrs. A total of 120 patients were modeled to have additional surgery (i.e. revision by 5 years). The average cost/QALY at 5 years was $179,002. Patients with significant disability, non-idiopathic scoliosis, previous surgery, and shorter fusions were more likely to be cost-effective at 5 years follow up.

Introduction: The cost-effectiveness of adult deformity surgery(ASD) is an important issue facing deformity surgeons today. A cost-effectiveness benchmark of cost/QALY of less than $100,000/QALY has been set by policy makers. This study projects the cost/QALY at 5 yrs follow up based on2 yr cost/QALY data and literature accepted revision rates and effects on HRQOL.

Methods: This is a retrospective analysis of a prospective consecutive, multicenter database including 499 surgical adult spinal deformity pts. Risk factors (RF) for revision between 2 and 5 yrs were compiled and applied to the population. High risk pts (>4RF) were identified and the cost of surgery was doubled to account for the cost of a revision surgery; all non revision pts maintained the cost of the initial surgery. Based on literature review, revision pts sustained a projected increase in ODI of 7 points and non-revised pts sustained a projected loss of 2 points. 120 pts were modeled to undergo revision surgery during the 5 yr post operative period: 20% known revisions in the cohort <2yrs and the projected literature reported 4.4% revision rate for 2-5 yr. Total cost was based on Medicare reimbursement. Chi Square, T-tests and regression analysis were utilized to compare cost effective and non cost effective pts.

Results: Based on these projections, the average cost/QALY at 5 yr follow up was $179,002. A total of 46.6% of pts were CE, cost/QALY <$100,000. Idiopathic scoliosis pts were less likely to reach cost-effectiveness compared to other diagnostic groups, with 37.8% vs. 56.1%. Pts intially treated with revision surgery were more likely to be CE compared to pts who underwent primary procedures, 54.2% vs 41.9%, (p=0.007). CE pts had higher pre-op ODI scores, 45 vs. 33 (p=0.001), lower pre-op total SRS, 2.8 vs. 3.02 (p=0.001), and shorter fusions, 8.88 vs. 9.91 (p=0.006).

Conclusion: The projected average cost/QALY at 5 yrs followup for ASD surgery was $179,002.98. 46.6% of pts who reached cost-effectiveness with a cost/QALY less than $100,000. Greater pre-operative disability, diagnoses of de novo scoliosis, degenerative scoliosis, and sagittal imbalance, previous surgery, and fewer fusion levels were associated with cost effectiveness.

51. Analysis of the Cost-Effectiveness of Surgical Treatment for Adult Spinal Deformity

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Summary: The cost-effectiveness (CE) of surgical treatment for adult spinal deformity (ASD) has not been reported in the literature. This is a retrospective, multi-center study of the average cost-effectiveness ratios (ACERs) and respective 95% confidence intervals of surgical treatment for different diagnostic categories of ASD. The range of ACERs, interpreted as the cost for an incremental point of improvement in health related quality of life (HRQOL) score, is from $3,405 for SRS Self-Image to $26,028 for SF-36 MCS.

Introduction: The average cost-effectiveness ratio (ACER) is the cost of care relative to the improvement in HRQOL. In a value-based health care economy, the ACER is an important consideration for resource allocation. This analysis concerns the estimation and statistical analysis of ACERs of surgical treatment for patients diagnosed with one of four categories of ASD: Primary Idiopathic Scoliosis (PIS), Primary Degenerative Scoliosis (PDS), Primary Sagittal Plane Deformity (PSPD), and Revision (R).

Methods: Multi-center, retrospective analysis of 323 consecutive ASD patients (ages 18 to 85, with an average age of 54). Patients were assigned to one of four diagnostic categories of ASD: PDS (n=59, 18%), PIS (n=102, 32%), PSPD (n=39, 12%), and R (n=123, 38%). HRQOL measures were based on the Medical Outcomes Study Short Form 36 (SF-36), the Oswestry Disability Index (ODI), and the Scoliosis Research Society (SRS) questionnaires after at least one year following surgery. SRS scores were translated to a 100 point scale. Costs were collected from hospital data and included direct costs (DC) incurred for the episode of surgical care. Confidence intervals were calculated using nonparametric bootstrap methods.

Results: For all categories of ASD, point estimates and 95% confidence intervals were estimated for the following measures: ACER MCS=$26,028 ($15,661 to $66,645); ACER PCS=$12,174 ($9,089 to $17,919); ACER ODI=$7,833 ($5,928 to $12,074); ACER SRS(Function)=$9,006 ($6,437 to $14,567); ACER SRS(Self-Image)=$3,405 ($2,936 to $4,021); and ACER SRS(Pain)=$4,198 ($3,508 to $5,135). ACERs and confidence intervals were also estimated for specific diagnostic categories of ASD.

Conclusion: The CE of care is an important determinant of resource allocation. This study establishes a baseline range of the cost of incremental improvement in HRQOL for patients undergoing surgical treatment for ASD. Further analysis will measure ACERs based on QALYs, allowing comparisons to other medical and surgical interventions.

52. Outcomes Following Three-Column Spinal Osteotomies: Impact of HRQOL and Age on Two-Year Follow-Up

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Summary: An analysis of HRQOL and age for 228 patients who underwent 3 column osteotomy (pedicle subtraction osteotomy or vertebral column resection) was conducted. Increased age was correlated with worse preop HRQOL scores. Older patients experienced a greater improvement in HRQOL but this improvement occurred more slowly. By the 1 and 2 year timepoints there were no differences in HRQOL between older and younger patients.

Introduction: Major osteotomies for adult spinal deformity include resection of all 3 spinal columns such as pedicle subtraction osteotomy (PSO) and vertebral column resection (VCR). The relationship between patient age and health-related-quality-of-life-outcomes (HRQOL) for patients undergoing major spinal deformity correction with PSO or VCR has not been well characterized.

Methods: 228 patients underwent a 3 column osteotomy (158PSO/70VCR) from two major institutions. Patients were stratified by age into groupings of ≤45, 46-64, and ≥65 years. HRQOL outcome included; ODI, SF36/SF12 and SRS22 at standard time points: preoperative, 1 month, 3 month, 6 month, 1 year, and 2 years. Differences and correlations between age and HRQOL were investigated.

Results: Age significantly correlated with preop ODI (r=0.26, p=0.0011) and 6 months ODI (0.28, p=0.097). A stratification by age (36pts ≤45yrs, 107pts 46-64yrs, 84pts ≥65yrs) revealed that the <45 yrs group had significant lower pre-operative ODI scores (39.2) than both 46-64yrs (51.3, p=0.0052) and ≥65yrs (53.0, p=0.0017) with no significant difference between 46-64yrs and ≥65yrs (p= 0.6). Immediate postop ODI scores were not significantly different between age groups. At 3 months, the >65yrs had significantly greater ODI scores (44.6) than the 46-64yrs group (36.4, p=0.03). The 6month ODI scores for the >65yrs group were significantly greater (45.2) than for the 46-64ys (36.1, p=0.0495) and ≤45 (26.2, p=0.006). At 1yr and 2 years, the ODI scores were not significantly different for all age groups.

Conclusion: The results suggest that patients over age 65 have greater preoperative disability and recover more slowly after 3 column osteotomy than younger age groups. Patients over age 65 experience a greater improvement after 3CO than younger patients but this improvement occurs more slowly over the course of 1 year.

53. Prevalence and Risk Factors for Pseudarthrosis following Lumbar Pedicle Subtraction Osteotomy (PSO) in Adult Spinal Deformity

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Summary: The prevalence of pseudarthrosis following a lumbar PSO in the adult patient population was 10.5% (18/171). Pseudarthrosis from a prior surgery, including at the PSO site, prior decompression and radiation to the lumbar spine, and presence of inflammatory disease/neurologic disorders were identified as risk factors. SRS and ODI scores improved after pseudarthrosis repair.

Introduction: We assessed the prevalence, risk factors and clinical outcomes for pseudarthrosis after a lumbar pedicle subtraction osteotomy (PSO). To our knowledge, this is the largest PSO series ever evaluated for pseudarthrosis.

Methods: We reviewed prospectively collected data on 171 consecutive adult spinal deformity patients undergoing a lumbar PSO by 2 surgeons at a single institution with a minimum 2yr F/U. Pseudarthrosis was confirmed by radiographic instrumentation failure, loss of sagittal alignment and intraoperative confirmation.

Results: 18 (10.5%) out of 171 pts developed pseudarthrosis after a PSO. 11 of the 18 pts (6.4% all pts/61.1% of all 18 pseudos) had pseudarthrosis at the PSO site, L3 being the most common site. Other locations were the L-S junction (4/18), TL junction (2/18) and upper thoracic spine (1/18). Preop pseudarthrosis level was a predictor of the postop pseudarthrosis level (93%). 15 of 18 pts (83%) had no interbody fusion performed directly above and/or below the PSO site. 16 of 18 (88%) pts had a history of pseudarthrosis at the time of PSO surgery and 2/3 pts who had prior radiation to the lumbar spine developed pseudarthrosis. Most pseudarthroses occurred within the first 2yrs (n=13/18), between 2-5yrs (n=3/18) and >5yrs (n=2/18) postop. Prior pseudarthrosis (P<0.0001), pseudarthrosis at the PSO site (P<0.0001), prior decompression in the lumbar spine (P=0.0037), prior radiation to the lumbar spine (P<0.0001) and presence of inflammatory/neurologic disorders (P<0.0036) were identified as risk factors. All 18 pts with pseudarthroses required revision surgery (posterior-only n=12, A/P n=6) due to loss of sagittal alignment and pain. The mean pre-revision SRS score was 85, post-revision was 95 (P=0.0166), and the mean pre-revision ODI score was 42.5, post-revision was 34.5 (P=0.0203).

Conclusion: The overall prevalence of pseudarthrosis after lumbar PSO was 10.5% with 11/18 (61%) occurring at the actual PSO site. Prior pseudarthrosis at the PSO site or other regions of the lumbar spine, prior laminectomy and prior radiation to the lumbar spine as well as preop inflammatory disease/neurologic disorders were all risk factors. SRS and ODI scores improved significantly following pseudarthrosis repair.

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54. Outcome and Complications of Sacro-Pelvic Fixation Using S2 Alar-Iliac (S2AI) Fixation in Adult Deformity Patients Fused to the Sacrum: A Prospective Study with Minimum Five-Year Follow-Up

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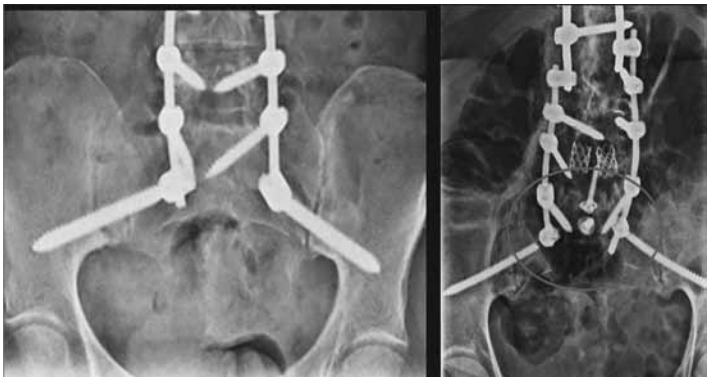
Summary: A prospective long term study to evaluate the clinical and radiographic outcome of S2 Alar-Iliac (S2AI) technique for sacropelvic fixation in adult deformity patients fused to the sacrum. Investigating its safety, efficacy and evaluating the complications and revision rate associated with its use.

Introduction: Adult deformity patients undergoing long fusion to the sacrum often require additional anchors into the ilium.Many techniques are available,some are technically difficult and require complex connectors that may affect the construct stability and have a high rate of complications and may require revision.

Methods: We prospectively reviewed 41 consecutive patients undergoing long fusion to the Sacrum using (S2AI) technique. This method uses a starting point in the sacral ala between the S1 and S2 foramina, directed toward the anterior inferior iliac spine, allowing in-line anchors without additional connectors or dissection. Clinical and radiographic outcomes, as well as complications were prospectively collected. 3 patients were excluded,one died during the study period, 2 did not complete the 5 year follow-up. 38 patients were included in the final analysis, average follow up 65 months (60-78).

Results: The mean age was 59.2 yrs (26-80). 31 were females, (95%) had multiple co-morbidities. Mean radiographic changes were (pre/post): thoracic kyphosis 8.3°(37/41.8),lumbar lordosis 12.2°(35/47.3),thoracic curve 12.75°(26.6/13.1),lumbar curve 19.08°(37.42/17.83), pelvic obliquity 1.93 (±5.8, -5.5-19.1). At 5 yrs, 95% of patients showed radiographic fusion at L4-S1. Re-operation was performed on 5 patients: revision of broken rods (1), pseudoarthrosis proximal to L4 (2), junctional stenosis (1), residual deformity (1). One patient had removal of instrumentation due to pain proximal to the lumbosacral junction. There was one superficial and one deep wound infection. Complications specific to S2AI fixation: 5 (6.5%) screws fractured in 3 patients; none required revision. There was no vascular injuries and no significant SI joint area pain. Screw loosening <2 mm (9.2%) 7 of 76 screws, loosening >2 mm, none. There was improvement in all SRS 22 domains, at post-op and final follow up; (pre/final): pain (2.2/3.2), self image (2.1/3.1), activity (2.5/3.2), mental (1.9/3.1), and satisfaction (1.8/2.9). ODI also showed a mean decrease (40.7/26).

Conclusion: S2 Alar-iliac (S2AI) fixation is a relatively safe & effective method for sacropelvic fixation. Complications related to the technique are rare with a lower revision rate compared to other available techniques.



Radiograph showing fracture of the S2AI screws. All screws that fractured were 7 mm in diameter. No fracture was seen in 8mm or 9 mm screws (also shown).

55. The Schwab-SRS Adult Spinal Deformity Classification: Assessment and Clinical Correlations Based on a Prospective Operative and Non-Operative Cohort

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USA

Summary: A prospective evaluation of a consecutive cohort of adult spinal deformity (ASD) patients was conducted using the Schwab-SRS Classification. Operatively treated patients had worse health-related quality of life (HRQOL) scores, worse radiographic sagittal spinopelvic alignment, and worse grades on all three classification modifier categories than patients treated nonoperatively ($p<0.05$). These data indicate that the Schwab-SRS Classification of ASD corresponds with disability and treatment preference for ASD patients.

Introduction: The Schwab-SRS Classification of Adult Spinal Deformity (ASD) is a validated system that provides a common language for the complex pathology of ASD. Classification reliability has been reported; however, correlation with treatment has not been assessed. Purpose: assess association between disability, classification type/modifier and ASD treatment.

Methods: Prospective analysis of consecutive ASD patients. Inclusion criteria: age ≥18 yrs and scoliosis ≥20°, sagittal vertical axis (SVA) ≥5cm, pelvic tilt (PT) ≥25° or thoracic kyphosis (TK)> 60°. All patients had 36" standing x-rays. Differences in demographics, health related quality of life (HRQOL; ODI, SRS, SF36), and classification curve type/modifier distribution between operative (OP) and nonoperative (NONOP) treatment were evaluated.

Results: 757 patients (mean age 53 yrs, range 18-85) met inclusion criteria. OP (n=311) were older (mean age 56 vs 51 yrs), had greater BMI (27.7 vs 25.7), more previous surgery (45% vs 19%), and greater Charlson comorbidity index (1.1 vs 0.85) than NONOP (n=446), respectively ($p<0.05$). OP had worse HRQOL scores on all surveys than NONOP ($p<0.05$). OP and NONOP had similar coronal alignment ($p<0.05$). OP had worse sagittal spinopelvic alignment for all measures than NONOP except cervical lordosis, TK and pelvic incidence (PI). OP had greater percentage of pure sagittal classification (type S; OP=23%, NON=14%; $p<0.05$).

OP had worse grades for all modifier categories: PT (26% vs 16%), PI-lumbar lordosis mismatch (37% vs 21%) and global sagittal alignment (29% vs 9%), OP vs NONOP, respectively ($p<0.05$).

Conclusion: Prospective analysis of OP vs NONOP treated ASD patients demonstrated OP patients were older, had more co-morbidities, greater disability and worse sagittal spinopelvic alignment as defined by the Schwab-SRS Classification subtype and sagittal modifiers. This classification is descriptive, correlates with HRQOL scores, and corresponds to treatment preference for ASD.

56. Ninety-Day Readmission Rate after Spine Fusion for Adult Deformity

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Summary: Cost-effectiveness and value in spine surgery are measured by impact of surgery compared with alternative care, duration of the effect, and incremental costs of care. Readmission and reoperation have a significant impact on the cost of care for adult deformity. This study evaluated the 90-day readmission rate after spine fusion for adult deformity, and assessed causes and associated risk factors.

Introduction: Surgical management of spinal deformity is associated with improved outcomes compared with non-operative care. Costs of care are high, and readmissions are an important cost driver. The objective of this study is to compare 90-day hospital readmission rates after short, medium and long spinal fusions for adult spinal deformity, and to identify readmission risk factors for readmissions.

Methods: Retrospective study of patients with adult spinal deformity treated with spine fusion from 2006 to 2011 without tumor or existing infection. Patients were grouped by fusion length: short (2-3 vertebrae), medium (4-8), and long (9 or more). The 90-day readmission rate and cause were determined by reviewing hospital records. Readmission rate and risk factors were analyzed with a time-to-failure and cox proportional hazards model.

Results: 738 patients were enrolled: 105 short, 341 medium, and 292 long fusions. The overall 90-day unplanned readmission rate was 9.6% (n=71) with 7.7% (n=57) planned readmissions for staged procedures. Long spine fusion had a higher readmission rate (12.0%) compared to medium (9.1%) or short (3.8%) fusions ($p < 0.05$, Figure 1). The main cause of readmission was infection at 30 days (n=25/47) and proximal junctional kyphosis at 60-90 days (n=2/5). Risk factors included long fusion, hospital stay greater than 10 days, discharge to a rehabilitation facility, diabetes, peripheral vascular disease, and valvular disease ($p < 0.05$), while short fusion and discharge to home were protective ($p < 0.05$).

Conclusion: Readmission rates are an important measure of quality, value, and cost-effectiveness of care. Surgical strategies and patient factors are independent predictors of readmission rates. Understanding risk factors for readmission may help to stratify patients by risk, and assist in decision-making on treatment options.

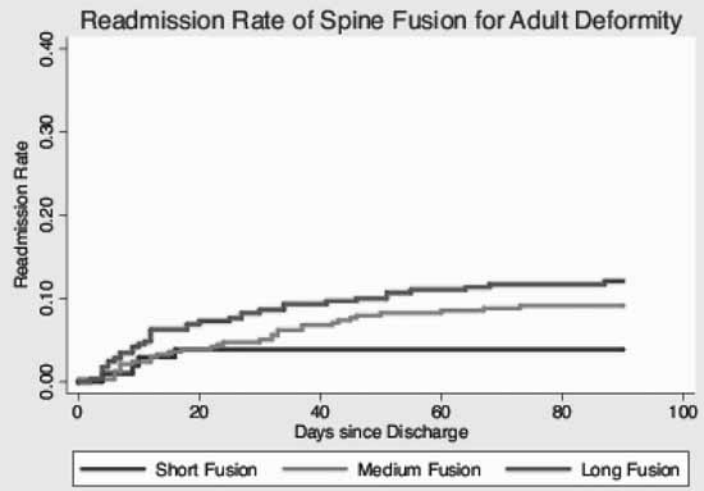

Figure 1: 90-day hospital readmission rates after spine fusion for adult deformity by fusion length. Longer fusions are associated with greater readmission rate ($p < 0.05$, logrank).

57. Preventing Spinal Cord Deficits in Adult Spinal Surgery with Intraoperative Monitoring: A Single Institution Experience

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Summary: Intraoperative monitoring (IOM) detected 155 adult patients meeting warning criteria of spinal cord (SC) monitoring modalities. 78 of these data changes were attributed to loss of function within the SC as opposed to peripheral nerves. Prompt interventions led to return of IOMData in 73% of cases, and 90% of patients had baseline function at long term follow up.

Introduction: IOM of the SC is widely but not universally utilized during spine surgery. The aim of this study was to better characterize SC monitoring events from a large database, to determine the reversibility of the data loss, interventions utilized, and long term neurologic outcomes associated with IOM events during adult spinal surgery.

Methods: From a database of 8993 patients, 155 were identified with warning criteria for somatosensory evoked potential (SSEP), descending neurogenic evoked potential (DNEP), and/or transcranial motor evoked potentials (TCEP). The etiology of the IOM changes were categorized into SC or peripheral nerve events. 78/155(50%) were attributed to loss of function of the SC. Further analysis was completed to characterize the interventions and neurologic outcomes.

Results: The 78 pts. with SC events were grouped into 4 etiologic categories: SC compression (n=31); Hypotension (n=22); Deformity correction (n=17); and implant placement (n=8). 57/78 (73%) patients with SC IOM events recovered data after interventions. Only 3/57 (5%) awoke with neurologic deficits, and all 57 ultimately regained normal function. However only 9/21 (43%) without return of IOMData awoke at neurologic baseline, and only 13/21 (62%) ultimately recovered to normal function. Deformity correction and hypotensive patients (n =39) had 100% return to normal function, compared to only 79% in the cord compression and implant placement groups (31/39), p=0.002.

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Conclusion: In 73% of cases (57/78 pts), IOM alerted the surgeon to SC issues that were corrected intraoperatively leading to normal neurologic outcomes. Return of IOMData following interventions, especially when due to deformity correction and hypotension, universally correlated strongly with normal long term neurologic outcome, justifying IOM use even when preoperatively the surgeon does not feel it will change the intraoperative technique.

Significance: In this large series of patients experiencing SC IOMData changes, 90% of permanent spinal cord deficits were prevented by prompt intervention.

58. Responding to Neuromonitoring Changes in Three-Column Posterior Spinal Osteotomies for Rigid Pediatric Spinal Deformities

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Canada

Summary: A retrospective review was performed on the neuromonitoring data of 37 posterior three column osteotomy in 29 pediatric patients with severe spinal deformities. Significant loss in MEP occurred in 4 prior to decompression (Type I), during decompression and bone resection (Type II) in 12, and following osteotomy closure (Type III) in 6 cases. Changes unresponsive to increasing the blood pressure occurring prior to osteotomy closure (Type II, n=5)were treated with closing the osteotomy, while those occurring after osteotomy closure (Type III,n=4)were treated with re-opening, manipulation, and subsequent re-closure of the osteotomy either with a cage or less correction. There were 6 immediate post-operative motor deficits, that resolved completely. The real time intra-operative information provided by the MEP provided the necessary information to direct key surgical decisions.

Introduction: The purpose of this study was to highlight the high risk steps during performance of cord level three column osteotomies for the correction of severe spinal pediatric deformities and to describe actions taken to avert major neurological injury in these cases.

Methods: Retrospective review of prospectively collected data was performed on neuromonitoring changes recorded during a consecutive series of cord level 3 column osteotomies between 2005 and 2011. A decrease in SSEPs and transcranial MEPs greater than 50% of baseline was considered an alert. Alerts were classified chronologically as Type I: prior to decompression, Type II: occurring during decompression and bone resection, Type III: occurring following osteotomy closure.

Results: 37 three column, cord level, spinal osteotomies were performed in 29 patients-congenital (17), syndromic (11), neuromuscular (5), or juvenile (4). SSEP alerts occurred in 3 patients, all of whom had significant MEP alerts. There were 4 type I, 12 Type II, and 6 Type III MEP alerts. Increasing blood pressure improved MEP in all with the exception of 5 Type II and 4 Type III. The unresponsive 5 Type II alerts were treated with osteotomy closure with the expectation that spinal shortening would improve spinal cord bloodflow. The unresponsive 4 Type III alerts all responded to re-opening, manipulation, and subsequent re-closure of the osteotomy either with a cage or less correction. There were 6 immediate post-operative motor deficits, all transient, and all resolved completely. No patient had a permanent deficit.

Conclusion: Significant MEP changes are common during the performance of three column, cord level, posterior spinal osteotomies in children. Changes unresponsive to increasing blood pressure occurring during decompression and bone resection (Type II) responded well to osteotomy closure. Unresponsive changes during osteotomy closure (Type III) were treated successfully with opening the osteotomy, cage adjustment and less correction. The real time intra-operative information provided by the MEP provided the necessary information to direct key surgical decisions.

59. Alarm Point of Transcranial Electrical Stimulation Motor Evoked Potentials for Intraoperative Spinal Cord Monitoring: A Prospective Multicenter Study

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Summary: We report the new alarm point of transcranial electrical stimulation motor evoked potentials for intraoperative spinal cord monitoring. We analyzed our 62 true positive cases between 2007 and 2009 and set a 70% decrease of amplitude as alarm point. The new alarm point achieved higher sensitivity and specificity by multicenter prospective study. We recommend this new criteria for intraoperative spinal cord monitoring of OPLL, spinal cord tumor and scoliosis surgery.

Introduction: Transcranial electrical stimulation motor evoked potentials (TcMEPs) is widely used for intraoperative spinal cord monitoring. And TcMEPs became gold standard due to the importance of motor function. But there is no definite alarm point of TcMEPs despite so many studies. We analyzed our 62 true positive cases which were experienced between 2007 and 2009. A 70% decrease of amplitude was set as alarm point. We report the new alarm point of TcMEPs for intraoperative spinal cord monitoring. The purpose of this study is to evaluate the new alarm point of MEPs by multicenter prospective study.

Methods: TcMEPs was performed under the unified monitoring condition among the hospitals belonging to the spinal cord monitoring working group members of Japanese Society for Spine Surgery and Related Research. Intravenous anesthesia was administered during intraoperative spinal cord monitoring, and 4 to 10 repetitive trains were stimulated transcranially. We performed intraoperative spinal cord monitoring using TcMEPs in 578 patients of scoliosis, ossification of posterior longitudinal ligament (OPLL) and spinal cord tumor between 2010 and 2011.Our alarm point was a 70% decrease of amplitude. TcMEPs variability and the pre- and postoperative motor deficit were analyzed prospectively.

Results: TcMEPs yielded 18 true positive cases, 43 false positive cases and 2 false negative cases in this study. So Sensitivity was 90.0%, and specificity was 91.7%. In 41 cases amplitudes of TcMEPs decreased during surgery, but recovered at final by the protective treatments of spinal cord injury. False negative cases recovered fully from their transient paralysis.

Conclusion: The alarm point of a 70% decrease of amplitude achieved higher sensitivity and specificity. We recommend this new criteria for intraoperative spinal cord monitoring of OPLL, spinal cord tumor and scoliosis surgery.

60. The Ability to Obtain and Maintain Transcranial Motor Evoked Potentials During Spinal Deformity Surgery in Patients with Neural Axis Abnormalities

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Summary: The ability to obtain baseline transcranial motor evoked potentials (TcEPs) was similar for patients with a neural axis abnormality (NAA) and those who had AIS. However, there was a greater incidence of critical changes in the NAA group which were predictive of neurologic deficits.

Introduction: Transcranial evoked potentials (TcEPs) are a safe and sensitive modality to identify impending spinal cord injury in adolescent idiopathic scoliosis (AIS). It is presumed that patients with a neural axis abnormality (NAA) have a more sensitive spinal cord when undergoing surgery. Previous studies have analyzed SSEP and neurogenic or mixed MEP without any study addressing the use of TcEPs in these patients.

Methods: An IRB-approved retrospective review was performed of a consecutive series of patients with NAA at a single institution and compared them to a random selection of AIS patients undergoing spine deformity surgery with spinal cord monitoring using TcEP and SSEP. The ability to obtain baseline data and the incidence of critical changes in TcEPs and SSEP's was compared between groups and a correlation to post-operative neurological deficits was performed.

Results: Thirty-eight patients with NAA (5 Chiari malformations, 23 syrinx, 4 spinal cord tumors, 6 tethered cords) were compared to 183 with AIS. Age (13.6 v. 14.7 yrs, p=0.029) was similar between the two groups but preoperative curve magnitude (69.1 v. 61.1, p=0.006) was greater in the NAA group. Good baseline data was obtained less frequently in the NAA group for TcEPs(94.7% vs. 100%) (p<0.001), and SSEPs (89.5% v. 100%) (p<0.001). There was trend toward a higher incidence of critical deviations from baseline in the NAA group for TcEPs, 3/38 (7.9%) vs. 5/184 (2.7%) (p=0.120); but not for SSEPs, 0/38 v. 3/184 (1.6%) (p=0.430). There was one postoperative delayed neurologic deficit in the NAA group that had diminished TcEPs intra-op, a normal exam on wake-up but a transient deficit 6 hours following surgery which recovered.

Conclusion: The ability to obtain good baseline SCM in patients with NAA approaches that of AIS and accurately identifies neurologic deficits with a high sensitivity. Surgeons should be confident that TcEP baseline data can be obtained but should be aware that the spinal cord is more sensitive to injury during spine deformity surgery when a neural axis abnormality is present.

61. Feasibility of Passive Correction in Congenital Scoliosis

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Summary: The results of passive correction and hemivertebrectomy for congenital scoliosis were compoared and the feasibility and indications for passive correction were examined. In the surgical treatment of congenital scoliosis, if a curve is flexible enough to allow sufficient correction using instrumentation only, satisfactory results can be obtained with passive correction and not using the more active correction method of hemivertebrectomy.

Introduction: Effective deformity correction can often be expected with passive correction by instrumentation and not using more invasive techniques such as hemivertebrectomy in congenital scoliosis. There have been few reports regarding the feasibility of passive correction with instrumentation only. The purpose of this study is to compare the results of passive correction and hemivertebrectomy and to examine the feasibility of and indications for passive correction.

Methods: Our study involved 25 patients with congenital scoliosis who underwent instrumented correction and fusion between 2004 and 2009. Passive correction by instrumentation was performed for 14 patients, and hemivertebrectomy was performed for 11 patients. Both patient groups were compared in terms of age at the time of surgery, preoperative magnitude and flexibility of the main curve, correction rates after surgery and at the final follow-up, surgery time, estimated blood loss, and complications.

Results: There were no significant differences in the average patient age (12.5 and 11.3 years) or curve magnitude (60.5 and 63.7 degrees) between the passive correction and hemivertebrectomy groups, although the preoperative curve flexibility was greater in the passive correction group (37.1%) than in the hemivertebrectomy group (21.0%). The correction rates immediately following surgery were high in both groups, although the correction rate in the hemivertebrectomy group (73.3%) was slightly higher than that in the passive correction group (60.3%). Mean operation time (308 and 366 minutes) and blood loss (1540 and 3547 mL) was significantly shorter and less in passive correction group than in hemivertebrectomy group.

Conclusion: In the surgical treatment of congenital scoliosis, if a curve is flexible enough to allow sufficient correction using instrumentation only, satisfactory results can be obtained with passive correction and not using the more active correction method of hemivertebrectomy. In addition, passive correction has the advantages of a shorter surgery time and reduced blood loss.

62. Analysis of Maternal Risk Factors Associated with Congenital Vertebral Malformations(CVM)

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USA

Summary: This study determines the relative contribution of maternal environmental factors (MEF) during pregnancy including maternal insulin dependent diabetes mellitus, valproic acid, phenytoin, alcohol,smoking ,hyperthermia, twin gestation, assisted reproductive technology, in-vitro fertilization and maternal clomiphene usage to CVMDevelopment.

Introduction: Congenital vertebral malformations(CVM) represent defects in formation and segmention of somites occurring with an estimated incidence of between 0.13-0.50 per 1000 livebirths. CVM may be associated with congenital scoliosis, Klippel-Feil syndrome, hemifacial microsomia and VACTERL syndromes,and represent significant morbidity due to pain and cosmetic disfigurement. Prior studies have identified CVM associated with various maternal exposures during pregnancy. The objective was to determine the relative contribution of maternal environmental factors (MEF) during pregnancy including maternal insulin dependent diabetes mellitus, valproic acid, phenytoin, alcohol,smoking, hyperthermia, twin gestation,

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assisted reproductive technology, in-vitro fertilization and maternal clomiphene usage to CVMDevelopment.

Methods: A multicenter retrospective chart review of 226 male and female cases with CVM and 269 controls with normal spine morphology between the ages of 1-50 years was performed in order to obtain the odds ratio (OR) of MEF related to CVM among cases vs. controls. CVMDue to an underlying syndrome associated with a known documented gene mutation or chromosome etiology in cases were excluded. An imputed analysis was performed in which subjects with no documentation of MEF history were treated as no maternal exposure.

Results: Of the 226 total cases, 102 cases had single or multiple CVM without additional congenital malformations (CM) (Group 1) and 124 cases had single or multiple CVM and additional CM (Group 2).

Eighteen percent of total cases had an identified MEF. The OR (95% CI) for MEF history for Group 1 was 3.58 (1.03-12.46, p=0.045). The OR for MEF history in Group 2 was 3.92 (95%CI) (1.12- 13.69, p=0.033). Logistic regression using numbers of risk factors (0,1→ 2) revealed a dose response with respect to MEF in Group 2 (p=0.039).

Conclusion: To our knowledge this study represents the first analysis of MEF associated with CVM.These results support a hypothesis for an association between the above MEF during pregnancy and CVM and have implications for development of prevention strategies. Further prospective studies are needed to quantify association between CVM and specific MEF.

63. Lumbosacral Hemivertebra Resection with Transpedicular Instrumentation by a Posterior Only Approach in Young Children

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Summary: A retrospective radiographic and clinical study to investigate the results of posterior lumbosacral hemivertebra resection with a minimum follow-up of 2 years.

Introduction: Lumbosacral hemivertebra resection by a combined anteroposterior approach has been previously described. However, few studies reported on lumbosacral hemivertebra resection via a posterior only procedure, the efficacy and safety of one-stage posterior lumbosacral hemivertebra resection has not yet been well documented.

Methods: From January 2002 to June 2008, a series of 16 congenital scoliosis due to lumbosacral hemivertebrae were managed by hemivertebra resection combined with transpedicular instrumentation using a posterior approach only. Radiographs were reviewed to identify the type and location of the hemivertebra, the coronal scoliosis curve, the degree of pelvic obliquity, and the sagittal spinal alignment preoperatively, postoperatively and at the last 2-year follow-up. Radiographs were also used to evaluate spinal fusion and implant failure. Operative reports and medical charts were reviewed to record any intra- and peri-operative complications.

Results: The mean age at surgery was 8.1 years (2-15 years). The mean follow-up was 33.6 months (24-63 months). The mean fusion level was 4.8 segments (2-8 segments). There was a mean improvement of 62.4% in the segmental scoliosis, from 29.5° before surgery to 11.1° at the last follow-up, and there was a mean improvement of 61.6% in the total scoliosis from 31.5° to 12.1° over the same time period. The mean compensatory curve was 31.8° before surgery and 14.9° at the last follow-up, representing a mean improvement of 53.1%. Trunk shift and pelvic obliquity were markedly improved after surgery and at the last follow-up. The mean final thoracic kyphosis and lumbar lordosis were within normal values. Two cases with transient pelvic obliquity and one case with minor neurological compromise after surgery had complete recovery at the last follow-up. There was one case of rod breakage that required revision.

Conclusion: Our results showed that one-stage posterior lumbosacral hemivertebra resection with transpedicular instrumentation can offer preferable correction and complete decompression without important neurologic complications. Early surgery in young children is able to avert the development of severe local deformities and secondary structural curves, thus saving motion segments.

64. Sacral-Alar-Iliac Fixation in Pediatric Deformity: Two to Five-Year Follow-Up

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USA

Summary: Sacral-Alar-Iliac (SAI) fixation enabled a high degree of pelvic obliquity correction. No SI problems were found. Pseudoarthrosis occurred only with additional predisposing factors. Screw diameter > 8 mm is advised to minimize implant fracture.

Introduction: Challenges in pediatric pelvic-fixation include improving anchor strength and corrective potential as well as lowering prominence. We assessed the performance and complication rate of SAI fixation in the pediatric population.

Methods: 85 Patients ≤ 18 yrs with spine surgery including SAI fixation from 2003-2009 having minimum 2-year follow up were reviewed. We studied spinopelvic deformity correction and fusion, as well as implant-related complications.

Results: 75 had >2-yr follow-up and 10 had 5-yr follow-up. Diagnoses were cerebral palsy-44, Marfan-10, Rett-5, and other neuromuscular scoliosis/syndromes-26. Mean age at surgery was 14.4±4.9; follow-up averaged 3.3±1.3 years. Screw length was 78mm (ranged, 45-100mm) and mean diameter 7.4mm (range, 5.5-10mm; mode 7). Pelvic obliquity correction was 17±13° for a postop pelvic obliquity of 6.3±4.8°. Nineteen patients had postop pelvic obliquity >10°. Complications included pain at SAI screw (1), radiographic lucency ≥2 mm (7), wound dehiscence (7), superficial wound infection (1), deep wound infection (3), breakage of screw neck (nine with one revision; 1= 6mm, 5= 7mm, 3 =8mm; no 9 or 10 mm), lateral screw protrusion (1), screw migration (1), and pseudoarthrosis (3, all with predisposing factors).

Conclusion: SAI fixation has the ability to provide significant correction of pelvic obliquity. Radiographic lucency occurred in 8%, but only 2% had clinical symptoms attributable to the SAI screws. Screw neck breakage occurred in 11% of patients and only with thread diameters ≤ 8mm.

65. Pedicle Screw Hubbing in the Adult and Immature Thoracic Spine: A Biomechanical and Micro-Computed Tomography Evaluation

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USA

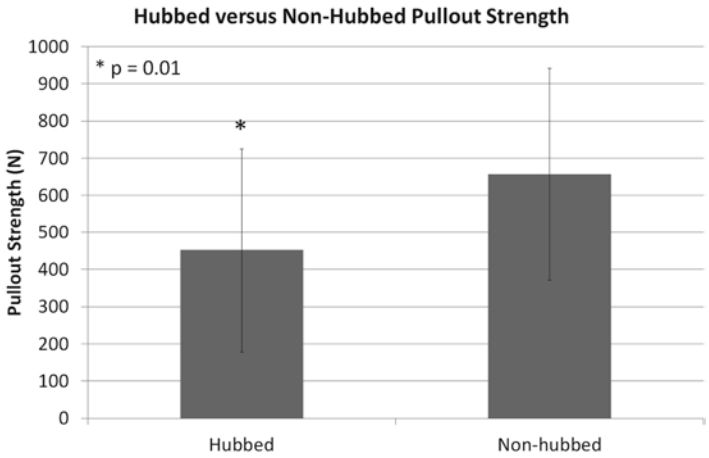
Summary: Pedicle screw "hubbing" has been postulated to improve biomechanical fixation strength. We found that hubbing of pedicle screws resulted in significantly lower pull-out strength compared to conventional pedicle screws in the adult and immature thoracic spine. There was also a high rate of iatrogenic fracture with the hubbing technique.

Introduction: Pedicle screw "hubbing" involves seating the screw head into the dorsal lamina. This technique is postulated to provide 1) a load-sharing effect thereby improving pullout resistance, and 2) a reduction in the moment arm thereby decreasing cephalo-caudad toggling and implant loosening. The purpose of our study was to evaluate pull-out strength (POS) of fixed-head pedicle screws after hubbing vs. standard insertion in the adult and immature thoracic spine.

Methods: Twenty-six (26) fresh-frozen human cadaveric and 22 fresh-frozen immature calf thoracic vertebrae were prepared. Osteoporotic BMD (n=16), normal BMD (n=6), and immature (n=12) specimens were instrumented with pedicle screws in Group I (non-hubbed, control) and Group II (hubbed) in the opposite pedicle. Cyclic, fatigue loading in a cephalocaudad direction was applied for 2000 cycles at a rate of 1 Hertz (Hz). Pull-out testing was performed in-line with the midline of the vertebra at 0.25 mm/sec and peak POS measured in Newtons (N). Micro-computed tomography (uCT) was used to evaluate trabecular architecture and incidence of iatrogenic microfractures in both adult (n=4) and immature (n=10) specimens.

Results: Hubbed screws resulted in significantly lower POS ($p<0.05$) in all specimens (452±274N vs. 656±285N), adult specimens (291±142N vs. 512±243N), and immature specimens (747±197N vs. 922±112N). With the hubbing technique, 50% of all adult specimens, and 83% of non-osteoporotic adult specimens had visible fractures of the dorsal cortex. For immature specimens, the dorsal cortex demonstrated plastic deformation and conformed to the screw head in 88% of cases. No visible fractures occurred in the control group. uCT demonstrated microfractures of the dorsal cortex in 4/4 adult and 10/10 immature hubbed specimens, and no fractures in 0/4 adult and 1/10 immature control specimens.

Conclusion: This is the largest cadaveric study ever performed to evaluate this topic. Hubbed pedicle screws have significantly lower pull-out strength in adult and immature thoracic vertebrae, and frequently cause iatrogenic fractures of the dorsal cortex (micro or visible). This study provides the surgeon with vital information to avoid this common misconception with screw insertion.



Hubbed vs. non-hubbed pedicle screw pullout strength (452±274N vs. 656±285N)

66. A Minimum Two-Year Follow-Up Study of Simultaneous Double Rod Rotation Technique for Adolescent Idiopathic Scoliosis

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Summary: A minimum 2 year follow-up clinical results of simultaneous double rod rotation technique showed that this technique was effective in both correction of scoliosis and creation of thoracic kyphosis with pedicle screw constructs.

Introduction: Although pedicle screw (PS) system can achieve sufficient correction of scoliosis, previous methods using PSs have a difficulty in creating thoracic kyphosis. To solve these problems, simultaneous double rod rotation technique (SDRRT) has been developed for correcting both scoliosis and hypokyphosis of the thoracic spine. The purposes of this study were to evaluate the capacity of 3 dimensional deformity correction of SDRRT and its functional outcomes with a minimum 2 year follow-up.

Methods: Forty patients (3 males, 37 females) with adolescent idiopathic scoliosis have been treated with this technique and followed for more than 2 years. Average age of the patients was 14.7 years. Follow-up periods ranged from 27 to 53 months with an average of 39 months. Curve patterns based on the Lenke classification, Risser grade, operating time, blood loss, Cobb angle and thoracic kyphosis (T5-12), vertebral rotation at the apex, complications and SRS-22 were evaluated.

Results: There were 29 patients with Lenke type 1, 1 with type 2, 6 with type 3 and 4 with type 5. Risser grade was 4.1 and fusion segments were 8.7 on the average. Average operation time was 283 minutes. Average blood loss was 1045ml. Major curve changed from 61.4 degrees before surgery and 18.5 degrees at the final follow-up (correction rate: 70.0%). Average thoracic kyphosis changed from preoperative 12.6 degrees to 21.9 degrees (improved by 9.3degrees) at the final follow-up. Average apical vertebral rotation at the apex changed from preoperative 26.8 degrees to 18.4 degrees at the final follow-up. Average scores of SRS-22 were 3.33 before surgery and 4.21 at the final follow-up. One patient required additional surgery due to screw malposition.

Conclusion: Simultaneous double rod rotation technique (SDRRT) is effective not only in correction of scoliosis but also in creation of thoracic kyphosis with pedicle

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screw constructs. The main correction procedure of SDRRT is to rotate two rods with different contours simultaneously to push the spine backwards. This technique is versatile to all curve patterns of adolescent idiopathic scoliosis.

67. A Genome-Wide Association Study Identified a New Susceptibility Locus for Adolescent Idiopathic Scoliosis

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Japan

Summary: Through a genome wide association study and a replication study, we identified SNPs near LBX1 significantly associated with susceptibility of AIS in Japanese. The significance level of the association definitely satisfied that of genome-wide significance.

Introduction: Adolescent idiopathic scoliosis (AIS) is a multi-factorial disorder. Genetic factor play an important roles in its etiology; however, there is few knowledge on its susceptibility gene(s). To identify common genetic variants associated with AIS, we conducted a genome wide association study (GWAS) using >500,000 single nucleotide polymorphisms (SNPs).

Methods: We recruited 1,050 female AIS patients with a Cobb's angle of 15° or greater who had been diagnosed with AIS between age 10 and 18 years and 1,474 female control subjects. Cases and controls were genotyped using the Illumina Human610 Genotyping BeadChip and the Illumina HumanHap550v3 Genotyping BeadChip, respectively. After confirming the data quality, we analyzed the results of 455,121 SNPs between 1,033 cases and 1,473 controls for association. To confirm the association, we first checked replication in females using an independent set of 670 AIS cases and 9,823 controls. We further checked replication in male using 108 AIS cases and 1,849 control subjects. For the replication study, cases and controls were genotyped using Invader assay and the Illumina Genotyping BeadChip, respectively.

Results: Through a GWAS, three SNPs satisfied a genome-wide significance threshold of P value<1.0×10^{-7} . P value of the most significant SNP was 1.27×10^{-10} . The three SNPs were in the same linkage-disequilibrium (LD) block of ~80 kb. The LD block harboring rs11190870 contained one gene, LBX1 (lady bird homeobox 1) . We replicated the association of all the three SNPs. P value of the most significant SNP was 9.13×10^{-18}. The rs11190870 SNP showed the strongest association with AIS in both the GWAS and the replication study, with a combined P value of 1.96×10^{-26}.Furthermore, the association of the three SNPs with AIS susceptibility was also present in Japanese males, with the most significant association by rs11190870($P = 1.95 \times10^{-6}$).

Conclusion: We identified common variants near LBX1 associated with AIS. The most significant SNP had combined P value of 5.85×10^{-31} ,far more significant than those in previous studies. This is the first identification of AIS susceptibility locus with definite genome-wide level significance. Our findings would provide new insight into the pathogenesis of AIS.

68. Comparing Apples and Oranges: Molecular Pathogenesis of Adolescent Idiopathic Scoliosis Varies by Patient Ancestry

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USA

Summary: Because different racial populations have variable genetic histories, DNA-based prognostic testing cannot be applied to all racial groups without modification. These observations have relevance beyond genetic studies, as many basic and clinical research results may contain hidden flaws if these ancestral differences are not considered.

Introduction: Adolescent Idiopathic Scoliosis (AIS) is a polygenic multifactorial condition. Family studies have shown that common gene variants play an important role in the pathophysiology. Usually the population frequency of disease-related genetic variants differs between racial and ethnic groups due to the different ancestral history of these groupings.

Methods: For this study we compared DNA samples from 400 AIS patients and 600 control patients with Asian ancestry, 400 AIS patients and 600 controls with African ancestry. All diagnoses were confirmed by medical record or radiograph review. Racial admixture was excluded by testing 50,000 ancestry informative DNA markers and principal component analysis. All samples were then tested with 53 genetic markers previously associated with AIS progression in Caucasian patients.

Results: 42 of the 53 markers showed large, significant statistically differences in allele frequencies between the racial cohorts ($p<0.001$). See attached table for examples. Several of the gene polymorphisms that DNA-based prognostic testing is dependent upon are not present (the sites are monomorphic) in Asian populations.

Conclusion: DNA markers related to AIS progression vary by race. Differences in gene variants will translate into differences in the underlying chemistry of AIS. Some of these differences are likely to result in different clinical expression.

69. Idiopathic Scoliosis Mutations in VANGL1, an Axial Development Gene

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USA

Summary: We used next generation sequencing (NGS) methods to discover a gene that harbors a mutation causing idiopathic scoliosis (IS) in a three generation family. We found an excess of mutations in this gene in subsequent screens of IS cases compared to controls. This is the first study to identify mutations that cause IS. This study also provides proof-of-concept for applying NGS methods to discover genetic mutations causing IS, a key step in understanding disease pathogenesis.

Introduction: Traditional studies of IS populations have revealed important genetic associations, but causal mutations are lacking. We hypothesized that searches of protein-coding regions of the genome in families with severe, heritable IS would yield high-risk mutations. Such mutations are of also of particular interest because they are biologically interpretable.We therefore elected to use next-generation sequencing (NGS) in an extended IS family to search for an IS candidate gene encoding a rare protein-altering mutation. We also wished to test whether mutations in the discovered gene are enriched in IS patient populations compared to controls.

Methods: We captured and sequenced the entire coding genomes of four members of a three-generation IS family using the Agilent Sure-Select and ABI SOLID systems, respectively. Novel, protein-altering mutations that were shared only in the affected individuals were identified and sequenced in the rest of the family. This revealed a mutation in a gene that we subsequently screened in follow-up cohorts by traditional DNA sequencing.

Results: Results in the index family revealed a novel (L226F) mutation in the VANGL1 gene that encodes van Gogh-like 1, a protein that participates in early axial development. We screened the VANGL1 gene in a non-Hispanic white cohort (572 independent samples; 192 cases compared to 380 controls) and found a significant excess of rare protein-coding mutations in IS cases (variable threshold (VT) weighted P = .001). Screens of a smaller African American cohort (148 independent samples; 70 cases compared to 78 controls) were also suggestive (weighted VT P = .009). VANGL1 participates in a biochemical pathway that is critical in axial development. This pathway is specifically important in controlling vertebrate neural tube development and spinal cord axon directionality. The latter is of particular interest, as genes involved in the development, growth, and maintenance of spinal cord neurons have been implicated in previous genetic studies of IS.

Conclusion: Our discovery of VANGL1 mutations implicates a specific developmental pathway in IS pathogenesis. Further VANGL1 screening is warranted in larger IS cohorts to adequately assess the risk conferred by these rare mutations.

70. The Effect of Prophylactic Local Epidural Steroid Delivery in a Spinal Cord Injury Model

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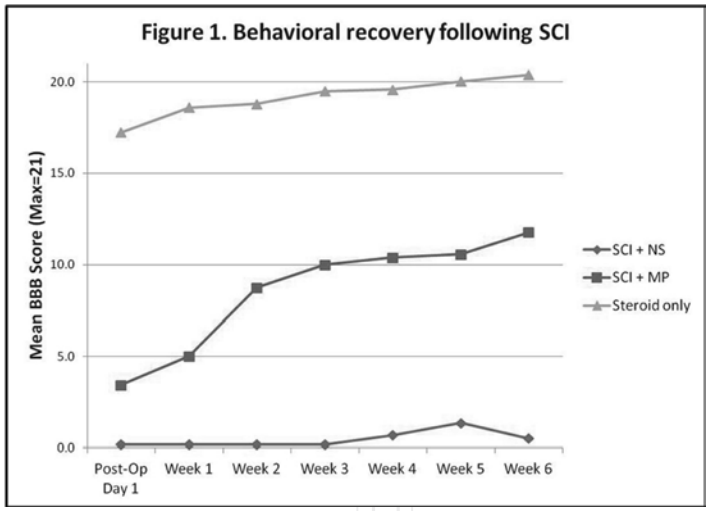
Summary: This study was performed to investigate if a prophylactic injection of the local epidural space with steroids prior to mechanical spinal cord injury (SCI) could reduce the long-term consequences of SCI.

Introduction: SCI during high-risk spinal deformity surgery still occurs despite physicians' best efforts to avoid it. Current neurophysiological monitoring strategies can only report an injury after it happens and some injuries fail to be captured. The intravenous administration of the corticosteroid methylprednisolone (MP) is currently used to reduce the secondary effects of SCI after primary insult. This procedure is associated with systemic side-effects and questionable efficacy.

Methods: In adult rats, a model of incomplete SCI was utilized by introducing a 2-French embolectomy catheter through a T10 laminotomy and compressing the cord at T8-9 by balloon inflation. There were three study groups: the treatment group with prophylactic local epidural injection of MP prior to SCI (SCI+MP); the 1st control group with pre-operative normal saline (NS) administered epidurally before SCI (SCI+NS); and, the 2nd control group with epidural injection of MP without SCI (Steroid Only). Rats were evaluated weekly for 6 weeks by two blinded evaluators utilizing the Basso-Beattie-Bresnahan (BBB) behavioral scoring system.

Results: The Steroid Only group recovered from surgery rapidly without any behavioral indication of SCI. At 6-weeks post-SCI (Figure 1), mean BBB scores were significantly different between the Steroid only group and both the SCI+NS group ($p<0.001$) and SCI+MP group ($p<0.05$). Mean BBB scores were significantly higher for the SCI+MP group than for the SCI+NS group at weeks 3, 4, and 6 ($p<0.05$), with final mean BBB scores calculated to be 11.8 and 0.5 for the SCI+MP and SCI+NS groups, respectively.

Conclusion: Rats in the SCI+MP group recovered faster and to a significantly greater extent when compared to the SCI+NS group. Prophylactic, epidural MP administration (6- and 8-point improvements at 3- and 6-weeks, respectively) has a greater effect on rat functional recovery than does intravenous MP delivered after SCI (compared to a 3-point improvement on average reported in the literature). Prophylactic treatment of high-risk spinal deformity surgery patients with a high concentration of epidural or intrathecal MP may have potential to mitigate the severity of SCI. This possibility deserves further investigation in animal and human subjects.



71. Are Volumetric Bone Mineral Density and Bone Micro-Architecture in Adolescent Idiopathic Scoliosis Associated with Leptin and Soluble Leptin Receptor?

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Summary: Previous studies suggested that leptin have profound effects on bone metabolism and growth. High Resolution Peripheral Quantitative Computed Tomography (HR-pQCT) was used to investigate bone quality in AIS and its association with leptin and soluble leptin receptor (sOB-R). AIS had deranged bone quality and a distinctly different pattern of association with leptin and sOB-R levels, indicating the presence of abnormal bone metabolism when compared with normal controls.

Introduction: Low bone mass in adolescent idiopathic scoliosis (AIS) has been well reported. Previous studies suggested that leptin have profound effects on bone metabolism and peri-pubertal growth. The aim of this study was to use High Resolution Peripheral Quantitative Computed Tomography (HR-pQCT) to investigate bone quality and its association with leptin bioavailability in AIS.

Methods: This was a case-control study involving 72 newly radiologically diagnosed AIS girls (Cobb angle 12-35°) aged 12 to 14 years old without prior treatment

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and 87 age and gender-matched normal controls. Anthropometric measurements such as body weight, height, arm span and sitting height were taken. Serum total leptin and soluble leptin receptor (sOB-R) were assayed with ELISA. Non-dominant distal radius was scanned with HR-pQCT for assessing bone quality in terms of bone morphometry, volumetric bone mineral density (vBMD) and trabecular bone micro-architecture (see Table 1 for list of parameters).

Results: AIS girls had lower cortical vBMD (p=0.006), lower cortical thickness (p=0.030), higher cortical bone perimeter (p=0.045) and higher trabecular bone area (p=0.038) when compared with controls. Correlation analysis (Table 1) on serum leptin level indicated that while its correlations with cortical bone parameters are present for both AIS and controls, the correlations with trabecular bone parameters are only present significantly in AIS group. As for correlation analysis on sOB-R, significant correlations are detected with cortical bone parameters only in control but not in AIS subjects.

Conclusion: This study showed that bone quality in AIS was deranged as compared with normal controls. In addition, the correlations between leptin and trabecular bone parameters were only present in AIS subjects while the correlations between sOB-R and cortical parameters were only present in control subjects. These distinct correlation patterns indicated abnormalities in bone metabolism and disturbance on leptin signaling. The implication and how this is linked to the generalized low bone mass and the etiopathogenesis of AIS warrant further studies.

72. Scoliosis Research Society-22 Results in 3,052 Healthy Adolescents Age Ten to 19 Years

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Summary: The SRS-22 was administered to 3,052 healthy adolescents 10 to 19 years of age from multiple racial/ethnic backgrounds to establish normative baseline values. Increasing age from 10 to 19 lowered scores in several domains and total SRS score. Whites had higher image and activity scores.

Introduction: The SRS-22 instrument was developed to assess treatment outcomes in patients with adolescent idiopathic scoliosis. To accurately assess real changes in outcome, comparative baseline scores for a normal population matched for age, gender, and race are necessary. Prior studies have been limited due to small patient numbers (n=400) and limited demographics. The purpose of our study was to evaluate a large population of adolescents from a broad mix of race/ethnic and age groups to better establish baseline normative values for the SRS-22.

Methods: The SRS-22 was administered to 3,052 healthy adolescents, 51% female, with a mean age of 14.6 years (range 10-19). We divided the children into 3 age groups for analysis: 10-12 years (362), 13-15 years (1487), and 16-19 years (1203). Racial/ethnic groups included: White 62%, African-American 14%, Hispanic 9%, Asian 6%, Native American 5%, Pacific Islander 4%. SRS-22 scores (1 worse to 5 better) were analyzed in each of 4 domains (activity, pain, image and mental) as well as total scores, to establish normative values for each group and note significant differences.

Results: Mean SRS-22 scores were: Activity (4.31 ± .48), Pain (4.44 ± .62), Image (4.41 ± .59), Mental (3.96 ± .79) and total (4.26 ± .50). Females had lower scores in the mental domain (3.90) compared to males (4.04) (p<0.000). 10-12 year olds had higher scores in the domains of activity (p<0.000), pain (p<0.000), mental p<(0.000), and total SRS score (p<0.000) compared to the 13-15 and 16-19 year olds, and the 13-15 year group had significantly higher scores than the 16-19 year olds (p<0.000) in each of the same categories. In regards to race/ethnicity, whites reported higher image (p<0.000), and activity (p<0.000), and Asians scored higher in pain (p<0.005).

Conclusion: To our knowledge, this is the largest study to date evaluating SRS-22 normative values in adolescents. Age, gender, and race had a significant impact on individual domain scores and total SRS-22 scores. In general, scores lowered as age increased from 10 to 19 years. These factors should be considered when using the SRS-22 instrument to assess patients treated for scoliosis.

73. The Natural History of Scheuermann's Kyphosis - A Comparative Study after 37-Year Follow-Up

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Summary: After 37 years of follow-up, 49 individuals with untreated Scheuermann's kyphosis have a significantly higher risk of having back pain and disabilty in comparison to a representative sample of the general population. Symptoms, however, do not restrict their working ability or employment status. No correlation between radiographic features and pain or disability were found.

Introduction: The purpose was to investigate back pain and disability and their relationship to radiographic changes in patients with untreated Scheuermann's after long-term follow-up.

Methods: Overall, 136 patients who had attended the outpatient clinics between 1950 and 1990 for Scheuermann's kyphosis were contacted, 49 of them (12 females, 37 males) responded and returned correctly filled structured questionnaires. There was no difference in the baseline data between responders and non-responders. From primary radiographs, th-kyphosis, l-lordosis, and scoliosis were measured. The number of affected vertebrae and the degree of wedging were registered. Anthropometric data, occurrence of back pain, disability scores, and employment status were compared to a representative sample (n=3835) of the normal population.

Results: After mean follow-up of 37 (6.5;25.9-53.7)y, their average age was 58.8 (8.2;44.4.-79.3)y. Male patients were significantly taller than the control subjects. At age 20, female patients were on average 6 kg heavier (P=0.016) and their mean BMI was higher (23.9 kg/m2 vs 20.8 kg/m2,P=0.001) than in the controls.

Females had a non-significant greater mean kyphosis than males. Scheuermann's patients had an increased risk for constant back pain (P=0.003), a 2.6-fold risk for disability because of back pain during the past 5 years (P=0.002), a 3.7-fold risk for back pain during the past 30 days (P<0.001), and a 2.3-fold risk for sciatic pain (P=0.005). The pain was localized in the upper back/neck in 16.3%, in the

lower back in 30.6%, and in the whole back in 28.6%. No pain at all was reported by 24.5%. Patients reported a poorer quality of life (p<0.001) and general health (p<0.001). There was no correlation between the degree of thoracic kyphosis or other radiographic parameters and disability. No difference in working ability and employment status between patients and controls was found.

Conclusion: Patients with untreated Scheuermann's kyphosis have a significantly higher risk of having back pain than the general population. Symptoms, however, do not restrict their working ability or employment status.

74. Deep Surgical Site Infection Following Growing Rod Surgery in Early Onset Scoliosis: How Does It Change the Course of Treatment?

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USA

Summary: The incidence of deep surgical site infection (DSSI) after index GR surgery was comparable to other pediatric spinal surgeries; however, the incidence was much greater following initiation of lengthenings. Whenever possible, partial implant removal for infection control will leave the patient with greater chance of later reinstrumentation to continue with lengthenings.

Introduction: Growing rod (GR) surgery is a growth-sparing technique commonly used for progressive early-onset scoliosis (EOS). Deep surgical site infection (DSSI) can potentially change the course of treatment. The goal of the study was to report the incidence of DSSI and its effects on the course of treatment and serial lengthenings.

Methods: 402 patients from a multicenter EOS database were retrospectively reviewed. Patients with at least one DSSI after GR surgery and minimum 2-year follow-up were included. DSSI was defined as an infection event requiring return to the operating room.

Results: 42 of 402 patients (24 M, 18 F) developed at least one DSSI (10.4%). 10 of 402 patients developed DSSI before the first lengthening for a total incidence of 2.5% DSSI following index surgery. 29 (7.5%) had DSSI during the course of lengthenings (mean of 4.7 lengthenings before the first DSSI), and 3 after final fusions. Mean interval between the index GR surgery and the first infection was 32.5 months (0.2-94). 21 patients (52.2%) had implant removal (11 complete, 10 partial) and their courses of treatment are summarized in table-1.

Mean age at index GR surgery was 5.9 years and mean post-index follow-up was 75.4 months (26.1-166.3). Etiologies included 17 neuromuscular, 11 congenital, 11 syndromic and 3 idiopathic EOS patients. 30 patients had stainless steel GR and 12 had titanium GR at the time of first infection.

Conclusion: The incidence of DSSI (2.5%) after index GR surgery was comparable to other pediatric spinal surgeries; however, the incidence was much greater following initiation of lengthening (7.5%). Patients with complete removal were never reinstrumented except at final fusion; however, 70% of patients with partial removal of implants were reinstrumented and continued with lengthenings.

Removal	N	Course of treatment after removal of implants	N
Complete	11	Implants replaced later at final fusion (Mean implant-free interval = 303 days)	7 (64%)
		Implants not replaced with no final fusion	4 (36%)
Partial	10	Implants replaced later with continuation of lengthenings (Mean implant-free interval = 107 days)	7 (70%)
		Implants replaced later at final fusion (Mean implant-free interval = 243 days)	3 (30%)

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

75. Major Perioperative Complications after Surgery for Cerebral Palsy: Assessment of Risk Factors

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USA

Summary: In this prospectively collected dataset of patients with CP who have undergone a spine fusion, the incidence of a major perioperative complication was 39%, which significantly increased time in the intensive care unit and hospital length of stay. Risk factors include greater kyphosis, staged procedure, lower body mass index, no antifibrinolytics, need for postoperative supplemental nutrition (PSN), and estimated blood loss, with the latter two being independent predictors of a major perioperative complication.

Introduction: Patients undergoing spine surgery for CP are at a relatively high risk for having a major perioperative complication. A prospectively collected cohort was queried to determine the incidence of a major perioperative complication and assess potential risk factors.

Methods: 127 patients with mean age 14.3 +2.6 years were identified. All major perioperative complications were stratified into: pulmonary, gastrointestinal, medical (including coagulopathy and severe hypotension), wound infection, neurologic, instrumentation related, and unplanned staged surgery. Risk factors studied included age, gender, body mass index, Gross Motor Function Classification System (GMFCS), ambulatory status, seizures, use of Depakote, curve size, pelvic obliquity, fusion to pelvis, pre-op albumin, white blood count, total protein, antifibrinolytic, EBL, operative time, surgical approach, staged or not, and PSN. After risk factors were identified, a multivariate regression analysis was performed.

Results: Overall, 39% of patients had a major perioperative complication as follows: pulmonary 30%, GI 19%, medical 12%, wound infection 5%, instrumentation related 2%, unplanned staged surgery 2%, and neurologic 1%. Complications (NC= no complication, YC= yes complication) resulted in a significantly increased ICU stay (NC=3.2, YC=7.8 days, p<.05) and hospital stay (NC= 7.7, YC= 15.6 days, p<.05). Risk factors identified included EBL (NC=1656, YC= 2843, p<.001), kyphosis (NC=40 degrees, YC=48 degrees, p=.05), staged procedure (NC=27%, YC=73%, p=.02), antifibrinolytics used (NC=70%, YC=30%, p=.05), supplemental postoperative nutrition (NC=45%, YC=55%, p<.001) , and a trend toward lower BMI (p=.08) as risk factors. Multivariate regression analysis revealed EBL and postoperative supplemental nutrition as independent predictors of a major perioperative complication.

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Conclusion: 39% of patients with CP undergoing spinal fusion experienced a major perioperative complication, with pulmonary being the most common. Complication occurrence lengthened both ICU and hospital stay. Risk factors include greater kyphosis, staged procedure, lower BMI, no antifibrinolytics, need for PSN, and EBL, with the latter two being independent predictors of a major perioperative complication.

76. Rates and Causes of Mortality Associated with Spine Surgery Based on 108,419 Procedures: A Review of the Scoliosis Research Society Morbidity and Mortality Database

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USA

Summary: This study provides rates and causes of mortality associated with spine surgery based on the SRS morbidity and mortality database. Rates of mortality are provided for a broad range of diagnoses, and the data include assessments for adult and pediatric patients. These findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

Introduction: Despite the best of care, all surgical procedures have inherent risks of complications, including mortality. Defining these risks is important for patient counseling and quality improvement. Our objective was to assess rates and causes of mortality associated with spine surgery.

Methods: The Scoliosis Research Society morbidity and mortality database was queried for spinal surgery cases complicated by death from 2004-2007, including pediatric (<21 years) and adult (>21 years) patients. Deaths occurring within 60 days and complications within 60 days of surgery that resulted in death were assessed.

Results: 197 mortalities were reported among 108,419 patients (1.8 deaths/1,000 patients). Rates of death/1,000 patients for adult and pediatric patients were 2.0 and 1.3, respectively. Based on primary diagnosis (available for 107,996), rates of death/1,000 patients were: 0.9 for degenerative (n=47,393), 1.8 for scoliosis (n=26,421), 0.9 for spondylolisthesis (n=11,421), 5.7 for fracture (n=6,706), 4.4 for kyphosis (n=3,600), and 3.3 for other (n=12,455). The most common causes of mortality included: respiratory/pulmonary (n=83), cardiac (n=41), sepsis (n=35), stroke (n=15), and intraoperative blood loss (n=8). Death occurred prior to hospital discharge for 109 (79%) of 138 deaths for which this information was reported. The specific post-operative day (POD) of death was reported for 94 (48%) patients, and included POD#0 (n=23), POD#1-3 (n=17), POD#4-14 (n=30), and POD#>14 (n=24). Increased mortality rates were associated with higher American Society of Anesthesiology (ASA) score, spinal fusion, and implants ($p<0.001$). Mortality rates increased with age, ranging from 0.9/1,000 to 34.3/1,000 for patients aged 20-39 years and >90 years, respectively.

Conclusion: This study provides rates and causes of mortality associated with spine surgery for a broad range of diagnoses and includes assessments for adult and pediatric patients. These findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

77. Thromboembolic Complications in Children with Spinal Fusion Surgery

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USA

Summary: In children, the incidence of developing thromboembolic complications including deep venous thrombosis (DVT) and pulmonary embolism (PE) after spinal fusion surgery is unknown. We report an incidence of 0.19%, and find that it is associated with older age and thoracolumbar fractures. The incidence of PE after spinal fusion for adolescent idiopathic scoliosis is 3.5 per 10,000 cases. (Prognostic Level II).

Introduction: The incidence of thromboembolic complications (TEC): deep venous thrombosis (DVT) and pulmonary embolism (PE) after pediatric spine deformity surgery is unknown. The aim of this study is to report the incidence of DVT and PE after pediatric spinal fusion surgery and to analyze the association with patient characteristics, in order to formulate preventive recommendations.

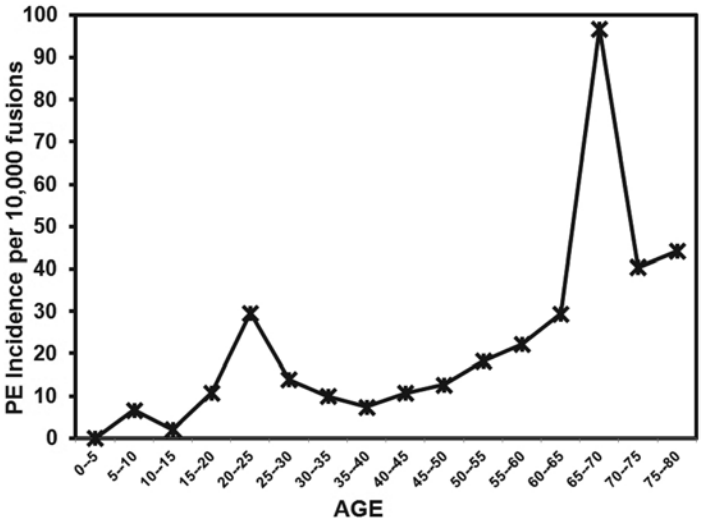
Methods: Using the Nationwide Inpatient Sample database, we identified children ≤18 years from 2000-2008, who developed DVT or PE after pediatric spinal fusion. Chi-square and logistic regression tests were used to analyze the effect of discrete and continuous variables on DVT and PE rates.

Results: The incidence of TEC in the 90,688 children who underwent spinal fusion surgery from 2000-2008 was 0.19%: 46 (0.05%) developed PE and 143 (0.16%) DVT. The youngest associated age was 9 years for DVT and 10 years for PE. For each additional year after age 10, the odds of developing DVT increased 1.4-fold ($P<0.01$) and of PE increased 1.6-fold ($P=0.03$).

Males had 1.5X DVT rate compared to females ($P=0.02$); difference in PE rate not significant ($P=0.2$). Caucasian children had 8.5X PE rate compared to African American children ($P=0.01$); difference in DVT rate not significant ($P=0.2$).

There was a significant difference in DVT rate by patient diagnosis ($p<0.01$): 1.1% in vertebral fractures, 0.15% in spondylolisthesis, 0.1% in congenital scoliosis, and 0.06% in adolescent idiopathic scoliosis (AIS). There was also a significant difference in PE rate by patient diagnosis ($P<0.01$). 25 (of 46) PE patients had vertebral fractures, 15 had AIS, 5 had spinal tumors and 1 had NF-1. Overall incidence of PE in AIS patients was 0.035. There was no significant difference in rate of DVT ($P=0.1$) or PE ($P=0.2$) between anterior vs. posterior spinal fusion in all patients. Six patients with PE died (all with vertebral fractures) resulting in an overall mortality rate of 6.6 deaths per 100,000 pediatric fusions.

Conclusion: The incidence of developing thromboembolic complications after pediatric spinal fusion surgery is about 0.19%; higher rates are associated with older age and vertebral fractures. Incidence of PE after routine spinal fusion in patients with AIS is 3.5 per 10,000 cases.



Overall, the odds of developing PE in patients ≤15 years of age were 9.8 times less than for the older age groups combined (P<0.01).

78. Reduced Rate of Late Infection after Posterior Spine Instrumentation with Titanium-Alloy vs. Stainless Steel Implants

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Summary: From a prospective operation registry of posterior spinal implants we have retrieved patients operated on a second time due to an infectious complication. We found a significant reduction of this complication when using Titanium implants (0.75% infection) compared with the use of Stainless Steel implants (7.3% infection).

Introduction: Implant associated late deep infection after posterior spine surgery is a significant complication, observed in 5-7 per cent of cases when carefully investigated. Clinically, it often ends with implant removal with sometimes a less favourable end result. It has been suggested that Titanium (Ti) implants may be protective against infection via formation of Ti-peroxy-gel covering the Ti implants.

Methods: A prospective registry of all consecutive patients undergoing instrumented posterior spine surgery from 1993 to 2009 was reviewed. Infection was defined as a patient undergoing a second posterior surgery for infection. The minimum follow-up time was 2 years.

Results: From 1993 to 2009 stainless steel (SS) implants had been used in 554 cases, and 2005-2009 Ti implants had been used in 544 patients. The diagnoses were scoliosis in 392, fracture 180, spinal stenosis 122, metastatic disorder 120, spondylolisthesis 74, other deformities 86, degenerative disorders 61, and other various diagnoses in 45 cases. Primary infectious spondylitis in 18 were excluded from the cohort. Among patients with SS implants we observed late developing infection in 40/546 (7.3%) vs. 4/534 (0.75%) in our Ti series ($p < 0.0001$).

The proportion of cases with index diagnosis scoliosis was in the SS group 155/546 (28%) and in the Ti group 237/534 (44%); with corresponding infectious complications necessitating any re-operation for SS 15/155 (9.7%) and for Ti 1/237 (0.4%).

Conclusion: The rate of infectious complications after instrumented posterior spine surgery was significantly reduced when using Ti compared with SS implants.

79. High Dose BMP-2 in Adults: Major and Minor Complications in 502 Cases

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Summary: Major and minor complications associated with high dose BMP (>40mg) were evaluated in 502 patients. 14.3% sustained major surgical complications and 12% sustained major medical complications. 1% radiculopathy rate 3 month post-op and 3.4% cancer prevalence at latest f/u were noted but did not correlate with increasing BMP dosage.

Introduction: Our objective was to document medical and surgical complications (major and minor) associated with high dose BMP (>40mg).

Methods: 502 adult consecutive patients receiving high dose BMP from 2002-2009 and managed by 3 surgeons at one institution were enrolled. Surgeries performed in the thoracic and lumbar spine were included. Major and minor complications were noted during intraoperative and perioperative time points. Complications potentially associated with BMP such as radiculopathy, sterile seromas and cancer were evaluated and their correlation with BMP dose was examined.

Results: An average of 115 mg of BMP was used. Average age was 52.4 (18-80). 410 females and 92 males were enrolled. 265 primary and 237 revision cases, including 110 ALIFs and 151 TLIFs, with an average of 11.5 instrumented vertebrae. Average follow up was 42 month (14-92). Diagnoses were idiopathic scoliosis (41%), degenerative scoliosis (31%) & fixed sagittal imbalance (18%). Intraoperative complications were 8.2%. Perioperative major surgical complications were 14.3%. Perioperative major medical complications were 12%. Minor medical complications were 19.7% and minor surgical complications were 2.6%. BMP related complications were radiculopathy (1%), cancer (3.4%) and sterile seroma (0.6%). Logistic regression analysis and Pearson correlation did not find a significant correlation between BMP dosage and radiculopathy ($r = -0.006$), seroma ($r = -0.003$) or cancer ($r = -0.05$).

Conclusion: This is the largest study to date to examine complications associated with high dose BMP. 14.3% sustained major surgical complications and 12% sustained major medical complications. 3.4% cancer prevalence was found but no correlation between increasing BMP dosage and cancer, radiculopathy or seroma was found.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

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80. Operative Time and Patient Age, Rather Than Recombinant Human Bone Morphogenetic Protein-2 (BMP) Use, Increase Major Complications in Adult Spinal Deformity (ASD) Surgery

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Summary: Multicenter, prospective, evaluation of 257 consecutive ASD patients demonstrated BMP use and location of BMP (posterior, interbody, or combined) did not increase major complications, superficial or deep infections, or complications requiring surgery compared to patients not receiving BMP. Mean BMP dose/level was: posterior=2.4mg/level, interbody= 2 mg/level. OR time most strongly correlated with major complications and deep infections, age with wound problems, and anterior levels fused and age with neurological complications. Further research is needed for higher BMP dosing.

Introduction: BMP is increasingly used off label. Complications may correspond to location of BMP use. Purpose: evaluate complications associated with location of BMP use in ASD surgery.

Methods: Multicenter, prospective analysis of complication rates following ASD surgery for 257 consecutive ASD patients. Patients divided into BMP (BMP; n=155) or no BMP (NOBMP; n=102). BMP divided into location of BMP use: posterior only (PBMP; n=93), interbody only (IBMP; n=8), and interbody + posterior (I+PBMP; n=54). Inclusion criteria: age ≥ 18 years and surgery for ASD. Complications for BMP location evaluated. Multivariate analysis performed.

Results: 257 ASD patients, mean age 57 years (range 18-84), mean follow up 20 months (range 2.2-38) evaluated. Mean BMP dose/level: posterior=2.4mg/level (range 0-12), interbody= 2mg/level (range 0-18). I+PBMP was older than PBMP (63 vs 54 years, respectively; $p<0.05$). Charlson comorbidity index was similar for all groups. Mean levels fused were similar for PBMP (13), I+PBMP (12) and NBMP (12), but fewer for IBMP (7.6 levels; $p<0.05$). Total OR time was greater for I+PBMP (491min) vs NBMP (412 min; $p<0.05$). EBL was greater for I+PBMP (2795ml) vs PBMP (1457ml) and NBMP (1748ml; $p<0.05$). Osteotomies/patient were similar for PBMP (4.3) and I+PBMP (4.1) but fewer for NBMP (1.5) and IBMP (1.1; $p<0.05$). 3 column osteotomies/patient were similar for IBMP (0.4), I+PBMP (0.3) and NBMP (0.3) but fewer in PBMP (0.1; $p<0.05$). Major complications, wound complications, superficial and deep infections, and complications requiring return to OR were similar for all groups. OR time most strongly correlated with major complications and deep infections, age with wound problems, and anterior levels fused and age with neurological complications.

Conclusion: Location of BMP use in ASD surgery, at reported doses, does not increase major complications, deep infections, or complications requiring surgery. Further research is needed to evaluate outcomes for higher BMP dosing.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

81. Change in Classification Grade by the Schwab-SRS Adult Spinal Deformity (ASD) Classification Predicts Impact on Health Related Quality of Life (HRQOL) Measures: Prospective Analysis of Operative and Nonoperative Treatment

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Summary: The Schwab-SRS classification of adult spinal deformity (ASD) provides a validated method to describe ASD and correlates with baseline health-related quality of life (HRQOL) measures. The current study investigated if the classification could predict changes in HRQOL values following treatment. ASD patients who demonstrated changes in classification modifiers following operative or nonoperative treatment had corresponding changes in HRQOL measures. This demonstrates that the Schwab-SRS classification is responsive to changes in disease state and can be used to predict treatment outcomes.

Introduction: ASD has traditionally been described using pediatric classifications that neglect sagittal spinopelvic parameters. Our hypothesis was that the Schwab-SRS classification, a validated system to classify ASD, will be responsive to and predict changes in HRQOL measures from baseline to 1 yr follow-up for operatively (OP) and nonoperatively (NONOP) treated ASD patients.

Methods: Multicenter, prospective, consecutive case series. Inclusion criteria: ASD, age>18, baseline and min 1 yr x-rays and HRQOL measures (Oswestry Disability Index [ODI], SRS-22 and SF-36). The Schwab-SRS classification includes 3 sagittal modifiers, each with 3 grades (normal, moderately poor and poor). These modifiers are sagittal vertical axis (SVA: <4, 4-9 or >9cm), pelvic tilt (PT: <20, 20-30 or >30°), and pelvic incidence/lumbar lordosis mismatch (PI-LL: <10, 10-20 or >20°). Changes in modifiers at 1 yr were assessed for impact on HRQOL from pre-treatment values.

Results: 391 patients met criteria (mean age=54 yrs; 85% women; OP, n=189; NONOP, n=202). Change in SVA modifier at 1 yr was associated with changes in ODI, SF36 physical component score (PCS) and SRS-22 total and all subscores ($p<0.03$), but not the SF-36 mental component score (MCS). Change in PI-LL modifier at 1 yr was associated with changes in SF-36PCS, SRS-22 total score and 4 of the SRS-22 subscores ($p<0.03$). Changes in SVA and PI-LL modifiers were associated with likelihood of achieving minimal clinical important difference for ODI and SRS subscores ($p<0.03$). Changes in PT modifier were not significantly associated with changes in HRQOL measures.

Conclusion: The Schwab-SRS classification of ASD provides a validated language and has significant association with HRQOL measures. The current study demonstrates that the classification modifiers are responsive to changes in disease state and reflect significant changes in patient reported outcomes.

82. Criteria for Determining LIV in Lenke 6C Curves: Suk Criteria vs. the End Vertebrate

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USA

Summary: This investigation assesses the efficacy of the EV and Suk's criteria with respect to radiographic and clinical outcomes. In the cohort, the observed rate of L3 selection was significantly higher than predicted by Suk criteria (40.3% vs. 59.7%), as surgeons attempted to save distal fusion levels. No differences in trunk shift, lumbar percent correction, lumbar prominence, and EIV measurements between the groups. Hence, Suk's Criteria may over estimate the need to select L4 as LIV.

Introduction: Several different criteria exist to aid in the determination of Lowest Instrumented Vertebrate (LIV) of Lenke 6C adolescent idiopathic scoliosis (AIS) curves (i.e. Suk et al, End Vertebrate). This investigation assesses the efficacy of the EV and Suk's criteria with respect to radiographic and clinical outcomes.

Methods: A multi-center prospective AIS database registry was used to identify Lenke 6C curve (lumbar curve greater than >45°), treated with greater than 80% Pedicle screw instrumentation, and minimum two years follow up The data was categorized based on two variables: Lowest Instrumented Vertebrate (LIV) relationship to end vertebrate (EV) and the Suk Criteria for LIV (Suk) selection in double major curves. The outcome variables evaluated were SRS scores, percent lumbar correction, EIV measurements, Trunk shift, and Lumbar Prominence.

Results: There were 67 patients in this cohort, 40.3% met Suk type A curve for fusion to L3. However, the actual rate of fusion to L3 was significantly higher at 59.7%(p=0.006). Furthermore, 62.6% were fused to distal EV, 13.4% to EV-1, and EV+1 to 20.8%. The radiographic and clinical outcome measures for patients fused to L3 and adhered to Suk criteria were statistically similar to those that did not (see Table 1). When using EV as criteria for distal level selection, we observed statistically similar outcomes in fusing to EV, and EV+1. However, EV-1 had significantly lower percent correction, larger lumbar prominence and larger amounts of truncal shift (see Table 1). No Differences in SRS scores were noted.

Conclusion: Using Suk's Criteria, the expected rate of selecting L3 vs. L4, as LIV was 40.3%. However, in the cohort, the observed rate of L3 selection was significantly higher as surgeons attempted to save distal fusion levels. There was no statistical difference in trunk shift, lumbar percent correction, lumbar prominence, and EIV measurements between the group fused to L3 and adhered to Suk Criteria and the group that did not. Hence, Suk's Criteria may over estimate the need to select L4 as LIV. Lastly, Fusing Short of the end vertebrate leads to poorer lumbar correction, increased trunk shift, and lumbar prominence.

Level Determinants	% Correction	LIV Tilt	LIV Translation	LIV disc Angulation	C7 to CSVL	Trunk Shift	Lumbar Prominence
L3	66 ± 12%	-4.9±7.9	-1.4±1.5	-4.4±4.1	-0.46±2.2	1.1±0.8	3.2±2.4
L4	72±13%	-6.8±8.2	-0.8±1.0	-5.6±7.2	-0.82±1.6	0.9±0.7	3.4±2.29
P-value	*p<0.05*	0.37	*p<0.05*	*0.644*	0.39	0.29	0.48
LEV-1	*57.± 12%*	*-5.8±5.3*	*-1.6±1.3*	4.8±3.3	-0.48±1.9	*1.4±0.6*	*5±2.78*
LEV L3	69±11	-4.7±5.4	-1.1±1.4	3.2±3.2	-0.41±1.1	1.0±0.7	3.5±2.1
LEV L4	71±12%	-6.9±8.5	-0.8±0.9	5.8±4.6	-0.81±1.3	0.9±0.7	3.2±2.8
LEV+1	73.±13%	-5.4±5.9	-0.7±1.2	3.5±3.5	-0.88±1.7	0.9±0.7	3.6±1.9
P-value	*p<0.05*	*0.261*	*p<0.05*	0.44	0.66	*p<0.05*	*p<0.05*
Suk Criteria* Adherence at L3 Type A - L3 crossing the mid-sacral line in right bending & L3 rotation ≤grade II in left bending.→Fused to EV/ L3 Type B - L3 does not cross the mid-sacral line in right bending & L3 rotation >grade II in left bending.→ fuse to the EV + 1-2,/L4.							
Yes	67 ± 14 %	-4.8±9.9	-1.2±1.41	-4.8±4.1	-0.3±0.97	1.1±1.1	3.43±2.39
No	64.± 11%	-5.0±7.2	-1.6±1.65	-4.1±5.7	-0.8±1.13	1.2±0.8	3.17±2.02
P-value	0.67	0.62	0.296	0.55	0.22	0.58	0.23

Table 1- Distal Level Selection in 6C curves treated with Pedicle screw instrumentation

83. Lowest Instrumented Vertebra Selection for Lenke 5C Scoliosis: A Minimum Two-Year Radiographic Follow-Up

Yu Wang, MD, PhD; Cody E. Bunger
Denmark

Summary: A 2-year radiographic follow-up

Introduction: 5C curves are relatively rare in AIS, and few studies have focused on this type of AIS. Such questions as "How does the curve change over time in the postoperative period?", "Is lowest instrumented vertebra (LIV) selection correlated with final correction and balance?" and "How should we select LIV for Lenke 5C curves?" need to be answered.

Methods: We reviewed all the AIS cases surgically treated in an institution from 2002 through 2008. Inclusion criteria were as follows: (1) patients with Lenke 5C curves who were treated with selective lumbar fusion; (2) minimum 2-year radiographic follow-up. Standing posteroanterior (AP) and lateral digital radiographs were reviewed at four junctures: preoperative, immediate postoperative, 3-months- and 2-years postoperative.

Results: Of the 278 patients reviewed, 30 met the inclusion criteria. The following results were observed: (1) From the perspectives of both Cobb angle and vertebral translation, significant correction was achieved; (2) The correction obtained by surgery was well retained in the postoperative period; (3) While preoperative spinal imbalance was common in this group of patients, the majority eventually attained balance at 2 years; (4) LIV selection was significantly correlated with the 2-year correction and balance; (5) The formula for predicting final correction was: final lumbar AV-CSVL distance = 14.1 + 1.2(Pre-op LIV-CSVL distance). The adjusted R2=0.58. The formula for predicting final trunk balance was: final thoracic AV-CSVL distance = 36.2 + 0.5(Pre-op thoracic AV-CSVL distance) + 0.7(Pre-op LIV-CSVL distance). In the literature as well as in the current study, the overall preoperative LIV-CSVL distance is 28 mm and the overall preoperative LIV tilt is 25 degree.

Conclusion: In Lenke 5C scoliosis, preoperative spinal imbalance is common, although the majority of patients attain balance at 2 years. Significant correction loss is not common in the postoperative period. LIV selection significantly correlates

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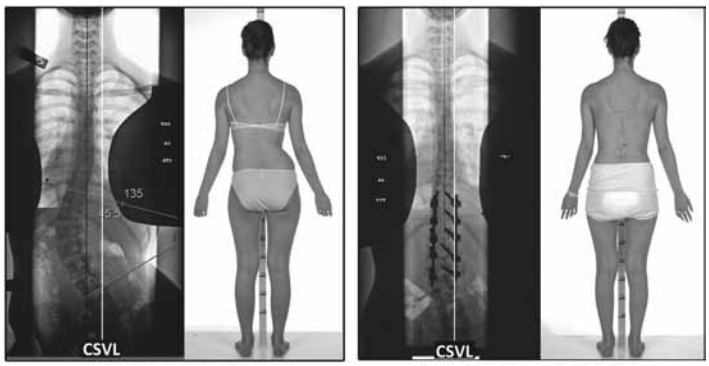
with 2-year correction and balance. A translation of 28 mm and a tilt of 25 degree may be used as a general criterion for selecting LIV.



Radiographs and clinical photos of a patient show a typical example of Lenke 5C scoliosis: Preoperative spinal imbalance is a common issue.

84. The Treatment of Thoracolumbar / Lumbar Adolescent Idiopathic Curves (Lenke 5C): Anterior vs. Posterior Approach with Modern Instrumentation

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USA

Summary: Lenke 5C adolescent idiopathic scoliosis (AIS) that fails conservative management has traditionally been treated by ASF, however, PSF with segmental instrumentation is an attractive alternative using the more common posterior approach. In this multicenter review, ASF with modern instrumentation was associated with fewer motion segments fused than PSF, equivalent major curve correction, less spontaneous correction of the compensatory curve, no kyphogenesis or pseudarthrosis, longer length of stay and operative time, and similar clinical outcomes at 2-year follow-up.

Introduction: Lenke 5C Adolescent Idiopathic Scoliosis(AIS) that fails conservative management has traditionally been treated by anterior spinal fusion(ASF) which may save a fusion level. Concerns about anterior convex curve compression causing kyphosis, recent advances in segmental instrumentation, and the more common posterior approach have made posterior spinal fusion(PSF) an attractive alternative.

Methods: A multicenter database was searched for Lenke 5C AIS patients undergoing ASF or PSF with a minimum 2-year follow-up. Clinical charts, operative records, pre- and post-operative radiographs were reviewed.

Results: Lenke 5C AIS patients(n=39: 33F,6M) at mean follow-up of 46.5±29.7 months underwent ASF(n=25) with large diameter single rods(n=11) or small diameter dual rods(n=14), or PSF(n=14). Patients undergoing ASF were younger(ASF 14.3±2.0 vs PSF 15.6±1.3yrs) (p<.05) and had fewer motion segments fused(ASF 3.9±0.5 vs PSF 4.7±0.8 levels)(p=.001). Hospital LOS was longer following ASF than PSF(7.1 vs 5.9days)(p<.05) as were operative times (239±46 vs 197±63min)(p<.05). There was no significant difference in EBL(p=.36).

Preoperative Cobb angles of the major and compensatory curves were similar between groups (p=NS). Postoperatively, major curve correction was to 12.7±6.4deg (75.4±12.6%) in the ASF group and 17.4±6.7deg (66.0±14.4%) in the PSF group (p<.05). The compensatory curve corrected to 22±8deg (28±26%) ASF and 16±10deg(49±31%) PSF(p<.05). There was no difference in curve correction between large diameter single rod and dual rod constructs(p=.11). There was no difference in T5-T12 kyphosis, T12-S1 lordosis, SVA, junctional kyphosis, or LIV tilt preoperatively or at final follow-up(p=NS). One major complication required re-operation following PSF and none following ASF. At most recent follow-up all patients went on to fusion and there was no difference in total or domain specific SRS-22 scores.

Conclusion: Lenke 5C AIS treated by ASF allow fusion of fewer motion segments and excellent curve correction at 2-year follow-up but increased hospital LOS and operative times. PSF allowed improved spontaneous correction of the non-structural curve. At a minimum 2-year follow-up, fusion rates and clinical outcomes were similar between ASF and PSF.

85. The Clinical Value of an Intermediate Risk Score with AIS Prognostic Testing

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USA

Summary: AIS-PT allows personalized risk assessments to guide clinical management. All patients with intermediate scores have a high enough risk of progression that they truly need to be followed by scoliosis specialists.

Introduction: A novel, DNA-based, AIS Prognostic Test (AIS-PT) became available for clinical use in 2009. The AIS-PT was developed to assess risk of curve progression in mild AIS patients– specifically to identify mild scoliosis patients who have a very low risk of progressing to a severe curve. At least, 25% of patients will get an "intermediate risk" interpretation because their AIS-PT score falls between 51 and 180. Some have questioned the clinical utility of scores in this intermediate range. The present study seeks to refine the predictions that can be based upon scores in the intermediate range.

Methods: The AIS-PT uses a DNA panel of 53 markers and the patient's current Cobb Angle to assign a risk of progression score of between 1-200. Data from independent validation cohorts were used to evaluate all patients with an AIS-PT score between 51 and 180. All patients were tested at skeletal maturity using their Cobb angle at initial presentation thus indicating what their score would have been at initial consultation. The clinical course of their AIS was documented prior to testing and therefore care was "blinded" with respect to the test result.

Results: Data were available on 340 patients with intermediate risk AIS-PT scores. Clinical outcomes were compared by score decile. For the 34 patients with score between 51 and 58, one patient progressed to a severe curve and only three patients progressed beyond 30 degrees. For the 34 patients in the highest decile (scores between 160 and 180), 25 patients progresses to a severe curve and 33 progressed to a Cobb greater than 30 degrees. There is a linear increase in the risk of progression and an exponential increase in the risk of progression to a surgical curve with increasing AIS-PT scores.

Conclusion: Within the intermediate score range, individual risks vary tremendously (>20 fold) based on the actual score observed.

86. Amicar vs. Tranexamic Acid: A Prospective Randomized Double-Blinded Study

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USA

Summary: A single center prospective double-blinded trial comparing the use of Amicar and Transexamic Acid in posterior spinal fusions. No significant differences between cohorts were found.

Introduction: Amicar and TXA have been shown to decrease blood loss in pediatric spinal deformity cases when compared with controls. In this study we compared the use of Amicar with that of TXA.

Methods: A randomized, double-blinded prospective trial was initiated in which patients were randomized to receive either Amicar or TXA during their scoliosis surgery. Patients received a pre-operative work-up through our Pediatric Blood Avoidance Service to screen for any bleeding abnormalities. On the day of surgery patients were randomized and the pharmacy supplied the anesthetist with either TXA or Amicar in a blinded fashion. Objective measurements (cell saver volumes and sponge weight) of blood loss were utilized in comparing blood loss. Baseline demographic comparisons included age at surgery, type of scoliosis, sex, height, and weight. Deformity comparisons included largest initial Cobb angle and largest remaining Cobb angle within instrumented segment. Intra-operative comparisons included: calculated blood loss, number of levels instrumented, number of osteotomies, and operative time, and allogenic transfusion.

Results: Forty-four patients were enrolled with data available for review (N=22 Amicar, N=22* TXA). Ten patients had neuromuscular scoliosis (Amicar 4 and TXA 6). No differences were seen in terms of age, sex, height, weight, levels fused (10.5), number of osteotomies performed, initial Cobb angles (66+/-18 vs 61+/-12), final Cobb angles (18+/-17 vs 14+/-10), OR time (264 min vs 251 min) and time per level (26 vs 27 min). The calculated blood loss was 1289+/-1089 ml in the Amicar group and 903+/-496 ml in the TXA group (p=0.4) with an average estimated blood loss per level at 117+/-72 in the Amicar group and 101 +/-89 in the TXA group p=0.3. No difference in transfusion rates (18 vs 14%) was observed.

Conclusion: This is the first prospective randomized trial to compare the use of the two clinically available anti-fibrinolytics in pediatric spinal deformity surgery. With our sample population we were unable to demonstrate a significant difference between medications.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

87. What Would Be the Annual Cost Savings if Fewer Screws Were Used in AIS Treatment in the US?

A. Noelle Larson, MD; David W. Polly, MD; Stacey J. Ackerman, MSE, PhD; Charles Gerald T. Ledonio, MD; Baron S. Lonner; Suken A. Shah, MD; Paul D. Sponseller, MD; John B. Emans, MD; B. Stephens Richards, MD; Minimize Implants Maximize Outcomes Study Group
USA

Summary: We estimate the economic impact of using fewer screws in the treatment of AIS. Our model assumes equivalent clinical results between low- and high-density pedicle screw constructs. We estimate that switching from a standard to a minimum strategic implant density pattern would prevent 1,223 malpositioned screws, avert 28 to 116 revision surgeries for implant malposition, and reduce the cost of hospitalization by 5% to 10% ($15M to $27M in total savings annually with $14M to $24M from implant costs alone).

Introduction: There is substantial heterogeneity in anchor density (screws per level fused) in AIS surgery. Assuming equivalent clinical outcomes between a high- vs. low-density screw pattern (Lonner, 2012), we aim to evaluate the potential cost savings of using fewer screws.

Methods: Descriptive analyses explored annual costs for AIS inpatient stays using discharge data from the 2009 KID-HCUP (AHRQ), a national all-payer inpatient database. Patients 10-17 years old were identified using the ICD-9-CM 737.30 in the primary diagnosis field. All inpatient stays were assumed to represent 10-level fusions with pedicle screws for AIS (Kamerlink, 2010). Standard screw density was defined as 1.48 (mean for PPSS database) and minimum strategic as 1.06 (Lonner, 2009). Surgical return for screw malposition was $23,762 (Watkins, 2010). A sensitivity analysis was performed by varying cost per screw ($600-$1000) and rate of surgical revisions for screw malposition (0.117% - 0.483% of screws, 0.8-4.3% of patients). Reported outcomes include estimated prevented malpositioned screws (set at 5.1%, Ledonio, 2011), averted revision surgery, and annual cost savings (2009 U.S. dollars), assuming similar clinical outcomes (rates of complications, revision) with a standard vs. minimum strategic implant density pattern.

Results: Total annual costs for 5,710 AIS hospital stays was $278M ($48,900 per patient). Substituting a minimal strategic for standard screw density yields 4.2 fewer screws implanted per patient (Table) with 1,223 malpositioned screws prevented, and 28-116 revision surgeries for implant malposition averted, with an annual cost savings of $14M-$24M (5%-10% reduction in the total cost of AIS hospitalizations).

Conclusion: A minimum strategic implant density pattern could potentially decrease national AIS hospitalization costs by 10% and may prevent up to 116 revision surgeries annually for screw malposition, which would improve the safety and efficiency of care. However, such a screw construct must first be proven safe and effective.

88. Surgical Treatment of Main Thoracic Adolescent Idiopathic Scoliosis: A Prospective Ten-Year Follow-Up Study

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USA

Summary: Ten-year outcomes in patients with surgically treated AIS.

Introduction: The purpose of this study was to prospectively evaluate the surgical outcomes in patients with idiopathic scoliosis at ten years following spinal instrumentation and fusion.

Methods: Forty-nine patients with major thoracic scoliosis treated with posterior (PO, n=16), anterior thoracoscopic (AT, n=17), and anterior open (AO, n=16) spinal instrumentation with 10y follow-up were evaluated. Patient data (radiographic measures, SRS scores) for the preoperative, two-year (2y), and ten-year (10y) postoperative time points, as well as complication rates were compared.

Results: The average major Cobb angle at 2y follow-up was 25 ± 7° and at 10y follow-up was 27 ± 9°. Three patients (2 AO, 1 PO) had >10° increase in the

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major Cobb angle between 2 and 10 years. The average T5-12 Kyphosis at 2y was 27 ± 12° and 10y was 27 ± 13°. One AO patient exhibited >10° increase in the sagittal plane. Three total patients had >10° increase in proximal junctional kyphosis (2 AO, 1 PO). The rate of major complications was 20% (AO 38%, AT 12%, PO 13%). Rod failure occurred in 2 patients (1 PO, 1 AT): the 1 AT patient required surgical revision with posterior spinal instrumentation and fusion (PSF). Three patients (all AO) had loss of screw fixation, and 1 required PSF. One AO patient had screw breakage requiring revision. Pseudoarthrosis was seen in 1 AO patient at 10y follow-up and 1 AT patient (required PSF). One AO patient exhibited the crankshaft phenomenon requiring revision PSF. One postoperative infection was observed in the PO group requiring removal of instrumentation. The 10y reoperation rate was 10% (AO 25%, AT 6%, PO 6%).

Conclusion: The 10 year outcomes were similar with regards to radiographic results and complication rates for the Posterior and Anterior Thoracoscopic approaches. The Anterior Open cases had 3x more major complications and revision procedures than either of the other treatments for thoracic AIS.

	Posterior	Anterior Open	Anterior Thoracoscopic
Preop Cobb	54±11	54±11	49±7
2 yr Postop Cobb	26±7	26±10	24±6
10 yr Postop Cobb	29±9	29±10	24±7
Preop T5-12 Kyphosis	20±13	17±13	19±12
2 yr Postop Kyphosis	23±10	26±11	30±14
10 yr Postop Kyphosis	22±10	29±14	28±13
Preop SRS total	4.1±0.5	4.1±0.5	4.1±0.5
2 yr Postop SRS total	3.4±0.7	3.6±0.7	3.4±0.6
10 yr Postop SRS total	3.7±0.8	3.7±0.9	3.3±0.7
Major complication rate	13%	38%	12%
Revision surgery rate	6%	25%	6%

89. Surgical Correction of Lenke 1A Curves: What are the Changes Taking Place in 3D?

Stefan Parent, MD, PhD; Marjolaine Roy-Beaudry, MSc; Jihane Rouissi; Jean-Marc Mac-Thiong, MD, PhD; Carl-Éric Aubin, PhD, PEng.; Peter O. Newton, MD; Suken A. Shah, MD; Hubert Labelle, MD
Canada

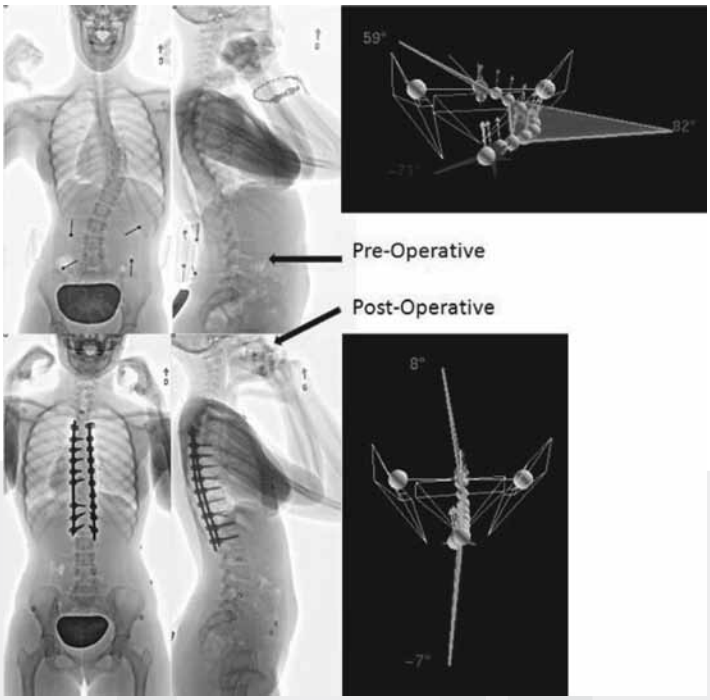
Summary: Three-dimensional analysis was performed to identify which parameters are modified following surgical correction of Lenke 1A curves. Thoracic and lumbar Cobb angles improved as did the planes of maximal deformity. Hypokyphotic curves improved following surgery. Cervical kyphosis was present pre-operatively and did improve following surgery. There seems to be a coupling effect between thoracic and lumbar parameters improvements following surgery.

Introduction: Surgical correction of AIS curves is thought to modify not only the coronal and sagittal profiles but also the 3D deformity. A new method based on a transverse plane projection (daVinci view) has recently been proposed by the SRS 3D Scoliosis committee to better understand the 3D deformity occurring in AIS. The objective of this study was to identify which 2D and 3D parameters are affected following surgery for Lenke 1A curves.

Methods: : All patients with Lenke 1A curves that underwent posterior fusion and instrumentation at one institution between 2006 and 2010 were recruited. Patient's characteristics, preoperative and postoperative measurements (Cobb angles, cervical, thoracic and lumbar sagittal curves and the daVinci representation) were recorded. Patients were first analyzed as one group by using the daVinci representation. Patients were then subdivided into two thoracic kyphosis subgroups (< 20° (hypokyphosis) and 20°-40° (normo-kyphosis)) to determine the impact of kyphosis on surgical correction.

Results: A total of 57 consecutive Lenke 1A patients were included (mean age of 15.6 years old for 50 girls and 7 boys). Thoracic and lumbar Cobb angles improved from 58° to 16° (p<0.001) and from 40° to 15° (p=0.002) respectively. The planes of maximal curvature (PMC) improved from 79° to 28° (p<0.001) for the main thoracic and from 52° to 22° (p<0.001) for the lumbar curve. Cervical kyphosis was found pre-operatively (12°) and improved to 8° (p=0.01). For the hypokyphosis group (19 patients), post-operative changes were still significant with the addition of improved sagittal profile for hypokyphosis (11 to 21°, p<0.001). No changes in the kyphosis were found in the normokyphotic group (33 to 31°, p=0.08). Lumbar correction was highly correlated with thoracic correction (r= 0.496; p=0.000) and lumbar PMC also followed thoracic PMC improvements (r= 0.442, p=0.001).

Conclusion: Surgical correction of Lenke 1A curves led to an improvement of several 3D parameters that are closely inter-related. There seems to be a coupling effect between the thoracic and lumbar 3D curve changes with general improvement following surgery. Cervical kyphosis was present pre-operatively and slightly improved post-operatively.



Pre-operative and post-operative radiographs with corresponding daVinci view showing improvement in the planes of maximal curvature.

90. Postoperative Shoulder Imbalance in Lenke Type 1A Curve and Related Factors

Morio Matsumoto, MD; Kota Watanabe; Noriaki Kawakami, MD, DMSc; Taichi Tsuji; Koki Uno, MD, PhD; Teppei Suzuki; Manabu Ito, MD, PhD; Haruhisa Yanagida, MD; Shohei Minami; Tsutomu Akazawa, MD
Japan

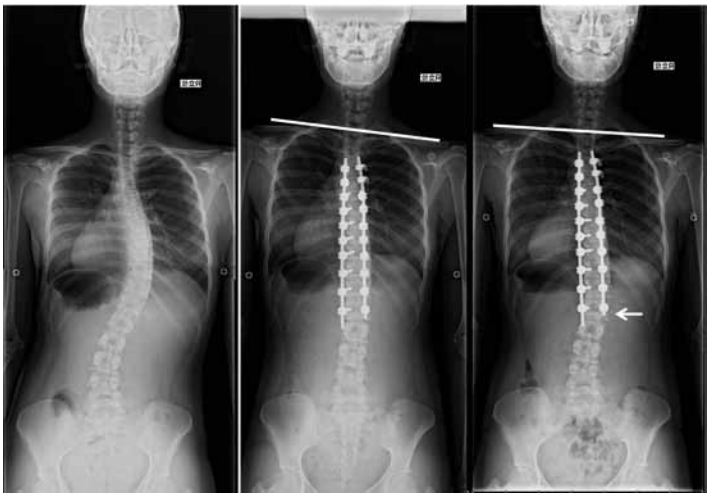
Summary: Postoperative shoulder imbalance and related factors was investigated in 106 patients with Lenke Type 1A curve. The clavicle angle at follow-up was significantly related with preoperative clavicle angle, correction rate of the main thoracic curve and spontaneous correction rate of the proximal curve, and it was significantly larger in patients treated with PS only constructs and tended to be smaller in patients with distal adding-on. These factors should be considered in Lenke type1A curve to prevent PSI.

Introduction: Postoperative Shoulder Imbalance in Lenke Type 1 curve has been one of the surgery-related problems. We investigated occurrence of PSI and related factors in Lenke type 1A curve in which determination of a distal fusion level as a confounding factor is more unarguable than type 1B and C.

Methods: 106 patients with Lenke Type 1A curve underwent posterior correction surgery and were followed more than two years (8 males, 98 females, mean age, 16.2 years). All PS constructs were used in 84 patients and hybrid constructs in 22. The clavicle angle was measured as an indicator of PSI.

Results: The mean Cobb angle of the main and proximal thoracic curves was 54.6±9.5 degrees and 26.7±7.9 before surgery and 14.5±7.5 and 14.9±7.1 at follow-up, respectively. The clavicle angle was -2.9±2.8 before surgery, 2.4±2.8 immediately after surgery and 1.8±2.1 at follow-up. The clavicle angle was positive only in 7 patients (6.6%) before surgery and in 79 patients (74.5%) at follow-up. Distal adding-on developed in 20 patients (18.9%). The clavicle angle at follow-up was significantly related with preoperative clavicle angle (r=0.34), correction rate of the main thoracic curve (r=0.24), and spontaneous correction rate of the proximal curve (r=-0.19), and it was significantly larger in patients treated with PS only constructs than those treated with hybrid constructs (PS; 2.0 degrees vs. hybrid 1.1, p=0.02) and tended to be smaller in patients with distal adding-on than those without (adding-on; 1.1 vs. non adding-on; 2.0, p=0.19).

Conclusion: The mean clavicle angle became positive in 75% of the patients at follow-up, indicating that PSI frequently developed after surgery in patients with Lenke type 1A curve. PSI was more common in patients with better correction of the main curve using PS constructs and those with larger preoperative clavicle angle. But, PSI may be compensated by development of distal adding-on. In the era of prevalent PS constructs for correction surgery of AIS that enable excellent correction of the main thoracic curve, these factors should be considered in the surgical treatment of Lenke type1A curve to prevent PSI.



A patient with PSI immediately after surgery improving at follow-up with development of distal adding-on.

91. Do Findings on Post-Operative Radiographs Result in the Need for Additional Surgery after Posterior Spinal Fusion?

Grant H. Garcia, BA; Min Jung Park, MD, MMSc.; Keith D. Baldwin, MD, MSPT, MPH; Denis S. Drummond, MD; David A. Spiegel, MD
USA

Summary: While postoperative x-rays are certainly useful in evaluating spinal alignment and balance after PSF, it is highly unusual for isolated radiographic findings to require surgical intervention. Consideration can be given to revising protocols for postoperative imaging with the goal of reducing radiation exposure and costs.

Introduction: To evaluate postoperative radiographs after posterior spinal fusion (PSF) and determine if implant related complications resulted in a change in management.

Methods: This is a retrospective review of 265 consecutive scoliosis patients treated by PSF (219 idiopathic, 33 neuromuscular, 13 congenital) from 2007 to 2011. Positive radiographic findings included implant loosening, fracture, migration or loss of fixation. We also noted which patients required additional surgery for a radiographic finding and/or clinical finding (neurologic deficit, intractable back pain, fever and elevated ESR, CRP or WBC).

Results: The average age at surgery was 14.9 years (8.2-21.8) with 2,990 x-rays evaluated. At an average follow-up of 16.3 months (12-24), only 20 (0.67%) demonstrated a radiographic finding. Of these, only 5 (0.17%) underwent additional surgery with all having a positive clinical exam. No patient returned to the operating room purely for a radiographic finding. The remaining 15 abnormal x-rays (0.5%) were not associated with a clinical abnormality and were managed non-operatively. The indications for revision surgery in 19 patients, with (5) and without (14) a radiographic finding, included infection (10), symptomatic implants (5), retained drain (1), suture abscess (1), wound dehiscence (1), and set contamination at case completion noted prior to implant placement at the index procedure (1). The timing of the 2nd operation ranged from 0.1 to 33 months (Avg 11 mos).

Conclusion: Only 0.67% of postoperative x-rays demonstrated an implant related

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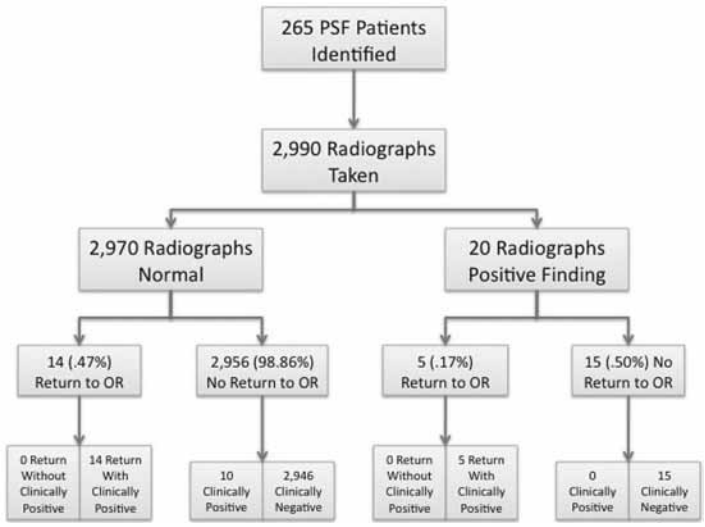
complication, and in the absence of clinical indications, none of these patients required surgical intervention.



92. Recurrence of Rib Prominence Following AIS Surgery with Pedicle Screws and Direct Vertebral Body Derotation

Amer F. Samdani, MD; Jahangir Asghar, MD; Firoz Miyanji, MD, FRCSC; Michelle C. Marks, PT, MA; Jane S. Hoashi, MD, MPH; Baron S. Lonner; Patrick J. Cahill, MD; Joshua M. Pahys, MD; Peter O. Newton, MD; Randal R. Betz, MD
USA

Summary: Recurrence of rib prominence (RRP) following surgery for AIS with pedicle screw constructs and direct vertebral body derotation (DVR) occurred in 16% of patients. Of these, 44% demonstrated a loss of axial vertebral body rotation. The presence of open triradiate cartilages is a risk factor, although the majority of patients were skeletally mature.

Introduction: Pedicle screw constructs combined with DVR provide a powerful corrective force of the rib prominence associated with adolescent idiopathic scoliosis (AIS). We evaluated the incidence and correlative factors associated with RRP developing postoperatively despite adequate initial correction.

Methods: From a prospectively collected multicenter AIS database, 103 patients were identified who underwent fusion with all pedicle screws and DVR without thoracoplasty, and had post-op scoliometer readings at 6, 12, and 24 months. Demographic, surgical, and radiographic data were reviewed. Patients with RRP (Y), defined as a post-op scoliometer increase >5°, were compared to those without recurrence (N) at the follow-up points above using ANOVA. There were 85 females and 18 males, mean age=14.8 years (N=14.8, Y=14.4, p=0.8).

Results: The mean rib prominence measured 14 degrees pre-op with correction of 50% at 6 months, 49% at 1 year, and 49% at two years. RRP was identified in 16/103 (16%) patients (correction 6 mo=57%, 1 yr=47%, 2 yr=40%, x2=0.02). The two groups had similar pre-op coronal Cobb (N=51.9 degrees, Y=52.5 degrees, p=0.34), curve flexibility (N=42%, Y=37%, p=0.33), and curve correction at 6 months and one year (N=67.1%, Y=65.8%, p=0.8). At two years, the RRP group demonstrated a trend toward less curve correction (N=62.7%, Y=57.4%, p=0.09). T5-12 kyphosis was similar for both groups pre- and post-op. A significantly higher number of patients with RRP had open triradiate cartilages (N=1%, Y=19% p=0.01). Furthermore, 7/16 (44%) patients with RRP had worsening apical vertebral rotation (AVR) at 2 years post-op. Surgical data, including rod material (CoCr, titanium, stainless steel) or the use of Ponte osteotomies were not correlated with RRP.

Conclusion: RRP after posterior fusion with all pedicle screw constructs and DVR occurred in 16% of patients. Those with open triradiate cartilage had a significantly higher rate of RRP, although most with RRP were skeletally mature. There was a trend towards loss of coronal correction and increased AVR at 2 years in patients with RRP. The potential for RRP after adequate initial correction should be discussed with patients.

93. Vertebral Body Stapling in the Treatment of Moderate Thoracic Adolescent Idiopathic Scoliosis in Immature Patients

Acke Ohlin, MD, PhD
Sweden

Summary: We report on a small consecutive series of 9 immature moderate thoracic adolescent idiopathic scoliosis who underwent endoscopically vertebral stapling. This operation did not prevent progression of scoliosis in 7/9 of our patients having a mean pre-operative Cobb angle of 38 degrees. Only 2/9 cases, both having curves less than 35 degress remained non-progressive, the others have subsequently had a definitive posterior correction and fusion.

Introduction: The treatment of moderate adolescent idiopathic scoliosis in immature patients is a continuous matter of debate. One suggested alternative to brace treatment in immature patients is intervertebral body staples (VBS), a method with endoscopically inserted staples.

Methods: Nine patients, 7 girls and 2 boys, with a mean age 11.3 (10-13) years, with idiopathic scoliosis with a mean Cobb angle of 38° (32-46) underwent surgery with VBS. All patients were skeletal immature with the Risser sign being zero. In nine cases there was a main thoracic curve and in one case there was a double curve in which we addressed both the thoracic and lumbar curves with VBS. All patients had preoperatively undergone an MRI of the whole spine showing no abnormalities.

Results: The initial correction of Cobb angle after primary VBS was in mean 6° resulting in a mean angle of 34° at the first postoperative standing film. Postoperative low-dose CT showed an acceptable positioning of all staples. Eventually, 7/9 patients showed a significant progress of the coronal deformity by in mean 20 degrees during follow-up necessitating a second definitive operation - posterior correction and fusion.

Conclusion: VSB did not halt progression of Cobb angle or prevent surgery in 7/9 patients who were Risser 0 with a mean curve of 38°. This series differs from the results presented by Betz et al. The chronological age and skeletal maturity of patients in the two cohorts seem to be similar. The preoperative Cobb angle in Betz's series was 35° and in ours 38°.

94. The Prevalence of Postoperative Pain in Adolescent Idiopathic Scoliosis and the Association with Preoperative Pain

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USA

Summary: Two year postop SRS scores were significantly worse in 41 patients with post-operative pain who had no obvious cause reported to their surgeons compared to 523 patients who did not complain of pain. These 41 patients also had significantly lower pre-operative SRS Pain scores (lower scores indicate greater pain), which did not significantly improve after surgery.

Introduction: While reportedly rare, post-operative pain can be a devastating situation for the adolescent idiopathic scoliosis (AIS) patient. The purpose of this study was to examine the incidence of post-operative pain and its impact on patient reported outcomes.

Methods: A prospectively enrolled multi-center database was queried. Patients with minimum 2 year follow-up and 2 year SRS scores were included. Pain, as reported by the patient to the treating surgeon in follow-up, is recorded as a complication in the database. Patients included in this series were grouped as either reporting pain or not to the clinical team post-operatively. Pre and post-op SRS scores were then compared between groups utilizing ANOVA ($p<0.05$).

Results: Five hundred and eighty-four patients were identified. Sixty-one (11%) reported pain at or prior to their 2 year follow-up. Thirteen were within the six month post-operative period. Of the remaining 48 reporting pain between 6 and 24 months post-op, 41 (7% of the total cohort) had no obvious cause for their pain. Over half of these patients (26/41) were referred for further treatment (physical therapy, referral to pain specialist, further imaging). These 41 patients had significantly decreased 2 year SRS scores in all domains except for function (Table, $p<0.05$). The patients with post-operative pain were found to have significantly decreased pre-operative Pain domain scores ($p<0.001$), indicative of greater pain, yet there were no other domains effected. Their pre to post-operative SRS Pain scores did not show significant change ($p>0.05$).

Conclusion: Unexplained pain after the 6 month post-operative period occurred in 7% of the cohort. The results indicate that patients reporting pain to their surgeons post-operatively have lower pain scores on a subjective outcome instrument thus further validating this measure. This reported pain appears to be associated with decreases in other SRS domains. Interestingly these patients also have lower pre-operative pain scores compared to those without postop pain. Further study into whether pre-operative education and expectations targeted at this population would positively impact outcomes is warranted.

		Patients with Pain	No Pain Reported	p
Two year Post-op SRS	Pain	4.1 ± 0.7	4.5 ± 0.6	**<0.001**
	Self-Image	4.3 ± 0.7	4.5 ± 0.5	**0.033**
	Function	4.7 ± 0.4	4.7 ± 0.5	0.389
	Mental Health	4.1 ± 0.9	4.3 ± 0.6	**0.027**
	Satisfaction	4.3 ± 1.1	4.6 ± 0.7	**0.018**
	Total	4.3 ± 0.6	4.5 ± 0.4	**0.003**
Pre-op SRS	Pain	3.8 ± 0.8	4.2 ± 0.7	**<0.001**
	Self-Image	3.4 ± 0.6	3.4 ± 0.6	0.53
	Function	4.5 ± 0.6	4.5 ± 0.6	0.86
	Mental Health	4.0 ± 0.7	4.1 ± 0.6	0.40
	Total	3.9 ± 0.4	4.0 ± 0.4	0.08

95. Perioperative Use of Gabapentin in Patients with AIS Improves Outcomes in Pain Management after Posterior Spinal Fusion

Curtis D. VandenBerg, MD; Suken A. Shah, MD; Peter G. Gabos, MD; J. Richard Bowen, Medical Doctor; Kenneth J. Rogers, PhD; Karen Sacks, MSN; Dinesh K. Choudhry, MD
USA

Summary: The optimization of pain control after PSF for AIS is a challenging problem. Novel approaches to address this clinical dilemma are necessary to maximize positive patient outcomes and enhance patient and family satisfaction. This study found gabapentin to be both safe and effective as an adjunct in this patient group. When gabapentin was used, opioid consumption decreased and patients could be converted from IV PCA to oral pain medication sooner. Additionally, mobility was enhanced in the early stages of recovery.

Introduction: Pain control after surgery for AIS can impact patient outcomes and is an important factor in patient and family satisfaction; however, there is a large degree of practice variability. This study assessed the efficacy of gabapentin for pain management in the perioperative period in patients with AIS undergoing posterior spinal fusion (PSF).

Methods: 94 consecutive patients who underwent PSF for AIS between 5/2010 and 9/2011 were assigned to one of three postop pain management regimens: Group 1-morphine PCA; Group 2-morphine PCA and ketorolac; or Group 3-morphine PCA, ketorolac, and gabapentin. Postoperatively, opioid use was calculated in mg/kg/time intervals. Pain scores and adverse effects were recorded. Physical therapy goals and length of stay were assessed as secondary outcomes.

Results: 94 patients (39 Group 1, 19 Group 2, and 36 Group 3) did not differ in demographics, surgical time, or in radiographic measurements of coronal and sagittal plane curve corrections. Visual analog pain scores did not differ between groups. Morphine consumption (mg/kg/h ± SD) was significantly lower in the gabapentin group on the first postop day (0.98 ± 0.31 Group 1 vs. 0.59 ± 0.26 Group 3; $p<0.001$). Also, a greater percentage of patients who received gabapentin were converted to oral pain medications on the first postop day (0% Group 1 vs. 25% Group 3; $p=0.005$). There was no difference in opioid-related side effects or length of stay. There was a trend showing that a greater number of patients who received gabapentin tolerated ambulation on the first postop day, but this was not statistically significant (26% Group 1, 22% Group 2, 52% Group 3; $p=0.058$). No adverse effects of gabapentin use were noted.

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Conclusion: Perioperative gabapentin reduced morphine consumption and facilitated transition to oral pain medication on the first postop day after PSF for AIS. There was also a tendency towards earlier ambulation. We did not demonstrate differences in pain scores or opioid-related side effects. Perioperative gabapentin seems to be a safe, effective adjunct to improve pain control and increase mobility in the early stages of recovery in pediatric patients undergoing PSF for AIS.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

96. Ioniizing Radiation Exposure in Early Onset Scoliosis IEOS) Patients Treated with Rib-Based Distraction

Nelson Astur, MD; Tyler A. Cannon, MD; Derek M. Kelly, MD; William C. Warner, MD; Jeffrey R. Sawyer, MD
USA

Summary: Rib-based distraction is an effective treatment of EOS. EOS patients, due to the frequent radiographic evaluations over many years, frequent comorbidities, multiple surgical procedures and increased complication rates, have extremely high radiation exposure. Surgeon experience and etiology influence the amount and type of radiation EOS patients receive. Neuromuscular patients have a 3-fold higher rate of exposure from non-orthopaedic studies. EOS IR exposure is much higher than for patients with other conditions which require frequent radiographic follow up such as cystic fibrosis and ventriculoperitoneal shunts. This information will lead to radiation reduction strategies in EOS patients.

Introduction: The evaluation and treatment of patients with EOS requires multiple imaging studies and involves potential exposure to high cumulative lifetime doses of ionizing radiation (IR). Growing distraction devices, including rib-based devices used in the treatment of EOS require numerous lengthening procedures and frequent radiographic follow-up. The purpose of this study was to quantify the IR exposure EOS patients undergoing rib-based treatment received and to identify factors which place EOS patients at greater risk of IR exposure.

Methods: Data were collected by an IRB-approved retrospective review of the records ofpatients with EOS treated exclusively at a single institution treated with a rib-based distraction deviice over a 4 year period (2007 to 2010). Diagnostic radiographs, computed tomography (CT), intraoperative fluoroscopy, and nuclear medicine studies were analyzed for IR exposure. Total radiation exposure was determined and compared for risk factors such as etiology (neuromuscular vs congenital) and surgeon experience. IR exposure related and unrelated to EOS treatment was compared.

Results: A total of 24 patients underwent 121 surgical procedures (mean 5.0/pt) and 962 imaging studies (mean 40/pt). The mean estimated cumulative radiation dose/ patient during total follow-up was 86.7 mSv (range: 42.6-174.9) with a mean annual dose of 34 mSv (range: 22.9-47.1). Patients with congenital scoliosis received greater mean amounts of radiation (35.2 mSv) than patients with neuromuscular scoliosis (31.9 mSv). Patients treated in the first two years of the study had higher IR exposure (42.4 mSv) compared to later patients(24.0 mSv) ($p<0.001$).

Conclusion: .Rib-based distraction is an effective treatment of EOS. Due to the frequent radiographic evaluations, large number of comorbidities, multiple surgical procedures and high complication rate, these patients have significant radiation exposure. Because by EOS affects young children, they have the potential to receive high lifetime cumulative exposure. Surgeon experience and etiology play a role in the amount and type of radiation EOS patients receive. This study will help develop new radiation reduction strategies in EOS patients.

97. Wound Infections after Spine Deformity Correction Cerebral Palsy: Risk Factors

Paul D. Sponseller, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Peter O. Newton, MD; Leslie M. Thaxton, MS, MBA; Tracey Bastrom, MA; Michelle C. Marks, PT, MA
USA

Summary: Risk factors for wound infection after spinal deformity surgery for cerebral palsy included: presence of G-tube, large pre-op curve, and longer OR time. Gram negative organisms predominated the deep cultures.

Introduction: Wound infection after spine fusion for Cerebral Palsy (CP) is more common than in most other diagnoses. A prospectively-collected cohort was evaluated in order to (1) assess risk factors for wound infection, and (2) identify most common causative organisms.

Methods: 204 consecutive patients with CP fused for spinal deformity at 7 institutions were studied prospectively. Mean age was 14 +2.6 yrs. Risk factors studied included age, weight, BMI, GMFCS, cognitive impairment, ambulatory status, tracheostomy, G-tube, medications, curve size, pelvic obliquity, pre-op albumin, WBC, total protein, pre-op antibiotic, antifibrinolytic, EBL, bone graft, intra-wound antibiotics, operative time, approach, implant, metal, baclofen pump, and institution. After risk factors were identified, multivariate regression analysis was carried out.

Results: There were 13 deep wound infections (DWI) (6.5%), and 7 superficial infections (SWI) (3.5%). Organisms were E. coli (5), pseudomonas (2), MSSA (1) and polymicrobial/other (5). Patients with DWI were older (15.4 vs. 13.0 y, p=0.048) and had larger curves (98o + 26 vs. 84 o +21, p=0.036), longer OR times (538+254 vs. 402 + 179 min, p=0.02) and higher pre-op WBC (9.2 vs. 7.2, p=. 0.014). Patients with G-tubes had more DWI (17.6 vs. 1.6%, p=0.002; highest multivariate score). None of 14 ambulatory pts had DWI. Primary kyphosis had a higher risk of infection (13.3 vs. 8.9% p=0.01). Adding antibiotics to the bone graft lowered rate of DWI (p=0.02). Non-associated factors included MR, GMFCS, pre-op albumin or total protein, implant, number of pre-op medications, presence of a baclofen pump, approach, EBL, antifibrinolytic, or institution.

Conclusion: Deep wound infection occurred in 6.5% of spinal fusions for cerebral palsy, and was not significantly different by hospital. Significant risk factors include: presence of a G-tube, large pre-op kyphosis and longer operative time. DWI patients were older. Ambulatory status and antibiotics in the bone graft were associated with a lower rate of infection.

98. Hip Subluxation, Pelvic Obliquity, and Scoliosis in the CP Population: A Random Triad or a Predictable Relationship?

Firoz Miyanji, MD, FRCSC; Amer F. Samdani, MD; Peter Sturm, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Peter O. Newton, MD
Canada

Summary: Previous research has noted that scoliosis in Cerebral Palsy (CP) is often accompanied by pelvic obliquity (PO) and hip subluxation/dislocation, although evidence of any relationship has been contradictory and inconclusive. We found larger curves to be associated with significant PO but no correlation with hip deformity was noted. The relationship between PO and hip subluxation/dislocation was also poor suggesting that the pelvis acts more as an extension of the spine with no significant effect on hip deformity in this population.

Introduction: Neuromuscular scoliosis in patients with CP more often involves the pelvis, with the pelvic deformity being postulated as having a significant effect on the femoral-acetabular relationship. The correlation between scoliosis, pelvic obliquity (PO) and hip subluxation in CP however remains unclear. The purpose of our study was to determine the association of hip subluxation, PO, and the severity of scoliosis in CP, and secondarily to analyze any potential predictors of curve severity and PO in this population.

Methods: Patients enrolled in a prospective longitudinal multi-center study evaluating operative outcomes of scoliosis in CP were included in the analysis. Pre-op hip subluxation for each hip, as measured by the Reimer's Migration Index (RMI), PO, and curve magnitude were the primary outcomes studied. Hips with prior surgery were excluded from the analysis. Multivariate linear regression was used to identify potential predictors influencing curve severity and PO.

Results: 115 subjects with a mean age of 14.2+2.7 years were included. There were 66 males and 49 females. The majority of the patients were GMFCS 4 (17%) and 5 (69.5%). The mean major Cobb was 81.5°± 28.4°. PO on average measured 63.3°+14.7°, and was directly related to the magnitude of the scoliosis. The RMI had no correlation to curve magnitude (ρ=0.25) and was also poorly associated with PO (ρ= -0.36). 69% of the hips were normal. Age, sex, and GMFCS level were not associated with curve severity or PO.

Conclusion: The triad of hip deformity, PO, and scoliosis does not appear to be significantly correlated in CP. Although PO was associated with larger curves, the relationship with hip subluxation/dislocation was poor suggesting that factors beyond spino-pelvic deformity affect hip pathology in this population.

99. Comparison of Life Expectancy between Surgical Treatment and Conservative Treatment Group in Flaccid Neuromuscular Scoliosis

Hyon Su Chong; Hak-Sun Kim, MD
Republic of Korea

Summary: A comparison of life expectancy of surgical group was higher than conservative group. And survival estimate of surgical group was negatively affected by duration of ICU care and time of mechanical ventilation after surgery.

Introduction: Galasko et al. reported that 5 year survival rates was be higher in patients who have undergone surgery (61%) vs. those who have opted conservative treatment (23%) in Duchenne muscular dystrophy (DMD) with small number. But other studies reported that surgery did not improved life expectancy in DMD scoliosis. Recently, marked advance of supportive management for neuromuscular(NM) scoliosis should be increased life expectancy in NM scoliosis . However, there was no comparison report about life expectancy between surgical group and conservative group. Aim of this study is to compare the rate of survival between surgical and conservative group, define the possible factors that could affect the outcome forsurvival, and compare with patients treated conservatively.

Methods: A comparison of 112 patients with surgical group and 92 patients with conservative group among NM scoliosis was done. Patients in non-surgical group were included when the Cobbs angle was more than 50 degree. Then medical records and radiographs were reviewed and time of death was surveyed by database of national bureau of statistics. Baseline parameters such as age, sex, ambulatory status, functionality, cardiopulmonary function, Cobbs angle, lumbar lordosis, pelvic obliquity, perioperative datas were evaluated. Kaplan-Meier survival analysis and Cox proportional hazards regression analysis were used for evaluating the survival estimation and relative risk factors for survival.

Results: Mean age (15.4 year vs 19.1 years) of each group were lower in surgical group and preoperative Cobbs angle (68.6 vs 43.1) and pelvic obliquity (90.9 vs 59.8) was higher in surgical group. Survival estimate of surgical group was higher (3.59 years vs 2.7 years) compared to non-surgical group (p=0.0156). Among surgical group, stay in intensive care unit (ICU) (p=0.0163) and time of mechanical ventilation (p=0.0280) after surgery were negative correlated with survival duration. But no parameters were correlated with survival duration in non-surgical group.

Conclusion: A comparison of life expectancy of surgical group was higher than conservative group. And survival estimate of surgical group was negatively affected by duration of ICU care and time of mechanical ventilation after surgery.

100. Hybrid vs. Total Pedicle Screw Instrumentation in Patients Undergoing Surgery for Neuromuscular Scoliosis: A Comparative Study with Matched Cohorts

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Finland

Summary: A matched cohort study comparing outcomes between hybrid or total pedicle screw instrumentation for neuromuscular scoliosis was conducted in 66 patients. Pedicle screw group showed a significantly better radiographic correction of scoliosis with less blood loss, shorter operative time and less need for anterior surgery.

Introduction: Total pedicle screw (TPS) instrumentation has been shown to provide better scoliosis correction and less loss of correction than hybrid constructs (upper laminar hooks, sublaminar wires, lumbar pedicle screws) in adolescent idiopathic scoliosis. Similar comparative studies in neuromuscular scoliosis (NMS) are few. The aim was to compare two-year clinical and radiographic outcomes in cohorts with neuromuscular scoliosis operated with hybrid or TPS instrumentation matched for age at surgery (±1 year), gender, curve size (±10 degrees), and basic neurologic condition.

Methods: A retrospective, matched comparison using prospectively collected data between hybrid and TPS instrumentation in patients undergoing surgery for

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NMS was performed. Sixty-six patients with NMS (30 males; 42 CP, 4 MMC, 7 Duchenne, 6 polyneuropathy, 6 syndromic, 1 SCI) underwent posterior or anteroposterior correction and fusion with hybrid (n=33, age at surgery 15.8 years [SD ± 3.0], 13 anteroposterior) or TPS instrumentation (n=33, age at surgery 14.7 years [± 2.5], 4 anteroposterior) with a minimum 2-year follow-up. None of the patients were lost for clinical and radiographic follow-up, and postoperative SRS-24 scores were available for 18 (55%) patients in the hybrid and 23 (70%) patients in the TPS groups, respectively.

Results: Major curve (SD) averaged 87° (± 29°) and 81° (±18) preoperatively (p=0.29) with similar correction on traction films, and 33° (± 20; 2-87) and 20° (± 12; 1-55) at two-year follow-up in the hybrid and TPS groups, respectively (p=0.0016). Average major curve corrections were 59% and 75% at two-year follow-up (p=0.0011). Mean operative times were 7.45 hours (± 2.18) and 6.04 hours (± 1.71) (p= 0.0012) and intra operative blood loss 3760 mL (± 2790) and 1785 mL (± 1110) (p=0.0015). There were no statistically significant differences in the sagittal or coronal balance, complication rates or total SRS-24 score at final follow-up.

Conclusion: Pedicle screw instrumentation provided better major curve correction with shorter operative time and less blood loss compared with hybrid constructs in patients undergoing surgery for NMS.

101. The Usefulness of Noninvasive Positive Pressure Ventilation in Surgery of Flaccid Neuromuscular Scoliosis Patients

Hyon Su Chong; Hak-Sun Kim, MD; Hyoung Bok Kim; Do-yeon Kim; Jea-Woo Lim; Mary Ruth A. Padua, MD; Dong-Eun Shin, PhD
Republic of Korea

Summary: 1. NIPPV is a useful treatment option in neuromuscular scoliosis patients with pre-existing pulmonary insufficiency (FVC<50%).

2. Neuromuscular scoliosis patients with severely decreased pulmonary function can underwent correctional surgery safely without increased incidence of pulmonary complications.

3. There is no increased incidence of post-operative pulmonary complications and need for tracheostomy with the use of NIPPV even in severely decreased pulmonary function.

Introduction: There is no report about the effects of noninvasive positive pressure ventilation (NIPPV) usage in neuromuscular scoliosis patient during perioperative periods. So aim of this study is to assess the effects of NIPPV by evaluation of outcomes and incidences of post-operative pulmonary complications in patients with flaccid neuromuscular scoliosis for pulmonary support in the perioperative period.

Methods: Seventy-three patients were divided by usage of NIPPV during perioperative period. Thirty-one patients given NIPPV for respiratory support and 42 patients with no mechanical ventilation were compared according to age, sex, body mass index, number of fusion levels, ETpCO2(end tidal pressure of CO2) and FVC(forced vital capacity) values. The incidence of pulmonary complications (pneumonia, atelectasis, pneumothorax, prolonged ventilator support, and postoperative tracheostomy) was evaluated.

Results: In between the two groups, the FVC (41% vs 64%, p<0.0001) were observed to be significantly decreased with NIPPV use. ETpCO2 was not statistically different between the two groups. Though statistically not significant, patients in the non-NIPPV group had a higher incidence of pulmonary complications (38% vs 22%, p=0.1584). None of the patients required tracheostomy. No other mortality or neurologic complications were noted post-operatively.

Conclusion: There is definite usefulness of NIPPV, because there is no increased incidence of post-operative pulmonary complications and need for tracheostomy with the use of NIPPV even in severely decreased pulmonary function.

102. Functional Effects of Cervical Spine Disease in Adults with Down Syndrome

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Summary: Cervical spine degenerative disease is almost twice as common as cervical instability in adults with Down syndrome and is a factor in the decline of ambulatory function.

Introduction: Cervical spine abnormalities can have profound effects on individuals with Down syndrome. This study delineates the occurrence of cervical spine disease in a cohort of institutionalized adults with Down syndrome, the majority with moderate to severe intellectual disability, and its effect on ambulatory function.

Methods: After IRB approval, the medical records and cervical spine imaging of all residents in a single facility whose orthopedic care has been provided by one of us were analyzed. Information collected included associated medical conditions, surgical interventions and functional assessments.

Results: From 1986 until 2006, 52 adults (29 males and 23 females) with Down syndrome whose average age was 46.2 years (range: 19-71 y) were examined annually for an average of 12.2 years (range: 2-22 y). Based on radiographs and other imaging taken during the study period, 19 individuals (37%) had evidence of upper cervical instability; 3 of these patients had clinical evidence of myelopathy. Thirty-seven individuals (71%) had moderate to severe cervical degenerative disease; 6 of these patients showed clinical signs of myelopathy or radiculopathy. Despite these findings, only 3 individuals experienced a significant decline in their ambulatory function that was attributed to cervical spine pathology and only 1 was recommended for spinal surgery. Decline in ambulatory function was noted in 14 others in the cohort. This decline was attributed to hip and knee osteoarthritis in 11 individuals, progressive CNS disease in 2 individuals, and cataracts in 1 individual.

Conclusion: Most adults with Down syndrome develop moderate to severe cervical degenerative disease. While cervical spine pathology may be a contributing factor in the decline of some individuals with Down syndrome as they age, lower extremity osteoarthritis and CNS deterioration are potentially more important causes of decline in ambulatory function in this patient population.

103. Minimum Five-Year Follow-Up of Posterior -Only Surgery for Thoracic and Thoracolumbar Kyphosis

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Summary: The radiographic and clinical results of 32 patients who underwent posterior only spinal fusion for thoracic or thoracolumbar kyphosis (TLK) are reported. Less than 1 degree of loss of correction was seen across the instrumented segment at the time of final f/u. Significant improvements were noted in the Oswestry Disability Index (ODI), and all but one domain of the Scoliosis Research Society - 24 (SRS-24) questionnaires at 5 years.

Introduction: Until recently, TLK was treated with combined A/P spinal fusion, however recently, there has been support for posterior only spinal fusion. To date, no intermediate or long term studies have been produced advocating the use of posterior only spinal fusion for the treatment of TLK.

Methods: Forty eight patients were identified as having had a posterior only spinal fusion for a primary diagnosis of TLK. Measurements were recorded from pre-op, post-op, and final f/u full length standing radiographs. Prospectively collected outcome scores were reviewed for the same time points, and patients' charts were examined for complications. Patients with neuromuscular disorders were excluded from the study.

Results: Patients averaged 44 years of age (11-77), and f/u averaged 68 months (60-122). Diagnoses included Scheuermann's disease (N=10, 31%), adult kyphoscoliosis (N=10, 31%), traumatic kyphosis (N=4, 13%), pseudarthrosis (N=4, 9%), adolescent kyphoscolios (N=3, 9%), and atypical kyphosis (N=1, 3%). An average correction of 26.41 degrees (39%; 68.2 pre-op vs 43.6 post-op) was achieved through posterior only surgery. Only 0.90 degrees (0-5) of loss of correction was seen in the instrumented segment at the time of final f/u. Complications included proximal junctional kyphosis of at least 10 degrees (N=4, 13%), loss of intraoperative monitoring data (N=1, 3%), and incidental durotomy (N=1, 3%). No pseudarthroses occurred. ODI scores improved an average of 22.3 points ($p=0.004$). SRS scores improved in the Pain ($p=0.008$), Image ($p<0.001$), Satisfaction ($p=0.005$), Mental ($p=0.012$), and Average ($p<0.001$) domains.

Conclusion: Pedicle screw constructs allow powerful posterior only corrections of TLK. Corrections are maintained at an intermediate f/u time point. Patients report improvements, as determined by outcome questionnaires, at that same intermediate time point.

104. Comparison of Different X-Ray Methods to Evaluate the Flexibility of Kyphosis in Scheuermann's Disease

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Summary: Flexibility x-rays (FXR) taken under general anesthesia reflects the flexibility rates and postoperative results better than the standard x-rays for Scheuermann's Disease patients surgically treated by pedicle screw instrumentation.

Introduction: Flexibility is traditionally evaluated by supine fulcrum x-ray or by lateral traction x-ray in patients with Scheuermann's Disease. We routinely use fulcrum and traction x-rays under general anesthesia (UGA) to eliminate the effect of muscle tonus. Aim of this retrospective study was to compare standard xr with FXR UGA to determine the best method which reflects the highest flexibility rates and in better agreement with postop results.

Methods: 26 patients (19M/7F) with minimum 2 years of f/up treated by posterior instrumentation and fusion without osteotomy were included in the study. Kyphosis angles were measured in preop and postop standing lateral (SL), preop hyperextension fulcrum (HF), preop traction lateral (TL), hyperextension fulcrum under general anesthesia (HFUGA) and traction lateral graphies under general anesthesia (TLUGA). X-rays UGA has been done after induction of anesthesia. Flexibility rates were compared by repeated measures of ANOVA and the agreement between the methods and postoperative results were examined by Bland-Altman method.

Results: The average age was 18y (13-27). Mean f/up was 44 (30-72) months. Mean preop kyphosis angle of $75.3°\pm6.6°$ was corrected to $38.3°\pm6.0°$ and found to be $41.9°\pm6.2°$ at f/up. Highest flexibility rates were provided by TLUGA followed by HFUGA, TL and HF respectively and the differences were statisticaly significant ($p<0.05$) (table 1). 95% limits of agreement with postoperative results were highest for HFUGA followed by TLUGA, TL and HF, respectively (table 2).

Conclusion: Flexibility xr taken under general anesthesia reflects the flexibility rates and postoperative results better than the standard x-rays for Scheuermann's Disease patients surgically treated by pedicle screw instrumentation. TLUGA demonstrates the highest flexibility rates and HFUGA has best agreement with postoperative correction rates.

105. The Prevalence of Abnormal Preoperative Neurologic Exam in Scheuermann's Kyphosis: Correlation with X-Ray, MRI, and Surgical Outcome

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Summary: The prevalence of abnormal neurologic exam was 9% in primary operative Scheuermann's kyphosis patients. No x-ray findings correlated with the abnormal preop neurologic exam. A normal MRI can be found with an abnormal neurologic exam, and a normal exam can also be seen with an abnormal MRI. Corrective surgery was beneficial in improving neurologic symptoms.

Introduction: There have been sporadic reports about abnormal neurologic findings in Scheuermann's kyphosis pts. The purpose of this study was to report the prevalence of abnormal neurologic findings detected by physical exam in Scheuermann's kyphosis, and to correlate it to x-rays, MRI findings and results of operative treatment.

Methods: Among 82 Scheuermann's kyphosis pts who underwent corrective surgery, 69 primary cases were selected. Patient charts were reviewed retrospectively in terms of pre and postop neurological exams. Sensory or motor change was defined as an abnormal neurologic exam. Their duration, associated problems, and various parameters on preop x-rays and MRI exams were also measured to search for any atypical findings associated with an abnormal neurologic exam.

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Results: There were 6 cases (9%) (Group AbN) with an abnormal neurologic exam ranging from severe myelopathy to a subtle change (e.g. sensory paresthesias on trunk). 5 pts recovered to a normal neurologic exam after corrective surgery. The remaining 1 severe myelopathic pt also showed marked improvement and was ambulatory unassisted by 2yr follow-up. In pts with a normal neurologic exam (Group N, n=63), only 1 pt had neurologic sequelae due to ant spinal artery syndrome after combined A/P correction. No preop x-ray parameters were significantly different between groups. Ave age was 21.3 (AbN) and 18.6 (N) yrs (P=0.55). Ave preop T5-12 kyphosis was 69.0 ° (AbN) and 72.5 ° (N) (P=0.61). 42 MRIs were obtained, all showed typical findings of Scheuermann's kyphosis. In abN, 5 pts had MRI (1 had a CT/myelo) and in 37 in N.

Conclusion: The prevalence of abnormal neurology in Scheuermann's kyphosis was 9%, emphasizing the importance of detailed preop neurologic exam. If congenital stenosis or herniated thoracic disc is combined, myelopathy can occur. No x-ray findings correlated with the abnormal preop neurologic exam. A normal MRI can exist in the face of an abnormal neurologic exam, and conversely, a normal neurologic exam can be seen with an abnormal MRI as well. Surgery was successful in alleviating abnormal neurologic issues. Deformity surgeons who correct Scheuermann's kyphosis should rule out neurologic issues preoperatively.

	Neurologic Finding (blank means normal)								Other symptoms			MRI	
	Motor (most severe muscle) (Rt:Lt)		Sensory loss (V: Vibration, L: Light touch, P:Paresthesia)		DTR (Rt/Lt)		abN Gait (+~+++)	Bowl /bladder dysfunction (+~+++)	Neurology at 2 Yrs.	Back pain	Leg pain (% of total pain)	Symptom duration	MRI (Y/N)	MR finding (T means typical finding)
Probable Causes	U/Ex	L/Ex	U/Ex	L/Ex	U/Ex	L/Ex				Y(++)/N	(If Leg pain, Rt:Lt)			
Congenital Stenosis		4:4		V, L	4+/4+	4+/4+	++	++	Normal	Y (++)	0%	2 Mo.	Y	T9-12 stenosis +T
Multiple Herniated Thoracic Disc		5:3		L (< T9)		3+/3+	+++	+++	Walker	Y(++)	25% (R>L)	3 Mos.	N	(T8-10 block at CT-myelo)
Thoracic Radiculopathy			P (on Back)						Normal	Y(++)	25% (R>L)	3 Yrs.	Y	T
Lumbar HNP		4:3		L					Normal	N	100% (Lt>Rt)	3 Wks.	Y	L3-4 (L4-5) HNP +T
Diabetic Neuropathy				L	-/-	+/+			Normal	Y(++)	0%	1Yr.	Y	Spinal Cord Tenting +T
Spincal Cord Tenting		5:4		L, P			+ (balancing)		Normal	Y(++)	0%	4 Mos.	Y	Spinal Cord Tenting +T

		MRI			
		Typical	Typical + Atypical	Atypical findings	Total
N/Ex	N	33	4	3: Spinal cord tenting, 1: Canal narrowing + Syrynx	37
	abN	1	4	2: Spinal cord tenting, 1: Congenital stenosis, 1:HLD	5
	Total	34	8		42

Typical finding: Schmorl's nodules, multiple disc degeneration, anterior cordal shifting without cord compression, and multiple body wedging.

106. Demographics and Outcomes Based on Spondylolisthesis Slip Grade

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Summary: Symptomatic L5/S1 isthmic spondylolisthesis requiring surgery presents with a bimodal peak of incidence. Patients with high grade slips require early corrective surgery, whereas patients with lower grade slips develop acquired degenerative changes. Both groups may require corrective surgery, usually a decompression and concurrent fusion. Although the incidence of revision was higher in high grade slips, the outcome scores in all groups were similar and were within normal scores two years after surgery.

Introduction: Developmental (Isthmic) L5/S1 spondylolisthesis may become symptomatic in adolescence or in adulthood. Surgical intervention in adolescents is required for unstable, progressive high grade spondylolisthesis while adult patients with low grade stable isthmic spondylolisthesis require surgery for superimposed acquired degenerative changes that cause new onset of back pain and radiculopathy. The purpose of this study was to investigate the natural history and results of surgery for L5/S1 isthmic spondylolisthesis based on slip grade.

Methods: This is a review of prospectively collected data on L5/S1 isthmic spondylolisthesis patients treated with surgery. Differences in demographics, surgical data and outcome measures (SF12) based on Meyerding slip grade were analyzed.

Results: Of the 181 patients identified, 40 had Gr1, 57 had Gr2, 62 had Gr3 and 22 had Gr4 slips. Patients with low grade slips presented at an older age (Gr1=32.0yrs, Gr2=32.5yrs) compared to those with high grade slips (Gr3=21.9yrs, Gr4=17.8yrs). There was no difference in sex, smoking status, race or BMI between groups. The blood loss was higher in the high grade slips (Gr1=326.1mL, Gr2=428.4mL, Gr3=669.9mL, Gr4=667.8mL, p=0.004). The incidence of revision surgery was also greater in the high grade slips (Gr1=2, Gr2=0, Gr3=2, Gr4=3, p=0.002). There was no difference in complication rates between the groups. At two years post-op, there were no differences in SF-12PCS (Gr1=46.9, Gr2=47.3, Gr3=49.2, Gr4=55.1, p=0.162) or SF12MCS (Gr1=55.4, Gr2=57.5, Gr3=54.4, Gr4=51.9, p=0.126) scores among the different slip grades, with all scores being within 1 standard deviation of normal scores.

Conclusion: Symptomatic L5/S1 isthmic spondylolisthesis requiring surgery presents with a bimodal peak of incidence. Patients with high grade slips require early corrective surgery, whereas patients with lower grade slips develop acquired degenerative changes. Both groups may require corrective surgery, usually a decompression and concurrent fusion. Although the incidence of revision was higher in high grade slips, the outcome scores in all groups were similar and were within normal scores two years after surgery.

107. Isthmic Spondylolisthesis with Concomitant Scoliosis. A Retrospective Report on 21 Operated Patients with Mean Follow-Up over Ten Years

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Summary: Out of 1667 scoliosis patients of a single institution, 151(9.1%) had L5 spondylolisthesis. Twenty-one (13.9%) of them had surgery for spondylolisthesis (11 low-grade, 10 high-grade).

The indication for surgery in low grades was pain in 3/11 and the intend to prevent progression of the lumbar curve in 8/11. High-grade slips were operated to prevent slip progression. At follow-up, 5 low-grade patients were pain-free, 4 had moderate pain, 2 had severe pain. Of the high-grade patients, 4 were pain-free and 6 had moderate pain. None of the lumbar curves needed surgery later.

Introduction: The purpose was to analyze preoperative symptoms, curve characteristics, and outcome of surgery in patients operated on for isthmic spondylolisthesis with concomitant scoliosis.

Methods: This is a retrospective review of charts and radiographs. Out of 1667 scoliosis patients, 151(9.1%) of had L5 spondylolisthesis. Twenty-one (13.9%) of them had surgery for spondylolisthesis (19 females, 2 males; 11 low-, 10

high-grade). Patients' age at admission was 13.5(10-17)y. Preoperatively, 5/21 were pain-free (1 high-grade, 4 low-grade), 7 (2 high-grade) had LBP, 2 (both high-grade) radiating pain, and 7 (5 high-grade) had both. Hamstring tightness was present in 5/10 high-grades. Scoliosis was primary thoracic in 3/11 low-grade and secondary lumbar with oblique rotated take-off of L5 in 8/11 low-grade patients. Of the high-grades, 7/10 had sciatic curves and 3 secondary lumbar. In low-grades, the main indication for surgery was pain in 3/11 and lumbar curve progression or the intent to prevent it in 8/11. The operative technique was uninstrumented posterolateral fusion in 8/11, instrumented L4-S1 fusion with reduction of L4-tilt in 2, and direct repair in 1 patient. High-grades were fused to prevent further slipping regardless of subjective symptoms (uninstrumented anterior 5, combined 2, instrumented reduction 3). The follow-up time was 10.6(2-21)y.

Results: Of the eleven low-grade patients, 5 were pain-free, 4 had moderate pain, and 2 had a severe chronic pain syndrome. One had broken pedicle screws without sequelae. Of the ten high-grade patients, 4 were pain-free, 6 had moderate pain. One had a pain-free peroneal weakness after slip reduction. Selective thoracic fusion for scoliosis was performed later in 3 patients. All sciatic curves resolved. None of the lumbar curves needed fusion.

Conclusion: Spondylolisthesis in patients with concomitant scoliosis can be treated by fusion if the indications are met. The need of subsequent scoliosis surgery seems to be rare.

108. Prevalence of Spondylolisthesis and Concomitant Adolescent Idiopathic Scoliosis

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Summary: This the first study in 25 years depicting the true incidence/association of spondylolisthesis and AIS. We found that 4.4% of AIS patients requiring surgical correction had concomitant spondylolisthesis. However, there was a much more significant percentage of patients presenting with spondylolisthesis having associated scoliosis (asymptomatic =19.7, symptomatic=29.2%). Patients presenting with either AIS or spondylolisthesis require evaluation for both conditions.

Introduction: The association of spondylolisthesis and adolescent idiopathic scoliosis (AIS) has never been thoroughly evaluated. Failure to appropriately identify a concomitant spinal disorder may result in inappropriate treatment and suboptimal outcomes. We set out to determine the prevalence of patients with both spondylolisthesis and AIS.

Methods: A prospective, multicenter database and radiographs were reviewed. All available radiographs were evaluated for the presence of AIS and spondylolisthesis. Patients were analyzed in three groups, which included: Group I - AIS patients requiring fusion (n=1132); Group II - symptomatic spondylolisthesis requiring fusion (n=66); and Group III - asymptomatic spondylolisthesis (n=149).

Results: The radiographs for 1266 patients were reviewed. In Group I, adequate radiographs were available for 1076 patients, and 47 (4.38%) were found to have concomitant spondylolisthesis. In Group II, adequate radiographs were available for 48 patients, and 14 (29.2%) were found to have concomitant true scoliosis, as well as 9 (13.6%) with sciatic scoliosis. In Group 3, adequate radiographs were available for 142 patients, and 28 (19.7%) were found to have concomitant true scoliosis, as well as 13 (9.2%) with sciatic scoliosis.

Conclusion: Our results suggest symptomatic and asymptomatic spondylolisthesis are associated with concomitant scoliosis in approximately 20-30% of patients. Therefore, routine scoliosis evaluation should be considered in patients presenting with symptomatic and asymptomatic spondylolisthesis. In contrast, the prevalence of AIS requiring fusion with concomitant spondylolisthesis was relatively uncommon (4.4%).

109. Treatment of Low Grade L5-S1 Developmental Spondylolisthesis: Predictors of Operative and Non-Operative Treatment

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Summary: Patients with low grade developmental spondylolisthesis were assessed for characteristics that distinguished non operative from operative treatment groups. Physical examination, radiographic and HRQoL features differed significantly in each group. These findings may assist patients and physicians in selection of appropriate treatment plans.

Introduction: Low grade developmental L5-S1 spondylolisthesis (Meyerding grade 0, 1, 2) is a common condition affecting adolescents. Symptomatic treatment ranges from observation and restricted activity to surgical treatment. Characteristics of patients that factor into the treatment decision are not well described in the literature. In this study, we compared the characteristics of each treatment group to gain insight into the choice of treatments.

Methods: 142 patients mean age 14.2 2.8 yrs. with low grade (grade 0, 1, 2) L5-S1 developmental spondylolisthesis were identified from a prospective multiple center data base. 71 non operative patients (NOP) and 71 operative patients (OP) were identified. Demographic data, physical findings, sagittal radiographic parameters, SF 12, and SRS 30 scores were compared for NOP and OP groups. Comparative statistics were performed with a significance level set at $p<0.05$.

Results: OP patients (15.2±3.2 yrs;F:45,M:26) tended to be slightly older(p=0.03) than NOP(14.2±2.4yrs; F:33,M:38) and more likely female than male. Nerve root symptoms(21% vs 0; p<0.001), restricted lumbar range of motion(60%vs 24%, p=0.03)) and hamstring tightness(66% vs 48%;p,0.001)) were found more often in the OP group. Sagittal radiographic measurements were significantly higher in the OP group for pelvic incidence, L5 incidence, pelvic tilt, sacral slope, lumbar lordosis, lumbar tilt and C7 balance. (see Table) Surgical patients had significantly lower scores on the SRS 30 for pain, appearance, activity, satisfaction, and total scores. Mental score did not differ significantly. On the SF 12, surgical patients had lower PCS, physical function, role physical, bodily pain and vitality scores. No statistical difference was found for BMI, medication history, non op treatment modalities, or co- morbidities.

Conclusion: Significant differences were found in physical examination, radiographic parameters and HRQoL scores between OP and NOP patients with developmental spondylolisthesis. Mental function did not differ. Measurable radiographic param-

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eters that distinguish OP from NOP patients may assist patients and physicians in appropriate treatment decisions.

110. Compensatory Mechanisms and the Effect of Age on Sagittal Balance in Spondylolisthesis

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Summary: A cross-sectional observational study of pre-operative radiographs, in 382 consecutive patients with spondylolisthesis (isthmic-85 and degenerative-297) who underwent surgery for pain or neurological deficit. We identify three distinct compensatory mechanisms have been identified in spondylolisthesis induced sagittal imbalance, and discuss the effects of age upon these mechanisms.

Introduction: Few studies have investigated the effect of age on spino-pelvic sagittal alignment and to the authors' knowledge; none have examined this effect in patients with spondylolisthesis. Knowledge of the effects of age on sagittal alignment in the degenerating spine may aid our understanding of the compensatory mechanisms, which patients adopt.

Methods: Measures of sagittal alignment were acquired manually from the pre-operative radiographs by two trained observers. Inter & intra-observer error was measured. Pearson's univariate correlations were tested between age and the measured parameters. Compensation mechanisms were explored by examining correlations between spino-pelvic parameters - for all patients and after stratifying into three age groups (<45-years, 45-60 and >60-years). Statistical analysis utilized SPSS software version 19.0. Significance was set at $p<0.05$.

Results: No significant correlations were found between age and any parameters in the degenerative spondylolisthesis patients. In the isthmic spondylolisthesis patients, correlations were found between age and total lumbo-pelvic lordosis ($r=-0.45$) and between age and pelvic angulation ($r=0.44$). In the younger age (<45years), isthmic patient subgroup, a strong correlation (-0.58, $p=0.02$) was found between the focal lordosis at the level of the slip and the lumbar lordosis above. Correlations between total lumbo-pelvic lordosis and pelvic angulation were observed in both the degenerative spondylolisthesis ($r=0.74$, $P<0.001$) and isthmic spondylolisthesis ($r=-0.69$, $p<0.001$) patients.

Conclusion: The hyperlordosis observed (above a spondylolisthesis) in younger patients may represent the primary compensation mechanism for a focal loss of sagittal alignment (Type I), while an increase in pelvic angulation (pelvic retroversion) appears to be a secondary compensation mechanism that is adopted by older patients, with stiffer spines (Type II). It is postulated that hip and knee-flexion may represent a third compensation mechanism, which is used when the limit of pelvic extension is reached (Type III).

111. A Line of Zebrafish with Progressive Spinal Curvature

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Summary: A Line of Zebrafish with Progressive Spinal Curvature has been observed with the degree of curvature ranging from 18° to 40°. This scoliotic model in a zebrafish line where the offspring exhibits a predictable frequency of scoliosis can be used to study the etiology and progression of scoliosis.

Introduction: The lack of a good animal model system has hindered studying the etiology of idiopathic scoliosis. Recently, it has become clear that several fish species appear to exhibit spinal curvatures. The purpose of this study was to determine if the affected tissue in a line of zebrafish with spinal deformities resembles the pathology observed in pediatric populations with scoliosis.

Methods: Potential founder fish with spinal curvatures were outcrossed with a wild type zebrafish line (AB) and the resulting siblings (F1 generation) crossed and the offspring (F2 generation) examined for signs of spinal curvature beginning at 14 days post fertilization (dpf). Spinal curvatures of the affected fish were visualized using either a Faxitron or by Alizarian red staining of the skeletons and the curvature measured from the resulting images in the thoracic, thoracolumbar, or lumbar regions. Affected and normal zebrafish were fixed, embedded, section and stained with hemotoxylin and eosin.

Results: The degrees of curvatures ranged from 18° to 40°. Histological data demonstrated structural changes as compared to normal fish spine. Out of 212 individuals in the F2 generation 28, or 13.2%, were observed to have spinal deformities at 21 dpf. Importantly, we did not observe spinal deformities in the F1 generation fish and similar age wild type fish, indicating the observed spinal deformities were due to a recessive mutation(s).

Conclusion: An increase in scoliosis in family members and the occurrence of abnormal spinal curvatures in twins suggest a polygenetic inheritance pattern. We have noticed several fish in our zebrafish colony with spinal curvatures reminiscent of human idiopathic scoliosis.

112. Ghrelin Levels in Adolescent Idiopathic Scoliosis

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Summary: Total ghrelin was measured in adolescent Idiopathic Scoliosis and control group. Higher average level of total serum ghrelin was found in AIS group compared to the control group 261.9 vs. 146.1; $p<0.001$). Elevation of ghrelin levels remained significant before and after adjusting for corrected BMI or corrected BMI Z-score. These results suggest that ghrelin plays a role in physiopathology of AIS.

Introduction: Ghrelin is a peptide hormone mostly produced by the human stomach. It plays various roles such as hunger stimulation, growth hormone secretion, energy metabolism and cell proliferation. It is involved in bone growth and metabolism. Adolescent Idiopathic Scoliosis (AIS) are often lean with high stature and low bone density. Therefore ghreline may be involved in the onset or progression of AIS. The aim of our study was to compare ghrelin serum level in patients with and without AIS.

Methods: 49 female patients were prospectively included in the AIS group (mean Cobb angle of 56°) and 15 females with matching age (12 to 17 years old) represented the control group. All patients included had no evidence of any endocrine disease or history of steroid intake. In AIS group, corrected height was computed by adjusting trunk loss using Bjure formula (Log Y = 0.011 x X - 0.177). Overnight

fasting blood was obtained for ghrelin level determination. Total ghrelin was measured using a radioimmunoassay with a 2 pg/ml detection limit.

Results: Higher average level of total serum ghrelin was found in AIS group compared to the control group 261.9 vs. 146.1; p <0.001). Elevation of ghrelin levels remained significant before and after adjusting for corrected BMI or corrected BMI Z-score. Unlike healthy controls, positive correlations were found between ghrelin and age in AIS girls. In subjects younger than 14 we observed a 34% higher total ghrelin concentration in the AIS group than in controls (231.5 vs 172.8, p=0.06). In subjects older than 14, there was a highly significant difference with a 174% higher total ghrelin concentration in the AIS group than in controls (291.0 vs 106.2, p=0.003).

Conclusion: Substantial increase of ghrelin serum level was measured in AIS suggesting its participation in physiopathology. We assumed the implication of cell resistance to ghrelin, much alike resistance to melatonin hormone.

113. The Relationship of Symptomatic Thoracolumbar Disc Herniation and Scheuermann's Disease

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Summary: Symptomatic thoracolumbar junction disc herniation may be a form of atypical Scheuermann's disease.

Introduction: Symptomatic disc herniations at thoracolumbar levels between T10/11 and L1/2 can be collectively called thoracolumbar disc herniation (TLDH). The etiology of this disorder is unclear. Furthermore, symptomatic TLDH is rare enough that its frequent occurrence with another spinal disorder (Scheuermann's disease, SD) warrants investigation. Although the simultaneous occurrence of symptomatic TLDH and SD has been observed previously, the limited number of cases reported makes it difficult to investigate the relationship between them that may explain the etiology of symptomatic TLDH.

Methods: Cohort of 63 patients with symptomatic TLDH who had surgery between June 2006 and June 2011 were investigated. Incidences of associated SD and its radiographic signs (Schmorl's node (SN), irregular end-plate, posterior bony avulsion (PBA) and wedge-shaped vertebrae) in the TLDH patients, average thoracolumbar kyphotic angle and incidences of disc herniation at segments with and without radiographic signs of SD were examined. Data from the TLDH group were compared with 57 patients undergoing surgery for lower lumbar disc herniation (LDH, L3/4-L5/S1) in the same period.

Results: Of the TLDH patients, 95.2% had associated SD, whereas the incidence of SD in lower lumbar disc herniation patients was only 17.5% (P=0.00). The incidences of SN, irregular end-plate, PBA and wedge-shaped vertebrae were all higher in the TLDH group than in the LDH group. The average thoracolumbar kyphotic angle of TLDH patients was 16.9°, while that of the LDH group was 7.6° (P=0.00). In the TLDH group, the incidences of disc herniation at segments with SN, irregular end-plate, PBA and wedge-shaped vertebrae were all higher than at segments where no sign of SD was found. Particular attention was given to the high incidence (85.7%) of PBA in TLDH patients and high incidence (96.8%) of disc herniation at segments with PBA.

Conclusion: Although it would be arbitrary to suggest that symptomatic TLDH in general is a form of SD, the high proportion of associated SD in symptomatic TLDH patients suggests a close relationship between these two disorders.

114. Relationship between Syringomyelia Size and Scoliosis in Patients with Chiari I Malformation

David H. Kim, BS, MS; Michael P. Kelly, MD; Tae S. Park, MD; Lawrence G. Lenke, MD; David D. Limbrick, MD, PhD
USA

Summary: A review was performed on 99 consecutive patients at a single institution with Chiari I Malformation meeting the criteria of cerebellar tonsil descent of at least 5 mm and the presence of Syringomyelia. Increasing syrinx diameter was associated with an increased risk of scoliosis.

Introduction: The association between Chiari I malformation, syringomyelia, and scoliosis has been noted in previous studies. However, the relationship between these conditions remains poorly understood. This study seeks to demonstrate a relationship between syrinx diameter and the presence of scoliosis.

Methods: A retrospective analysis of patient records from 1990 to the present day yielded 99 consecutive patients at one institution, who had imaging records allowing confirmation of Chiari I malformation with cerebellar tonsil descent of at least 5 mm and syringomyelia. Syrinx size was estimated by anterior-posterior diameter (mm). Presence of scoliosis was examined with radiographic or magnetic resonance imaging. Logistic regression was performed to evaluate the relationship between syrinx diameter and the presence of scoliosis.

Results: Of 78 patients with Chiari I malformation (>5 mm) and syringomyelia equal or greater than 3 mm max AP (Mean Age 10.0 yo, 1.3 -17.6), 61/78 (78%) patients had scoliosis. Of 21 patients with Chiari I malformation (> 5 mm) and syringomyelia less than 3 mm max AP (Mean Age 11.6 yo, 0.8 -17.8), 5/21 (24%) patients had scoliosis. Syrinx diameter was associated with the presence of a scoliotic deformity (OR: 1.31, p = 0.001). Age was not associated (p=0.24).

Conclusion: The results from this retrospective analysis demonstrate a positive correlation between syrinx diameter and the presence of scoliosis in patients with Chiari I-associated syringomyelia. With increasing syrinx diameter, the likelihood of a scoliosis increased. The sharp difference in rates of scoliosis at 3 mm max AP syrinx size may indicate a useful clinical cutoff to assess risk of development of scoliosis in patients with Chiari I malformation and syringomyelia.

115. Management of Delayed (Greater than One Year) Deep Infection after Spinal Fusion

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USA

Summary: A 3% incidence of delayed deep infection following instrumented spinal fusion was identified at a single center. Propionibacterium acnes was the most common organism identified and took nearly one week to grow in culture. Removal of implants and targeted antibiotic therapy is recommended to eradicate delayed infection after spinal fusion.

Introduction: Despite being beyond the CDC definition of surgical site infection, a high incidence of delayed (>1 year) deep infection after instrumented spinal fusion

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was identified at our institution. We evaluated the efficacy of our management of these patients.

Methods: 1390 patients underwent instrumented spinal fusion from 2000-2009. 42 patients developed deep infection >1yr after index procedure (3%). Infection occurred at an average patient age of 18 yrs (range 14-25) with follow-up averaging 0.7 years after delayed infection and 4.1 years after index surgery. Clinical records and microbiology reports were reviewed for details of operative and post-operative management.

Results: Surgical debridement was done in all patients to obtain cultures and remove infected and necrotic tissue. Advanced imaging was only obtained in 6 patients (5 CT, 1 MRI). Offending organisms were identified in 39/42 patients (P. acnes: 21, Coag neg staph: 7, Polymicrobial with P. acnes: 6, Strep: 2, Enteric: 1, Staph aureus: 1, and Mycobacteria: 1). P. acnes grew in culture at a median of 6 days (range: 3-10), significantly longer than all other organisms, which grew in a median of 1 day (range: 0-8) [p<0.001]. Implants were removed at the index hospitalization in 40 patients. Implant retention was attempted in 2 patients; one failed and required implant removal due to recurrence 2.2 months after initial debridement. The second grew P. acnes from cultures taken during pseudarthrosis repair, was treated medically, and did not develop deep infection. Primary closure was done in 37 patients, the remainder had multiple debridements (4 planned, 1 unplanned). VAC closure was not utilized. All patients were treated with organism specific IV antibiotics and transitioned to oral antibiotics on average in 34 days (range: 2-186). Total length of antibiotic therapy was an average 132 days (range: 34-363).

Conclusion: P. acnes was the most common organism identified and took nearly one week to grow in culture. Treatment is generally successful with thorough debridement, removal of implants, and antibiotic treatment.

116. Prevalence of Intra-Operative Tissue Bacterial Contamination in Posterior Pediatric Spinal Deformity Surgery

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USA

Summary: With a prevalence of 23%, the risk factors for intra-operative bacterial contamination include neuromuscular cases with pelvic fusion, children older than 11 years, and surgery longer than 6 hours.

Introduction: Surgery to correct pediatric spinal deformity surgery has risks for early or late surgical site infection (SSI). The primary purpose of this pilot study was to determine the prevalence of positive intra-operative microbial tissue cultures that would stem from bacterial contamination of the surgical site.

Methods: 114 consecutive cases of posterior instrumented deformity surgery for pediatric scoliosis were retrospectively identified. All patients had received preoperative and q 4 hour intra-operative antibiotics, and 3M™ Ioban™ 2 Antimicrobial Incise Drape. Preoperative photos of patients' backs were used to correlate contaminant bacteria with presence of back acne. Lab cultures were obtained from paraspinal muscle that was debrided prior to incision closure.

Results: Of the 114 cultures obtained, 26(23%) were positive in 11/53 (21%) idiopathic, 13/35 (37%) neuromuscular (OR 3, CI 1.210-7.437, p= 0.02), 2/14 (14%) congenital and 0/12 (0%) syndromic. Contaminant bacteria included P Acnes 18/26 (69%), Staphylococcus 6/26 (23%), Coryneform 1/26 (4%) and Clostridium 1/26 (4%). P Acnes was seen only in children 11 years or older (OR 23.5, CI 1.0-529 p=0.02) and only with visible back acne (OR 73.4, CI 4.3-1258, p <.0001). 8 of 19 (42%) patients with pelvic fusion had positive cultures (OR 3.1, CI 1.1-8.8, p=.04) with all 8 cases seen in neuromuscular patients. 21 of 26 (81%) culture positive patients were older than 11 years of age. (OR 3.8, CI 1.3-11.8, p= .01). 18 of 26 (69%) patients with positive cultures had surgery lasting greater than 6 hours (OR 2.9, CI 1.2-7.5, p =.03). Overall, 3/114 (2.7%) patients developed an early deep SSI, all with positive cultures (OR 26.4, CI 1.3-528, p=.01). All infected cases were neuromuscular patients with fusion to pelvis.

Conclusion: Neuromuscular patients fused to the pelvis, children older than 11 years, and duration of surgery greater than 6 hours was associated with positive cultures. Back acne is a preventable risk factor that was specific for P Acnes seeding in adolescents. New methods such as consult with dermatology, antimicrobial wash, and appropriate timing of antibiotics may be helpful additions to reduce bacterial contamination.

117. Intravenous Vancomycin to Prevent Surgical Site Infections: Impact and Complications of a New Prophylaxis Protocol at a Large Pediatric Spine Center

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USA

Summary: In a trial of mandatory vancomycin prophylaxis protocol for spine surgery patients, we noted a high rate of adverse events and operative delays; we have abandoned IV vancomycin prophylaxis and now use local administration of vancomycin powder to the surgical site immediately before wound closure.

Introduction: The use of intravenous (IV) vancomycin prophylaxis in pediatric spine patients has not been reported. After institutional implementation of a new multidisciplinary protocol mandating the addition of IV vancomycin to the standard prophylactic regimen for all spine surgery patients, we sought to identify peri-operative benefits and problems related to this change in protocol.

Methods: We reviewed consecutive patients undergoing spine surgery after the institution of a new antibiotic protocol, analyzing peri-operative antibiotic adverse events, operative delay time and 30-day infection rates.

Results: 74 consecutive patients received adjunctive, prophylactic IV vancomycin in addition to standard antibiotic regimens for spine surgery; during the same time period, 30 patients received only standard prophylactic antibiotics. There was a much higher rate of adverse events in the adjunctive vancomycin group, including: red man syndrome (3 patients, causing operative delay), complaints of itching and rash (8 patients), hypotensive episodes (2 patients), and IV infiltrations (4 patients). In the control group, there were no episodes of red man syndrome, itching, IV infiltrations; there was 1 rash and 1 hypotension episode. There was no statistically significant difference in the rate of 30 day surgical site infections between the two groups (3 cases in the vancomycin group and 2 in the control group).

Conclusion: Our trial of mandated IV vancomycin prophylaxis resulted in a high rate of antibiotic-associated peri-operative adverse events including red man syndrome,

IV infiltrations, and operative delay time, with no significant difference in SSI during the study period. We have abandoned IV vancomycin prophylaxis and now use local administration of vancomycin powder to the surgical site immediately before wound closure.

118. Postoperative Drains and the Risk of Surgical Site Infection Following Spinal Surgery

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USA

Summary: Various combinations of the placement of a spinal drain, the duration of time a drain remains in place and the prophylactic antibiotic regimen used are analyzed and discussed with respect to the occurrence of surgical site infections.

Introduction: The use of postoperative drains has been evaluated extensively in the joint arthroplasty literature, but to a much lesser extent in the spine literature. The purpose of this study is to determine if the placement and duration of a spinal drain and the prophylactic antibiotic regimen used affect the occurrence of surgical site infections (SSI) in spine patients.

Methods: The medical records of patients that were enrolled in a previous randomized, controlled trial were reviewed. Perioperative measures were statistically compared between groups. Patients with drains by the length of their postoperative antibiotic treatment - some patients received postoperative antibiotics for 24 hours (TF), while others received antibiotics for the duration of time the drain was in place (DUR); others did not receive drains and received postoperative antibiotics for 24 hours (ND). Risk factors for infection were also evaluated.

Results: ND patients had lower mean age ($p<0.01$), ASA score ($p<0.02$), operative time ($p<0.01$), estimated blood loss ($p<0.01$), transfusion rate ($p<0.01$), and length of stay ($p<0.01$) than patients that received drains. ND patients (n=129) had a mean infection rate of 7.0%; this was not significantly different from TF patients (12.1%, n=199, p=0.14). The infection rate in ND patients was significantly different than the infection rate amongst DUR patients (14.4%, n=167, p=0.05). TF patients with drains for fewer than 3 days (n=156) had a significantly lower rate of infection (8.3%) than those with drains for longer than 3 days (23.8%) (n=42) (p=0.03). There were significant differences in infection rates between ND patients and those who had drains for more than 3 days, regardless of antibiotic treatment (TF, p=0.02; DUR, p=0.03).

Conclusion: Patients with drains appear more likely to develop a surgical site infection than patients without drains if their postoperative antibiotics are continued for the duration of time the drain is in place. Patients with spinal drains for longer than 3 days also had a higher rate of developing postoperative surgical site infections. There may be a need to revise prophylactic antimicrobial measures in spine patients that have postoperative drains, especially for those that have them for more than 3 days.

119. Outcome and Treatment of Post-Operative Spine Surgical Site Infections: Predictors of Treatment Success and Failure

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USA

Summary: We treated 225 patients with surgical site infections and analyzed 197 (>1 year follow-up) patients to identify risk factors associated with treatment failure. Forty-three cases had treatment failure including patients with ongoing infection after 90 days of treatment (23 cases), the need to remove and/or implants (15 cases), and death due to sepsis (5 cases). Multivariate regression revealed late infection was the independent risk factor associated with treatment failure. Superficial infection and MSSA were predictors of early resolution.

Introduction: Surgical site infection (SSI) is an important complication after spine surgery. The management of SSI is characterized by significant variability and there is little guidance regarding an evidence-based approach. The purpose of this paper is to report the treatment and outcome of 225 SSIs, and to identify risk factors associated with treatment failure.

Methods: Retrospective study of consecutive spine surgeries between July 2005 and July 2010 were studied. Treatment success was defined as resolution within 90 days with at least one year with no further surgeries. Treatment failure included delayed resolution (>90 days treatment), persistence (implant removal/reimplantation), or death. Fisher's exact or X2 test and logistic regression were used to identify significant associations.

Results: 225 surgical site infections were identified. Microbial distribution of 222 cultured cases: 44% Staphylococcus aureus (28% MSSA, 16% MRSA), 35% polymicrobial, 27% Staphylococcus epidermidis, 16% Enterococcus, 10% E coli, 7% P acnes, 5% Pseudomonas, 5% Enterobacter, 3% Fungi, and 3% culture negative. Early resolution was achieved in 92% of 50 non-instrumented cases and 73% of 147 instrumented cases. A total of 43 cases had treatment failure including patients with ongoing infection after 90 days of treatment (23 cases), the need to remove and/or implants (15 cases), and death due to sepsis (5 cases). Risk factors for treatment failure included late infection (first detected more than 90 days after, 38%), fusion with fixation to ilium (67%), poly microbial (68%), > 6 spine levels (67%), instrumented (73%) and P acnes (43%). Multivariate regression revealed late infection ($P = 0.011$) was the most significant independent risk factor associated with treatment failure.

Conclusion: Post-operative spine infections were treated with aggressive surgical debridement and antibiotic therapy. Superficial infection, short fusion and MSSA were predictors of early resolution. High rates of treatment failure occurred in cases with late infection, long instrumented fusions, poly microbial infections, and P acnes. Removal of implants and direct or staged reimplantation may be a useful strategy in cases with high risk of treatment failure.

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120. Plastic Surgery-Assisted Management of Spinal Surgical Site Infection Reduces Risk of Implant Removal by Half

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USA

Summary: This study evaluates factors related to implant retention in the setting of spinal SSI. Retention was not related to acuity or type of metal. But, multi-disciplinary management with multiple washouts, wound VAC therapy, and flap closure more than doubled the rate of retention to 80%.

Introduction: Reports have shown that patients usually cannot clear spinal surgical site infection (SSI) without implant removal. The purpose of this study is to evaluate factors related to implant retention in spinal SSI.

Methods: This is a retrospective single-center study of 31 consecutive cases of SSI after spinal fusion for deformity. Inclusion criteria are: spinal deformity surgery, documented deep SSI, and 2-year follow-up. Acute SSIs are those occurring <3 months after index surgery; delayed SSIs are those occurring ≥3 months. In 2008, we began consulting plastic surgery to assist with spinal SSI management, resulting in multiple washouts, wound VAC therapy, and flap closure, as opposed to orthopedic management alone. Implants are retained only in the absence of signs of active infection. Z-test was used to compare differences in rates.

Results: We show an overall 61% rate of implant retention after an average follow-up of 4 years (range, 2-10 years). Of the 31 cases, 18 SSIs were acute; 13 SSIs were delayed. There is an increased rate of implant retention in acute SSIs (70%) vs. delayed SSIs (39%) (p=0.16). There is also an increased rate of implant retention with titanium implants (75%, 6/8) vs. stainless steel implants (48%, 11/23) (p=.24). Importantly, there is a trend for increased rates of implant retention when plastic surgery assisted with multiple washouts, wound VAC, and flap closure (80%, 8/10) vs. cases managed without this protocol (38%, 9/21)(p=.07).

Conclusion: Despite previous reports showing that implant removal is often necessary to clear delayed spinal SSI, we find that implant retention with delayed SSI is possible. Importantly, multi-disciplinary management with multiple washouts, wound VAC therapy, and flap closure more than doubled the rate of implant retention to 80% at long-term follow-up.

121. Pedicle Screw Misplacement in Apical and End Vertebrae: A CT-Based Review of 285 Pediatric Patients

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USA

Summary: Pedicle morphology, pedicle screw misplacement, and misplaced screws in proximity to vital structures were compared at apical and end vertebrae in patients who underwent correction of spinal deformity. Pedicle screw misplacement was more common in foundation vertebrae than in apical vertebrae. The anatomical and technical difficulties commonly encountered in the upper thoracic spine may account for this finding.

Introduction: It is largely believed that the concavity of the curve apex is the most difficult part of the spine to instrument because the pedicles are the smallest and most deformed. However, technical difficulties may also affect the accuracy of instrumentation and may lead to screw misplacement in other areas. The purpose of this study is to determine if foundation screws are more often malpositioned than screws at the curve apex.

Methods: CT scans of 285 pediatric patients with spinal deformity were reviewed for pedicle morphology and screw placement in the upper and lower instrumented vertebrae and the apical vertebra of the major and minor curves. Pedicle morphology was classified according to our previously described CT-based classification system. Screws of concern were defined as those adjacent to or in contact with blood vessels, pleura, esophagus, diaphragm, or trachea. Chi square analysis and logistic regression were used to compare the incidence of abnormal pedicles and screw placement between foundation and apical vertebrae.

Results: 1216 vertebrae were studied, including: 346 at the apex of major curves, 180 at the apex of minor curves, 346 at the L.I.V., and 344 at the U.I.V. There was a significant difference in the incidence of abnormal pedicles and in the accuracy of screw placement among the groups (p<0.001). U.I.V. had the highest percentage of abnormal pedicles and the highest rate of screw misplacement. Fisher's exact test showed significantly more screws of concern in the U.I.V. than in the other groups (p=0.0335). Logistic regression demonstrated a significantly higher risk of screw misplacement in upper instrumented vertebrae than in apical vertebrae (p=0.023).

Conclusion: Foundation vertebrae had more pedicle screw placement error than apical vertebrae. Of note, significantly fewer caudal foundation screws were malpositioned than cephalad foundation screws. Caudal screws were in the lumbar spine, which has larger pedicles and thus is more easily visualized. Cephalad pedicles were in the upper thoracic spine with kyphosis and soft tissue constraints making visualization difficult. Apical vertebrae had more ease in visualization and accessibility, thus less placement error.

122. The Accuracy of Pedicle Screw Placement in Scoliosis Surgery: Comparison between O-Arm-Based and Conventional Computed Tomography-Based Navigation

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Japan

Summary: We compared the accuracy of O-arm-based navigation vs. CT-based navigation in scoliotic surgery. O-arm-based navigation facilitates pedicle screw insertion as accurately as conventional CT-based navigation. The use of O-arm-based navigation successfully reduced the time needed for computer-assisted surgery, demonstrating advantages in safety and accurate pedicle screw placement for scoliotic surgery.

Introduction: The latest developed O-arm-assisted spinal navigation is the only technology that involves acquisition of high-resolution images and 3D data sets on the operating table and allows fully automatic registration. Presently, no reports about pedicle screw insertion in scoliotic surgery comparing the results of O-arm-based navigation vs. conventional computed tomography (CT)-based navigation have been published. The purpose of the present study is to compare the accuracy of O-arm-based navigation vs. CT-based navigation in scoliotic surgery.

Methods: Sixty-three consecutive scoliotic patients who underwent posterior corrective surgery from Jan 2010 to Aug 2011 were retrospectively reviewed. Overall, 254 pedicle screws were implanted in 31 patients using CT-based navigation from Jan 2010 to Oct 2010 (group C) and 416 screws were implanted in 32 patients using O-arm-based navigation from Nov 2010 to Aug 2011 (group O). Postoperative CT was performed to assess screw accuracy using the established Neo classification (Grade 0: no perforation, Grade 1: perforation <2 mm, Grade 2: perforation ≧2 and <4, Grade 3: perforation ≧4 mm). The time to position one screw, including registration, was calculated.

Results: In group C, 217 (85.4%) of the 254 pedicle screw placements were categorized as Grade 0, 26 (10.2%) were Grade 1, 11 (4.3%) were Grade 2, and 0 were Grade 3. In group O, 351 (84.4%) of the 416 pedicle screw placements were categorized as Grade 0, 52 (12.5%) were Grade 1, 13 (3.1%) were Grade 2, and 0 were Grade 3. Statistical analysis showed no significant difference in the prevalence of Grade 2-3 perforations between groups C and O. The time required for the registration procedure and insertion of one pedicle screw was 10.8±3.1 minutes in group C, but significantly decreased to 5.4±1.1 minutes in group O.

Conclusion: O-arm-based navigation facilitates pedicle screw insertion as accurately as conventional CT-based navigation. The use of O-arm-based navigation successfully reduced the time needed for computer-assisted surgery, demonstrating advantages in safety and accurate pedicle screw placement for scoliotic surgery.

123. Radiation Dose from 3D O-Arm Imaging in Adolescent Idiopathic Scoliosis (AIS) Surgery

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USA

Summary: This phantom study provides practical dose references to clinicians regarding 2D and 3D imaging modalities for AIS PSF surgery.

Introduction: Portable imaging systems with three dimensional (3D) imaging capabilities enable orthopedic surgeons to confirm accurate placement of thoracic pedicle screws during posterior spinal fusion (PSF) AIS surgery without moving patients from the OR for conventional CT imaging. It is important to ascertain the radiation dose consequence of this practice. This study compares the radiation dose from 3D O-Arm imaging (3D-Oarm) with that of conventional CT and traditional 2D fluoroscopy.

Methods: AIS PSF surgical imaging procedures were performed on a 15 yr old anthropomorphic phantom. Radiation doses were evaluated for three modalities (3D O-Arm, 2D C-Arm, and CT) for thoracic and lumbar regions. Effective radiation doses from 3D O-Arm and 2D C-Arm were calculated using the Monte Carlo x-ray dosimetry software, PCXMC.

Results: The effective dose for a 3D O-Arm spin was estimated to be ~4.9 mSv on the medium patient setting, and ~3.5 and ~7.1 for the small and large patient settings, respectively. Nationally published effective doses for spine CT are 1.5 -10 mSv. We estimate the effective dose from our optimized lateral 2D C-Arm imaging to be 0.14 and 0.44 mSv/minute for T- and L-Spine respectively. The effective doses from 2D C-Arm were in the same range as published effective doses from another pediatric hospital.

Conclusion: AIS surgical procedures may utilize 2 to 4 O-Arm spins. The resultant radiation doses are significant and comparable to CT imaging. Variability in settings for C-Arms between manufacturers and institutions limit the usefulness of dose comparison between C-Arm and O-Arm. For example, one medium patient T-Spine spin is equal to ~33 min of fluoroscopy using our optimized 2D C-Arm, but has been reported as low as less than 1 min. CT output references levels are published by ACR and RSNA and effective dose ranges have been documented in the scientific literature making CT a reasonable metric for comparison of O-Arm effective doses to patients.

124. Incidence, Diagnosis and Management of Sacral Fractures Following Multi-Level Spinal Arthrodesis

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USA

Summary: Sacral fractures following instrumented spinal arthrodesis are generally not evident on plain radiography. Cross-sectional imaging is required for definitive diagnosis. Fusion constructs greater than four intervertebral levels and osteoporosis are both risk factors for this complication. Anterolisthesis >2mm or kyphotic angulation are both significantly associated with failure of conservative management.

Introduction: Fractures of the sacrum are a rare complication following instrumented spinal fusion with only thirty-four cases previously reported in the literature. Previous series have generally been limited to five or fewer cases. The objective of this study was to determine the incidence of sacral fractures caudal to instrumented spinal fusion constructs, identify risk factors for fracture and for failure of conservative management, as well as to describe strategies for surgical treatment of these fractures.

Methods: Review of clinical and radiographic data from a prospectively collected patient database from 2002-2011.

Results: Twenty-four patients developed sacral fractures caudal to instrumented spinal fusion constructs during the study time period. The overall incidence was 6.1% and was significantly greater in fusions greater than four levels (14.5%). The mean time from index surgery to fracture was 4.3 months. Only one fracture was evident on plain radiography at the onset of symptoms. CT, MRI and nuclear scintigraphy can all be used to establish the diagnosis. Eight patients were successfully treated conservatively. The mean time to fracture union was 21 weeks. Anterolisthesis of the fracture greater than 2mm and kyphotic angulation were significantly associated with failure of conservative management (see Figure). Surgical intervention included posterior extension of the fusion construct to S2 and the iliac wings with sacroiliac joint fusion. In ten cases, a combined anterior and posterior approach was used which consisted of either revision anterior lumbar interbody fusion or transacral posterior lumbar interbody fusion.

Conclusion: Sacral fractures following instrumented posterior spinal fusion are an uncommon complication that is often unrecognized on plain radiographs. Risk factors include ostoporosis and long spinal fusions. Anterolisthesis and kyphosis of the fracture is associated with failure of conservative management.

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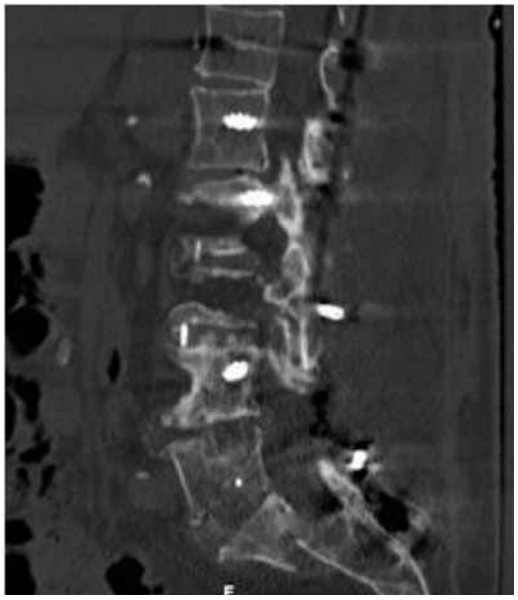

Sacral fracture below instrumented spinal arthrodesis construct displaying significant anterolisthesis of the fracture fragments

125. Revision Spinal Fusion in Patients Older than 75: Is it Worth the Risks?

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USA

Summary: 38 patients >75 years undergoing revision spinal fusion were compared with 54 age-matched patients undergoing primary fusion. Although both groups demonstrated similar and significant improvement at 1 year post-op, revision patients did substantially worse at 2 years while having more complications.

Introduction: The benefits of spinal fusion in patients older than 65 is well-documented. However, the clinical benefit to patients older than 75 of revision surgery, which often yields worse outcomes with higher complication rates, is uncertain.

Methods: 92 consecutive patients > 75 with minimum 2 year follow-up (f/u) underwent spinal fusion as either a primary (n=54) or revision (n=38) operation. Diagnoses were spondylolisthesis (n=39), scoliosis (n=26), and other degenerative spinal disorders (n=27). Outcomes were obtained prospectively by visual-analog pain scale (VAS) and Oswestry Disability Index (ODI) at pre-op, 1 year, 2 year, and latest f/u.

Results: Revision patients had significantly worse scores compared with primary patients at all time intervals, for both VAS (pre-op: 6.6 vs 5.6, 1yr: 3.6 vs 2.2, 2yr: 4.7 vs 2.4) and ODI (pre-op: 52.0 vs 44.3, 1yr: 36.4 vs 24.6, 2yr: 48.2 vs 24.3). Both groups improved significantly at 1 year post-op. At 2 years, the results of revision surgery deteriorated (VAS: -1.9, ODI: -3.8) while the benefits of primary procedures were maintained (VAS: -3.2, ODI: -20.0). Complications were greater in the revision group and included revision surgery (8[21.1%] vs 6[11.1%]), non-union (2[5.3%] vs 2[3.7%]), adjacent level fracture (5[13.2%] vs 3[5.6%]), infection (5[13.2%] vs 3[5.3%]), foot drop (1[2.6%] vs 3[5.3%]), imbalance (3[7.9%] vs 1[1.8%]), pulmonary failure (1[2.6%] vs 1[1.7%]), and death (1[2.6%] vs 2[3.6%]).

Conclusion: Despite having worse initial ODI and VAS scores, revision patients >75 initially benefit as much as patients >75 undergoing primary operations. However, at 2 years revision patients do not have a sustained benefit despite a higher complication rate. While spinal fusion can be beneficial in elderly patients, revision surgery has an unfavorable risk to benefit profile.

126. The Prevalence of Endocrine Abnormalities in Patients with Pseudarthrosis after Spinal Fusion

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USA

Summary: This prospective study reports the prevalence of metabolic/endocrine abnormalities in twenty four patients with CT verified pseudarthosis after 6 months from initial surgery. Overall, 87.5% (21/24) of patients had an endocrine or metabolic abnormality identified.

Introduction: The occurrence of pseudarthrosis after spinal fusion surgery often leads to considerable patient concern and morbidity. Metabolic and endocrine abnormalities have been identified as significant risk factors for pseudarthrosis.

Methods: Twenty-four consecutive patients were prospectively identified over a 36-month period with symptomatic pseudarthrosis. Pseudarthrosis was diagnosed by CT at a minimum of 6 months following the initial surgery. Patients were referred for standardized bone metabolic/endocrine work-up by an endocrinologist specializing in metabolic bone disease. Standardized blood draws, DEXA scans, and health questionnaires were completed on all patients. Patients underwent correction/optimization of abnormality before revision arthrodesis with iliac crest autograft. Patients were evaluated at a minimum of 6 months follow up.

Results: Mean age was 52.5 +/-8.0 years with 75% female and 37.5% smokers. Initial arthrodesis was performed in the cervical region in 46% of patients and lumbar in 54% of patients. Iliac autograft was used in 16.7% of the initial surgeries while allograft was used in 83.3%. Overall, 87.5% of patients had an endocrine or metabolic abnormality identified. Newly diagnosed abnormalities were found in 70.8% of patients, while insufficient management of known endocrine abnormalities were found in 25%. Vitamin D inadequacy (25 OH-D <32 ng/ml) was documented in 46% of patients, and Vitamin D deficiency (<20 ng/ml) in 13% of subjects. Based on DEXA scans, 46% of patients were newly diagnosed with osteoporosis/osteopenia. Other significant abnormalities were discovered in 50% of patients. 18 patients underwent revision arthrodesis, with no occurrence of pseudarthrosis.

Conclusion: Patients with pseudarthrosis after spinal fusion surgery were noted to have a high prevalence of metabolic/endocrine abnormalities. Vitamin D inadequacy/deficiency and osteoporosis/osteopenia were the most common, but other abnormalities were seen in half of the patients. This study emphasizes the importance comprehensive screening for intrinsic abnormalities and/or endocrinology evaluation in the setting of pseudarthrosis. Correction of these abnormalities optimizes the patient for successful treatment.

127. Results of Corrective Osteotomy in Ankylosing Spondylitis with Fixed Kyphotic Deformity

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Summary: We retrospectively analyzed ankylosing spondylitis patients with fixed kyphotic deformity who underwent corrective osteotomy and report the results focusing on technical aspects, correction obtained, clinical outcomes and complications.

Introduction: No one has reported results of corrective osteotomy in 248 patients performed by a single surgeon over a 14 years period.

Methods: We retrospectively analyzed ankylosing spondylitis patients who underwent corrective osteotomy between 1996 and 2009. Radiographic assessments included the sagittal vertical axis(SVA), correction angle, correction loss, thoracic kyphosis, lumbar lordosis and occipito-cervical range of motion(OCROM). Clinical outcomes were assessed by SF-36 and Oswestry Disability Index(ODI) scores. Clinical datas were collected by reviewing medical charts and operative notes.

Results: A total 292 corrective osteotomies were performed in 248 patients with a mean follow-up of 40.1 months (range, 24-104 months). There were 183 cases of single pedicle subtraction osteotomy(PSO), 19 cases of multiple Smith-Peterson osteotomy(SPO), 17 cases of PSO+SPO, 14 cases of single SPO, 6 cases of posterior vertebral column resection(PVCR) and 5 cases of PSO + partial pedicle subtraction osteotomy(PPSO) and 4 cases of PPSO. Mean difference of SVA before and after surgery were 87.3±25.1mm in PSO, 43.9±19.4mm in SPO, 90.7±27.8mm in PVCR and 57.3±21.5mm in PPSO. Mean correction angle were 31.9°±11.7° in PSO, 14.3°±8.4° in SPO, 38.3°±12.7° in PVCR, 19.3°±7.1° in PPSO. Outcome analysis showed a significant improvement in overall SF-36 and Oswestry score($p<0.005$). Statistical analysis revealed that SF-36 and Oswestry score improvements correlated significantly with the postoperative SVA and OCROM($p<0.005$). There were 38 surgery-related complications in 25 patients(10.1%).

Conclusion: Corrective osteotomy in ankylosing spondylitis patients is an effective and safe treatment with an acceptable rate of perioperative complications. Clinical outcomes according to the SF-36 and Oswestry scores were generally favorable. Postoperative SVA and OCROM were important factors to determine outcomes.

128. The Effect of PVCR on Pulmonary Function Improvement in Severe Rigid Spinal Deformity Patients with Respiratory Dysfunction

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China

Summary: Severe rigid spinal deformity is often associated with respiratory impairment, which increased the risk of pulmonary complications following surgical correction.Improvement of postoperative pulmonary function was regarded as more important goal than correction.PVCR has been reported as more effective to treat severe spinal deformities,however,few research involved postoperative PFT changes.

Introduction: To determine the change in pulmonary function test (PFT) following PVCR in severe rigid spinal deformity patients with respiratory dysfunction.

Methods: 24 PVCR patients with severe rigid spinal deformity with respiratory dysfunction were enrolled. The mean age was 18.9±8.2 years(range 11-45 years). The preoperative average scoliotic Cobb angle was 110.1°±14.6° and kyphotic 80.6°±29.2°.Patients were divided into 2 groups according to the preoperative vital capacity(VC):moderate (40%~60%) impairment and severe(<40%) impairment. PFT parameters were measured at preoperative,postoperative 2-week,3-month,6-month,1-year and 2-year ,which included VC, FVC, FEV1,VC%,FVC% and FEV1%. The relationship between PFT parameters, as well as pre- and post-operative subjective symptom improvement (respiratory distress, pulmonary inflammation, exercise capacity and quality of life),and postoperative recovery period were assessed according to the Metabolic Equivalent of Energy(MET) grade scale.

Results: Compared to the preoperative, all involved PFT parameters were significantly declined at postoperative 2-week, then gradually increased to get to the preoperative baseline from 3-month to 1-year, and notable improved (VC:17.1%, FVC:18.7%, FEV1:14.4%) at 2-year final follow up. The arterial blood gases value and MET grades has been shown similarly recovery tendency. In addition, there were positive correlation between recovery time,changes of postoperative PFT and improvement in subjective symptom.

Conclusion: Patients with severe rigid spinal deformity had significant decrease in PFT parameters values at 2-week postoperative, increased up to preoperative baseline at 1-year postoperative,and significantly improved at 2-year after surgery compared to the preoperative.The PFT deterioration at postoperative 2-week was probably due to prolong operative time,great amount of bleeding, pleura perforation intraoperation.Pulmonary function improvement following PVCR was deemed as a process of multi-factors influenced.Enlarged thoracic cage volume and released pulmonary alveolous following correction provided more space for ventilation. Moreover,the cardiopulmonary vessel resistance was decreased,and indirectly improved ventilation/blood flow (VA/Q) ratio.

129. Predictors of Pulmonary Improvement after Vertebral Column Resection for Severe Spinal Deformity

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USA

Summary: Pediatric patients undergoing posterior-only vertebral column resection (PVCR) for severe deformity demonstrated improved postoperative pulmonary function testing (PFTs), while adult PVCR patients did not demonstrate significant change. Pediatric PFT improvement correlated with younger age, diagnosis of angular kyphosis, no previous spinal surgery and preoperative halo traction.

Introduction: PVCR enables surgical correction of severe spinal deformity via a posterior-only approach, eliminating the need for a combined anteroposterior (A/P) approach that has been shown to have deleterious effects on PFTs. Knowing which pts are likely to have PFT improvement after PVCR will help with pt selection and perioperative care.

Methods: PFTs in 49 pts (27 peds/22 adult) who underwent PVCR at a single institution were reviewed. Mean age at surgery was 28.7yrs (range 8-74), and mean f/u was 2+6yrs (range 2-6). There were 30 females/19 males. Preop

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diagnoses were kyphoscoliosis (n=24), angular kyphosis (n=13), global kyphosis (n=9), severe scoliosis (n=3). Thoracic PVCRs (T5-11) were performed in 31 pts vs thoracoabdominal PVCRs (T12-L5) in 18 pts. Immediate preop as well as postop PFTs were obtained at regular f/u intervals. We compared PVCR PFTs to control groups of pediatric and adult deformity pts who underwent combined A/P fusions.

Results: In pediatric pts, PVCR resulted in both increased FVC (2.10 to 2.43L, p=0.0005) and FEV1 (1.71 to 1.98L, p=0.001). There were no significant differences in %predicted values (%PV) for FVC (69% to 66%, p=0.51) or FEV1 (64% to 63%, p=0.77). In adult pts, there were no significant changes in FVC (2.73 to 2.61L, p=0.35) or FEV1 (2.22 to 2.07L, p=0.51) after PVCR; also, changes in adult %PV for FVC (79% to 76%, p=0.47) and FEV1 (78% to 74%, p=0.40) were not significant. In pediatric PVCR pts, improved PFTs were correlated with younger age (p=0.02), diagnosis (angular kyphosis showed most improvement, p=0.02), no previous spine surgery (p=0.04), and preop halo traction (mean 0.38L increase, p=0.02). Comparison of PFT changes between the PVCR pts and a matched control group who underwent a combined A/P approach revealed no significant differences.

Conclusion: In pediatric pts, PVCR resulted in small but significant increases in postop FVC and FEV1 values. In adult pts, no significant change in PFTs was found. Our analysis suggests that pts who have the most remaining potential for lung and thoracic cage growth after spinal correction will most likely have improved pulmonary function after PVCR surgery. Preop halo traction contributes to improving PFTs in pediatric pts.

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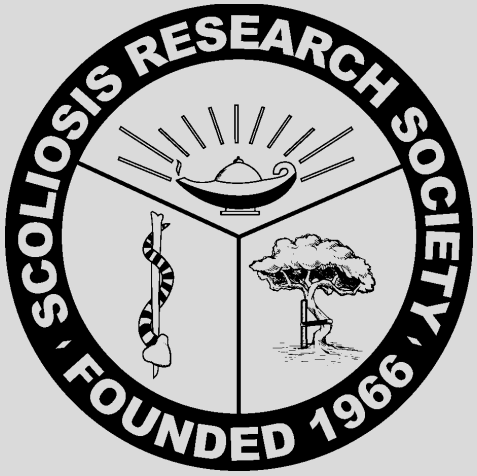
SCOLIOSIS RESEARCH SOCIETY
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‡201. Prediction of Scoliosis Surgery in Neurofibromatosis Type-1 Patients

Marios G. Lykissas, MD, PhD; Alvin H. Crawford, MD; Elizabeth K. Schorry, MD; Viral Jain, MD
USA

Summary: The aim of this study was to identify radiographic features than can predict the need for surgery in patients with NF1. NF1 patients in whom imaging evaluation showed a focal, short-segment curve had a significant 13.57 times greater odds of requiring surgery. Patients with 3 or more dystrophic features had a significant 36.43 times greater odds of requiring surgery. NF1 patients with no dystrophic features and no tumors were unlikely to progress to need for surgery.

Introduction: Scoliosis is the most common skeletal manifestation of neurofibromatosis type-1 (NF-1). The aim of this study was to identify radiographic features than can predict the need for surgery in this patient population.

Methods: The medical records of 694 patients with NF-1 followed in a multidisciplinary Neurofibromatosis Center from 1990-2008 were retrospectively reviewed. Detailed data was collected on those patients with a curve of more than 15 degrees and complete imaging available for analysis. Patients with 3 or more of these features were defined as having a dystrophic curve.

Results: The medical records of 56 patients were reviewed by two independent investigators. Of these patients, 59% had evidence of paraspinal tumors, 52% vertebral wedging, 36% vertebral rotation, 29% rib penciling, 55% vertebral scalloping, 36 % dural ectasia, 29% spindling, and 18% thoracic lordosis. A focal, short-segmented curve was found in 55% of the patients. Sixty-six percent had 3 or more dystrophic features. Ninety-four percent of patients with 3 or more dystrophic features required surgery. Surgery was indicated in 69% of patients with paraspinal tumors and 78% of patients with focal short-segmented curve. Only one patient with non-dystrophic curve required surgery. Scoliosis and need for surgery were equally distributed between males and females. Statistical analysis revealed that patients with NF-1 associated with paraspinal tumors had a significant 3.67 times greater odds of requiring surgery ($p = 0.030$). NF-1 patients in whom imaging evaluation showed a focal, short-segment curve had a significant 13.57 times greater odds of requiring surgery ($p < 0.001$). Patients with NF-1 who had three or more dystrophic features had a significant 36.43 times greater odds of requiring surgery ($p < 0.001$). The presence of an idiopathic curve associated with a significant 0.016 times smaller odds of requiring surgery than the presence of a dystrophic curve ($p < 0.001$).

Conclusion: The presence of 3 or more dystrophic features, paraspinal tumors, or focal, short-segmented curve was highly predictive of the need for surgery. NF-1 patients with no dystrophic features and no tumors were unlikely to progress to need for surgery.

202. Scoliosis in Neurofibromatosis Type 1: A Retrospective Review of 131 Patients

Marios G. Lykissas, MD, PhD; Elizabeth K. Schorry, MD; Alvin H. Crawford, MD; Viral Jain, MD
USA

Summary: From a population of 694 NF1 patients, 131 were found to have scoliosis with curves ranging from 10 to 120 degrees. Patients were followed for a median of 5 years. Mean age at diagnosis was 9 years. Racial distribution involved 85% Caucasian, 12% African American, and 3% other. Males and females were equally represented. Eighteen patients had onset of scoliosis before age 6 years. 46 patients required surgical repair. Tumors near the spine were found in 65% of patients requiring surgery.

Introduction: The goal of the study was to determine incidence, demographics, and radiographic features of scoliosis associated with NF1.

Methods: The medical records of 694 patients with NF1 followed in a multidisciplinary Neurofibromatosis Center from 1990-2008 were retrospectively reviewed. Detailed data was collected on those patients who had evidence of scoliosis. Data included age at diagnosis of scoliosis, gender, race, maximum degree of curvature, location of curve, and need for surgical intervention.

Results: From a population of 694 patients meeting diagnostic criteria for NF1, 131 (19%) were found to have scoliosis of at least 10 degrees with curves ranging from 10 to 120 degrees. Patients were followed for a median of 5 years after diagnosis of scoliosis (range; 1-30 years). Mean age at diagnosis was 9 years, with a range of 1 to 17 years. Demographics were representative of the racial distribution seen in our overall clinic population, with 85% Caucasian, 12% African American, and 3% other. Males and females were close to equally represented, with 53% being female. Eighteen patients (15%) had onset of scoliosis before age 6 years. Primary curves were mostly located in thoracic (53%) and thoracolumbar (39%) regions, with 10% primarily affecting cervical vertebrae and 6% involving primarily lumbar vertebrae. Forty six patients (35%) required surgical repair, usually anterior/posterior spinal fusion with rod placement. Six young children had growing rods successfully placed. Tumors near the spine were found in 65% of patients requiring surgery.

Conclusion: In our multidisciplinary clinic population, 19% of NF1 patients had a scoliotic curve of greater than 10 degrees. When corrected for 18 patients who were referred from outside our usual 3-state region, the prevalence of scoliosis was 16%. In contrast to idiopathic scoliosis, in the NF1 scoliosis population, the genders are equally represented: 53% of NF1 scoliosis patients were female.

203. Meta-Analysis of Adult Degenerative Scoliosis Surgical Treatment Outcomes

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USA

Summary: Systematic literature review and meta-analysis of outcomes after surgical treatment for adult degenerative scoliosis were conducted. Despite significant heterogeneity among studies, random-effects meta-analysis models did show significant improvements in Cobb angle, coronal balance, VAS and ODI after surgical treatment.

Introduction: There is increasing awareness of adult degenerative or "de novo' scoliosis, Surgical treatment when indicated can be challenging and resource intense. Surgical randomized controlled trials are rare, and observational studies pose limitations due to heterogeneity of surgical practices, techniques, and patient populations. Pooled analysis of the current literature may identify effective treat-

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ment strategies and guide future efforts at prospective clinical research. The purpose of this meta-analysis was to synthesize existing data on the surgical outcomes for adult degenerative scoliosis.

Methods: Pubmed, Medline, Cochrane and Web of Science were searched using key words and limited to English language. Abstracts were reviewed by spine surgeons and were further evaluated if they contained surgically treated cohorts of adults with degenerative scoliosis. Full text articles were reviewed as a team to determine inclusion, and relevant data abstracted. Meta-analyses were conducted on using random effects models and heterogeneity was estimated with I2. Random-effects meta-regression models were used to investigate association of treatment effects with preop levels of each outcome.

Results: The literature search yielded 482 articles. Of those 24 articles with 34 surgically treated groups (n=805) met inclusion criteria and were abstracted. Outcomes included: Cobb angle, coronal and sagittal balance, visual analog scale for pain (VAS) and Oswestry Disability Index (ODI). Despite significant heterogeneity among studies, random-effects meta-analysis did show significant improvements in Cobb angle, coronal balance, VAS and ODI postoperatively ($p<0.001$). Meta-regression models showed that the preop values for Cobb angle, coronal balance and VAS were statistically significantly associated with surgical treatment effect ($p<0.05$).

Conclusion: Literature review yielded 24 studies reporting pre and postoperative data of the surgical treatment of adult degenerative scoliosis. No randomized controlled trials were identified. Despite significant heterogeneity, meta-analysis showed significant improvement in Cobb angle, coronal balance, and VAS after surgical treatment of adult degenerative scoliosis.

Forest plots of surgical outcomes

‡204. Health-Related Quality of Life and Low Back Pain of Patients Surgically Treated for Scoliosis with a Minimum 21-Year Follow-Up: Comparison among Non-Idiopathic Scoliosis, Idiopathic Scoliosis, and Healthy Subjects

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Japan

Summary: We reported on HRQOL, low back pain, and marital status in healthy subjects, and non-idiopathic and idiopathic scoliosis patients 21 years or more after surgery. The non-idiopathic and idiopathic scoliosis patients had similar HRQOL and low back pain. The non-idiopathic scoliosis patients had a particularly low marriage rate at 39.6%.

Introduction: Satisfactory long-term clinical results have been reported in patients after surgery for idiopathic scoliosis. There have been a very small number of reports on long-term results of surgery for non-idiopathic scoliosis. There have not been any reports that compare non-idiopathic scoliosis, idiopathic scoliosis, and healthy subjects. The aim of this study was to compare health-related quality of life (HRQOL) and low back pain of healthy subjects with those of non-idiopathic and idiopathic scoliosis patients 21 years or more after surgery.

Methods: The scoliosis subjects were 602 patients who had undergone surgery between 1968 and 1988. The SRS-22, Roland-Morris Disability Questionnaire (RDQ) and our institution's original questionnaire were used for evaluating long-term clinical outcomes. The 136 respondents consisted of 56 non-idiopathic scoliosis patients (Non-IS group) and 80 idiopathic scoliosis patients (IS group). The follow-up period was 30.9±5.2 years (range: 23-41 years) in Non-IS group and 31.3±5.6 years (21-41 years) in IS group. The control group (CTR group) consisted of 80 healthy volunteers who were age- and BMI-matched to the scoliosis groups.

Results: In Non-IS vs. IS vs. CTR groups, mean RDQ score was 3.4 vs. 2.4 vs. 1.4, respectively; and mean SRS-22 domain scores were 4.0 vs. 4.2 vs. 4.7 for function; 4.3 vs. 4.3 vs. 4.2 for pain; 2.8 vs. 2.9 vs. 3.7 for self-image; and 3.6 vs. 3.8 vs. 3.7 for mental health, respectively. There were no significant difference among 3 groups in pain and mental health of SRS-22. As for RDQ, function and self-image domains of SRS-22, Non-IS group was equivalent to IS group, but their data was significantly inferior to CTR group ($p<0.05$). The percentage of marriage was significantly low in the Non-IS group compared to other groups (Non-IS: 39.6%, IS: 69.6%, CTR: 88.8%; $p<0.001$).

Conclusion: The non-idiopathic and idiopathic scoliosis patients had similar HRQOL and low back pain. The non-idiopathic scoliosis patients were found to have lower function and self-image in the SRS-22 questionnaire and more severe low back pain in the RDQ compared with healthy subjects. The non-idiopathic scoliosis patient had a significantly lower marriage rate compared with the other two groups.

205. Clinical Tolerance to Sagittal Imbalance Varies with Age

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Spain

Summary: Self-reported disability increases with loss of lumbar lordosis (LL) and anterior sagittal balance. The effect of age in the clinical impact of loss of lumbar lordosis and sagittal imbalance is still unknown. Our study shows that clinical tolerance to sagittal imbalance and loss of LL varies with age. Older people (with weaker compensatory mechanisms) show greater impact and disability. The importance of achieving an ideal lordosis as a part of treatment increases with the patients' age.

Introduction: Previous studies have shown that self-reported disability increases with loss of lumbar lordosis and anterior sagittal balance. Compensatory mechanisms to maintain an upright posture have been described in patients with reduced lumbar lordosis. The effect of age in the clinical impact of loss of lumbar lordosis and sagittal imbalance is still unknown.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Methods: 181 patients (77.9% females) with adult spinal deformity, mean age 44.4y (range 18 to 85), were analyzed. Health-related quality of life was assessed using SRS22 questionnaire. Radiographic measurements included global balance and sagittal spinopelvic parameters. Patient's ideal lordosis was calculated according to the formula Ideal Lordosis= 0.54PI + 32.56. The "lordosis gap (LGap)" was defined as the difference "Ideal Lordosis minus Real Lordosis".

Results: Mean values for radiographic parameters were: coronal Cobb 47deg SD24.5; thoracic kyphosis 40.3deg SD18.6; lumbar lordosis 50.3deg SD17.9; Pelvic Incidence (PI) 54.4deg SD14.1 and T1-Spino-Pelvic-Inclination (T1SPI) -2.7deg SD5.6. LGap averaged 11.8deg SD22.5.

Data analysis was performed stratifying by age (Table)

In 77 patients younger than 40, 41.2% had appropriate LL (LL=PI+/-9), 11.8% LL<PI-9 and 47.1% LL>PI+9. Mean LGap was 0.57 SD18.1 and mean SRS22-subtotal 3.6 SD0.6. LL, In this age group T1SPI and LGap did not affect SRS22.

In 52 patients between 40 and 60 years of age, 35.7% had LL=PI+/-9, 45.2% LL<PI-9 and 19% LL>PI+9. Mean LGap was 16.83 SD21.3 and mean SRS22-subtotal 3.0 SD0.8. In this age group LGap correlated (p=0.03, r=-0.33) with SRS22-Function and LL correlated (p=0.05, r=-0.29) with SRS22-subtotal significantly.

In 44 patients older than 60, 22.9% had LL=PI+/-9, 65.7% LL<PI-9 and 11.4% LL>PI+9. Mean LGap was 23.12 SD22.8 and mean SRS22-subtotal was 3.1 SD0.7. In this age group SRS22-function correlated with LGap (p=0.01, r=-0.39) and SRS22-subtotal with LGap (p=0.00, r=-0.49), LL (p=0.01, r=-0.41) and T1SPI (p=0.01, r=-0.40) significantly.

Conclusion: Clinical tolerance to sagittal imbalance and loss of LL varies with age. Older people (with weaker compensatory mechanisms) show greater impact and disability. The importance of achieving an ideal lordosis as a part of treatment increases with the patients' age.

206. Surgery for Adolescent Idiopathic Scoliosis (AIS): Two Steps Forward, One Step Back for Coronal Plane Correction

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Turkey

Summary: This study aimed to analyze the results of controlled trials (CT) on surgical treament of AIS published over 30 years, and compare the results of these CTs with each other for coronal correction.

Introduction: Surgery remains to be the gold standard in the treatment of AIS with curves over a certain magnitude. The rate of correction of curves in the coronal plane has been the main outcome measure by which different surgical instrumentation systems and techniques had been compared. Our hypotheses were that although coronal plane correction appears to be improved over 30 years the newly introduced techniques might be associated with a positive bias.

Methods: : 8355 articles and 775 abstracts were screened, and 79 articles were retrieved in full; and only 19 studies (3 for Harrington vs CD, 2 for CD vs CD like system, 3 for hybrid vs all hook and 7 for hybrid and all screws, 4 for all screws vs anterior) were found to be of adeqaute standards to be included in the review. As studies included are cohort studies with disparity of surgical interventions, heterogeneity of outcome measures and different qualities, a meta analysis could not be performed. Instead, a systematic review was performed comparing the results of systems with each other based on whether they were the newly introduced system or existing standard at that time.

Results: Our findings can be seen on Table 1. It was seen that the average correction in the frontal plane improved gradually from 38.3% in Harrington instrumentation to 59.9% in all screw systems. Likewise, loss of correction from post-op to the end of follow up has improved from 19.4% for Harrington to 3.2% for all screw systems. Although all screw systems' overall correction rates was similar from the beginning of the usageof these systems , interestingly, for CD or similar and hybrid systems, the overall correction rates were much higher when the system was compared to the existing standard (Harrington for CD and like and CD and like for hybrid) (Fig 1).

Conclusion: These findings suggest that there was a gradual improvement in coronal correction and its' maintenance over 30 years. However, except all screw systems, there may be a positive bias for new systems as they are introduced or a negative bias for systems that are compared as standards of the day. Being aware of this phenomenon may be important in critical reading of reports on research in this area.

207. Correlation Between PFT's and Exercise Tolerance in Children Following Surgery for AIS

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USA

Summary: This is the first study to correlate exercise tolerance via treatmill testing with pulmonary function testing in patients with AIS undergoing fusion. While PFT's correlated with thoracic hypokyphosis, VO2max did not. Although postop PFT's improved, an increase in exercise tolerance is not realized by patients who, on average, became more sedentary.

Introduction: While scoliosis is known to affect pulmonary volume, it is unknown if the ability to exercise is similarly affected by spinal deformity.

Methods: 43 patients (ave age 14.5 y) with AIS underwent pulmonary function testing (PFT's) and exercise tolerance testing via a submaximal graded treadmill protocol where VO2 max was predicted using the Cosmed K4b2 telemetry unit. PFT's and treadmill testing were repeated at a mean 2.2 y postop (range 1.9-3.0 y).Activity level was graded on a three point scale: 1-none, 2-recreational, and 3-organized sport. Preop and postop radiographs were measured, and Cobb angle, thoracic kyphosis, and Lenke classification noted.

Results: Mean preop Cobb angle was 59.6 deg (±13.2 deg), postop Cobb angle 26.7(± 17.7 deg), and mean thoracic sagittal kyphosis improved from 24.4 deg preop to 33.3 deg. FVC improved from 2.77L to 2.97L postop (p=0.0004), and FEV1 increased from 2.32 to 2.56L (p=0.0022). Although VO2max decreased from 42.9 to 40.2 ml/kg/min postop (p=0.01), neither pre or postop VO2max differed significantly from normal values. Postop activity level decreased from 1.79 to 1.5 (ns). While PFT's correlated with preop thoracic hypokyphosis, exercise tolerance did not correlate with either preop coronal or sagittal Cobb angles.

E-POSTER ABSTRACTS

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

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Conclusion: Improvement in PFT's postop do not result in increased exercise tolerance as measured by VO2max. Patients become more sedentary 2 yrs following spinal fusion for AIS.

208. Posterior Vertebral Column Resection for Kyphosis Correction in Juveniles from West Africa: Intra-Operative, Early and Two-Year Outcomes and Complications

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USA

Summary: This is a retrospective review of outcomes and complications of posterior vertebral column resection for kyphotic deformity in juvenile patients treated at a single facility in West Africa. This series demonstrates that PVCR is a safe and effective technique for correction of kyphosis that is tolerated fairly well in juveniles.

Introduction: Posterior vertebral column resection for correction of kyphotic sagittal plane deformity is an evolving and complex procedure. Spinal fusion in juveniles possesses distinct characteristics and considerations particular to the growing spine. This study aims to describe our experience of the PVCR technique in juvenile patients in an underserved region of West Africa.

Methods: This is a retrospective case series of 22 consecutive patients under the age of 10 years that underwent PVCR for correction of kyphoscoliotic deformity and had greater than 2 years follow-up. All surgeries were performed in Ghana, West Africa. Patients with complete pre-operative and 2 year follow-up data were included in the series. Radiographic parameters were measured by a single observer using the Surgimap Spine software. Complications were categorized as occurring intra-operative, early and at 2 years follow-up.

Results: Between 2002-2009, 22 patients mean age 7.54 years (4-10) 14 males /8 females underwent PVCR. 14 patients had a diagnosis of TB kyphosis, 8 congenital kyphosis. Mean pre-operative maximum kyphosis was 92.9°(50-140°) over mean of 5.14 levels (3-8)was corrected to 55.8°(23-102°). Preoperative thoracic kyphosis & lumbar lordosis were 60.2°(1-165°) & -60.5(-100- +41°) respectively, and 55.6°(5-82°) and -49.8°(-9 - -85°%) post-operatively. 6/22 patients (27.3%) had intra-operative complications, 3 pleural tears requiring chest tube placement, 3 MEP changes-2 without neurologic sequelae, one patient with neuropathy resolved at 6 month follow up. 2 patients had complications requiring return to OR at less than 2 years, one for proximal junctional kyphosis, the other for anterior cage dislodgement. One patient had an early postoperative wound infection treated locally. There were no permanent spinal cord injuries or deaths.

Conclusion: PVCR for correction of severe sagittal plane deformity in juveniles is a safe and effective procedure. The most common complications were pleural tear and MEP changes intra-operatively. Two patients were revised at 2-yr follow up for hardware related complications.

209. Long Term Outcomes of Long Fusions to the Sacrum for Adult Scoliosis: A Comparison of Unilateral, Bilateral Iliac, or Sacral Screws Alone

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USA

Summary: This retrospective review compares long fusions in adult spinal deformity (ASD) patients by comparing return to OR (RTO) rates between distal instrument fixations. While no significant differences were seen in early or late RTO rates between instrumentation groups, the unilateral iliac screws had less RTO complications than SS at long term.

Introduction: Iliac screws are included in long constructs because of the mechanical advantage they provide in maintaining sagittal alignment by crossing anterior to the sagittal axis of the body's center of mass. Their addition is not without complication or need for revision. The purpose of this study was to determine the difference in revision rates of patients treated with either uni- or bilateral iliac fixation or sacral screws alone at minimum 5 years of follow-up.

Methods: This is a retrospective review of patients who underwent anterior-posterior spinal fusion from the thoracic spine to the lumbosacral pelvis for adult spinal deformity that had a minimum of 5 years follow-up. Patients were separated by sacro-pelvic fixation as A)Sacral screws alone (SS) and B)both Unilateral Iliac (IL1) and Bilateral Iliac Screws(IL2). Return to OR (RTO) complications were grouped according categories relating to 1. infection 2. neurologic 3. fusion status 4.hardware & 5. global alignment and stratified by early, late, and long term, respectively <2-yrs, <5 years, & >5 years.

Results: 132 consecutive patients, 80 IL (62 IL1, 18 IL2) and 52 SS patients; 13 men & 119 women; mean age 56.1(37-74); 69 primary and 63 revisions surgeries were included in the analysis. Mean follow up was 5.55years (4.80-12.8 years). RTO rates were SS(19.2, 9.6, 9.6%), IL1(19.4, 3.2, 8.1%), & IL2 (5.6, 22.2, 5.6%) at respective time points. No statistically significant differences were seen between groups with respect to particular complications. IL1 had a lower RTO rate at late time range.

Conclusion: Patients with long fusions had a significant number of RTO complications performed by five year follow up and beyond. IL1 screws had less RTO between 2-5 yrs f/u than the SS group.

210. Multimodal Intraoperative Neurophysiologic Monitoring in Young Childen

Alpaslan Senkoylu; Murat Zinnuroglu; Alp Borcek; Irfan Gungor; Necdet S. Altun
Turkey

Summary: Defining success rate and performance of multimodal intraoperative neurophysiological monitoring in two different age groups of children (0-5 years and 5-11 years) were aimed. Standard anesthesia protocol was given to both groups. SSEP and MEP's were recorded in all patients. Ten serious events were observed in both groups. Kyphosis was found as the most important risk factor for the serious events. MIONM can be performed successfully in younger ages of childhood with a specified anesthesia procedure.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

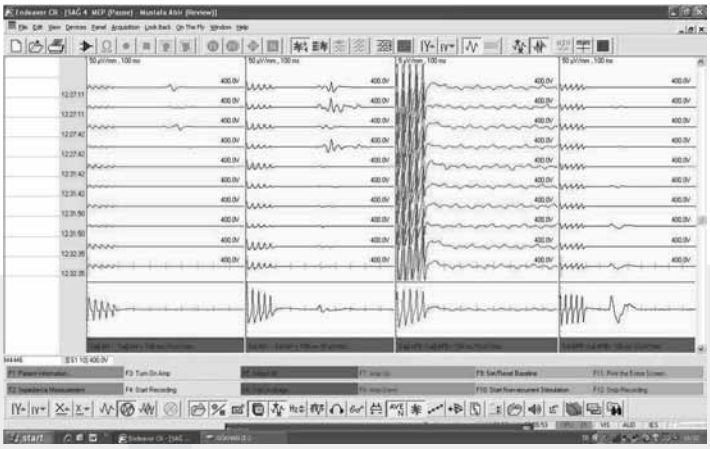
Introduction: Incomplete maturation of the corticospinal tract in children leads to differences in structural and electrophysiological characteristics which are considered as normal in adults. Aim of this study is to define success rate and performance of multimodal intraoperative neurophysiological monitoring (MIONM) in two different age groups of children.

Methods: A consecutive series of 44 patients were included in this study. Patients were divided into two cohorts according to their age. Patients aged below 5 years was Group A (n=16) and above 6 was Group B (n=28). Standard total intravenous anesthesia protocol was given to both groups. After propofol induction, baseline somatosensory evoked potentials (SSEPs) and transcranial motor evoked potentials (MEPs) were recorded. Then all patients were entubated under single dose of atracurium 0.5mg/kg. Maintenance of anesthesia was provided with the combination of propofol, remifentanil, ketamine HCl.

SSEPs and MEPs were monitored during the operations in all patients. Threshold levels and amplitudes compared in both groups. The 50% decrements in the MEP amplitude as compared to the baseline values were accepted as serious event.

Results: MEPs and SSEPs were recorded in all patients. No false negative results were noted. Ten serious events (Group A=3, Group B=7) were observed in both groups. Diagnosis was congenital kyphoscoliosis in 6 patients, diastematomyelia in two patients, post traumatic kyphosis in one patient, post-TB kyphosis in one patient. MEPs recovered to the baseline values at the end of the operation except one patient with post-TB kyphosis. In this patient revision operation was done and complete neurologic recovery was achieved.

Conclusion: Maturation of the peripheral and central nervous system may not be complete in younger age group of childhood. Kyphosis was found as the most important risk factor for the serious events in both age groups in children. MIONM can be performed successfully in younger ages of childhood with a specified and safe anesthesia procedure. Partial or complete loss of MEPs was noted more frequently in patients with kyphosis.



211. Analysis of Radiation Exposure Reduction After Implementing Multidetector CT in an Early Onset Scoliosis (EOS) Treatment Algorithm

Ajeya Joshi; Heather Brandfellner, DO; Alicia A. DiGiammarino, BA; John J. Doski, MD; Robert Fajardo, PhD; Hope Trevino, AA; James W. Simmons, DO, PhD; Robert M. Campbell, MD USA

Summary: Children with Early Onset Scoliosis and Thoracic Insufficiency Syndrome who have been treated using Vertical Expandable Prosthetic Titanium Rib are routinely exposed to radiation through frequent radiographic studies. Limiting radiation exposure in children with significant medical illness and comorbidities is an important patient safety concern that can be addressed by using newer volume CT scanning with up to 320-detectors per rotation and through selective use of radiographic imaging.

Introduction: Early Onset Scoliosis (EOS) with Thoracic Insufficiency Syndrome (TIS) is often treated using Vertical Expandable Prosthetic Titanium Rib (VEPTR). CT scanning in the management of EOS/TIS patients includes radiation exposure at a young age. We sought to quantify the chest CT radiation exposure decrease due to a CT scanner update in our institution; and to catalog all radiologic studies VEPTR/EOS patients received over time.

Methods: Chest CTs from VEPTR patients were collected retrospectively from two scanners: a 64-detector CT (LightSpeed, GE) and a 320-detector CT (Aquilion ONE, Toshiba). Each case was reviewed for scanner [voltage (kV), current (mA), pitch, CT dose index (CTDI) (mGy = milligray), and dose length product (DLP) (mGy*cm)] and patient [height, weight, age, age at CT] parameters. Effective radiation dose (ED) (mSv = millisieverts) was derived as: DLP x [age-based conversion factor]. Total study count per patient tallied: total studies, CT by subtype (chest, head, other), x-rays, MRI, fluoroscopy, nuclear medicine, and other studies.

Results: Chest CTs on the 64-detector scanner (n=85) vs. the 320-detector scanner (n=93) showed no difference in patient parameters (height, weight, BMI, age, age at CT); while voltage was reduced, current and pitch factor were increased on the 320-detector scanner. ED was reduced from 23.78±7.01 mSv to 8.06±4.07 mSv using the newer 320-detector CT scanner ($p<0.0001$).

Forty-three patients with minimum 2 year involvement in the VEPTR program had 52.96±38.99 total scans, comprised of 6.58±4.37 chest CTs, 1.09±2.32 head CTs, 1.16±1.72 other CTs, 38.07±34.85 x-rays, 3±2.98 MRIs, 0.02±0.15 fluoroscopic procedures, 0.91±0.98 nuclear medicine studies, and 0.98±1.73 other non-radiation studies over 56±19.28 months (range 24-122 months).

Conclusion: While CT scanning guides evaluation and management of children with TIS undergoing VEPTR treatment, limiting radiation exposure remains a patient safety priority. Significant medical comorbidities often require frequent, varied radiographic investigations over time, including CTs. Radiation exposure may be greatly reduced by using judicious indications for CT scanning and newer volume CT scanning with up to 320-detectors per rotation.

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212. A Prospective, Randomized, Placebo-Controlled, and Blinded Trial of Bupivacaine for Long-Term Pain Reduction after Iliac Crest Bone Graft Harvest for Spine Surgery

Kevin R. O'Neill, MD, MS; Dennis T. Lockney, BS; Jesse E. Bible, MD; Colin G. Crosby, MD; Clinton J. Devin, MD
USA

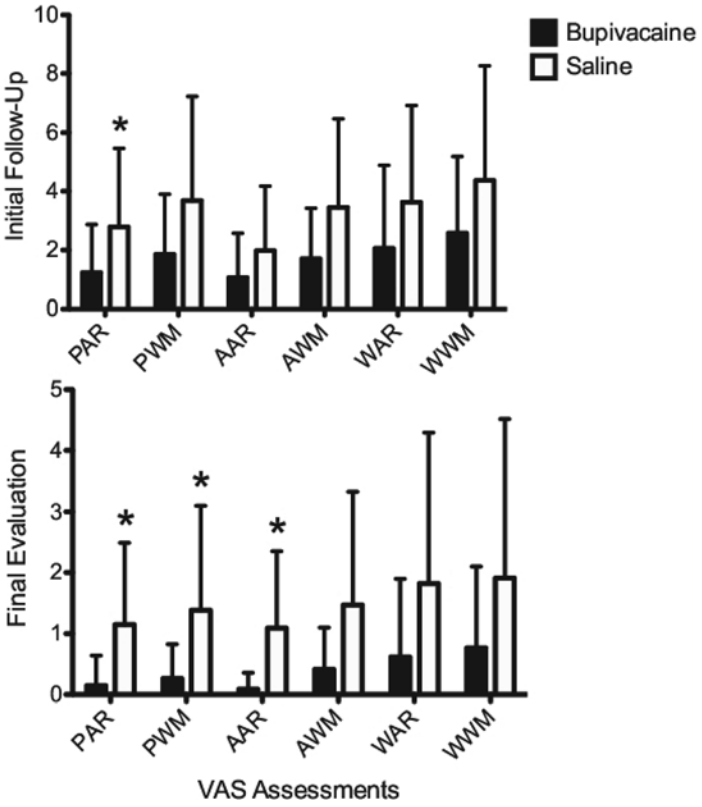
Summary: In a prospective, randomized, placebo-controlled, and blinded study, a single administration of bupivacaine at the iliac crest bone graft (ICBG) harvest site was found to reduce long-term pain and improve outcomes in patients undergoing posterior spinal fusion.

Introduction: ICBG remains the gold standard in achieving spinal arthrodesis, but chronic pain is a significant complication following graft harvest. Previous studies have indicated that a single administration of local anesthetic after surgery reduces short-term pain, but studies have not adequately investigated the possible longer-term benefits. The goal of this study was to determine whether administration of bupivacaine after ICBG harvest results in reduced long-term pain and improved patient-reported outcomes.

Methods: A prospective, randomized, placebo-controlled, and blinded study was conducted at a single academic medical center. Forty patients were identified over 1 year who underwent posterior spine fusion at any level utilizing ICBG. Patients were randomized to receive either a single administration of 10ml 0.25% bupivacaine (treatment group) or saline (control group) at the ICBG site. Pain was determined by 12 VAS and NRS assessments prior to surgery and at 4-6 weeks and 4-6 months post-operatively. SF-12 PCS and MCS, EQ-5D, and ODI (for lumbar fusions) assessments were made at baseline and 3 months post-operatively. Finally, patient satisfaction and self-reported outcome were determined.

Results: There were 20 patients in each group. All baseline pain and outcome assessments were similar ($p>0.05$). No complications were found from bupivacaine use. The treatment group was found to have significantly lower VAS and NRS pain scores at a mean follow-up of 5 weeks (6 of 12 assessments) and 20 weeks (3 of 12 assessments). No difference was found in SF-12 and EQ-5D scores. For lumbar fusion patients (treatment group n=18, control group n=16), the treatment group had significantly lower ODI scores at a mean follow-up of 16 weeks. Lastly, significantly more patients in the treatment group reported that surgery met all expectations.

Conclusion: This study demonstrated reduced long-term pain and improved outcomes in patients receiving a single administration of bupivacaine at the ICBG harvest site during posterior spine fusion surgery. This study is the first to demonstrate the potential for long-term benefits of a single application of local anesthetic at the ICBG site.



*Visual analog pain (VAS) scores at initial (mean 5 weeks) and final follow-up (mean 20 weeks). PAR=pain at rest, PWM=pain with movement, AAR=average pain at rest, AWM=average pain with movement, WAR=worst pain at rest, WWM=worst pain with movement. * = $p<0.05$.*

213. Complications after Surgical Treatment of Adult Idiopathic Scoliosis

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Spain

Summary: Less information is available concerning postop complications in adult idiopathic (age>20) scoliosis (AdIS) vs adolescents. Our study shows that the relatively high (14% major medical and 21.5% mechanical) complication and (19%) reintervention rates after surgery for AdIS do not modify patient's perceived effect of surgery. Pedicle screw constructs reduce the risk of mechanical complications and should be recommended.

Introduction: Less information is available concerning postop complications in adult idiopathic (age>20) scoliosis (AdIS) vs adolescents. The aim of our study was to evaluate the role of patient, radiographic and instrumentation factors in development of complications.

Methods: A prospectively collected database of 79 AdIS pts (68F,11M) operated in 2 centres (>2y f/up) were retrospectively analyzed for major medical and mechanical complications. Patient's characteristics (age, ASA, BMI), radiographic preop and postop parameters, surgical and instrumentation data were evaluated for their relevance. The effect of complications was analyzed with a validated 15-points scale measuring the global perceived effect of the intervention (GOS).

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Results: 48 (60.8%) patients had Th, 25(31.6%) had TL and 6(7.6%) had L curves. Mean f/up was 36 months. X-ray measurements and surgical data are included in Table. Surgeries were post in 61(77.2%), and combined ant-post in 14(17,7) cases. Pedicle screws (PS) had been used at the lower foundation for all pnts whereas upper foundations were PS in 60(75.9%) and hooks (H) in 19(24.1%). LIV was above L4 in 61(77.2%), S1-ilium in 8(10.1%) and L5 in 10(12.7%). UIV was T2 in 34(43%), T3-T6 in 35(44.3%), T7-T10 in 6(7.6%) and T11-L3 in 4(5.1%). As for complications, 11(13.9%) major (1 neurologic deficit and 10 wound infections) and 17(21.5%) mechanical complications occurred, 15 (19%) of which were reoperated (10 wound infections and 5 mechanical complications). Mean GOS was 4.9±3.3. Age was not correlated with the development of postop complications. Mechanical complications were significantly (p=0.03) associated to the use of H at the upper foundation (36.8% H vs 13.3% PS). The rate of mechanical complications varied by the UIV as well, 14.7% with UIV at T2, 22.9% with UIV at T3-T6 and 33.3% with UIV at T7-T10 had complications. At f/up, GOS was not significantly different between pnts sustaining a complication/reintervention and those who did not.

Conclusion: The postop complication and reintervention rates in AdIS are relatively high, but once treated they do not affect pnt satisfaction. PS constructs reduce the risk of mechanical complications and should be recommended.

214. Long-Term Clinical Outcomes and Complications After Fusion for Deformity or Degenerative Disease in Diabetic vs. Non-Diabetic Adults

Dennis Crandall, MD; Robert A. Waldrop, MD; Jan Revella, RN; Michael S. Chang, MD; Ryan McLemore, PhD
USA

Summary: Diabetic vs. non-diabetic patients were studied in this 5 year average follow-up on 380 consecutive patients (DM- 47, Non-DM- 333) undergoing either short or long fusion for degeneration or deformity. Diabetic patients had about twice the infections (6.4% vs 3.3%) and nonunions (8.5% vs 4.5%). While both groups improved, diabetics improved less on VAS and ODI at 2 years. Results were underpowered for statistical significance.

Introduction: Diabetes in total joint arthroplasty carries a higher infection risk and inferior clinical outcome. The impact of diabetes(DM) on clinical outcomes and complications after arthrodesis for spinal deformity or spondylosis has not been studied. How DM compares to Non-DM patients for primary vs. revision surgery, and the impact of differing fusion length also remain unknown. We studied the long-term clinical outcomes and complications of diabetics vs. non-diabetics after instrumented spinal arthrodesis.

Methods: 380 consecutive adults(DM- 47, Non-DM- 333) age 63 years(19-90) underwent posterior fusion for Deformity(129, 12DM) or degenerative disease(251, 35DM) at one deformity center; Fusion length: Deformity- 8 levels(4-15), Degen-3 levels(1-3). Prior surgery-256(67%; 47 Deformity, 209 Degen). Clinical and radiographic data was obtained preop, 1 year, 2 years, and latest followup. Infection rates were evaluated with Fisher's Exact test, VAS and ODI scores were evaluated by the Mann-Whitney test.

Results: Follow-up averaged 5years(24-188months). DM patients had about double the complications. Infection: DM-3(6.4%, 2 Degen, 1 Deformity), NonDM- 11(3.3%, 7 revision Deformity). Nonunions: DM-4(8.5%, 3 Deformity), NonDM-15(4.5%, 12 Deformity). Clinically, both groups improved, but DM patients improved less than nonDM at 2 years. VAS preop: DM-6.2, NonDM-6.2; 2years:DM-4.2 (p=0.0023), NonDM-3.45 (p=0.0005), p=0.1709 comparison. ODI preop: DM-52, NonDM-49.4; 2years:DM-37(p<0.001), NonDM-31.2(p<0.001), p=0.1794 comparison.

Conclusion: DM carries double the risk of infection and pseudoarthrosis in spinal fusions done for deformity or degenerative disease. DM had more pain and lower function at 2 years than NonDM patients in this sample. Power calculations indicate a further study with at least 240 patients in the diabetic arm and 1160 in the non-diabetic arm will be necessary to detect a statistically significant difference in clinical outcomes.

Ω215. The Ventral Lamina and Superior Facet Rule: A Morphometric Analysis for Ideal Thoracic Pedicle Screw Start Point

Ronald A. Lehman, MD; Daniel G. Kang, MD; Lawrence G. Lenke, MD; Rachel E. Gaume, BS; Haines Paik, MD
USA

Summary: The "ventral lamina" is the roof of the spinal canal, which becomes confluent with the medial pedicle wall. We found the "ventral lamina" and "superior facet rule" to be valid and reproducible at every level in the thoracic spine. By placing the starting point of thoracic pedicle screws 2-3mm lateral to the midpoint of the superior articular facet ("superior facet rule") the surgeon should not violate the spinal canal at any level in the thoracic spine.

Introduction: With the increasing popularity of thoracic pedicle screws, the freehand technique has been espoused to be safe and effective. We set out to define the morphologic relationship of the ventral lamina (VL) to the pedicle in order to determine the optimal screw starting point in the thoracic spine.

Methods: One hundred fifteen (113) thoracic spine vertebral levels (n=229 pedicles) were evaluated. After the vertebral body was removed, K-wires were inserted retrograde along the four boundaries of the pedicle. Using digital calipers, we measured width of the superior articular facet (SAF) and pedicle at the isthmus, and from the borders of the SAF to the boundaries of the pedicle. We calculated the morphologic relationship of the VL and center of the pedicle (COP), to the SAF.

Results: The VL was identifiable in all specimens forming the roof of the spinal canal, and confluent with the medial pedicle wall (MPW). The mean distance from SAF midline to the MPW was 1.34±1.25 mm medial. The MPW was lateral to SAF midline in 34 (14.85%) pedicles, with a mean distance of only 0.52±0.51 mm lateral. The mean distance from SAF midline to COP was 2.22±1.49 mm lateral. The COP was medial to SAF midline in only 11 (4.80%) pedicles.

Conclusion: The ventral lamina is an anatomically reproducible structure, consistently located medial to the midline of the superior articular facet (85%). We also found the center of the pedicle consistently lateral to the SAF midline (95%). This study asserts that the optimal/safe starting point for thoracic pedicle screws should be 2-3 mm lateral to the SAF midline ("superior facet rule").

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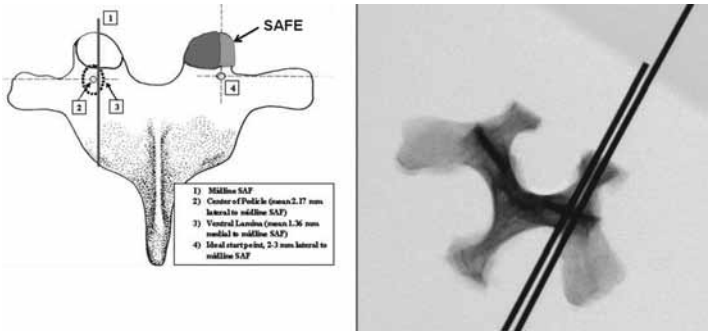

Thoracic spine with superior facet rule demosntrating safe medial-lateral start point. Axial radiograph of a thoracic verteba with "yellow" line outlining ventral lamina.

216. Is There Any Role for the Five-Degree Rule?

Patrick J. Cahill, MD; Jane S. Hoashi, MD, MPH; Randal R. Betz, MD; Tracey Bastrom, MA; Michelle C. Marks, PT, MA; Harms Study Group; Amer F. Samdani, MD
USA

Summary: The original Lenke classification system had a caveat that a secondary curve should be considered to be structural if it was within 5 degrees of the primary curve regardless of its flexibility. We compare cases that fall under this rule in two treatment subsets (selective and non-selective fusions) to similar cases with flexible curves 5 to 10 degrees less thant the primary. We found little difference in outcomes. The "within 5 degrees rule" does not and probably should not influence surgical planning.

Introduction: Non-structural curves are defined in the Lenke classification system for AIS as bending out to < 25 degrees. A caveat in the Lenke classification paper states, however, that if the difference in Cobb magnitude between the major and minor curves is < 5 degrees, then the minor curve should be considered structural, regardless of its Cobb magnitude. It is unclear whether following this rule affects patient outcomes.

Methods: A multicenter, retrospective study using a prospectively collected database was performed on surgical AIS patients with 2-year minimum follow-up. All patients had a lumbar curve that was < 25 degrees on bending x-ray. Group NS (non-selective): lumbar curve within 5 degrees of thoracic. Treatment: both curves fused. Group STF (selective thoracic fusion) 1: lumbar curve within 5 degrees of thoracic. Treatment: selective thoracic fusion. Group STF2: lumbar curve 5-10 degrees bless than thoracic. Treatment: selective thoracic fusion. Pre- and two-year postoperative radiographic and SRS-22 parameters were compared.

Results: Of 59 patients, there were 14 NS, 11 STF1, and 34 STF2. The NS group had larger preoperative curves than STF1, but obtained better lumbar correction. In comparing STF1 to STF2, no differences were found at 2 years. Pre- and postoperative lumbar magnitudes were similar for STF1 and STF2. There were no differences in SRS-22 preoperatively and at 2 years for all groups.

Conclusion: Almost half of the cases with curves within 5 degrees of each other did not follow the 5 degree rule, suggesting that there is variability among surgeons in their definition of what is truly structural. Selective thoracic fusion cases behaved similarly regardless of whether or not the lumbar curve was within 5 degrees of the primary thoracic. The results of our revisit of the 5 degree caveat challenge its utility as a criterion for defining structural secondary curves.

217. Consideration of Pedicle Screw Misplacement on a Per Patient Basis: Can We Better Delineate Surgical Risk?

Vishal Sarwahi, MD; Preethi M. Kulkarni, MD; Beverly Thornhill, MD; Jonathan J. Horn; Terry D. Amaral, MD; Adam L. Wollowick, MD
USA

Summary: Evaluation of screw placement using a novel classification system found 40% of patients with potentially significant screw misplacement. A discrepancy exists between the estimated 10% screw misplacement rate and the number of patients with potential screw related morbidity.

Introduction: Accuracy rate of pedicle screw (PS) placement varies from 85-95%. This demonstrates technical ability but does not represent the impact of misplacement on individual patients. This study quantifies the rate of screw misplacement on a per patient basis to highlight its effect on potential morbidity.

Methods: A retrospective review of charts, x-rays and low dose CT scans of 106 pediatric patients who underwent spinal fusion with pedicle screws for spinal deformity was performed. Screws were divided into three categories. Type A: well placed or misplaced screw of no concern (in fat, muscle, costovertebral junction). Type B: screw of some concern (adjacent to aorta, viscera, or 2-4 mm medial breech). Type C: screw of major concern (impinging on aorta, viscera, medial displacement ≥ 4mm).

Results: 2229 screws were placed in 106 patients. 1952 screws were placed accurately (87.6%). 19% of patients had all screws placed accurately. In the remaining 81%, the mean number of misplaced screws was 3.25 per patient. Overall, there was a mean of 2.64 misplaced screws per patient. Type C screws (N=29) account for only 1.30% of total screw placements despite occurring in 17% of patients, and Type B screws (N=44) account for 1.97% of total screw placements despite occurring in 23% of patients. Overall, even with an 87.5% accuracy rate, 40% of patients had screws of concern (Types B or C).

Conclusion: Although the overall screw misplacement rate is low, it does not reflect the potential impact on patient morbidity. When analyzed per patient, a higher number of patients had screws of some or major concern. With an increasing number of pedicle screws being placed in patients with spinal deformity, the number of patients with misplaced screws is likely to increase proportionally. The misplacement rate is relevant from a technical standpoint, but underestimates potential patient consequences. With 40% of patients having screw misplacement of some or major concern, better strategies need to be devised for evaluation of screw placement, including establishment of a national database of deformity surgery, use of intra-operative image guidance, and reevaluation of post-operative low-dose CT imaging.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

218. Abnormal Bone Quality in Osteopenic Adolescent Idiopathic Scoliosis Girls - A Case-Control Study

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China

Summary: Adolescent Idiopathic Scoliosis was associated with osteopenia. In this study, we evaluate bone quality and compare their correlation with osteopenia in AIS and non-AIS controls. It is found that the bone quality in osteopenic AIS patients was uniquely different from that of osteopenic non-AIS controls. Alterations in the trabecular compartment in association with osteopenia were only present in AIS subjects, including lower measurements in trabecular vBMD, bone volume to tissue volume and trabecular thickness.

Introduction: Adolescent Idiopathic Scoliosis (AIS) was associated with osteopenia which was found to be a significant prognostic factor for curve progression. Previous assessment of bone mineral density (BMD) by Dual Energy X-ray Absorptiometry (DXA) was confined to areal-BMD (aBMD). With advances in imaging technique, high resolution pQCT (XtremeCT) is now available for in-vivo measurement of major bone quality parameters including Bone Morphometry, Volumetric BMD (vBMD) and Trabecular Bone Micro-architecture. The objective of this study was to evaluate bone quality and compare their correlation with osteopenia in AIS and non-AIS controls.

Methods: AIS (n=112) and non-AIS girls (n=115) between 11-13 years old were recruited. aBMD of femoral necks was measured by DXA. Subjects were classified into the osteopenic (Z-score≤-1) and non-osteopenic (Z-score>-1) group. Bone Morphometry, Ttrabecular Bone Micro-architecture and Volumetric BMD (vBMD) were measured at the non-dominant distal radius using the XtremeCT.

Results: In AIS, the osteopenic group had lower measurements in Cortical Area, Cortical Thickness, Average vBMD, Compact Bone vBMD, Trabecular Bone vBMD, Trabecular Bone Volume to Tissue Volume Ratio and Trabecular Thickness when compared with non-osteopenic AIS subjects. In contrast, among the non-AIS controls, the osteopenic group had lower measurements only in Bone Morphometry, Average vBMD and Compact Bone vBMD but not in Trabecular vBMD and all other Trabecular Bone Microarchitecture parameters.

Conclusion: This is the first study utilizing XtremeCT to compare the correlation of bone quality with osteopenia in AIS and non-AIS subjects. Bone quality in osteopenic AIS patients was uniquely different from that of osteopenic non-AIS controls. Among those with osteopenia, abnormality in Bone Morphometry was noted in both AIS and non-AIS group. In contrast, alterations in the trabecular compartment in association with osteopenia were only present in AIS subjects. Further studies in these areas are warranted for characterizing the bone quality and its role in the etiopathogenesis of AIS.

219. Total Hip Arthroplasty and Total Knee Arthroplasty vs. Posterior Spinal Fusion for Degenerative Lumbar Spondylolisthesis: Cost Effective Analysis Utilizing Markov Modeling

Brian P. Cunningham, MD; Ryan McLemore, PhD; Dennis Crandall, MD
USA

Summary: Markov modeling compared Health Related Quality of Life(HRQOL) from 1000 patients each after total hip arthroplasty(THA), total knee arthroplasty(TKA), and single level posterior spinal fusion for degenerative spondylolisthesis(PSF). Using 2011 Medicare DRG, index surgery was $13,000 for THA and TKA, $20,900 for PSF. The 10 year QALY projections: THA-496 ($27,450/change in QALY); Knee-229 ($59,165/change in QALY); PSF-613 ($34,100). PSF fell between THA and TKA in terms of cost effectiveness. Spine fusion is as cost effective as total joint arthroplasty.

Introduction: Economics have become increasingly important in determining the value of a surgical intervention. The primary metric used to compare different treatments outcomes has been Quality Adjusted Life Years. Arthroplasty has long been considered the gold standard while spine surgery has been criticized based on anecdotal evidence. The purpose of this study was to compare the cost effectiveness of total hip arthroplasty(THA) and total knee arthroplasty(TKA) to posterior spinal fusion(PSF) for the treatment of degenerative spondylolisthesis.

Methods: A Markov model was constructed for three cohorts of 1000 patients (3000 total), age 55. The three cohorts:1) THA, 2) TKA, 3) PSF. Pre-operative and post-operative HRQoL scores were utilized to model disease states. The PSF scores were collected from a single surgeon's prospective database, converted from ODI; THA and TKA scores were collected from the literature. Cost was estimated utilizing average Medicare DRG re-imbursement for the index procedure in 2011 dollars. Revision was assumed to be a sink state for all groups and the cost of revision surgery was not incorporated into this model.

Results: Hip and knee had replacement had reported cost of $13,000/case. Spine fusion had reported cost of $20,900/case. Over a 10-year model projection, our Markov THA cohort amassed 496 QALY across 1000 patients while our Markov TKA cohort amassed 229 QALY. Our PSF cohort amassed 613 QALY over the same time frame. The THA group had a cost of $27,450 per change in QALY, the PSF group had a cost of $34,110 per change in QALY, and the TKA group had a cost of $59,165 per change in QALY.

Conclusion: The more expensive index procedure for spinal fusion was offset by the significant clinical improvement as expressed in quality of life years. PSF actually fell between THA and TKA in terms of cost effectiveness. PSF for the treatment of degenerative spondylolisthesis is as cost effective as THA and TKA.

‡220. SRS Outcome Scores are Sensitive to Both the Occurrence and Resolution of a Complication in the Surgical Treatment of AIS

Burt Yaszay, MD; Tracey Bastrom, MA; Carrie E. Bartley, MA; Michelle C. Marks, PT, MA; Peter O. Newton, MD; Harms Study Group
USA

Summary: The SRS questionnaire appears to be sensitive to complications. At 2 years post-op, those patients experiencing a complication have worse results than

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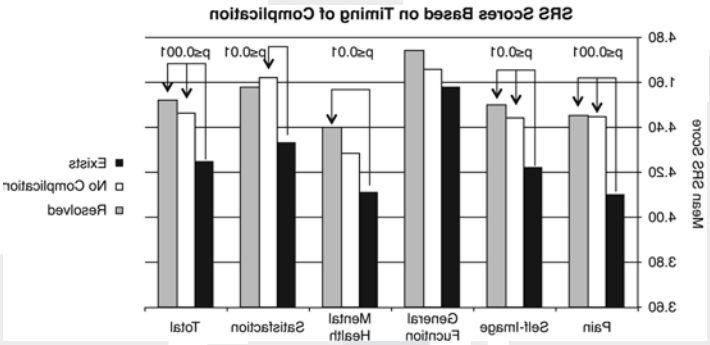
those who had no complication or a complication that has resolved. Patients who had a complication resolve have similar outcome scores to those who never had a complication.

Introduction: There is limited evidence as to whether the Scoliosis Research Society (SRS) questionnaire is sensitive to complications in post-operative adolescent idiopathic scoliosis (AIS) patients. Studies comparing 2 year SRS scores in patients with and without complications often report no difference. The purpose of this study was to examine the effect of a complication on SRS scores during its occurrence and after its resolution.

Methods: Data for AIS surgical patients with 2 year follow-up was queried from a prospective, multi-center database. Complications were classified into major and minor. Timing of the complication in relation to the 2 year visit was also classified; the complication was noted as either "existing" at the 2 year follow-up or was "resolved" (resolution by 12 months post-op). Two-year SRS scores were compared using ANOVA ($p<0.05$).

Results: Of 604 patients, complications were noted in 192 (131 minor, 40 major, and 21 both major and minor). Sixty-five existed during their second year of follow-up and 127 had resolved within the first year of follow-up. For Pain, Self-image, and Total scores, patients with existing complications scored significantly lower than both non-complication patients and patients with resolved complications ($p<0.05$, Figure 1). The existing group had lower Mental Health scores than the resolved group ($p<0.05$) and lower Satisfaction scores than the no complication group ($p<0.05$). There was a trend toward lower scores for General Function in the existing group compared to the resolved group ($p=0.07$). There were no significant differences between the non-complication and the resolved groups. Degree of complication (major vs. minor) did not appear to influence scores; however major complications were primarily peri-op and resolved by 2 years.

Conclusion: The SRS outcome instrument appears to be sensitive to complications, provided responses are obtained in temporal proximity to the complication. Patients who have resolved a complication prior to their 2nd year of follow-up have similar SRS scores at 2 years as those who have not experienced a complication. This suggests minimal effect of a resolved complication on clinical outcome as measured by the SRS questionnaire.



221. Retrograde Ejaculation after Anterior Lumbar Fusion with or without RhBMP-2

J. Kenneth Burkus, MD; Randall F. Dryer, MD; John H. Peloza, MD
USA

Summary: To determine the incidence and assess specific risk factors in the postoperative development of retrograde ejaculation (RE) in men treated for degenerative lumbar disc disease at the L4-L5 or L5-S1 level with stand-alone anterior interbody implants with or without recombinant human bone morphogenetic protein-2 (rhBMP-2), we performed a combined analysis of 5 prospective, randomized, multicenter FDA-approved investigational device exemption studies.

Introduction: The risk factors for retrograde ejaculation (RE) in men treated for degenerative lumbar disc disease with anterior interbody implants with or without recombinant human bone morphogenetic protein-2 (rhBMP-2) are controversial.

Methods: Patients enrolled in 5 prospective, randomized, multicenter studies were followed for a minimum of 2 years. Of 508 men with lumbar disc disease who had anterior interbody fusion at L4L5 or L5S1, 207 were treated with fusion cages and rhBMP-2. The control groups (n = 301) were treated with fusion cages and iliac crest autograft or a metal-on-metal disc arthroplasty device. Multivariate analyses of RE were performed to assess the influence of treatment (rhBMP-2), surgical approach, and treated level. Data were analyzed for each trial individually and for the data pooled from the 5 trials.

Results: RE occurred at the highest rates in the earliest trial. Of the 146 men, 6 (4.1%) developed RE postoperatively. In the subsequent studies, the rates of RE ranged from 0% to 2.1 %. In the combined trials, RE was reported in 7 (3.4%) of 207 patients who received the rhBMP-2 treatment compared with 5 (1.7%) of 301 patients who received autograft or lumbar disc treatment (P = 0.242, Fisher's exact test). RE occurred in 7 of 445 patients (1.6%) with a retroperitoneal spinal exposure; RE occurred in 5 of 58 patients (8.6%) with a transperitoneal approach. The difference between surgical approaches was significant (P = 0.007, Fisher's exact test). There was no difference in rates of RE based on lumbar level (P = 0.739). Multivariate analyses were consistent with the conclusions from Fisher's exact tests; after adjusting for effects of surgical approach and treated level, the difference in RE between the treatment groups (rhBMP-2 versus controls) was not significant; however, the difference in RE between the surgical approaches was significant.

Conclusion: The use of rhBMP-2 was associated with a higher incidence of RE (3.4% versus 1.7%) but did not reach statistical significance. Based on surgical approach, the difference in rates of RE was statistically significant.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

222. Resource Utilization in AIS Surgery: Is There Opportunity for Cost-Savings?

Baron S. Lonner; Courtney Toombs, BS; Suken A. Shah, MD; Harry L. Shufflebarger, MD; John M. Flynn, MD; Peter O. Newton, MD
USA

Summary: Understanding variability in resource utilization by surgeons performing surgery for Adolescent Idiopathic Scoliosis may provide opportunity for increasing

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
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uniformity of care, thereby decreasing cost and increasing value. A multicenter, retrospective study of AIS surgical cases matched for age and gender revealed significant differences in resource utilization between surgeons, despite equivalent outcomes. Opportunities for cost-savings include implant usage, metal type, LOS and transition to IV analgesics.

Introduction: Recent healthcare reforms have raised the importance of value in the management of disease. Value is a function of benefit and cost. Understanding variability in resources utilized by surgeons to achieve similar outcomes may provide an opportunity for cutting costs. The purpose of this study is to evaluate differences in use of hospital resources among surgeons performing AIS surgery.

Methods: A multicenter prospective AIS database was queried. Patients were matched for Lenke type and curve magnitude, resulting in 5 surgeons, 35 groups (N= 175). Mean age was 14.9 yrs, curve 50°. Parameters of interest were compared between surgeons and for each surgeon over time: early (2005-2007) vs late (2008-2010). An ANOVA and a Bonferroni pairwise comparison was performed for each parameter.

Results: There was no significant difference in % curve correction or levels fused between surgeons. Significant differences were found for % posterior approach, operative time, LOS, EBL, cell saver transfused, metal type, screw density, number of screws, use of antifibrinolytics, cessation of IV analgesics. Despite differences in EBL and cell saver used, there were no differences in bank blood use. Over time, individual surgeon resource utilization also varied significantly.

Conclusion: Significant variability in resource utilization was noted between surgeons performing AIS operations, although radiographic outcomes were equivalent. Cost-containment opportunities include implant usage, and type of metal, LOS, and transition to IV analgesics, as these factors are the largest contributors to cost in AIS surgery.

223. Perioperative Complications of Posterior Vertebral Column Resection of the Thoracic Spine

Michael D. Daubs, MD; Brandon Lawrence, MD; Prokopis Annis, MD; Darrel S. Brodke, MD
USA

Summary: We analyzed the perioperative complications of pVCR performed in the thoracic spine. Our major complication rate was 19% and the minor complication rate was 31%. There were no neurologic complications.

Introduction: Posterior vertebral column resection (pVCR) allows for wide decompression of anterior compressive lesions as well as the correction of severe deformity from the posterior approach. Complex osteotomies performed in the thoracic spine are accompanied by unique risks and complications, including the increased risk for spinal cord injury. The purpose of our study was to evaluate the perioperative complications (0-90days) of pVCR performed exclusively in the thoracic spine.

Methods: We reviewed 26 patients, 16 females and 10 males mean age 26 years (range(r) 13-80) that underwent a thoracic pVCR at our institution. The diagnosis was severe kyphosis or kyphoscoliosis in 22 patients, and tumor/infection in 4 patients. All patients had tcMEP, SSEP, and EMG neurologic monitoring during the procedure. Descriptive data and analysis of complications were limited to the perioperative time - within 90 days of surgery. No patients were excluded for lack of long-term follow up to accurately report all complications. Data analyzed included: OR time, length of stay (LOS), EBL, blood products, comorbidities, neurologic complications, and medical complications. Complications were analyzed as major and minor.

Results: pVCR were performed at levels T3 through T12. The most common levels were T6, T10, and T12. The mean OR time was 461 minutes (r 271-761), mean levels fused 9 (r 2-15), mean EBL 1712 cc (r 250-4500), mean LOS 8.2 days (r 3-16), mean ICU stay 1.35 days (r 0-6), and mean patient comorbidities 1.5 (r 0-4). Five patients (19%) had a major complication, and 8 (31%) had a minor complication. All major complications were pulmonary related: hemothorax, pulmonary embolus, respiratory distress, and pneumonia. There was one perioperative death due to a pulmonary embolus. There were no neurologic complications. Superficial wound infection was the most common minor complication.

Conclusion: The major complication rate was 19% and the minor complication rate was 31%. All major complications were pulmonary related. There were no neurologic complications.

224. Impact of Restored Global Sagittal Alignment on Outcomes of Three-Column Osteotomy

Richard Hostin, MD; Michael F. Obrien, MD; Ian McCarthy, PhD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Munish C. Gupta, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Frank Schwab, MD; Virginie Lafage, PhD; Vedat Deviren, MD; Khaled Kebaish, MD; International Spine Study Group
USA

Summary: This study analyzes the impact of global sagittal alignment (GSA) on outcomes for patients undergoing Pedicle Subtraction Osteotomy (PSO) surgery for adult spinal deformity (ASD). Although there are agreed-upon thresholds to identify GSA from a radiographic perspective, results indicate that alternative thresholds are needed to distinguish patients in terms of health related quality of life (HRQOL) improvements. Results also find that increased PT corrections may not offer significant quality of life improvements relative to more mild PT corrections.

Introduction: The purpose of this study is to analyze the impact of GSA on HRQOL among patients undergoing PSO surgery and to identify thresholds of GSA beyond which average HRQOL improvements significantly differ from the average of patients below the threshold.

Methods: Multi-center, retrospective analysis of 183 consecutive patients undergoing PSO surgery with at least one year follow-up (ages 20 to 81, with average of 56). HRQOL measures were based on the SF-36 (MCS and PCS), ODI, and SRS questionnaires after at least one year following surgery. Improvement in GSA was defined as the percentage improvement in SVA and PT relative to an SVA of 2.5cm and PT of 20deg (threshold beyond which additional GSA improvements generally had no statistical impact on HRQOL improvements).

Results: Patients experienced an average improvement of 66% in SVA and 65% in PT. Based on a series of paired t-tests, patients with 100% improvement in SVA and at least 70% improvement in PT reported higher improvement in MCS ($p<0.05$). Differences in MCS improvements were generally not significant at lower

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GSA thresholds (p>0.05). For PCS and SRS-pain, significant differences in HRQOL improvements were discernable after at least 20% improvement in SVA and PT (p<0.05), despite post-operative SVA>5cm and PT>25deg for 22 of these patients (18%). Differences in SF-PCS and SRS-pain improvements did not persist with PT improvement beyond 70% (p>0.05).

Conclusion: Results suggest that various HRQOL measures have different radiographic thresholds past which improvements are statistically distinguishable, and that increased PT corrections may not offer significant quality of life improvements relative to more mild PT corrections. Given the growing role of HRQOL measures in assessing medical care, it appears that patient preference and pre-operative conditions need to be taken into account when determining, from an economic perspective, relevant thresholds of surgical correction.

225. Screening MRI in AIS Patients Should be Standard of Care

Edgar D. St. Amour, MSc; Richard E. McCarthy; Jason M. Rogers, MD
USA

Summary: We reviewed screening MRI for neuro-axis (N-A) abnormality in 248 consecutive patients with AIS that underwent spinal deformity correction. 15% of all of these patients had an MRI diagnosed N-A abnormality, which is significant since 34% of those with anomalies (5% of all patients) required neurosurgical (NSGY) intervention. Therefore, this study provides strong evidence that screening MRI should be a standard of care for all patients.

Introduction: The role of screening MRI in patients with AIS remains controversial. There have been some reports that indicate screening MRI might be appropriate for patients with a specific pattern of findings that would necessitate further NSGY work-up; however, these patterns have not been consistent amongst studies. Our aim was to explore the value of screening MRI for our patients.

Methods: Retrospective review of preoperative MRI, radiographs, and clinic notes for 248 consecutive AIS patients that underwent corrective surgery at our institution.

Results: 38 patients (15% of all patients) undergoing instrumentation had screening MRI diagnosed N-A abnormalities. The most common were syrinx (13), Chiari (12), and tethered cord(TC) (4). There was no association between neuro exam and MRI abnormality. There was no association between syrinx, Chiari, or tethered cord and sagittal alignment. Ten patients with abnormal MRI were male (22% of all males), and 28 were female (14% all females). All patients with abnormal MRI were referred to NSGY for evaluation. Thirteen patients (34% patients with abnormal MRI, 5% all) required neurosurgical intervention. Of these 13, 5 were male (11% all males) and 8 were female (4% all females); 3 had left-sided curves; 3 had hyperkyphosis; and 3 were hypokyphotic. The average preoperative curve was 66 for the NSGY treated patients versus 52 in the non-NSGY treated patients with abnormal MRI. All 248 patients underwent deformity corrective surgery with no neurologic complications.

Conclusion: Screening MRI is essential to rule out N-A abnormalities since our study showed 15% had MRI diagnosed abnormality, and of this group, 1/3 required neurosurgical intervention. Our study shows that male gender and greater preoperative curvature are associated with MRI diagnosed N-A deformities. But in our AIS patients, there is no evidence that curve pattern, sagittal alignment, age at presentation, pain, nor other physical or neurological exam findings were associated with increased risk as indicated by other studies. Therefore, this study supports the argument that MRI screening should be the standard of care for patients with AIS, particularly with male patients and greater preoperative curvature.

Ω226. Does BMP-2 Really Cause Cancer? A Systematic Review of the Literature

Samuel K. Cho, MD; Steven M. Koehler, MD
USA

Summary: Of 93 studies that examined the role of BMP-2 in cancer, there was no evidence of BMP-2 causing cancer de novo. However, 46% of studies suggested BMP-2 enhances tumor function, motivating further research on this clinically important topic.

Introduction: Recently, the use of recombinant human bone morphogenetic protein-2 (rhBMP-2) in spine surgery has been the topic of much debate as rhBMP-2 has been reported to be associated with a higher incidence of developing new malignancy (3.8% vs. 0.89% in control) (Carragee, Spine J 2011).

Methods: A systematic review of the published literature in the English language was performed using MEDLINE. Only studies that directly addressed BMP-2 and cancer were included. Articles were categorized by the type of study (in vitro, animal, or human), primary malignancy, cancer attributes, and whether BMP-2 was pro-malignancy or not.

Results: 4466 articles were reviewed. Of those, 412 mentioned both BMP-2 and cancer, and 93 studies were found to directly examine the role of BMP-2 in cancer. 21 articles examined the role of BMP-2 in prostate, 17 in lung, 12 in breast, 8 in oral, 8 in ovarian, 7 in osteosarcoma, 6 in gastric, 4 in pancreatic, 4 in colon, 3 in melanoma, 2 in chondrosarcoma, 1 in bladder, 1 in renal cell carcinoma, 1 in liver, 1 in giant cell tumor, and 1 in adrenocortical cancers. 42 studies were in vitro, 32 studies used human specimens, and 23 were animal studies. 55 studies discussed the primary growth (22 in vitro, 21 human, 12 animal), 16 the invasiveness (11 in vitro, 3 human, 2 animal), 7 the angiogenesis (2 in vitro, 1 human, 4 animal), and 20 the metastasis (in vitro, 7 human, 6 animal) of various malignancies. 43 studies (46%) concluded that BMP-2 enhanced tumor function, whereas 12 studies (13%) found that BMP-2 suppressed malignancy. 38 studies (41%) did not examine whether BMP-2 enhanced or suppressed tumor function. No study showed that BMP-2 causes cancer de novo, i.e., transformation of normal cells into malignant cells.

Conclusion: Currently, conflicting data exist with regard to the effect of exogenous BMP-2 on cancer. Most were in vitro studies (43%) and examined the primary growth of malignancies (56%). Of 93 studies, there was no demonstration of BMP-2 causing cancer de novo. However, 46% of studies suggested BMP-2 enhances tumor function, motivating more definitive research that also includes clinically meaningful dose- and time-dependence on this important topic.

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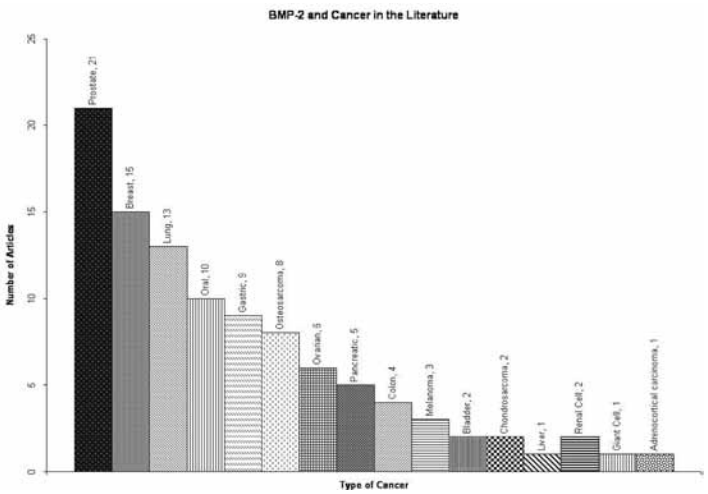

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‡227. Recurrent Stenosis Following Transforaminal Interbody Fusion (TLIF) Using Bioresorbable Cages and Bone Morphogenic Protein

Jeffrey D. Coe, MD; Michael W. Cluck, MD, PhD
USA

Summary: The use of BMP is associated with heterotopic bone formation and post-operative complications. In this study, we followed patients treated with TLIF procedures and ICBG or BMP for a minimum of 2 years post op to determine the reoperation rate. Nearly 20% of patients treated with TLIF and BMP required revision surgery for repeat stenosis at the previously operated level(s). Conversely, no patients treated with TLIF and ICBG required repeat surgery for recurrent stenosis.

Introduction: Transforaminal lumbar interbody fusion (TLIF) is a common technique for decompression and stabilization of the lumbar spine, performed with a variety of structural grafts and non-structural graft materials. The purpose of this study is to compare the reoperation rate in patients undergoing open TLIF procedures using bioresorbable cages and either iliac crest bone graft (ICBG) or allograft bone with demineralized bone matrix (DBM) and rhBMP-2 bone morphogenic protein (BMP).

Methods: Between December 2001 and December 2003, 31 patients underwent an instrumented TLIF procedure using bioresorbable interbody implants (PLDLA) with ICBG and 47 patients underwent an instrumented TLIF procedure using PLDLA implants, allograft bone, DBM and BMP; all performed by a single surgeon (JDC) between December 2001 and December 2003. Only patients with a minimum follow-up of 2 years were analyzed. Data analyzed included fusion and reoperation rate and reoperations associated with BMP usage.

Results: Twenty-three ICBG patients and 36 BMP patients met the follow-up criteria. The mean follow-up for the ICBG group was 79.3 months (range 24-119) and for the BMP group was 68.8 months (range 24-110). All patients in both groups were judged to be solidly fused at final follow up. In the BMP group, 8 patients (22.9%) underwent additional lumbar surgery. One was operated for adjacent segment disease (ASD), however 7 patients (19.4%) underwent decompression for foraminal stenosis resulting from bone overgrowth which encased the exiting nerve root at the operative level(s). In the ICBG group, 2 out of 23 (8.7%) (NS) patients underwent additional lumbar surgery; however none of these patients required reoperation for recurrent stenosis at a previously operated level ($p < 0.05$).

Conclusion: BMP is commonly used as an iliac crest bone graft substitute in TLIF procedures. While some studies show there are no symptoms related to heterotopic bone growth, we found that 19.4% of TLIF patients using BMP required reoperation for heterotopic bone growth and nerve root compression, whereas none of the TLIF patients using ICBG required reoperation for heterotopic bone growth.

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228. Complications of Pedicle Screws in Children Ten Years or Less

Yaser M. Baghdadi, MD; A. Noelle Larson, MD; Anthony A. Stans, MD; Amy L. McIntosh, MD; William J. Shaughnessy, MD; Mark B. Dekutoski, MD
USA

Summary: Complications associated with pedicle screw placement in children are rare (0.33%), and rates are similar for children 10 years or less and a matched cohort greater than age 10. No neurologic complications resulted from pedicle screw use.

Introduction: Pedicle screws are considered 'off-label' in young children, but are frequently used for spinal deformity treatment. We compare complications in a consecutive series of skeletally immature patients 10 years or less to a matched cohort of children greater than 10. We hypothesized that there would be a low rate of implant-related complications.

Methods: 299 screws were placed in 36 consecutive pediatric patients 10 years or less undergoing 38 procedures with pedicle screw insertion. Radiographs and medical records were retrospectively reviewed. Mean age was 7.5 years (range, 2 to 10); mean follow-up was 3.0 years. Deformity diagnoses included congenital (13), syndromic (5), idiopathic (2), neuromuscular (8), other (8). Screws were typically placed using freehand or fluoro open technique. Primary outcome measures were intra-op screw revision, return to surgery for screw revision or screw-related complication. A control group of 72 children greater than 10 was matched to younger patients by diagnosis and fusion level.

Results: Of the 299 screws placed in children 10 or less, one (0.33%) resulted in a screw-related complication (dural tear in a neurofibromatosis patient). The malpositioned screw was removed intraoperatively and the dural tear was repaired. In the 72 patients > 10 years old, there were 557 screws placed, with no observed screw-related complications. In the younger cohort, three screws were revised intraoperatively (1%) compared to 7 screws in the older group (1.3%) ($p > 0.05$). No patients required revision surgery due to screw malposition. There were no implant-related neurologic injuries. A mean of 8.3 screws were used in children 10 or less per procedure (range, 2 - 31) with screw diameters ranging from 3.5 to 6.5 mm.

Conclusion: In this limited series, 299 pedicle screws were placed in 36 patients 10 years or younger. Complications due to pedicle screws were infrequent (0.33% of screws, 2.8% of cases) and similar to a matched cohort of children > 10 years of

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age. This provides baseline data supporting the use of pedicle screws in skeletally immature patients for the treatment of complex spinal deformity.

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229. Analysis of Sagittal Spinal Alignment in 181 Asymptomatic Children

Hyounmin Noh; Choon Sung Lee, MD, PhD; Dong-Ho Lee, MD, PhD; Chang Ju Hwang, MD, PhD; Hyougmin Kim; HeeSang Lee, MD
Republic of Korea

Summary: To determine the "normal" radiographic parameters of the sagittal profile of the spine in asymptomatic children. Analysis of 181 children without spinal pathology was performed. The mean cervical lordosis was -4.8 ± 12.0° (negative = lordotic). Cervical kyphosis was found in approximately 40% of our study cohort.

Introduction: To determine the "normal" radiographic parameters of the sagittal profile of the spine in asymptomatic children. There was consensus that cervical kyphosis is pathologic, but we suspected that the cervical kyphosis or loss of cervical lordosis is abnormal in asymptomatic children and adolescents. And we measured the pediatric sagittal profiles including the cervical lordosis for asymptomatic subjects.

Methods: Analysis of 181 children without spinal pathology was performed. Radiographic measurements consisted of the following: cervical lordosis; thoracic kyphosis; thoracolumbar sagittal angle; thoracic apex; lumbar apex; lumbar lordosis; sacral inclination; sacral slope; pelvic tilt; and sagittal vertebral axis.

Results: The mean cervical lordosis was -4.8 ± 12.0° (negative = lordotic), sagittal vertebral axis -2.1 ± 2.4 cm, thoracic kyphosis +33.2 ± 9.0°, thoracolumbar sagittal angle 5.6 ± 8.4°, lumbar lordosis -48.8 ± 9.0°, sacral inclination 43.9 ± 7.6°, sacral slope 34.9 ± 6.6°, and pelvic tilt 9.4 ± 6.1°. 109 (60.2%) patients had hypolordotic cervical spine (≥ -5°). Cervical kyphosis was present in 80 (44.2%) patients.

Conclusion: We found a high rate of cervical hypolordosis in young patients (71.0% of 13- to 17-year-olds and 65.6% of 8- to 12-year-olds). The overall prevalence of cervical kyphosis in our population of 3- to 20-year olds was approximately 40%. Gender was not found to play a significant role in the sagittal spinal alignment. Cervical lordosis decreased with age, whereas thoracic kyphosis, lumbar lordosis, sacral inclination, sacral slope, and pelvic tilt increased with age.

230. Comparison between Prader-Willi Syndrome (PWS) and Idiopathic Patients for Characteristics of Scoliosis: Analysis of 58 Scoliosis Patients with PWS

Yutaka Nakamura, MD, PhD; Toshirou Nagai; Takahiro Iida, MD; Satoru Ozeki; Yutaka Nohara, MD
Japan

Summary: The purpose of this study was to compare the characteristics of scoliosis in Prader-Willi syndrome patients (Group PWS) versus idiopathic patients (Group I). We investigated 114 patients (58 Group PWS, 56 Group I). Most PWS patients had a lumbar or thoracolumbar curve. On the other hand, IP patients typically had thoracic scoliosis. There was no statistically significant difference between the two groups with respect to either curve angle or BMI. All patients of PWS had the mental retardation.

Introduction: It has been reported that many complications occur during surgery to correct scoliosis in PWS patients. However, growth hormone (GH) treatment has contributed to improvements in height and body composition. The purpose of this study was to compare the characteristics of scoliosis in Prader-Willi syndrome patients (Group PWS) versus idiopathic patients (Group I).

Methods: We investigated 114 patients (58 Group PWS, 56 Group I) who were followed for a two-year minimum. We identified 197 PWS patients who were diagnosed using genetic testing. Scoliosis was found in 58 PWS patients, 32 of whom were treated with GH. Fifty-six idiopathic patients were consecutively selected from an outpatient clinic over the course of one year. The mean age was 17.9 years and 16.9 years, respectively. The deformity was measured by: 1) Lenke classification 2) Cobb angles preoperatively or at final follow-up, 3) L4 tilt, 4) thoracic kyphosis at T2-5 and T5-12, 5) lumbar lordosis at T12-S1, and 6) saggital alignment at C7 plumb line. BMI and mental retardation were also recorded.

Results: 1) The Lenke classifications (Group PWS/Group I)were as follows: Type 1 (9/26), Type 2 (2/5), Type 3 (3/15), Type 4 (0/0), Type 5 (32/8), Type 6 (13/2). 2) The average cobb angles were 32.2° and 35.5° (not significant). 3) L4 tilt was 10.5° and 9.1° (not significant).4) Thoracic kyphosis was 18.3° and 15.7° (not significant) at T2-5, and 17.3° and 10.1° (not significant) at T5-12. 5) Lumbar lordosis at T12-S1 was 47.2° and 45.5° (not significant). 6) C7 plum line was 10.5° and 5.3° (not significant). BMI was 26.0 and 19.2 (P=0.042, not significant). Mental retardation was 100% and 0%.

Conclusion: Most PWS patients had a lumbar or thoracolumbar curve (Type 5, 6). On the other hand, IP patients typically had thoracic scoliosis (Type 1, 2, 3). There was no statistically significant difference between the two groups with respect to either curve angle or BMI. All patients of PWS had the mental retardation.

231. The Efficacy of Intraoperative Gardner-Wells Skull Tongs -Unilateral Femoral Traction in Correction of Pelvic Obliquity in Non-Ambulatory Cerebral Palsy Patients; A Retrospective Comparative Study

Zaid T. Al-Aubaidi, MD; David E. Lebel, MD, PhD; Andrew Howard, MD, MSc, FRCSC; Benjamin Alman, MD; Reinhard D. Zeller, MD, FRCSC; Unni G. Narayanan, MBBS, MSc, FRCS(C); Clifford Lin, MD MASc.; Stephen J. Lewis
Denmark

Summary: The use of intraoperative Halo-femoral traction is well described and well practiced In patients with idiopathic scoliosis, to the best of our knowledge this the first report describing the use of Gardner-Wells tongs and unilateral femoral traction intraoperatively. This study could not confirm that that the use of intraoperative skull-femoral traction can end with better correction. However the use of intraoperative skull femoral traction as an adjunct in the treatment of patients with scoliosis and pelvic obliquity should be left to the discretion of the surgeon. In cases where traction is considered, our results support the use of a simplified technique using Gardner-Wells tongs.

Introduction: Paralytic scoliosis is the most common cause of pelvic obliquity. When present, pelvic obliquity can add to a skewed trunkal balance, leading to bad seating and pressure sores. The aim of this study is to examine the efficacy of using the Gardner-Wells tongs and unilateral femoral traction on the correction of pelvic obliquity.

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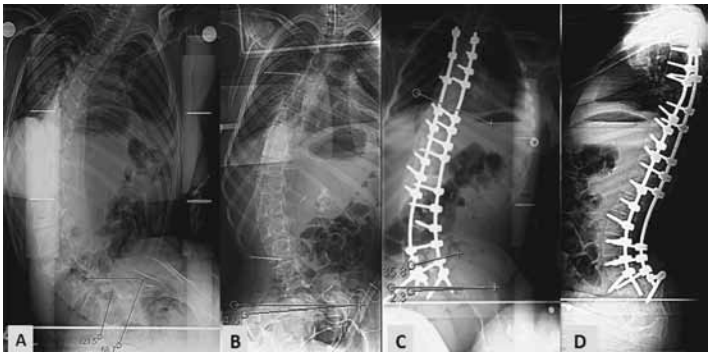
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Methods: We assembled a consecutive series of 39 patients diagnosed with spastic cerebral palsy (CP) GMFCS level V and a severe scoliotic curve, all treated with posterior spinal instrumented fusion (PSIF) from T2 or T3-Pelvis in the period from 1999 to 2009 in a single institution. The treatment group consisted of 22 patients who underwent PSIF with intraoperative skull-femoral traction as adjunct. The control group consisted of 17 patients treated without traction - 12 treated with PSIF and 5 treated with combined anterior release and PSIF.

Results: The two groups matched regarding their age, gender, curve severity and curve type. There was a significant difference in pelvic obliquity between the two groups. The average correction of scoliotic curves and pelvic obliquity was 66% and 76% in the traction group and 62% and 60% in the control group, respectively. These were unchanged at follow up. There were no statistically significant differences in the two groups regarding correction of their coronal and sagital balance. We did not have any traction related complications. There were no significant differences regarding surgical time, blood transfusion or hospital length of stay between the two groups. There were no cases with crankshaft phenomenon documented clinically or radiologically in any of the patients.

Conclusion: The use of skull unilateral femoral traction is well practiced using halo traction. In this study, we looked at the use of Gardner-Wells tongs traction. Using the Gardner-Wells tongs seems to be safe, fast and gives good clinical results, although not statistically distinguishable from the results seen in our historical controls. We had no complications related to skull-tongs traction, reported series of halo traction application have recorded drawbacks and complications related to the halo itself. We recommend this simplified technique when intraoperative traction is considered.



232. Use of Bipolar Sealer Device Reduces Blood Loss and Transfusions in Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Zachary L. Gordon, MD; Jochen P. Son-Hing, MD, FRCSC; Connie Poe-Kochert, BSN; George H. Thompson, MD
USA

Summary: Use of a bipolar sealer device in posterior spinal surgery (PSS) for idiopathic scoliosis (IS) significantly reduces blood loss and transfusions.

Introduction: Reducing perioperative blood loss and transfusions in patients undergoing PSS is important. In addition to epsilon aminocaproic acid (Amicar), we are using a bipolar sealer device (Aquamantys, Salient Surgical Technologies) as an adjunct to electrocautery to reduce perioperative blood utilization.

Methods: Using a prospectively maintained database, we reviewed the operative time, estimated blood loss, cell saver use, and intraoperative and postoperative transfusion rate in patients who underwent PSS for IS. Fifty patients were identified who fit these criteria since initial use of the bipolar sealer device. We compared these to a control group of the preceding fifty patients for whom the device was not used. All patients, including those in the study group, received Amicar (infusion of 100 mg/kg over 15 to 20 minutes, then 10 mg/kg per hour throughout the remainder of the procedure). The surgical technique did not differ between the two groups.

Results: Baseline characteristics between the two groups were similar except for the number of levels fused, which was larger in the investigational group (12.5 versus 11.8, p=0.027). There was no difference in operative time or hospital length of stay. Intraoperative blood loss was 597mL in the study group and 1085mL in the control group (p<0.0001). Total perioperative blood loss, including postoperative drain output, was 1266mL in the study group and 1600mL in the control group (p=0.01). Intraoperative cell saver transfusion was 127mL in the study group and 200mL in the control group (p=0.001). Eleven patients in the study group and twenty-six patients in the control group required additional intraoperative or postoperative transfusions (p=0.004). The number of packed red cell units transfused per patient was 0.26 in the study group and 0.58 in the control group (p=0.034), reducing the transfusion rate by over 50%. Total blood volume transfused, including cell saver, was also significantly lower in the study group (212mL vs. 388mL, p=0.001.

Conclusion: Use of a bipolar sealer device significantly reduces total perioperative blood loss and transfusion requirements, when compared with a control group in PSS for IS.

234. Development and a Validation Study of a New Questionnaire for Adolescent Idiopathic Scoliosis

Katsushi Takeshita, MD; Yasuhisa Arai, MD PhD; Osamu Shirado, MD, PhD; Tokuhide Doi; Ken Yamazaki, MD; Koki Uno, MD, PhD; Haruhisa Yanagida, MD
Japan

Summary: A multidisciplinary team developed and verified the validity of the new questionnaire for adolescent idiopathic scoliosis (Scoliosis Japanese Questionnaire-27: SJ27). A validity study of 404 girls with AIS resulted in an excellent internal consistency (Cronbach α: 0.91) and a good to excellent correlations with SRS22. The SJ27 had a moderate correlation with the Cobb angle (0.352, p<0.001).

Introduction: Though the SRS questionnaire is a gold standard for assessment of spinal deformity, some questions may not be optimal outside Western countries. The purpose of this study was to develop and validate a new patient-reported outcome measure for adolescent idiopathic scoliosis.

Methods: The development committee which was composed of spinal surgeons, rehabilitation doctors, a pediatric psychiatrist and a biostatistician spent two years to develop a new questionnaire (Scoliosis Japanese Questionnaire- 27: SJ27). The SJ27 has 27 questions which cover pain, appearance, participation, and cognition. The total score ranges 0 to 108 points, and a higher score indicates lower QOL.

We recruited patients with adolescent idiopathic scoliosis, and investigated patient profiles, radiographic properties of scoliosis (the angle Cobb, level of apex, kypho-

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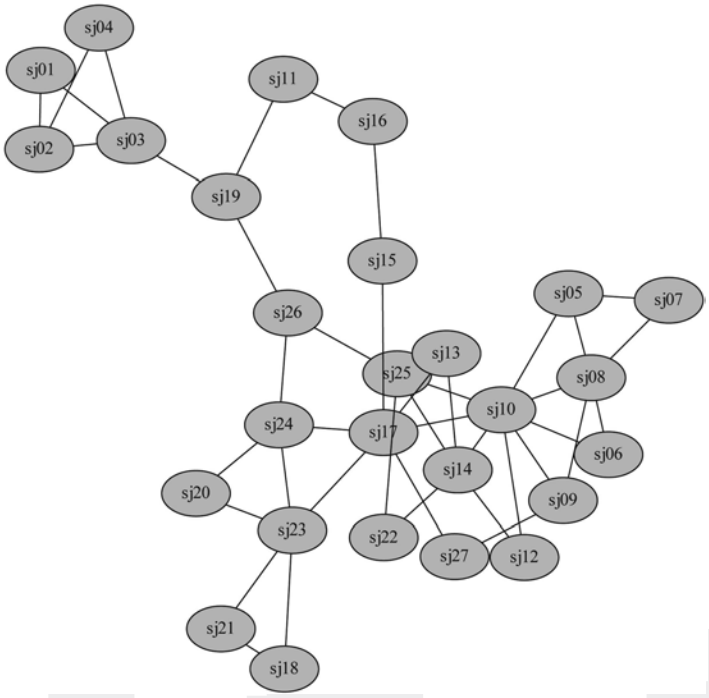
sis), treatment, SJ27 and SRS22. Internal consistency was evaluated by Cronbach alfa. Criterion-related validity was evaluated by calculating correlative coefficients (CC) between SJ27 and SRS22. Repeatability as well as responsiveness will be reported after the second survey is completed this March.

Results: A total of 404 girls with an average age of 14.6 (SD2.6) responded the survey. The mean (SD, 95%CI) of the Cobb angle of the main curve was 29.7degrees (14.7, 6 to 88). 318 patients were under non-operative treatment, and 86 patients were in postoperative status. The SJ27 score averaged 23.3 (16.8, 0 to 86). Every question had a good correlation with other questions which was shown in Table by the Akaike's Information Criterion network. The Cronbach ρwas 0.91, which indicates an excellent internal consistency. Those of the SRS22 were 0.66 to 0.83. The SJ27 had good to excellent correlative coefficients with the four domains of the SRS22 (0.43 to 0.60). The SJ27 had a moderate correlation with the Cobb angle (0.352, $p<0.001$), but not with kyphosis. The correlation between the SRS22 and the Cobb angle was moderate (0.308, $p<0.001$).

Conclusion: A multidisciplinary team developed and demonstrated the validity of the new questionnaire for adolescent idiopathic scoliosis.



235. Correction of Thoracic AIS with Pedicle Screw Instrumentation: Forty-Eight Patients with Minimum Ten-Year Follow-Up

Kan Min, MD; Christoph Sdzuy, MD; Mazda Farshad, MD, MPH
Switzerland

Summary: Posterior correction of thoracic AIS with pedicle screw instrumentation (n=50) achieves a stable long-term (10y) correction with a good patient satisfaction.

Introduction: Pedicle screw instrumentation has become standard of care for posterior correction of adolescent idiopathic scoliosis (AIS). There has however been very little report on long term results. We report clinical, radiological and pulmonary function results of 50 patients with minimal 10y follow-up.

Methods: 50 patients (44 female, 6 male, mean age at surgery 15.3 years) with 42 Lenke 1 (A=19, B=10, C=13), 6 Lenke 2 and 2 Lenke 3 curves (Risser 0-3 (n=26), >3 (n=24)) were operated for AIS from posterior with pedicle screw alone instrumentation. The data was prospectively collected preoperatively, at 6 weeks, 2 years and 10 years postoperatively. COBB angle, sagittal and coronar balance, fusion levels, adjacent disc angle and lowest fused vertebral tilt were documented at all time-points. The overall outcome as well as the outcome of different curve types were analyzed statistically.

Results: Overall the main thoracic curves was corrected from 57±12° to 21±09° ($p<0.05$). There was no significant change after 2 years (23±10°) or 10 years (26±10°). This effect was seen in all curve types. While the coronar balance (C7-S1 plumb line) restored during the follow-up period by tendency, there was a significant restoration of overall sagittal balance (T1 -S1 plumb line) from preoperative 7.3mm to -3.8mm ($p<0.05$). The adjacent disc angle decreased from 6±3° to -2±4° postoperatively and remained stable at 10 years. The lowest fused vertebral tilt decreased from 22±7mm preoperatively to 5±5mm postoperatively and 7±5mm at 10 years. The %FVC remained unchanged at 75% from preoperative to 2 year and 10 year after the operation. The SRS-24 score did not change from 94±15 at 2y postop to 98±15 at 10 y postop.

Conclusion: Posterior correction of thoracic AIS with pedicle screw instrumentation achieves a stable long-term correction with a good patient satisfaction.

236. Pedicle Screw Instrumentation with Rod Derotation, Direct Vertebral Rotation(DVR) and Stiff Rod Results in Restoration of Thoracic Kyphosis in Single Thoracic Adolescent Idiopathic Scoliosis (AIS)

Se-Il Suk, MD; Jin-Hyok Kim; Sung-Soo Kim, MD; Dong-Ju Lim; Tai-Wan Kim; Dong-Kyun Jang; Jung-Hee Lee
Republic of Korea

Summary: Pedicle screw instrumentation with rod derotation and DVR using stiff rods restored and maintained thoracic kyphosis in single thoracic AIS.

Introduction: AIS is characterized by thoracic lateral spine curvature and hypokyphosis. It has been reported that posterior segmental instrumentation tends to restore thoracic kyphosis insufficiently and induces proximal junctional kyphosis (PJK). The purpose of this study was to evaluate the thoracic sagittal curve and proximal junctional change in single thoracic AIS patients after pedicle screw instrumentation with stiff rods, rod derotation and DVR.

Methods: A total of 122 AIS patients with single thoracic curves treated with pedicle screw instrumentation, rod derotation and DVR with stiff rods were retrospectively analyzed with an average of 4.0 years (2~10 years). Radiographic measurements were taken from standing long-cassette films and were analyzed including various sagittal parameters for preoperative, early postoperative and last follow-up exams. The proximal junctional sagittal cobb angle was measured between the lower end plate of the uppermost instrumented vertebra and the upper end plate of second vertebrae above. The sagittal curve between T5-12 in each

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.

 The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

case was measured. An abnormal PJK was defined as a proximal junctional sagittal angle of 10° greater than the preoperative measurement.

Results: The preoperative T5-12 thoracic kyphosis of 17.8°±10.4° was restored to 23.5°±7.2° (P<0.0001) seen in the first postoperative film and was well maintained at 25.9°±7° (P<0.0001) at last follow-up. The preoperative proximal junctional sagittal angle (PJK) of 7.0°±5.4° was changed to 8.5°±6.1° at last follow-up. PJK was found in 2 (1.6%) patients immediately after surgery and 7 (5.7%) patients in last follow-up, but there was no statistically significant difference (P=0.44) and there were no adverse clinical effects.

Conclusion: In the treatment of patients with single thoracic AIS, pedicle screw instrumentation with rod derotation and DVR using stiff rods restored and maintained thoracic kyphosis. PJK was not of significance in this series.

237. A Novel Technology for Measuring Cobb Angles

Christopher Kestner, MD; Patrick J. Cahill, MD
USA

Summary: A new technology on a free iPhone app allows one to accurately and reliably measure cobb angles on hard copy x-rays digital radiographs.

Introduction: Measuring the Cobb angle in patients with scoliosis is most commonly performed using either a goniometer for hard-copy X-rays or an angle-measuring tool supplied with the viewing program for digital radiographs. The accelerometer feature in recent iphone technology allows an observer to quickly make angle measurements using the iphone itself as a reference. We hypothesized that the accuracy and reliability would be within the acceptable error range, making the iphone a viable alternative for measuring Cobb angles.

Methods: Cobb angle measurements were made by six investigators on forty randomly selected scoliosis patients. Twenty were made using hard copy X-rays, and twenty using a digital radiograph-viewer angle measurement device. The iPhone application iHandy level (iHandy software, Inc) was then used to measure the same forty Cobb angles and the results were tested for accuracy, interobserver and intraobserver reliability.

Results: The intraclass correlation coefficient (ICC) two-way mixed model analysis-of-variance on absolute agreement was used to measure reliability. The ICC is a ratio of the variance between subjects to the total variance. Values of ICC can range from 0 to 1, with a higher value indicating better reliability. Summary statistics from the mixed model analysis-of-variance were used to compute 95% confidence intervals for each ICC. Statistical analyses were performed using SPSS 17.0 software (SPSS Inc., Chicago, IL). The intrarater ICC for the iphone vs goniometer was 0.997 and 0.960 for the iphone vs computer. The interrater ICC was 0.993 and 0.961, respectively. Accuracy analysis demonstrated that the mean difference between the iphone application and the goniometer was 0.264 with a standard deviation of 1.01 degrees. The mean difference and standard deviation comparing the iphone application and a digital computer angle measuring device were 0.273 and 2.24 degrees, respectively.

Conclusion: The results from this study demonstrate that the free angle measuring application available on iphones may serve as an accurate alternative to making Cobb angle measurements.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

238. Reducing Adverse Event Reporting Bias in Spine Surgery

Joshua D. Auerbach, MD; Kevin B. McGowan, PhD; Marci Halevi; Greg Maislin, MS, MA
USA

Summary: There is an increasing need for greater transparency in adverse event reporting from industry-sponsored spine surgery trials. The use of an independent Clinical Events Committee to evaluate all adverse events from a randomized, prospective, IDE trial revealed that 37% of all adverse events were re-classified, the vast majority of which were upgrades in severity. An independent CEC can help mitigate potential adverse event reporting bias and should be considered for use in future clinical trials.

Introduction: Recent articles in the lay press and in peer-reviewed publications have raised concerns about the ability to report high quality, honest adverse event (AE) data from an industry-sponsored spine surgery study in which investigators may have a perceived conflict of interest. No study to date has quantified the degree to which investigator bias is present in AE reporting, nor the effect that an independent Clinical Events Committee (CEC) has on mitigating this potential bias.

Methods: The coflex® Investigational Device Exemption (IDE) study is a prospective, randomized, multicenter study to compare the safety and effectiveness of the coflex® device compared to laminectomy and posterolateral fusion for the treatment of spinal stenosis and spondylolisthesis. Investigators classified the severity of each AE, and the relationship of the event to surgery and device. An independent CEC, composed of 3 independent, blinded spinal surgeons without affiliation to the study sponsor, reviewed all AE reports submitted by the investigators and re-classified all AE reports. All CEC adjudications were binding to the sponsor.

Results: Overall, the CEC reclassified the level of severity, relation to surgery, and/or relation to device in 394 of the 1,056 total (37.3%) reported AE's. It was 5.3 (95% CI 2.6 to 10.7) times more likely for the CEC to upgrade the AE than to downgrade the AE. Similarly, it was 7.3 (95% CI 5.1 to 10.6) times more likely for the CEC to upgrade the relationship to surgery and 11.6 (95% CI 7.5 to 18.8) times more likely for the CEC to upgrade rather than downgrade the relationship to the device. The status of the investigator's financial interest in the company had little effect on the reclassification of AE's.

Conclusion: Thirty-seven percent of AE's were reclassified by the CEC, the vast majority of which were upgrades in the level of severity, or a designation of greater relatedness to surgery or device. An independent CEC can identify and mitigate potential inherent investigator bias and facilitate a more accurate assessment of investigational device safety profile, and further, should be considered a requisite component of future clinical trials.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

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239. Indications and Treatment Protocols for Halo Gravity Traction in Severe Pediatric Scoliosis: A Survey of the Experts

Joshua M. Pahys, MD; Patrick J. Cahill, MD; Charles R. d'Amato, MD, FRCSC; Jahangir Asghar, MD; Randal R. Betz, MD; Chest Wall and Spine Deformity Study Group; Amer F. Samdani, MD
USA

Summary: A group of 30 surgeons with extensive experience in halo gravity traction (HGT) responded to a survey evaluating indications, treatment protocols, and management of complications of HGT in severe spinal deformity. There was extensive variability in surgeon responses with only a few statements reaching >70% agreement amongst the group. A prospective study on HGT is needed to establish treatment guidelines for HGT use.

Introduction: Halo-gravity traction (HGT) is considered a viable adjunctive treatment for the care of severe spinal deformity. However, no clearly defined indications or treatment protocols have been consistently established in the few retrospective HGT studies to date.

Methods: A group of 35 experienced SRS surgeons were identified who utilize pre- and/or perioperative HGT for the treatment of severe spinal deformity prior to definitive fusion. Of this group, 30 surgeons (86%) responded to a 63 question survey evaluating indications, treatment protocols, and management of complications for HGT.

Results: Survey respondents utilize HGT in 1-10 cases/year (73%), while 27% use HGT in 11-20 cases/year. The most common response(s) to survey questions in each category are stated below, along with the percentage of respondents in agreement with each statement listed in parentheses.(Table 1) Radiographic indications for HGT are a coronal and/or sagittal Cobb angle of >90°-110° (66% respondents agree) and curve flexibility <20% (30%), while flexibility is not a factor for 27% surveyed. Contraindications are open fontanelles (68%) and osteogenesis imperfecta (OI) (43%). Paradoxically, 30% of respondents listed OI as an indication for HGT. Goal traction weight: >50% of patient weight (52%). Pin care is performed in 83% surveyed, with 5 different solutions reported. When initiating HGT, 83% of respondents utilize a period of HGT prior to any surgery (mode time: 4 weeks (33%)). Staged procedures utilizing HGT are performed by 90% surveyed (mode time interval between surgeries: 2 weeks (40%)). The most common reported complication is pin site drainage (67%), treated initially with pin care (100%) and/or antibiotics (60%).

Conclusion: The survey results highlight the considerable variability amongst experienced SRS surgeons with regards to indications and protocols for HGT. A mark of >70% agreement amongst respondents to a particular statement has been used in previous studies (Downs et al Spine 2009) to define consensus for expert opinion. This level of concordance was rarely achieved among those surveyed for this project. Further studies are required to maximize the efficacy and safety of HGT in the treatment of severe spinal deformity.

240. Radiographic and Clinical Outcomes of Posterior Column Osteotomies in Adult Spinal Deformity Correction: Analysis of 128 Patients

Ian G. Dorward, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Woojin Cho, MD, PhD; Linda Koester, BS; Brenda A. Sides, MA
USA

Summary: We reviewed 128 patients undergoing PCO with at least 2-year follow-up. Average kyphosis correction was 8.8° per PCO, but varied significantly by the region of the spine in which PCOs were used. PCOs did not cause increased complications, and were associated with improved SRS and ODI outcomes scores.

Introduction: Despite being common, posterior column osteotomies (PCOs—Smith-Petersen or Ponté) have not been well studied with respect to radiographic and clinical outcomes. To our knowledge, this is the largest reported series of pts with PCOs for spinal deformity correction.

Methods: 128 consecutive adult and pediatric pts underwent PSF with PCOs with min 2-year follow-up (FU). 75 were primary surgeries and 53 were revisions. We excluded those with a concomitant PSO, VCR or anterior release/fusion at PCO levels.

Results: 128 pts aged 37.6±21yrs underwent 518 PCOs (avg 4.0±2.2) with 14.4±3 avg levels of instrumentation, with 3yr (range 2 to 6.8) avg FU. 73% of PCOs were primary and 27% were through a fusion mass or pseudarthrosis. PCOs were used for kyphosis correction in 49%, scoliosis correction at the apex of a curve in 13%, and both in 38%. Avg kyphosis correction per PCO was 8.8°±7.2, but varied with pt age (10.2° for <21 vs 7.7° for ≥21, P<0.0001) and region of the spine: TL 11.6° > L 9.4° > MT 7.2° > PT 3.6°. Mean sagittal Cobb for PCO segments decreased from 30°±30 to 8.6°±22 (P<0.0001). For PCOs at the apex of a curve, mean max coronal Cobb decreased from 66°±21 to 31°±14 (P<0.0001). Avg EBL was 1419±887mL and correlated with greater age (P<0.0001) and more instrumented levels (P<0.0001), but not with number of PCOs (P=0.32). Complications occurred in 31 (24.2%) pts: 4 postop radiculopathies (none attributable to PCOs); 1 postop death (failed reintubation attempt for respiratory failure in ICU); 5 implant failures, and 4 confirmed pseudarthroses (1 at a PCO level). Complications did not correlate with number of PCOs (P=0.5). 6 (4.7%) pts had a failed intraop wake-up test or loss of motor evoked potentials (MEPs) that could be attributed to overcorrection with PCOs, but none had postop neurologic deficits. ODI scores improved pre v postop (34.4±17 v 23.6±18, P<0.0001), as did normalized SRS-30 scores (63.7±13 v 76.4±15, P<0.0001).

Conclusion: PSF with PCOs was a safe and effective technique for spinal deformity correction even without anterior releases. The number of PCOs did not correlate with increased EBL or complications. The main technical concern with PCOs was overcorrection, but intraop MEPs and wake-up tests prevented postop deficits.

241. Minimally Invasive Treatment of Adult Scoliosis with XLIF: Radiographic Outcomes from a Prospective Multicenter Study

Frank M. Phillips, MD
USA

Summary: This study presents 24mo radiographic results of adult degenerative scoliosis patients treated with XLIF.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Introduction: The purpose of this report is to examine the radiographic correction of adult degenerative scoliosis treated with XLIF emphasising supplemental fixation-dependent differences in deformity reduction.

Methods: 107 adult scoliosis patients treated with XLIF were enrolled in a prospective multi-center study. Radiographs were collected pre-op and at 0.5, 3, 6, 12, and 24 months. Radiographic measures and fusion were assessed by an independent core lab using AP and lateral films and CTs. Measures include L1-S1 lumbar lordosis, coronal Cobb, disc height and interbody bridging.

Results: This analysis includes 99 patients treated with XLIF at 302 levels (T11-L5). Patients were treated with up to 6 XLIF levels (ave: 3.3/patient). Supplemental fixation included (by patient) bilateral pedicle screws (48%), unilateral pedicle screws (29%), lateral plating (7%); and none (16%). All unilateral screws were placed percutaneously. Bilateral pedicle screws were placed percutaneously (44%) and open (56%). Initial coronal Cobb correction was achieved in all fixation scenarios and maintained from post-op to 24mo in all scenarios except standalone. In patients treated with bilateral pedicle screw fixation, those with open vs perc placement resulted in greater coronal correction (14° vs. 10°). Coronal correction was maintained in patients treated with open bilateral pedicle screws (p=0.937). 36 patients were hypolordotic (lordosis >-40°) at baseline. In hypolordotic patients, lordosis improved from an ave of -28° to -38° after XLIF (p<0.001), and an ave of -32° at 24 months. Ave disc height was increased in all fixation scenarios with the greatest increases in bilateral pedicle screw patients and the least in standalone. Partial loss of disc space ht was observed at 24mo in all scenarios. Partial consolidation or solid bridging bone was apparent in 92% of interbody levels with the highest incidence of solid bridging in segments with bilateral pedicle screws (p<0.001).

Conclusion: The current study supports that supplemental posterior fixation, specifically bilateral fixation, optimized coronal plane deformity correction and interbody fusion after XLIF.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

242. Validity of Failure Classification for Pelvic Fixation Used in Long Construct Fusions in Adult Deformity Patients

Woojin Cho, MD, PhD; Jonathan R. Mason, MD; Adam Wilson, MD; Christopher I. Shaffrey, MD; Francis H. Shen, MD; Adam L. Shimer, MD; Wendy Novicoff, PhD; Kai-Ming Fu, MD, PhD; Joshua E. Heller, MD; Vincent Arlet
USA

Summary: This study analyzed SRS and ODI scores of adult deformity patients with failure of pelvic fixation. It validates minor failure as expected loosening or breakage of pelvic screws due to motion at SI joints following solid fusion in long constructs used for adult deformity. It defined major failure as radiographic evidence of pseudarthrosis or prominent screws and supported these definitions with clinical outcome scores.

Introduction: Pelvic fixation failure can occur due to pseudarthrosis at the base of long constructs. Even with solid fusion, radiographic signs of failure around pelvic fixation occurs because the SI joint is still mobile. There is no accepted definition regarding the failure of the pelvic fixation. We proposed a definition of major and minor pelvic fixation failure and provided clinical validity to the definition.

Methods: Methods:190 adult deformity patients who underwent long construct instrumentation with iliac screws were included and their SRS and ODI scores were reviewed. Two year follow up was required. Patients were divided into two groups: Failure(F)and Non-Failure(N-F). Failures were defined as major and minor according the previous definition (Cho et al. SRS 2011:"Major F included rod breakage between L4 and S1, failure of S1 screws (breakage, halo formation, or pullout), and prominent iliac screws requiring removal. Minor F included rod breakage between S1 and iliac screws and failure of iliac screws. Minor F did not require revision surgery."). For the three groups (Major F, minor F, N-F), the improvement of SRS and ODI score was compared between preop and final f/u.

Results: 4 of the 8 Major F pts had complete clinical outcome measures, 6 of the 15 minor F and 15 of the 43 N-F. The Major F pts had their pre revisions scores compared to their pre operative scores. They did not show a statistically significant difference in their SRS or ODI scores (P value 0.536). The minor F pts did show a statistically significant increase in both scores when pre operative scores were compared with two year follow up. The SRS score went up from 2.33 to 3.23 (P value 0.013). The ODI score went from 26.4 to 13 (P value 0.032). A one way ANOVA test showed a statistical significant difference between the groups for post operative ODI (P value 0.001). The Non failure group also showed a similar statistically significant increase in SRS scores (2.4 up to 3.0, P valvue 0.001) and improvement in ODI scores (29.2 to 23.9, P value 0.013).

Conclusion: The results validated the definition of pelvic fixation failure. Minor failure (haloing or breakage around the pelvic fixation) is not clinically significant, but major failure does affect clinical outcomes.

	Pre op SRS score	Post op SRS score	P value Paired T test
Major failure (Major F)	2.73 ± 0.7	3 ± 0.14	0.54
Minor failure (minor F)	2.33 ± 0.5	3.23 ± 0.65	0.01
Non failure (N-F)	2.4 ± 0.53	2.96 ± 0.55	0.00
	Pre op ODI score	Post op ODI score	
Major failure (Major F)	24.25 ± 8.6	24.75 ± 2.9	0.92
Minor failure (minor F)	26.4 ± 2.8	13 ± 6.9	0.32
Non failure (N-F)	29.2 ± 5.9	23.9 ± 4.6	0.01

243. The Use of Barbed Sutures During Scoliosis Fusion Wound Closure: A Quality Improvement Analysis

Alfred Mansour, MD; Ryan Ballard; Sumeet Garg, MD; David Baulesh; Mark A. Erickson, MD
USA

Summary: This quality improvement project compared traditional layered interrupted suture closure and running bidirectionally barbed suture closure. Barbed suture closure of spinal fusion incisions results in a 40% reduction in closure time, resulting in an $884.60 decrease in hospital charges related to operating room time. This may represent significant yearly cost savings in a high-volume spine fusion center and warrants further investigation comparing patient-related outcomes.

Introduction: Growing evidence in the orthopaedic arthroplasty literature supports the use of running bidirectionally barbed suture (barbed suture) for closure of knee arthrotomies. The studies cite more rapid wound closure and suture line integrity

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as its major advantages. No studies demonstrating similar findings during spinal deformity surgery exist. The purpose of this project is to compare wound closure times and hospital charges using traditional closure versus barbed suture closure of scoliosis fusion wounds to potentially justify its use in this setting.

Methods: A quality improvement project was initiated at a single tertiary-referral children's hospital spine program evaluating traditional layered interrupted suture closure (Group 1) and running bidirectionally barbed suture closure (Group 2). Data regarding wound closure time, length of incision, fusion levels, suture cost, and hospital charges were prospectively collected over a one-month period.

Results: Ten incisions comprised Group 1 and fifteen comprised Group 2. The average wound closure times were 29.5 and 17 minutes, respectively, p=0.006. The wound lengths between groups were statistically comparable (p=0.15). Taking into account wound length, the average closure time in Group 1 was 1.29 cm/minute compare to 1.97 cm/minute in Group 2 (p<0.01). When accounting for the extra cost associated with the use of barbed sutures ($62.54; p<0.0001), the impact of a more rapid closure resulted in a difference in hospital charges of $884.60 per case (p=0.0013).

Conclusion: Barbed suture closure of spinal fusion incisions results in a 40% reduction in closure time, resulting in an $884.60 decrease in hospital charges related to operating room time. This may represent significant yearly cost savings in a high-volume spine fusion center and warrants further investigation comparing patient-related outcomes.This quality improvement analysis provides preliminary justification for using barbed suture for scoliosis fusion wound closure resulting in decreased operating room times and subsequent hospital charges.

244. Relationship between Spino-Pelvic Parameters and QOL in Adult Spinal Deformity in Japanese Patients: Which Factor is Important for Better QOL in Treatment of Adult Spinal Deformity?

Yu Yamato; Yukihiro Matsuyama, MD; Manabu Ito, MD, PhD; Ken Yamazaki, MD; Hiroshi Taneichi, MD; Yutaka Nohara, MD; Morio Matsumoto, MD; Tanaka Masato; Nobumasa Suzuki, MD
Japan

Summary: A multi-centered, cross sectional study to find out the impact of radiographic parameters on QOL in adult spinal deformity. Lumber lordosis, pelvic parameters and sagittal global balance can affect lumbar and social function and low back pain. Coronal plane radiographic parameters are less critical.

Introduction: Adult thoraco-lumbar spinal deformity causes low back pain, gait disturbance and gastroesophageal reflux disease. No consensus exists on treatment of adult spinal deformity, decision-making and surgical planning. We investigated the relationship between spino-pelvic radiographic parameters and QOL measurements in Japanese adult spinal deformity patients.

Methods: One hundred six patients, who have spinal deformity without neurological deficit, underwent whole spine antero-posterior and lateral radiography in standing position and completed clinical questionnaire in 5 institutions. Radiographic measurements included curve type, curve location, curve magnitude, coronal alignment, sagittal alignment, pelvic position, incidence of vertebral fracture and antero-posterior and lateral olisthesis. Oswestry disability index (ODI), Japanese Orthopaedics Surgery Association Back Pain Evaluation Questionnaire (JOABPEQ) and Scoliosis Reserch Society (SRS-22) patient questionnaire were utilized for QOL evaluation.

Results: The mean age of the patients in this study was 67.8 years (range 20-87). Mean Cobb angle on coronal plane was 31.8 degree. Significant correlation was observed in sagittal plane parameters, global balance and pelvic parameters with QOL measurements. Lumbar lordosis (T12-S1) correlated with ODI, JOABPEQ (walking ability, social life function), SRS-22(function, pain, self image and total). SVA correlated with ODI, JOABPEQ (lumbar function, walking ability, social life function) and SRS-22 (function, self image). Pelvic parameters (pelvic tilt and sacral slope) correlated with ODI, JOABPEQ (walking ability, social life function) and SRS-22 (function, self image) According to multiple logistic regression analyse, SVA conferred an odds ratio 1.012 (95%CI 1.004-1.021, p=0.003) for dysfunctional patients (ODI above 50). Coronal plane parameters and global balance revealed no significant correlation with function or pain.

Conclusion: Lumber lordosis, pelvic parameters and sagittal global balance can affect lumbar and social function and low back pain. Coronal plane radiographic parameters are less critical. This study suggests planning of collection in adult spinal deformity should be considered for sagittal alignment and global balance.

245. Mid-Term Follow-Up of Vertebral Column Resection for Severe Pediatric Spinal Deformity

Todd Lincoln, MD; Kaveh Barami
USA

Summary: Excellent clinical and radiographic results for patients presenting with severe deformity can be achieved with VCR at mid-term follow-up with an acceptable rate of complication and high patient satisfaction.

Introduction: Vertebral column resection is a powerful tool for treating severe and rigid spinal deformities in the thoracic and lumbar spine. With modern techniques and neuromonitoring, the surgery can be performed with a low rate of major and minor complications. However, VCR should be reserved for cases that cannot be addressed with smaller procedures or more stable osteotomies.

Methods: Restropective review of all patients (n=11) treated with VCR between 2002-2006 were included for study. The etiology of the spinal deformity was congenital scoliosis in 3, congenital kyphoscoliosis in 6, achondroplasia in 1, and syndromic scoliosis in 2. Eight patients had a single level VCR, while three had a 2-level VCR. Six of 11 VCR surgeries were done as a revision procedure. Cobb angle, sagittal balance and coronal balance was measured on pre-operative, post-operative and most recent radiographs. Medical records were reviewed for complications, neurologic deficits, and reoperations. SRS-24 questionnaire at most recent follow-up was collected and scored.

Results: Average follow-up was 6.3 years (minimum of 4.5 years). Eight of 11 patients had recent radiographs for measurement, and 9 of 11 patients completed the SRS-24 questionnaire. Average pre-operative radiographs measured 48 degrees scoliosis and 73 degrees kyphosis. Average post-operative Cobb angle was 20 degrees (58% correction) and average kyphosis 21 degrees (68% correction). Post-operative sagittal balance averaged 1.1 cm from center vertebral sacral line. Average

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SRS-24 score of 4.6, indicating a high degree of patient satisfaction. Total complication rate was 54%: one patient developed post-operative paraparesis, two transient neurologic deficits that resolved within 24 hours with no treatment, two durotomies, one coagulopathy, one urinary tract infection, and one cutaneous yeast infection.

Conclusion: The clinical results for pediatric vertebral column resection are excellent with minimal pain or disability at mid-term follow-up. All patients reported being satisfied and all patients were able to heal their spines with no hardware complications in this small series. The risk of neurologic complication is high, but acceptable given the nature of the procedure.

246. Accuracy and Reliability of Central Sacral Vertical Line (CSVL) on Scoliosis Radiographs

Dinesh Thawrani, MD; Steven Agabegi, MD; Emily Eismann, MS; Peter Sturm, MD
USA

Summary: In clinical practice, although physicians are not highly reliable in drawing CSVL, its influence on selecting SV or determining LM is not affected.

Introduction: CSVL is frequently utilized on scoliosis radiographs for surgical planning. However, none of the studies assessed the accuracy and reliability of drawing CSVL in practice.

Methods: Thirty digital posteroanterior X-rays of adolescent idiopathic scoliosis were provided to 5 raters (3 fellowship trained spine surgeons and 2 fellows) at two different times (3 week interval) to determine SV and LM. An independent observer then assessed the accuracy of CSVL drawn by the raters. The CSVL was considered accurate if it was drawn perpendicular from the middle of the S1 vertebra. To avoid conscious bias, raters were kept blinded from the actual purpose of the study. To avoid technical bias, study was conducted on research-PACS and raters used desktop computers, similar to one used in clinic practice.

Results: Accuracy of Drawing CSVL: Based on absolute values, the CSVL was, on average, drawn a significant 2.26(±1.88)mm away from the center during 1st round ($t=14.77, p<0.001$) and a significant 2.39(±2.05)mm during the 2nd round ($t=14.31, p<0.001$). Based on raw values, the lines were, on average, left of the center on both the 1st (-1.02±2.76mm) and 2nd round (-0.89±3.03mm).

Reliability and Reproducibility of CSVL: Fair inter-rater reliability was observed among the 5 raters during 1st round, ICC 0.23(95%CI=-0.33-0.59) and substantial reliability during 2nd round, ICC 0.70(95%CI=0.49-0.84). Intra-rater reproducibility was moderate across two rounds, ICC 0.47(95%CI=0.27-0.62).

Influence of drawing CSVL on determining SV and LM: The variation in drawing CSVL from center was not significantly associated with the selection of SV in either 1st ($r=-0.02, p=0.78$) or 2nd round ($r=-0.11, p=0.19$). Similarly, variation was not associated in determining LM ($r=-0.02, p=0.78$) in 1st round but was found significantly influencing LM in 2nd round ($r=0.24, p=0.003$).

Conclusion: Although, physicians draw CSVL significantly away from the center of S1 vertebra (mean 2.3mm) its influence on determining SV or LM is not affected in routine practice. However, larger changes in the location of CSVL trend toward increasing the likelihood of changing the selection of SV and LM.

247. Correction of Sagittal Imbalance: A Relationship between Proximal Junctional Kyphosis and Reversal of Compensatory Pelvic Retroversion?

Siddharth B. Joglekar; Roy S. Norris, BS; Nathan L. Hartin, MD; Amir A. Mehbod, MD; Ensor E. Transfeldt, MD
USA

Summary: It is expected that the magnitude of correction of sagittal imbalance would have a direct effect on the reversal of compensatory pelvic retroversion as well as proximal junctional kyphosis (PJK). However the relationship between reversal of compensatory pelvic parameters and PJK has not yet been explored. Our study detected that the reversal of compensatory pelvic retroversion is associated with greater improvement in lumbar lordosis however this comes at the cost of an increased incidence of PJK.

Introduction: Pelvic orientation has an impact on spinal alignment and pelvic parameters are used in predictive formulas when planning correction of sagittal imbalance. Adequate correction of sagittal imbalance should reverse compensatory pelvic retroversion. The magnitude of correction of sagittal imbalance has been shown to be related to Proximal Junctional Kyphosis (PJK). Does a relationship exist between PJK and Reversal of Compensatory Pelvic Retroversion?

Methods: 41 consecutive patients (50-82 yrs) who had surgery for sagittal imbalance (sagittal vertical axis (SVA) $\geq$ 5cm) from 2005 to 2010 were evaluated retrospectively. Spinopelvic parameters were measured on the full spine standing x-rays preoperatively and postoperatively (6 week, 6 month and 1 year). Patient demographics and surgical details were also studied. Regression analysis was performed to determine predictors of PJK.

Results: 29 F and 12 M with a mean age of 64 underwent correction of sagittal imbalance with spinal osteotomy (13 PSO / 2 VCR / 26 SPO). In 28 patients (68%) the imbalance occurred in the context of previous fusion surgery. Age was an independent predictor of PJK on regression analysis ($p=0.02$, OR=1.10 [1.01-1.21]). There was a strong trend toward change in sacral slope (δS) ($p=0.06$, OR=1.08 [0.99-1.17]) and female sex ($p=0.05$, OR=0.21 [0.04-1.13] as predictors of PJK. 18 patients (44%) demonstrated reversal of pelvic retroversion with a rise in sacral slope ($\delta S \geq 5°$). δS was noted to be associated with preoperative sacral slope ($p<0.001$) and with change in lumbar lordosis ($p<0.001$), but not change in SVA. Patients who had not undergone previous fusion surgery demonstrated a greater δS ($p=0.01$).

Conclusion: Improvement in lumbar lordosis is directly related to reversal of compensatory pelvic retroversion. This change in distal spinal alignment seems to affect proximal regional spinal alignment as manifested by a trend to PJK in cases with a large δS. While restoration of compensatory mechanisms may help prevent future spinal imbalance, care must be taken not to precipitate PJK.

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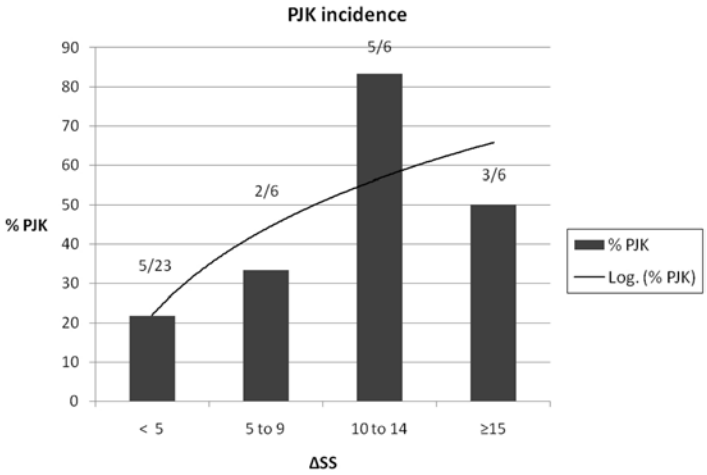

Incidence of PJK (%) in Relation to ΔSacral Slope

248. Nasal Screening for Patients Scheduled for Spine Surgery: Is it Cost Effective?

Shirvinda Wijesekera, MD; Anne R. Moore, DNP
USA

Summary: All elective patients of one spine surgeon were screened preoperatively for Staphlococcus aureus using nasal cultures and analyzed.

Introduction: The controversy between the need for targeted or universal Methicilllin-resistant Staphylococcus aureus (MRSA) screening continues. Spine surgery is projected to increase by 54% over the next ten years. MRSA surgical site infections increase morbidity and mortality. The cost of revision surgery has been reported to surpass the cost of screening.

Methods: All elective patients of one spine surgeon were screened preoperatively for Staphlococcus aureus using nasal cultures. A retrospective analysis of 122 consecutive patients was done to determine the prevalence of MRSA and to examine the correlation with subsequent wound infections. 37 (30.3%) patients tested positive for culture MRSA or MSSA. 36/37 used chlorhexidine wipes on the surgical site the evening before and morning of surgery. 25/37 (67.6%) were treated with mupirocin. All patients who tested positive for MRSA received vancomycin perioperatively and standard precautions for MRSA were followed.

Results: None of the patients with a positive nasal swab developed a deep wound infection. Three of these patients developed wound drainage and were successfully treated with antibiotics; two with augmentin and one with ciprofloxacin due to a penicillin allergy.

One patient with a negative screen developed a deep wound infection with positive cultures for MRSA. This patient required an additional hospital visit for incision and drainage of his wound and ultimately removal of hardware.

The total costs to the facility follow: screening of each patient $20.00; treatment of each patient with a positive screen including a five day application of mupirocin nasal ointment and the use of vancomycin rather than cefazolin perioperatively $5.32; treatment of the patient with the deep wound infection, not including the original surgery, $29049.

Conclusion: The cost of the one infection far exceeded that of screening patients scheduled for spine surgery and treatment of positive cultures. As noted, a negative screen does not ensure that a wound infection will not occur. However, the preemptive treatment of patients with positive screens is recommended considering the increased morbidity and cost of spinal infections.

249. Active SRS Members Demonstrate Huge Variation in Implant Density when Planning Routine Adolescent Idiopathic Scoliosis Constructs

Carl-Éric Aubin, PhD, PEng; A. Noelle Larson, MD; Franck Le Naveaux; Hubert Labelle, MD; Peter O. Newton, MD; David W. Polly, MD; Minimize Implants Maximize Outcomes Study Group
Canada

Summary: We documented significant heterogeneity of screw density strategies among 13 surgeons evaluating the same 5 AIS cases. Between 7 and 14 levels were instrumented and the preferred number of implants ranged between 12 and 26 (mean 1.81 implant/level; range 1.18-2). All surgeons found some variation in implant density acceptable for clinical treatment. Alternate acceptable screw density configurations ranged from 0.78 to 2.0. Further biomechanical investigation and analysis of clinical outcomes are needed to determine the impact of anchor density on correction and safety.

Introduction: Existing literature reports variable anchor density for pedicle screw constructs, currently trending toward increased density for the correction of idiopathic scoliosis. However there is significant patient and surgeon heterogeneity in these reports. Our objective were to document the variability of screw density planning among surgeons for the same AIS cases, and to determine minimal and maximal screw densities the surgeons would be willing to consider in a randomized trial.

Methods: 13 spine surgeons individually provided their detailed preferred posterior instrumentation planning (vertebral levels; implant types and location; rod material and diameter; correction maneuvers) using a graphical worksheet and the pre-operative X-rays for 5 Lenke 1 AIS patients (mean Cobb thoracic 57°, lumbar 43°). They were also asked to provide 2 alternate acceptable screw configurations ("minimum" and "maximum" screw density) they felt were acceptable.

Results: The fused segment averaged 11 levels (3 to 7 levels of variation between the 5 cases). The "preferred" implant density was 1.81 implant/fused level on average (range: 1.18-2) with an average of 19.4 screws (12-26) (Fig. 1). The "minimum" acceptable implant density was 1.25 (0.78-1.8) with an average of 13.4 implants (7-21), while the "maximum" acceptable density was 1.97 (1.4-2) with an average of 21.5 implants (14-28). Overall the choice of implants was screws (53% uni-axial, 27% poly-axial, 15% fixed) and hooks (5%). The range of difference between the minimum and maximum acceptable densities for the surgeon cohort varied from a low of 0.42 (surgeon 13) to a high of 1.22 (surgeon 4) (average min-max difference of 0.86), demonstrating wide variation in what surgeons believe to be acceptable number of implants.

Conclusion: Significant variability of acceptable implant density was documented among experienced spine surgeons. This heterogeneity indicates the absence of a "best solution" and merits further investigation. It also provides data for designing prospective randomized trials to identify "ideal" number of implants for a given

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patient. It appears that 12/13 surgeons would have sufficient equipoise to enroll patients in a randomized trial if the assigned implant density varied between 1.5 and 2.0.

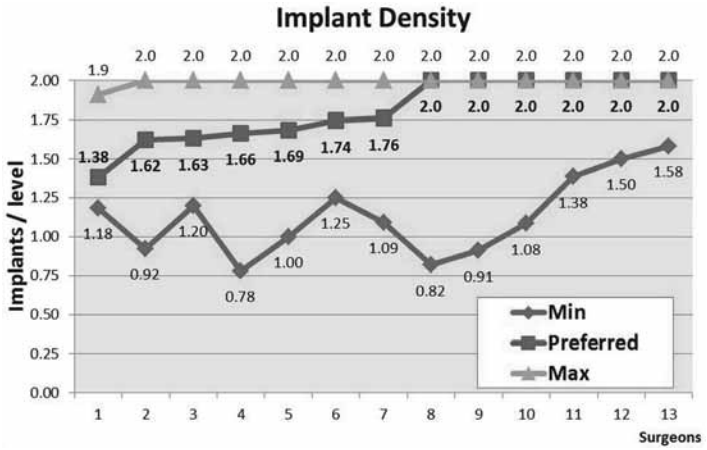

Figure 1 - Preferred and two alternate (min, max) "acceptable" screw densities

250. The Biomechanical Strength of the Sacral Reconstruction after Total Sacrectomy Utilizing Bilateral Fibular A-Frame or Truss Technique

Robert K. Eastlack, MD; Rapin Phimolsarnti, MD; Paul M. Huddleston, MD; Franklin Sim; Ronald R. Hugate, MD; Kai-Nan An; Michael J. Yaszemski, MD, PhD
USA

Summary: Lumbosacral reconstruction with bilateral fibular strut grafts via A-frame technique after total sacrectomy markedly increases the stiffness and load to failure over reconstruction without such grafts.

Introduction: Complete resection of the sacrum for tumor leads to skeletal discontinuity between the lumbar spine and the pelvis. Biomechanically, reconstitution of the spinopelvic junction is challenging because of the high loads passing across the area. We have previously reported on a lumbopelvic reconstructive technique after total sacrectomy that employs lumbopelvic internal fixation and bilateral structural and vascularized fibular grafts. The improvement in axial biomechanical strength afforded by fibula augmentation over traditional fixation techniques is not currently known. The purpose of this study was to determine the vertical stability of this newly proposed reconstruction technique in comparison with the conventional method of reconstruction.

Methods: Twenty intact lumbopelvic cadaver specimens underwent total sacrectomy. The specimens were then randomly assigned to undergo lumbopelvic reconstruction with internal fixation from L3-ilium alone (Group 1) or with bilateral fibular strut grafts (Group 2). Each specimen then underwent compression testing utilizing direct axial load to failure and stiffness as primary endpoints. Bone density scanning on all specimens was utilized to normalize the obtained mechanical data.

Results: Application of fibula strut grafts significantly increased the load to failure, with Group 2 averaging 1125.04 newtons (N) versus 560.15 N in Group 1 ($p < 0.001$). Stiffness was also significantly increased in Group 2 at 55.97Nm versus 22.15Nm ($p < 0.001$). There was no significant difference in average bone density of the specimens in Groups 1 and 2 ($p = 0.23$).

Conclusion: Utilization of bilateral fibula strut grafts (A-frame technique) as described substantially increases the stiffness of lumbopelvic reconstruction after total sacrectomy over internal fixation alone. It also resulted in significantly increased load to failure. Failures of the constructs occurred primarily at the ilium bone-screw interface, although a minority of constructs with fibula struts suffered primary failure of the fibulae.

251. Optimism: A Key to Post Operative Pain Management in Adolescent Idiopathic Scoliosis

Felipe Rossel, MD; Teresa Valois Gomez, MD; Neil Saran, MD, MHSc, FRCSC; Jean A. Ouellet, MD
Canada

Summary: Using the validated Children's Attribution Style Questionnaire, we prospectively explored the association between preop optimism and post op pain in 21 patients with AIS undergoing posterior spinal fusion. We found a significant inverse correlation between levels of optimism and PCA consumption. Identifying patient related factors in the pre-operative period that have an impact in post-operative outcomes provides new areas for the development of interventions (coping strategies, analgesia tutorials) to help patients in the peri operative period.

Introduction: Multiple studies in adult populations have demonstrated an association between dispositional optimism (DO) and postoperative pain, complications, recovery time, and faster return to normal activities.

In spine surgical literature, patient related factors, in particular attitudinal aspects, have received little attention. Our primary aim is to explore the association between DO and pain management in the postoperative period in adolescents undergoing surgery for Adolescent Idiopathic Scoliosis (AIS). We report the results from our pilot study.

Methods: After approval by the local IRB committee we prospectively recruited patients diagnosed with AIS who were scheduled for posterior spinal fusion. They completed the validated Children's Attributional Style Questionnaire (CASQ) before surgery. It consists of 24 hypothetical positive and 24 negative events varying on one of the attributional styles at a time (internality, stability, or globality). The anesthesia technique was standardized. All surgeries were performed by the same board certified surgeon. Postoperative pain was measured using the VAS Scale. PCA consumption as well as complications were recorded. The researcher analyzing the CASQ data was blinded to the patient cohort. Demographical and study variables were analyzed using SPSS 20.

Results: We studied 21 patients (81% females), of mean age 13.5 ± 2 years. For the 1st 48 hrs after surgery, the Pain VAS Scale range from 2 to 5. The mean CASQ score was 6.5 ± 10. The Morphine PCA consumption was twice among the least optimistic with a mean for the whole group of 123 ± 56 mg. A significant inverse statistic correlation (Pearson: -0.490) was established between the Optimism score and the PCA consumption (p=0,033).

Conclusion: To our knowledge this is the first study that shows a relationship between DO, AIS and postoperative analgesia. Identifying, in the pre-operative period, patient related factors that may have an impact in post-operative outcomes provides new areas for the development of interventions (coping strategies, analgesia tutorials) to help patients better cope with the surgical procedure as well as return to normal activities

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‡252. Cervico-Thoracic Malalignment: Unreported Late Complication after Operative Intervention for Early Onset Scoliosis

Teppei Suzuki; Koki Uno, MD, PhD; Hiroshi Miyamoto, MD; Yoshihiro Inui
Japan

Summary: Nine patients with severe cervico-thoracic malalignment after operative intervension for early onset scoliosis were examined. Of the 9 patients, one suddenly died and 3 had clinical symptoms such as dyspnea or dysphagia which might be caused by the malalignment. Occipito-cervico-thoracic fusion was performed in those patients. Although this is unreported and rare late complication and usually asymptomatic, special care should be taken and drastic operation is necessary for the patient with clinical symptoms.

Introduction: Pediatric proximal junctional kyphosis(PJK) was well recognized after growing rod(GR) surgery. PJK sometimes developed and resulted in severe cervico-thoracic malalignment (cervical hyperlordosis and upper thoracic hyperkyphosis) in some of the patients. However, there was no report examining the malalignment and its management. The purpose of this study is to introduce this complication and examine its character and discuss its treatment.

Methods: There were 9 patients(male 3 female 6). Etiology included neurofibromatosis(2), bone dysplasia(2), and unknown syndromic deformity(5). Initial surgeries performed were GR in 7 and short fusion in 2 patients. Average age at the initial surgery was 6.1±3.0 years and average follow up was 8.1±2.6 years.

Results: All patients had repetitive dislodgement of upper instrumentation and PJK developed several years after initial surgery. Between pre-initial surgery and pre-last surgery or last follow up period, C2-7 cervical lordosis increased from -46±33 degree to -59±14 degree, T1 inclination increased from 49±18 degree to 70±8 degree, T1-12 thoracic kyphosis increased from 66±37 degree to 106±17 degree. One patient with severe mental retardation suddenly died 2 years after definitive fusion of GR. Occipito-cervico-thoracic fusion was performed in three patients who had clinical symptoms such as dyspnea and dysphagia which might be caused by cervico-thoracic malalignment.

Conclusion: Severe cervico-thoracic malalignment is rare complication after surgery for early onset scoliosis. Soft tissue and facet joint damage around cervico-thoracic region due to repetitive surgery, poor bone quality may be risk factors. Main strategy of this complication is observation. However when clinical symptoms such as dyspnea or dysphagia may develop, drastic operation might be necessary.

253. Spino-Pelvic Alignment following Surgical Correction of Developmental Spondylolisthesis: A Prospective Study

Jesse Shen; Hubert Labelle, MD; Jean-Marc Mac-Thiong, MD, PhD; Julie Joncas; Stefan Parent, MD, PhD
Canada

Summary: This study is a prospective analysis of spino-pelvic sagittal alignment of 35 patients following surgical correction for L5-S1 developmental spondylolisthesis in order to evaluate the effectiveness of surgical reduction as a method of treatment. Spinal and pelvic alignment were measured on standing lateral digitized x-rays. The results showed a significant increase for sacral slope and decrease for pelvic tilt along with improvements in SRS-30 and SF-12 health outcome scores. This study supports the contention that surgical reduction can be indicated.

Introduction: This study is a prospective single-centre analysis of changes in spino-pelvic sagittal alignment after surgical correction of L5-S1 developmental spondylolisthesis. Whether L5-S1 high grade spondylolisthesis should or should not be reduced remains a controversial subject. Spinal instrumentation with pedicle screws has generated a renewed interest for reduction, but the indications for this treatment and its effect on spino-pelvic alignment remain poorly defined. Recent evidence indicates that reduction might be indicated for subjects with an unbalanced (retroverted or vertical) pelvis. The purpose of this study was to determine how sagittal spino-pelvic alignment is affected by surgery, with the hypothesis that surgical correction at the lumbo-sacral level is associated with an improvement in the shape of the spine and in the orientation of the pelvis.

Methods: This is a prospective single-centre analysis of 35 subjects (mean age 14 ± 2.5 years) with developmental spondylolisthesis and an average follow-up of 3.5 years after posterior fusion with or without reduction with spinal instrumentation. Spinal and pelvic alignment were measured on standing lateral digitized X-rays using a dedicated computer software.

Results: The most important changes were noted for an increase in sacral slope (SS) and a decrease in pelvic tilt (PT), which all changed significantly towards normal adult values. In addition, after classifying high-grade patients into balanced (56.9 ± 8.2 SS/ 24.5 ± 21.8 PT) and unbalanced pelvis (43.8 ± 10.7 SS/ 38.6 ± 14.0 PT), significant improvements were noted in pelvic alignment in both the sub-groups, with 35% of cases switching groups, the majority from an unbalanced to a balanced pelvis. Furthermore, significant changes were also noted in both SRS-30 and SF-12 patient questionnaires with results indicating a positive outlook from all patients. There were no neurological complications associated with surgical reduction.

Conclusion: These results emphasize the importance of subdividing subjects with high grade developmental spondylolisthesis into unbalanced and balanced pelvis groups, and further support the contention that reduction techniques might be considered for the unbalanced retroverted pelvis sub-group.

254. The Importance of L5 Incidence Measurement in High-Grade Spondylolisthesis

Rami El Rachkidi; Marion Burnier; Pierre Roussouly, MD
France

Summary: The correlation between the L5 incidence (L5I) and other traditional parameters was studied in 184 high-grade spondylolisthesis cases. The L5I and its components (the L5 tilt and the L5 superior slope) showed much better correlation with the pelvic retroversion, the slip percentage, the lumbar lordosis and the tilt of lumbar spine than any of the traditional parameters such the pelvic incidence, the sacral slope and the Dubousset angle.

Introduction: Many angles are traditionally measured in high-grade spondylolisthesis to evaluate the importance of slip, the degree of lumbosacral kyphosis and the pelvic retroversion. In dome-shaped sacrum, the pelvic incidence and sacral slope measure-

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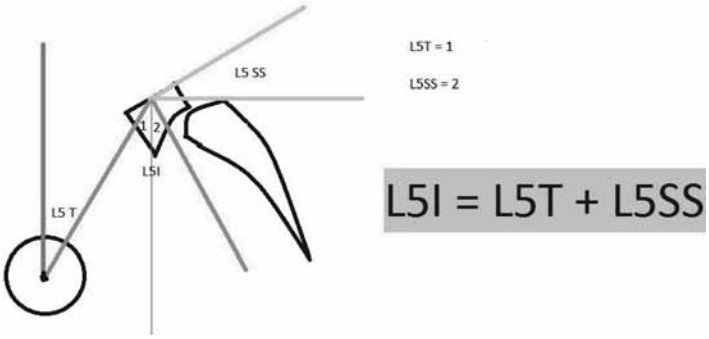
ments are not reliable.The L5I is an interesting angle, taking into account the position of L5 over the sacrum and the amount of pelvic retroversion (Fig.1). The correlation between this parameter and other traditional ones has not been evaluated before.

Methods: The preoperative radiographs of 184 patients with high-grade spondylolisthesis (multicenter study) were analysed using a validated software. In addition to L5I, measured angles were: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), L5 tilt (L5T), L5 superior slope (L5SS), Dubousset lumbosacral angle, slip percentage, L5 superior lordosis (L5SL), tilt of lumbar spine, spinal tilt and C7 barrey ratio. Correlations between different parameters were evaluated using the Pearson coefficient and a multivariate linear regression.

Results: There were 129 females and 55 males. Average age was 19.8 years.The L5I showed a strong correlation (r>0.5) with the PT (r=0.7), the L5T (r=0.77), the L5SS (r=0.83), the Dubousset angle (r=-0.63), the slip percentage (r=0.56), the L5SL (r=0.7) and the tilt of lumbar lordosis (r=0.51). From all parameters, the L5I and its pelvic component (L5T) showed the best correlation with the pelvic tilt (r=0.7 and r=0.95 respectively). While showing a strong correlation with the L5I (r=-0.63) and the L5SS (r=-0.61), the Dubousset angle showed an average correlation with the PT (r=-0.37). The L5SL is best correlated with the L5I (r=0.7) and with the L5SS (r=0.88).

Conclusion: The L5I and its components (L5T and L5SS) are important parameters in high-grade spondylolisthesis. They showed much better correlation with the pelvic retroversion, the slip percentage, the lumbar lordosis and the tilt of lumbar spine than any of the traditional parameters such the pelvic incidence, the sacral slope and the Dubousset angle.



255. Effect of Upper Instrumented Vertebra (UIV) on Adult Spinal Deformity (ASD) Correction, Maintenance of Correction, and Health Related Quality of Life (HRQOL) following Lumbar Pedicle Subtraction Osteotomy (PSO)

Christopher P. Ames, MD; Justin K. Scheer, BS; Vedat Deviren, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Richard Hostin, MD; Eric Klineberg, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Michael F. Obrien, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Khaled Kebaish, MD; Frank Schwab, MD; International Spine Study Group
USA

Summary: Retrospective analysis of LPSO procedures from a large, multi-center adult spinal deformity (ASD) osteotomy database demonstrated that UIV in upper thoracic spine (UT; T2-T5) had better early sagittal alignment, better maintenance of sagittal correction and better maintenance of sagittal vertical axis <5cm than patients with UIV in the thoracolumbar (TL; T9-L1) region at 2 year follow up. HRQOL values were similar between UT and TL. Long term evaluation will determine if these differences impact HRQOL values, complication and revision rates.

Introduction: Lumbar PSO (LPSO) is frequently used to correct sagittal spino-pelvic malalignment (SSM), however, proximal junctional kyphosis (PJK) and unfavorable reciprocal changes in the unfused thoracic spine may lead to poor postoperative sagittal alignment and loss of correction. Purpose: evaluate maintenance of sagittal spino-pelvic correction following LPSO based upon UIV in UT vs. TL regions.

Methods: Retrospective evaluation of ASD patients enrolled into a multicenter spinal osteotomy database. Inclusion criteria: LPSO for SSM and distal fusion to the pelvis. Radiographic and HRQOL evaluation time points: preoperative and 6 week, 3 month, 6 month, 1 year and 2 year postoperative. Subjects stratified by UIV (UT vs TL). Sagittal alignment correction and correction maintenance evaluated and correlated with HRQOL values and sub-analysis performed for correction maintenance for patients with very high SVA >15 cm.

Results: 328 ASD patients met inclusion criteria. UT and TL had similar preoperative SVA and pelvic incidence/lumbar lordosis (PI/LL) mismatch. UT had greater preop pelvic tilt (PT; 33.4; p=.048). UT had lower SVA than TL at 6 week postop (11mm vs. 54mm; p<0.05), however beyond 6 week postop, all sagittal radiographic parameters were similar UT vs TL. UT and TL maintained similar sagittal correction through 2 years. UT and TL initially maintained threshold criteria good sagittal alignment (SVA<5cm, PT<25, PI-LL <11) however mean TL SVA was > 5cm at 1 year (5.3cm). HRQOL values were similar for UT vs TL for all time points except SRS-22 at 6 weeks (3.4 vs 2.6) and VAS at 1 year (5.2 vs 3.1).

Conclusion: Analysis of UIV location for LPSO procedures demonstrated UT and TL achieve and maintain acceptable sagittal correction, however, UT maintained better SVA correction (<5cm) than TL at 2 year postop. Both groups demonstrated loss of initial PT correction at 2 years postop. Long term evaluation will determine if these differences impact HRQOL values, complication and revision rates.

256. Impact of Body Mass Index on Hospital Stay and Complications at One and Two-Year Follow-Up after Major Spinal Surgery

Tyler Koski, MD; Sara E. Thompson, BA; Jamal McClendon, MD; Timothy R. Smith, MD, PhD, MPH; Frank L. Acosta, MD; Patrick A. Sugrue, MD; Brian A. O'Shaughnessy, MD
USA

Summary: Obesity is a major risk factor for health disability. Patients with a higher BMI have lower functional status, increased pain, and worse physical condition than those at ideal weight. Our goal was to determine associations between BMI categories on patient outcomes after major spinal surgery.

Introduction: Obesity is a dominant public health concern, and has been linked to high-morbidity spinal conditions. Few studies have examined the direct impact of obesity in major spinal surgery.

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Methods: Consecutive adult patients who underwent elective spinal fusions ≥5 levels between 2007-2010 were retrospectively analyzed with follow-up ≥1 year. One way ANOVA examined outcome variables based on BMI categories. Linear regression analysis evaluated BMI, hospital stay, and complications at 1 and 2 years, controlling for confounders. Mean and median follow-up were 2.1 and 2.0 years, respectively.

Results: 193 surgeries on 114 patients (31M:83F), mean age of 59.5 years and mean BMI of 29.8 were analyzed. Morbidly obese patients had longer hospital stay, worse ODI scores, and more complications at 1 and 2 years than ideal weight patients ($p<0.05$). Regression analysis revealed gender ($p=0.02$), cardiac medications ($p=0.02$), CSF leak ($p=0.01$), and BMI category of ideal vs. non-ideal ($p=0.04$) influenced length of hospital stay. Regression analysis showed that BMI >30 ($p=0.01$), preoperative ODI ($p<0.01$), and PSO performed ($p=0.02$) influenced all complications at 1 year. Mean complications at 2 years for the morbidly obese were 3 times more than underweight, and 8 times more than ideal weight. Controlling for age, gender, and length of stay, obese and morbidly obese patients have more complications at 2 years ($p<0.01$); morbidly obese patients have worse 2 year ODI ($p=0.01$).

Conclusion: BMI is an independent predictor of length of hospital stay and all complications at 1 and 2 years in patients receiving major spinal surgery.

257. Post Operative Balance Influences Disc Properties in the Free Motion Segment in Adolescent Idiopathic Scoliosis

Kariman Abelin-Genevois, MD; Jerome Sales de Gauzy, PhD; Jerome Briot, PhD; Franck Accadbled, MD, PhD; Pascal Swider, PhD
France

Summary: Properties of discs in the free motion segment were evaluated prospectively with MRI and correlated to the surgical outcome.

The main factors correlated to disc properties modifications were the Cobb angle correction and the frontal balance. The specific behaviour at L5S1 disc was explained by the pelvic sagittal parameters.

This study demonstrated the importance to achieve frontal and sagittal balance post operatively reducing the incidence of early degenerative changes.

Introduction: Surgical correction of AIS to achieve optimal balance in the spine to prevent early degenerative changes. MRI is an accurate method to depict intervertebral disc (IVD) degeneration.

Methods: A prospective evaluation of disc properties was conducted on surgically treated AIS. Sixty five patients (mean age: 15.1 years) were included. Mean preoperative Cobb angle was 53,3°. Mean correction of the main curve averaged 65 and remained stable at latest follow up. Instrumentation ended at L1 in 12 patients. L2 in 9, L3 in 19 and L4 in 6 patients.

MRI of the spine was performed before and 3 months, 1 year and 2 years after surgery (T2-weighted sequence). Contours of inner and outer complex were semi-automatically detected and 3D reconstruction was achieved using a custom-made image processing software (Matlab®). Hydration was assessed by the nucleus-disc ratio. Frontal and sagittal parameters were assessed on full spine radiographs: curve correction , frontal C7 plumb line, wedging in the first disc under fusion and sagittal parameters (thoracic kyphosis; lumbar lordosis, sacral slope, pelvic incidence).

Results: Surgical correction induced significant changes in IVD below fusion. Disc hydration significantly improved after 1 year ($p = 0.01$) while disc volume remained stable. Nucleus/disc ratio correlated to the size of the mobile segment. L5-S1 disc showed the highest changes especially in selective thoracic fusions (+37% at 3 months. $p = 0.089$; +43.30% at 1 year. $p = 0.06$). Curve correction over 65% was related to disc volume increase ($p = 0.02$). In selective fusions, disc reshaping occurred two levels down to fusion. The first disc under fusion showed abrupt disc volume increase without rehydration. Delayed changes occured after 1 year. (figure 1). Strong correlation was maintained between lumbar lordosis and pelvic parameters.

Conclusion: Our study confirmed the relationship between postoperative balance and IVD behavior below fusion. The surgical correction induced forced redistribution of energy into free segments. These findings advocate for selective fusions and accurate choice of low level to avoid coronal imbalance. When extending the fusion to the lumbar levels, adequate lordosis should be restored.

258. Analysis of Sagittal Balance of Ankylosing Spondylitis using Spinopelvic Parameters

Jung Sub Lee, MD, PhD; Jeung Il Kim; Jong Min Lim; Tae Sik Goh; Shi Hwan Park
Republic of Korea

Summary: The aim of this study was to determine differences between ankylosing spondylitis (AS) patients and normal controls using sagittal spinal alignment and pelvic orientation and to indentify relationships between sagittal spinopelvic parameters and AS.

Introduction: There are little data on the relationship between the sagittal spinopelvic parameters and AS.

Methods: The study and control group comprised 90 AS patients and 40 controls. The participants were classified into 3 groups: normal (n=40), sagittal balance (n=58) and sagittal imbalance (n=32) groups. All underwent lateral radiographs of whole spine including hip joints. The radiographic parameters were sacral slope, pelvic tilting, pelvic incidence, overhang of S1, thoracic kyphosis, lumbar lordosis, and C7 plumbline.

Results: The AS patients and controls were found to be significantly different in terms of sagittal balance, sacral slope, pelvic tilt, pelvic incidence, S1 overhang, and lumbar lordosis. However, no significant intergroup difference was observed for thoracic kyphosis ($P > 0.05$). There was a significant difference in sacral slope, pelvic tilting, pelvic incidence, overhang of S1, thoracic kyphosis and lumbar lordosis among the 3 groups. The imbalance group had a significantly lower sacral slope and lumbar lordosis than either the balance or normal groups, and the balance group had a lower value than the normal group. The mean pelvic tilting of imbalance group was significantly higher than that of either the balance or normal group. However there was no significant difference in pelvic tilting and C7 plumbline between the balance and normal groups. The mean pelvic incidence and S1 overhang of balance group were significantly lower than those of either the imbalance or normal groups. Comparing the thoracic kyphosis, the imbalance group had a significantly higher

value than either the balance or normal groups, and balance group had lower value than the normal group. Regarding severity of pain, C7 plumbline, sacral slope, pelvic tilt, S1 overhang, lumbar lordosis, and thoracic kyphosis were found to be correlated with Visual Analogue Scale (VAS) scores in AS patients.

Conclusion: AS patients and normal controls were found to be significantly different in terms of sagittal spinopelvic parameters. There were significant relationships between sagittal spinopelvic parameters in AS patients. Furthermore, VAS scores were significantly related to sagittal spinal parameters which were closely related with pelvic orientation in AS patients.

259. Sagittal Spinal Profile and Spinopelvic Balance in Parents of Scoliotic Children, as Compared to Normal Controls

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Netherlands

Summary: To test the hypothesis that the well-known familial trend in AIS may be explained by the inheritance of a sagittal spinal profile, we prospectively analyzed freestanding lateral radiographs of parent couples of girls with severe progressive AIS and age-matched controls. The sagittal spinal profile of the fathers of scoliotic children was significantly flatter than the sagittal spinal profile of fathers of non-scoliotics, indicating that fathers may contribute through their sagittal spinal profile to the inheritance of AIS.

Introduction: It has been suggested that the sagittal spinal profile is partly hereditary. The relationship between the sagittal spinal profile and spinal biomechanics has also been established. In this study we test the hypothesis that the well-known familial trend in AIS may be explained by the inheritance of a sagittal spinal profile, that has been shown to make the spine less resistant to rotatory forces.

Methods: Freestanding lateral radiographs of 51 parent couples of girls with severe progressive AIS (AIS group) and 102 age-matched controls (control group) were taken. Parents with manifest spinal deformities or spinal pathology were excluded, to avoid distorted sagittal images with unreliable measurements. Parameters of sagittal spinal profile and spinopelvic balance were semi-automatically calculated, and analyzed between the fathers of both groups, and between the mothers of both groups.

Results: In the fathers of the AIS group, the plumb line of T4 was significantly less posteriorly positioned relative to the hip axis, vertebrae T11-L2 were significantly less backwardly inclined, and a significantly flatter spine was found as compared to the fathers of the control group. No statistically significant difference was observed between the mothers of both groups. (Fig. 1)

Conclusion: The sagittal spinal profile of the fathers of scoliotic children was significantly flatter than the sagittal spinal profile of fathers of non-scoliotics. No difference was found in the sagittal spinal profile of the mothers of scoliotics as compared to mothers of nonscoliotics, possibly due to an inevitable normalization of the study population (exclusion of parents with spinal pathology) mainly in the mothers. Although, it is well known that scoliotic mothers have an increased risk of getting scoliotic offspring, this study indicates that fathers may contribute as well through their sagittal spinal profile to the inheritance of AIS.

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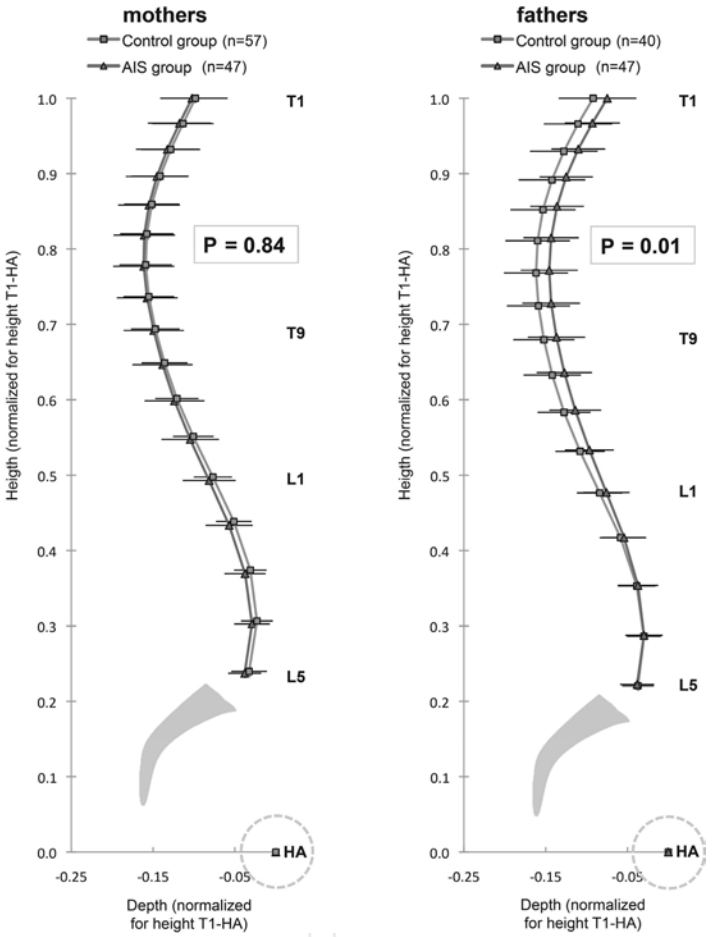


Mean sagittal spinal profile in the mothers and fathers in both groups. Profiles were normalized in height and depth, based on the vertical distance of the midpoint of T1-hip axis (HA), and the HA was set as origin.

260. The Use of OP-1 (rhBMP-7) in Surgical Treatment of Pediatric Patients Affected by Symptomatic Grade I Isthmic Spondylolisthesis: A Seven-Years Follow-Up Study

Guido La Rosa, MD; Leonardo Oggiano, MD
Italy

Summary: Osteogenic protein-1 (rhBMP-7) is a member of the transforming growth factor-beta superfamily of extracellular proteins involved in bone growth and formation. This is the first report on use of OP-1 in paediatric spinal surgery. Fourteen patients affected by symptomatic grade I isthmic spondylolisthesis were treated by intertrasversary in situ fusion.spinal arthrodesis was achieved in 85% of paediatric patients by a short operative time, low bleeding and reduced postoperative pain, with a mild incidence of seroma at 3-month follow-up (21%).

Introduction: Osteogenic protein-1 (rhBMP-7) is a member of the transforming growth factor-beta superfamily of extracellular proteins involved in bone growth and formation. Spinal fusion studies have been demonstrated the efficacy and safety of OP-1 in adults. This is the first report on use of OP-1 in paediatric spinal surgery.

Methods: The trial was approved by the local Ethical Committee. Between 2004 and 2006 14 patients (mean age 13 years, range 8-16) affected by symptomatic grade I isthmic spondylolisthesis were treated by intertrasversary in situ fusion (Wiltse approach). All patients gave written informed consent. A mixture of small bone chips obtained from in situ decortication, OP-1 (eptotermin alfa, 3.5 mg) and autologous stem cells taken from iliac bone was used in all procedures. A TLSO brace was used in the postoperative time for two months.

Results: Results were evaluated by X-rays and CT at 1, 3, 6, 12 months and yearly thereafter. Fusion mass was evaluated according to Carreon criteria. Mean follow-up was 60 months (range 50-84). Mean operative time was 120 minutes (range 90-150) with mean blood loss of 300 ml. Overall complete fusion was observed at one-month X-rays control in all but 2 patients (85%) presenting with unilateral fusion. These results were confirmed at following X-rays and CT controls. At 3-months follow-up 3 seromas were recorded (21%); complete recovery was achieved by steroid therapy in 1 case and reintervention in 2 cases.

Conclusion: This is the first experience on OP-1 (rhMBP-7) use in paediatric spinal surgery. Many studies reported the safety and efficacy of OP-1 as a replacement for iliac crest autograft in posterolateral lumbar fusion in adults. In children OP-1 has recently proven to be effective in healing of persistent nonunion with no major adverse event recorded. In the present study spinal arthrodesis was achieved in 85% of paediatric patients by a short operative time, low bleeding and reduced postoperative pain, with a mild incidence of seroma at 3-month follow-up (21%). Further studies are needed to better understand the efficacy and benefit of this technique in pediatric patients.

261. Correction of Severe Rigid Scoliosis (Cobbs>90 Degree) by Anterior Release and Posterior Osteotomies

Upendra Bidre, MS; Bhavuk Garg; G. Raghavan, MS (Ortho); Arvind Jayaswal, MS (Ortho); Pankaj Kandwal, MS (Ortho)
India

Summary: The Key to good surgical correction is a good and extensive release of contracted anterior and posterior soft tissues as well as bony resection (osteotomies if required) along with judicious use of instrumentation.

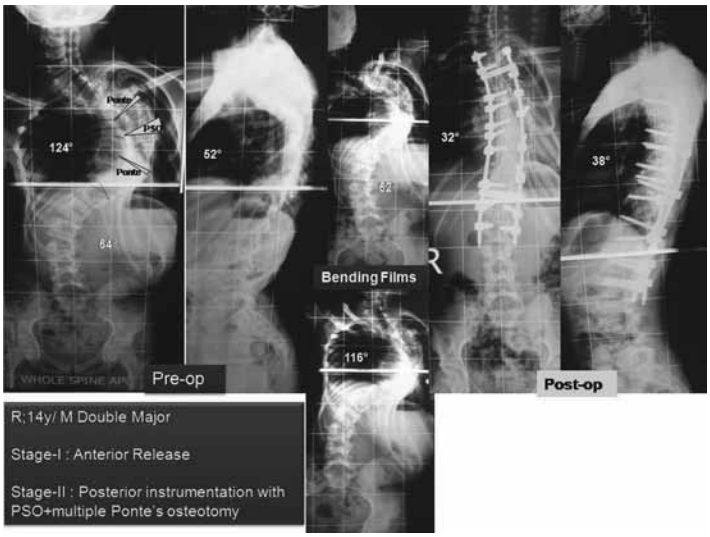
Introduction: Long standing curves become rigid (little or no flexibility), have increased cobbs angle (> 90degree) and are grossly rotated at the apex. Various strategies for management of these severe curves have been reported viz. a two stage anterior and posterior correction, anterior releases with halo distraction followed by posterior correction, and more recently correction based on a single stage posterior alone vertebral column resection (PVCR)

Methods: Twenty eight patients (8 males & 20 females): average age was 14.4yr, with severe rigid scoliosis (>90degree Cobb's) were managed with a two staged procedure involving Anterior release in Stage I and Posterior osteotomies in Stage II (asymmetric Pedicle subtraction osteotomy and/or Ponte's Osteotomies) with all pedicle screw Instrumentation and fusion. 6 having congenital scoliosis, 20 neglected Idiopathic scoliosis and 2 syndromic children. Average follow-up was 32 months (26- 48 mth).

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Results: The Pre-op scoliosis was 110.71degree (101-124 degree), which improved to 78.09 degree (64-88degree) after anterior release and the final post-op Cobb's was 26.6 degree (22 -32degree), with a total of 75.97% correction. The average blood Loss was 1.8lt (1.2-2.8lt) for the posterior procedure and 580ml (400-980ml) for anterior release. The mean operative time for anterior release was 223 min(165-315min) and posterior surgery was 314min (5hr; 14 min; range 280-420min). The mean apical RVA sag(vertebral rotation) of 56degree improved to 28degree postoperatively($p<0.05$). One patient had transient monoparesis which recovered spontaneously after 3weeks; one patient had local skin necrosis. There was a significant improvement in self-image/appearance (mean 4.4) with a high satisfaction rate (mean 4.6) according to SRS-30 questionnaire.

Conclusion: Anterior release as a first stage procedure helps in partially correcting the deformity and reduces the need for a more extensive osteotomy from the back during the second stage of correction.



262. Effectiveness of Bracing in Patients with Scoliosis Secondary to Chiari Malformation after Posterior Fossa Decompression: A Comparison with Patients Treated by Observation Alone

Yong Qiu; Shifu Sha; Zezhang Zhu; Xu Sun; Tao Wu; Xin Zhen; Zhen Liu
China

Summary: The current study investigated the efficacy of brace treatment in 26 patients with Chiari malformation-associated scoliosis(CMS) after posterior fossa decompression(PFD). Fourteen patients treated with observation alone were also evaluated as a comparison. By last follow-up, 18 patients(69.2%) were treated successfully with bracing. While for patients treated by observation, only 5 patients (35.7%) met the criteria for success. The success rate of the braced group was significantly higher than that of the non-braced group. For patients with CMS, bracing treatment is effective after PFD.

Introduction: Brace has been widely used in preventing the progression of idiopathic scoliosis, while few studies have investigated the efficacy of bracing in patients with CMS after PFD.

Methods: From June 2002 to June 2007, 40 patients with CMS received posterior fossa decompression in our hospital. Twenty-six patients who were treated with brace after PFD constituted the braced group (average age: 10.2±1.7 years, range 8.0-13.2 years ; initial Cobb angle of major curve: 32.3°±7.7°). Fourteen patients who refused bracing treatment were assigned into the non-braced group (average age: 9.8±2.8 years, range 6.5-14.7 years; initial Cobb angle of major curve: 32.2°±8.0°). Patients were analyzed according to 3 groups: (1) success (progression equal or less than 5°), (2) progression more than 5° (but not requiring surgery), and (3) surgery (curve progressing to greater than 50°) with failure of bracing treatment during skeletal immaturity.

Results: There was no significant difference between the two groups in the average initial age, Risser grade, sex ratio, Cobb angle of the main curve or the distribution of curve pattern. Within the braced group, 18 patients(69.2%) were treated successfully with 1 patients progressing and 7 patients requiring surgery. While in the non-braced group, 5 patients (35.7%) met the criteria for success, with 2 patients progressing and 7 patients eventually requiring spinal fusion. The success rate of the braced group was significantly higher than that of the non-braced group (P=0.041). For the patients treated with brace, curve progression correlated with female, higher Risser grade and larger magnitude of curve.

Conclusion: For patients with Chiari malformation associated scoliosis, bracing treatment is effective after posterior fossa decompression. Female, more mature growth status and larger curve size might be risk factors for the failure of bracing treatment.

263. Proximal Adding-On Phenomenon after Anterior Selective Fusion for Lenke type 5C Idiopathic Scoliosis: Incidence and Risk Factors

Ding Qi; Yong Qiu; Xu Sun; Bin Wang; Zezhang Zhu; Yang Yu; Feng Zhu
China

Summary: The present study is to investigate the incidence and related risk factors of proximal adding-on phenomenon after anterior selective fusion for Lenke type 5C adolescent idiopathic scoliosis (AIS).

Introduction: To investigate the incidence and related risk factors of proximal adding-on phenomenon after anterior selective fusion for Lenke type 5C AIS.

Methods: Lenke type 5C AIS patients with a Cobb angle of 45-80° treated with anterior selective fusion were recruited in this study. All patients had a minimum 2-year postoperative follow-up. The patients were grouped according to the relationship between the upper instrumented vertebrae (UIV) and the upper end vertebrae (UEV), the patients' Risser sign and the relationship between UIV and C7 plumb line (C7PL). The radiographic data were compared between patients with and without proximal adding-on, and the incidence of proximal adding-on was analyzed in terms of determination of UIV and Risser sign to identify the risk factors of this phenomenon.

Results: 130 patients were included in this study, and 11 patients were identified with proximal adding-on (8.5%). The average age, Cobb angle and Risser sign was 14.8±1.6 years, 45.6±5.9° of major thoracolumbar/lumbar curve (TL/L), 25.4±7.4° of proximal thoracic curve (PT) and 3.6±1.1, respectively. At last follow-up postoperatively, the average Cobb angle of TL/L and PT was 8.7±3.5° and 11.4±4.8°, respectively. The average Risser sign of patients with

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adding-on (2.4±1.6) was obviously lower than that of patients without (3.7±1.0, P=0.018). Moreover, the incidence of adding-on in Grade 0 to 1 (37.5%) was higher than that of Grade 2 to 3 (12.1%) and Grade 4 to 5 (4.5%). The incidence of adding-on in UIV lower than UEV group (20.6%) was obviously higher than that of UIV higher than or equal to UEV group (4.7%). The incidence of adding-on for patients with C7PL falls away from UIV (19.5%) were obviously higher than that of patients with C7PL falls between the pedicle and lateral margin of UIV(3.6%) and between bilateral pedicles of UIV (3.0%). Each group shows significant difference for the incidence of adding-on by Fisher's Exact Test (P<0.05).

Conclusion: There exists the risk of proximal adding-on phenomenon, with a not low rate, after anterior selective fusion for major TL/L curve AIS. The determination of UIV relative to UEV and the skeletal maturity of the patient are the two factors closely associated with the presence of such a phenomenon.

264. Bone Density Values Compared with Cobb Angles in AIS Patients: Does the Use of a Brace have an Effect on Bone Density?

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Turkey

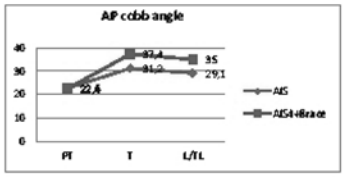
Summary: We investigated the relationship between Cobb angles and bone density in AIS patients and the use of a brace in treatment.

Introduction: Bone density values in adolescent idiopathic scoliosis (AIS) patients can vary in comparison with the population at large.

Methods: Bone density in the lumbar spines of AIS patients was measured using DEXA method. Patients aged 8-18 with a Cobb angle >10° were included in the study. The Cobb angle relationship with age, gender, height, weight, BMI, bone mineral density (BMD) and Z-score was examined. Patients using a brace and those who did not were evaluated.

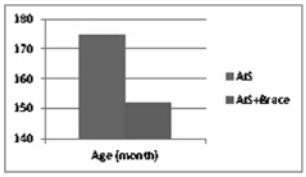
Results: Between 2000-2011, 140 patients (124 female, 16 male) with a Cobb angle >10° were evaluated. Average age and standard of deviation was: 172.11±30.3 months, BMI (kg/cm2) 19.03±3.27, Height (cm) 159.81±10.19, Weight (kg) 49.43±10.75.BMD (total) value in the lumbar region was 0.83±0.17, Z-score -0.28±1.23. On the AP plane Cobb angle in the proximal region was 22.58°±12.04° and 31,99°±17,82° in the main thoracic region and 29,91°±12,1° in the lumbar and thoracolumbar region. Meaningful correlations were observed when comparing BMD values for the entire lumbar region with BMI, age, and weight. There was no difference observed in the correlation with Cobb angles. A negative meaningful correlation was observed when comparing the Z-scores of lumbar spines with age. Comparing Z-scores with Cobb angles a negative significant difference was observed only in the L2 and L3 proximal thoracic region and a positive correlation was found in the lumbar/thoracolumbar region. Comparing the total Z-score with the proximal Cobb angle a negative correlation was observed. There were no meaningful differences observed between the two genders. Comparing the 15 patients using braces and those who did not, there was a meaningful difference in terms of age and bone density values and no meaningful differences in terms of BMI, height, weight, Z-score and Cobb angle.

Conclusion: Our study found that the use of a brace for AIS patients significantly reduced bone density levels. Although there was no apparent relationship between BMD and Cobb angles (except L4), all other parameters showed a positive correlation. Comparing all parameters of both genders no meaningful difference was observed.



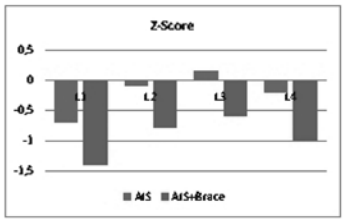
(AP cobb angle; p>0.05)

AP COBB ANGLE	AIS	AIS+Brace	p
Proximal Thoracic	22,6±12,7	22,4±8,9	0,628
Main Thorasik	31,2±17,9	37,4±16,6	0,144
Lumbar/Thoracolumbar	29,1±11,8	35±12,7	0,111



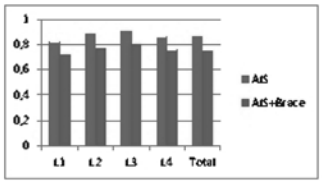
(Age; 0.05>p)

	AIS	AIS+Brace	p
Age (mounth)	174,5±29	151,8±33,7	0,011



(Z-Score; p>0.05)

Z-Scor	AIS	AIS+Brace	p
L1	-0,7±1,1	-1,4±1,1	0,058
L2	-0,1±1,2	-0,8±1,2	0,077
L3	0,1±1,3	-0,6±1,4	0,068
L4	-0,2±1,3	-0,9±1,5	0,108
Total	-0,1±1,2	-0,9±1,3	0,078



(BMD; 0.05>p)

BMD	AIS	AIS+Brace	p
L1	0,8±0,1	0,7±0,1	0,046
L2	0,8±0,1	0,7±0,1	0,029
L3	0,9±0,1	0,8±0,1	0,029
L4	0,8±0,1	0,7±0,1	0,032
Total	0,8±0,1	0,7±0,1	0,027

Ω265. Vitamin A Deficiency Induces Congenital Spinal Deformities in Rats

Zheng Li; Jianxiong Shen, MD
China

Summary: To investigate the effect of maternal vitamin A deficiency on the formation of congenital spinal deformities in the offspring.

Introduction: Most cases of congenital spinal deformities were sporadic and without strong evidence of heritability. The etiology of congenital spinal deformities is still elusive and assumed to be multi-factorial. Recent work on vertebrate segmentation has provided a conceptual framework that all major types of spinal malformation result from abnormal formation and segmentation of somites. Retinoic acid (RA) is a signaling molecule synthesized from vitamin A that controls somitogenesis through its ability to control gene expression by functioning as a ligand for nuclear RA receptors (RARs). We postulate that vitamin A deficiency during pregnancy may cause congenital spinal deformities in this model.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
The Louis A. Goldstein Award is given to the best Clinical Poster or E-Poster and the John H. Moe Award is given to the best Basic Science Poster or E-Poster at the SRS Annual Meeting.

Methods: The rats were randomized into two groups: (1) control group, in which the mothers were fed a normal diet. (2) vitamin A deficient group, in which the mothers were given vitamin A-deficient diet from 2 weeks before mating till delivery. Three random neonatal rats from each group were euthanized the next day of parturition. The remaining neonates were fed a normal diet for 2 weeks until euthanasia. Serum levels of vitamin A were assessed in the adult and filial rats. Anteroposterior (AP) spine radiographs were obtained at week 2 after delivery to evaluate the presence of spinal deformities. Liver and vertebral body expression of retinaldehyde dehydrogenase 1 (RALDH1), RALDH2, RALDH3, RAR-α, RAR-β and RAR-γ mRNA was assessed by reverse transcription-real time PCR.

Results: Fifty-eight and fifty-six neonatal rats were born in the vitamin A-deficiency group and the control group, respectively. The incidence of spinal deformities was 13.79% (8/58) in the filial rats of vitamin A deficiency group and 0% in the control group. Furthermore, vitamin A deficiency negatively regulate the liver and verterbral body mRNA levels of RALDH1, RALDH2, RALDH3, RAR-α, RAR-β and RAR-γ.

Conclusion: Vitamin A deficiency in pregnancy may induce congenital spinal deformities in the postnatal rats. The decreases of RALDHs and RARs mRNA expression induced by vitamin A deprivation suggest that vertebral birth defects may be caused by a defect in RA signaling pathway during somitogenesis.

‡ Goldstein Award Nominee for Best Clinical Poster or E-Poster. Ω Moe Award Nominee for Best Basic Science Poster or E-Poster.
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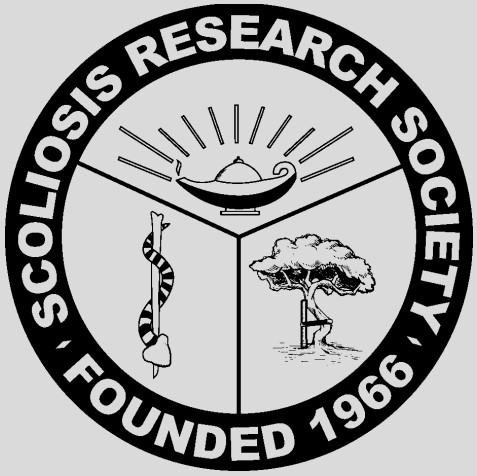
Traditional Poster Abstracts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301. Intrawound Vancomycin Powder Decreases Acute, Deep Staphylococcus Aureus Infection Rates in Posterior Instrumented Spinal Arthrodeses

Aaron Heller, BA; Terence E. McIff, PhD; Sue Min Lai, PhD; Douglas C. Burton, MD
USA

Summary: We reviewed 372 consecutive patients from Oct. 2008 to Sept. 2011 who underwent posterior instrumented spinal arthrodesis and received intrawound vancomycin powder prior to closure and compared their acute, deep infection rate to 372 consecutive patients from Oct. 2008 to Apr. 2005 who underwent posterior spinal instrumented arthrodesis and did not receive intrawound vancomycin powder. We found the use of intrawound vancomycin decreased the acute, deep S. aureus infection rate from 1.61% to 0 (p=0.0306). Vancomycin powder is an effective way to decrease acute, deep S. aureus infections following spine surgery.

Introduction: Surgical site infection is a serious complication for patients undergoing instrumented spinal surgery. S. aureus is the most common causative agent associated with post-op wound infections. Recent studies have reported a decreased infection rate with intrawound vancomycin use in spine surgeries. We sought to determine if intrawound vancomycin would decrease the rates of acute, deep S. aureus infections in our posterior instrumented spinal arthrodesis patients.

Methods: This is a historical cohort study. All procedures were performed by a single surgeon. 372 consecutive patients undergoing posterior instrumented spinal arthrodesis received intrawound vancomycin in addition to standard antimicrobial prophylaxis beginning in Oct. 2008 through Sept. 2011 (Vanco group). We compared them to 372 consecutive patients from Oct. 2008 to Apr. 2005 who did not receive intrawound vancomyin (Non-Vanco group). We excluded any superficial infection (above the lumbosacral fascia) or any infection occurring after 90 days. Infection rates were analyzed with Fisher exact test.

Results: We found 7 (1.88%) acute, deep infections in the Non-Vanco group: 1 Enterococcus and 6 (1.61%) S. aureus. We found 4 (1.08%) acute, deep infections in the Vanco group, none of which were S. aureus. There were 2 E.coli, 1 Klebsiella and 1 anaerobic Streptococcus. The difference in total acute, deep infection rate between the Non-vanco and Vanco group was not significant (p= 0.5458), but the decrease in the S. aureus infection rate in the Vanco group was significant (p=0.0306).

Conclusion: Intrawound vancomycin has decreased the rate of acute, deep S. aureus infections in our posterior instrumented spinal fusion patient population from 1.61% to 0. Our Vanco group was significantly older and underwent a significantly greater number of surgeries with pelvic fixations, though had fewer infections. This work is adding to the growing body of evidence in support of this effective adjuvant to standard antimicrobial prophylaxis.

302. The Effects of Obesity on Deformity Correction in Adolescent and Juvenile Idiopathic Scoliosis

Christina Hardesty, MD; Jochen P. Son-Hing, MD, FRCSC; Connie Poe-Kochert, BSN; George H. Thompson, MD
USA

Summary: Increased body mass index (BMI) in adolescents and juveniles undergoing spinal deformity surgery is associated with increased preoperative kyphosis, number of postoperative complications, and difficulty with administration of spinal anesthesia.

Introduction: Obesity is associated with an increased rate of complications in the peri-operative period, especially in adults. Elevated BMI has been related to greater thoracic kyphosis before surgery compared to children with a healthy weight. This retrospective analysis was done to examine the relationship between BMI and surgical outcomes in adolescent and juvenile idiopathic scoliosis.

Methods: A retrospective review of the computerized pediatric spinal deformity database was performed. 236 patients with idiopathic scoliosis underwent spinal deformity correction surgery between 1992 and 2010. Demographic data, radiographic measurements, intraoperative and postoperative data, and complications were collected. The BMI was calculated for each patient. Pearson correlation coefficients were calculated to evaluate the correlation between body mass index and each of the outcome measures.

Results: Two hundred thirty-six patients (187 females, 49 males) with average age 14.43 (range 11-22) with a minimum of one year follow up met the inclusion criteria for this study. The average BMI was 21.63 (range 10-46). The pearson correlation coefficient was highest for preoperative thoracic kyphosis at 0.75. The correlation was lower, at 0.25, for total operative time and amount of fluids given intraoperatively. The amount of intraoperative blood loss, postoperative drainage, and total blood loss did not show any significant correlation. The correction of deformity was similar regardless of the BMI as well. The percentage of complications was much higher in the obese children (39%) compared to healthy children (15%). Children who are obese were unable to receive a pre-operative spinal anesthetic 17% of the time compared to 1% of the healthy children.

Conclusion: Increased BMI in adolescents and juveniles undergoing spinal deformity surgery correlated strongly with increased preoperative kyphosis, number of postoperative complications, and difficulty with administration of spinal anesthesia. It correlated less strongly with total operative time and amount of fluids required intraoperatively. There was no significant correlation with intraoperative blood loss, postoperative drainage, total blood loss, or correction of curvature.

303. Increase in Percent Vital Capacity after Posterior Surgery in Patients with AIS

Katsuki Kono
Japan

Summary: We examined %VC increase after posterior fusion for AIS. The increase of %VC was negatively correlated with preoperative %VC. The magnitude of scoliosis correction contributes to %VC increase. Surgical treatment improves pulmonary function and even can be expected to restore normal %VC (>=80%) in AIS patients with pulmonary impairment.

Introduction: Surgical treatment might improve %VC in AIS patients with pulmonary function impairment. We examined the %VC increase after posterior fusion for AIS.

Methods: We included 187 AIS patients (181 women; mean age, 14.1 years; range, 10.2-16.9) who had undergone initial posterior corrective fusion for thoracic curves. All patients were treated with conventional hybrid constructs using hooks, wires, and pedicle screws. The rod rotation maneuver was performed in 138 patients. Preoperative (%VCpr) and 2-year postoperative %VC (%VC2y) were examined. Multiple regression analyses were performed to determine the increase

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in postoperative %VC (Δ%VC: %VCpr subtracted from %VC2y), with selected explanatory variables.

Results: The mean Cobb angle was 56.4° (range, 40-122) preoperatively and 15.7° (range, 0-65) 2 years postoperatively (correction rate, 73%). The mean (±SD) preoperative and postoperative thoracic kyphosis angle (T2-T12) was 23.9° (±12.7) and 31.0° (±10.2), respectively. Preoperative %VC was 78.9% (±14.8), and it increased significantly to 86.2% (±13.6) 2 years after surgery (P<0.001). %VCpr and %VC2y (R=0.76, P<0.001) were positively correlated, while %VCpr was negatively correlated with Δ%VC (R=-0.45, P<0.001). Multiple regression analyses showed that Δ%VC was correlated with the following: %VCpr (standard partial regression coefficient [β]=-0.41, F=37.3, P<0.001), correction of the Cobb angle (β=0.16, F=5.77; P=0.017), and age at surgery (β=-0.13, F=4.01, P=0.047) (R=0.50; P<0.001). In the group of patients with %VCpr <65% (n=24), Δ%VC was significantly greater (P<0.001) and the percentage of patients achieving Δ%VC >=10% was significantly higher (P<0.001) than those in other groups. In this group, 25% patients had normal pulmonary function (%VC >=80%) 2 years after surgery (Table).

Conclusion: The magnitude of scoliosis correction contribute to %VC increase. It was shown that surgical treatment improves pulmonary function and even can be expected to restore normal %VC (>=80%) in AIS patients with pulmonary impairment.

304. Effect of Spinal Fusion on Static and Dynamic Sagittal Spinal Alignment

Pranitha Gottipati, PhD; Stefania Fatone; Tyler Koski, MD; Aruna Ganju, MD
USA

Summary: Normal sagittal spinal alignment plays an important role in maintaining balance during standing and walking. While the traditional C7 plumb line assesses sagittal spinal alignment during standing, it is inadequate for assessing sagittal alignment during ambulation. In this study, in patients undergoing reconstructive spinal surgery for positive sagittal balance, motion analysis technique was utilized to assess dynamic and stationary sagittal spinal alignment pre- and post- operatively.

Introduction: Normal sagittal spinal alignment (SSA) is necessary to maintain balance during standing and walking. Clinicians use the C7 plumb line method on standing x-ray to assess SSA before and after surgery in patients with positive sagittal spine balance (PSSB). While x-ray provides a good estimate of static SSA, the relationship with dynamic SSA during activities such as walking is uncertain. Motion analysis can be used non-invasively to measure both static and dynamic SSA. We hypothesized that both static and dynamic SSA would improve after surgery to correct PSSB.

Methods: Nine subjects undergoing surgery for PSSB were prospectively identified. Subjects underwent gait analysis pre- and 6 months post-operatively using an 8-camera digital real-time motion capture system. Static and dynamic SSA were measured while subjects stood stationary and while they walked on a 10m walkway using the anterior-posterior distance between markers placed on C7 and S1 vertebrae. Pre- and post-operative measurements were compared using a paired t-test with p=0.05.

Results: Positive dynamic SSA was larger than static SSA pre- and post-operatively. Surgery significantly improved both static and dynamic SSA (p=0.0008 for static; p=0.0003 for dynamic). Mean static SSA was 19.0±10.6cm pre- and 3.9±2.3cm post-operatively. Mean dynamic SSA was 21.6±10.7cm pre- and 7.5±4.1cm post-operatively.

Conclusion: Greater positive dynamic SSA during walking compared to standing is consistent with normal walking wherein the trunk oscillates about a slightly flexed position but is neutral in standing. Improved static SSA post-operatively coincided with improved dynamic SSA where oscillations of the trunk occurred about a less flexed position. PSSB shifts the body center of mass out of the base of support leading to instability during standing and walking. Using motion analysis to assess static and dynamic SSA provides insight into how SSA and surgery affect function.

Ω305. Three-Dimensional Visualization of the Intervertebral Disc: The Effects of Growth Modulation

Diana A. Glaser, PhD; Christine L. Farnsworth, MS; Josh Doan, MEng; Peter O. Newton, MD
USA

Summary: Anterolateral spinal tethering in a growing animal model on three-dimensional (3D) disc morphology was found to decrease disc height, without a tethered vs. non-tethered side height differences.

Introduction: Spinal growth modulation may correct deformities without fusion. Maintained motion requires disc health. Disc shape from tethered bovine spines was evaluated using 3D micro-computed tomography (μCT) reconstructions. Disc heights on the instrumented side vs non-instrumented side and between tethered spines and surgical sham controls were compared.

Methods: Six 5-week old calves received 4 consecutive thoracic anterolateral vertebral body (VB) screws connected with a flexible tether (Tether Group); 6 calves had sham surgeries (screws only, Sham Group). Spines were harvested after 3 months of growth. An apical motion segment was harvested from 3 spines in each group and proximal and distal segments harvested from 3 each, resulting in 9 motion segments in each Group. Individual motion segments were embedded in methylmethacrylate for previous histology. Samples were imaged by microtomograph (Skyscan, Belgium) at 35μm resolution, 0.4 degree rotation step, 100mA, 100KV, using a 1.0mm Aluminum filter. Vertebral surface reconstructions were created using MIMICS (Materialise, Belgium). VB epiphyses were identified. Using a custom MATLAB (Mathworks, MA, USA) script, inter-epiphyseal distances were calculated, generating disc-space height maps. Average height values were calculated for the right (instrumented) and left (non-instrumented) sides of each cross-sectional map. Two-tailed unpaired student t-tests evaluated left-right disc height differences and tethered vs. sham results. Significance was p<0.05.

Results: Sham group: left-side disc height was significantly less than right-side disc height (normalized left-right height difference shows inverse disc wedging, Table 1). Tether group: left and right-side disc heights were not significantly different (p=0.27). Disc height was less in the tethered vs the sham group (Table 1, p<0.01) with average Tether group disc thickness decreased on the left by 24% and on the right by 34% compared to the Sham group. All discs received a Thompson Grade I upon harvest[1].

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Conclusion: Significant wedging away from the instrumentation in the Sham group suggests that the screws alone or the surgical approach affected disc shape. Tethering resulted in thinner, though healthy appearing discs.

1.Newton et al. Spine 2008

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

307. Proximal Junctional Fracture with Neurologic Deficit Following Adult Deformity Surgery

Mark D. Rahm, MD; Khaled Kebaish, MD; Robert W. Gaines, MD; Hani Mhaidli, MD PhD; Complex Spine Study Group
USA

Summary: Proximal junctional fracture with neurologic injury is a devastating complication following adult deformity surgery. This retrospective case series reviews 8 patients with this injury. All were treated surgically with improvement of neurologic deficit, however 50% of patients had further proximal junctional fracture.

Introduction: Proximal junctional kyphosis (PJK) following adult deformity surgery is a known complication. It can occur acutely with proximal junctional fracture (PJF), rarely being associated with spinal cord injury (SCI) and neurologic deficit. The results of treatment following PJF with SCI are not well delineated.

Methods: This study is a multi-center retrospective case series. Patients were identified who had PJF with SCI following fusion with instrumentation from the sacrum to T12 or above for adult deformity. Data collected included sex, age, levels instrumented, use of vertebroplasty, time from initial surgery to PJF, levels and types of PJF, Frankel grade, treatment and neurologic results.

Results: 8 patients were identified. The average age was 65 years (48-78), 5 patients were female. Time from surgery to PJF averaged 14 weeks (range 3-32). The upper instrumented vertebrae (UIV) were T12, T11, T9, T8 (3), T5 and T2. All patients had screw fixation at the UIV except the T2 level where hooks were utilized. One patient (T11) had prophylactic vertebroplasty. PJF occurred at the UIV with all patients having significant kyphosis with subluxation. All patients had incomplete neurologic deficits with Frankel grade C in 6 patients and D in 2 patients at time of PJF. All patients were treated surgically with extension of the instrumentation cephalad. Follow-up after treatment ranged 1 to 5 years (mean 2 yrs 2 months). All patients improved neurologically, final Frankel grades were D in 6 patients and E in 2 patients. Complications following PJF treatment included 2 deep wound infections, and 1 pseudoarthrosis. 4 patients had PJF at the new UIV (T5, 2 at T4, T1) without SCI, 2 of which have undergone further surgery, and 1 has surgery planned.

Conclusion: PJF with neurologic injury is a devastating complication following adult deformity surgery. Neurologic deficits improved in all patients. Complications following treatment were common, and 50% of patients had further significant PJF after treatment.

308. Prognostic Factors for Curve Progression in Patients with Idiopathic Scoliosis by Logistic Regression Analysis

Masaaki Chazono, MD, PhD; Shigeru Soshi, MD, PhD; Takeshi Inoue; Yoshikuni Kida; Takaaki Tanaka, MD; Keishi Marumo, MD, PhD
Japan

Summary: We conducted a study to analyze height velocity (HV) concurrently with several established measures of skeletal maturity to determine which of these are significant prognostic factors for curve progression in idiopathic scoliosis patients. Multivariate logistic analysis determined that HV was the only significant independent variable. The assessments of the risk of curve progression in patients with AIS should include HV along with measures of skeletal maturity.

Introduction: Recently, much attention has been paid to height velocity (HV) as a possible prognostic factor for curve progression in patients with idiopathic scoliosis (IS). The aim of this study was to investigate HV concurrently with several established measures of skeletal maturity to determine which of these are significant prognostic factors for curve progression in patients with IS.

Methods: The study comprised 97 AIS females with a mean age of 13 years at the start of the study. A full-spine standing AP view and right hand X-rays were taken each time the patients visited the outpatient clinic, every 4 to 6 months. Cobb angle and Risser sign (R-sign) were calculated from the spine X-rays. Digital skeletal age (DSA) staging was evaluated based on the Sander's classification, using the hand X-rays. Height measurements were recorded at each clinic visit, and HV was calculated as change in height during the time interval (in centimeters) divided by time interval (in years). In this study, curve progression was divided into progression and non-progression groups. The following variables were analyzed: chronological age (C-age), pubertal status (M-stage), Risser sign, DSA stage, and height velocity (HV). Our outcome measures consisted of calculating the distributions of HV values as functions of C-age, M-stage, Risser sign, and DSA stage. We then performed univariate and multivariate logistic regression analyses using a stepwise procedure to identify significant prognostic factors for curve progression, expressed as an odds ratio (OR).

Results: The HV values peaked at 10 years of age (C-age), 1 year before menarche (M-stage), Risser sign 0, and DSA Stage 2. Chi-square testing revealed that the intergroup differences in M-stage, Risser sign, DSA stage, and HV were statistically significant. Multivariate logistic analysis indicated that HV was the only significant independent variable, with an OR ratio of 4.31.

Conclusion: The present study showed that menarche and development of the Risser sign lagged behind achievement of DSA stage 2 or3, which appeared to coincide with the growth peak. Our study suggests that HV is a significant predictive indicator for curve progression defined as an increase in Cobb angle greater than 30 degrees.

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309. Radiation Exposure in the Modern Treatment of Adolescent Idiopathic Scoliosis

Steven M. Presciutti, MD; Mark C. Lee, MD
USA

Summary: Radiation exposures for scoliosis patients differ significantly between treatment groups. Operative patients have strikingly greater radiation exposures that non-operatively treated patients and receive almost 99% of their radiation exposure during surgery.

Introduction: Adolescent idiopathic scoliosis (AIS) patients treated before the 1990s have a 1-2% increase in the lifetime risk of developing breast and thyroid cancer as a result of ionizing radiation from plain radiographs. While current radiographic techniques have been able to reduce some of the risks from plain radiographs, modern treatment algorithms for scoliosis often include computed tomography and intraoperative fluoroscopy. The exact magnitude of the exposure to ionizing radiation by adolescents during modern scoliosis treatment therefore remains unclear.

Methods: A retrospective chart and film review was performed of AIS patients treated between 2007-2012, aged 9-18 yrs and followed for at least 2 yrs. The number of plain films for each patient was recorded along with radiation exposures from fluoroscopy and CT scan. Published data was used to estimate the radiation exposure from digital plain radiographs. Total radiation exposure per year was then calculated for each patient. Patients were divided into 3 treatment groups (operative, brace, observation) and a single-factor ANOVA (α=0.01) with a Tukey HSD post-hoc analysis was used to test differences.

Results: 267 patients were evaluated: 86 operative, 80 brace, 101 observation. All groups had similar demographics and curve types. There was a significant difference between groups in the mean number of plain radiographs received per year: operative (12.2), brace (5.7) and observation (3.5) [p<0.001]. The mean radiation exposure per year (mRad/yr) inclusive of all studies was significantly different between groups: operative (78,900), brace (446) and observation (274) [p<0.001]. Importantly, almost 99% of the radiation in the operative group was attributable to the operative fluoroscopy exposure.

Conclusion: Significant differences exist in the radiation exposure per year for scoliosis patients with different treatment regimens. Almost 99% of the annual radiation exposure for operative patients occurs during surgery. Since children are notably more sensitive to the carcinogenic effects of ionizing radiation, a search for imaging methods with limited radiation in the treatment of scoliosis is necessary.

310. Risk Factors of Postoperative Shoulder Asymmetry in Lenke I Adolescent Idiopathic Scoliosis Following Posterior All Pedicle Screws Instrumentation and Fusion

Ming Li; Chuan-Feng Wang; Zi-Qiang Chen, MD.
China

Summary: To analyze risk factors of postoperative shoulder asymmetry(PSA) in Lenke I adolescent idiopathic scoliosis(AIS) following posterior all pedicle screws instrumentation and fusion.

Introduction: There are no studies evaluating risk factors of postoperative shoulder asymmetry(PSA) in Lenke I adolescent idiopathic scoliosis(AIS) following posterior all pedicle screws instrumentation and fusion.

Methods: A total of 110 consecutive AIS patients with a minimum 2-year follow-up (average, 3.7 years; range, 2.0-5.3 years) treated with posterior all pedicle screws instrumentation and fusion were evaluated. Radiographic measurements analyzed included coronal and sagittal parameters on preoperative, early post-operation and final follow-up standing long cassette radiographs. The parameters of shoulder balance such as T1 tilt, clavicle angle and Radiographic shoulder height (RSH) were also measured. Postoperative Scoliosis Research Society (SRS)-22 outcome scores were evaluated. PSA was defined as the absolute value of RSH grade at final follow-up was greater than preoperative RSH grade.

Results: The incidence of PSA at final follow-up was 16.4% (18 of 110 patients). Factors that were statistically significant for PSA were as follows: preoperative positive T1 tilt(P=0.000), preoperative positive clavicle angle(P=0.010), preoperative shoulder balance(preoperative RSH grade=0) (P=0.000), preoperative proximal thoracic(PT) Cobb(PT≥30°) (P=0.024), difference between preoperative main thoracic(MT) and PT Cobb(<25°)(P=0.025), ratio of MT correction rate to PT at final follow-up (≥1.8) (P=0.013). The level of PT low end vertebra and uppermost instrumented vertebra did not affect the PSA incidence (P>0.05). SRS-22 outcome scores did not demonstrate any significant differences (P>0.05) between the PSA and non-PSA groups.

Conclusion: Lenke I AIS patients with PT tending to structural curve or with balanced shoulder preoperatively are more prone to PSA.Over correction of MT is an important reason for PSA.

311. AIS Prognostic Test (AIS-PT) Testing of Patients with Advanced Cobb Angles Provides Further Validation of the Test Algorithm

Lesa M. Nelson, BS; James W. Ogilvie, MD; Kenneth Ward, MD
USA

Summary: AIS-PT testing is currently indicated for patients with mild scoliosis. Data from samples collected on patients who already have a moderate or severe curve provide additional confirmation of the value of AIS-PT algorithm in predicting curve progression. Since clinical interest in testing more advanced curves is high, a risk of progression curve is under development for patients with a moderate curve.

Introduction: A novel, DNA-based, AIS Prognostic Test (AIS-PT) became available for clinical use in 2009. The AIS-PT was developed to assess risk of curve progression in mild AIS patients– specifically to identify mild scoliosis patients who have a very low risk of progressing to a severe curve. Test requests for patients with moderate or severe curves are "considered out-of-indication for use" because these patients can never be considered low risk and the test algorithm has not been adjusted for the higher baseline risk in these patients.

Methods: The AIS-PT uses a DNA panel of 53 markers and the patient's current Cobb Angle to assign a risk of progression score between 1-200. The current test has been validated only for Caucasian patients with a mild curve. In the first 36 months of use- samples from 124 patients with a moderate curve (26-40 degree Cobb) and 12 patients with a Cobb greater than 40 degrees were submitted for testing. These samples were not tested or reported clinically, but they have now been analyzed as a further validation of the AIS-PT test. Saliva samples (rejected as outside of indications for use) were de-identified and tested to determine an AIS-PT

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score. Since the algorithm does not allow initial Cobb angles >25 degrees, a Cobb angle of 25 degrees was assumed for all samples.

Results: 124 patients with moderate curves (mean Cobb angle 32 degrees) had a mean AIS-PT score of 179 (range 23-200). Only 1 patient (0.8%) had a "low-risk" score (score of 1-50), 32 (26%) had "intermediate risk" scores (score of 51-180), and 91 (74%) had "high-risk" scores (score of 181-200). Twelve patients with severe curves had a mean AIS-PT score of 197 (range 197-200). Although we do not know how many of the moderate patients will progress to a severe curve, the one moderate patient with low risk scores had a Cobb angle of less than 30 degrees.

Conclusion: Patients with an advanced curve showed elevated AIS-PT values providing additional validation of the testing algorithm. None of the patients who progressed to severe curves had low risk scores.

312. A Modified Technique to Prevent PJK Following Surgical Treatment of Scheuermann's Disease

Meric Enercan; Cagatay Ozturk, MD; Sinan Kahraman; Alauddin Kochai; Ahmet Alanay; Azmi Hamzaoglu, MD
Turkey

Summary: In this study, we have defined a surgical strategy to prevent PJK after surgery for Scheuermann's Disease.

Introduction: In our practice, we have observed 30% PJK despite all efforts to avoid causative factors such as excessive junctional soft tissue dissection, overcorrection and improper end vertebra selection. We hypothesized one of the possible causes to be excessive stresses created at the ligaments (L) and facet joints (FJ) between adjacent segment (AS) and UIV during cantilever (CL) and compression (C) forces used for correction. Excessive forces can cause ligamentous and facet joint capsule injury which may lead to gradual subluxation of FJ causing PJK. We have modified technique to prevent this possible mechanism. Aim of this study is to compare patients treated with standard vs. modified correction techniques in terms of PJK.

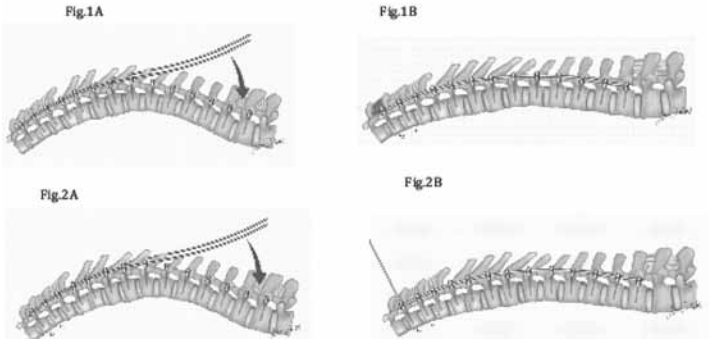
Methods: 46 consecutive pts. with SD treated by posterior instrumentation and fusion and with > 2y f/up were included. Pts. were divided in 2 groups as; standart technique (ST, n=13 pts) and modified technique (MT n=33 pts.). ST included CL reduction of the rods on screws at distal foundation after tightening the set screws of all upper foundation screws. CL or C maneuvers cause distraction in L and FJ capsule between UIV (T2) and AS when rod is securely tightened at UIV. In MT, the rods are placed at UIV but not tightened and left free. As there is no forces applied to UIV during CL and C maneuvers, less or no stresses are created in between UIV and AS. The rods are secured at UIV after the CL and C manuevers are completed (Fig. 1). X-ray analysis included measurement of sagittal plane parameters. PJK was defined as >10° at junction preop to postop.

Results: Two groups were similar according to demographics and radiographic parameters (table 1). Four pts (%30) in ST developed PJK and 2 had extension of fusion due to symptoms. None of the pts. developed PJK in MT group. The difference was significant (p=0.016) 2 in ST and 1pt. in MT groups had superficial infection treated successfully.

Conclusion: Our study shows that overstress created at adjacent FJ and L by forcefull CL and C forces may cause PJK and this can be prevented by not tightening the rods at UIV during correction and preventing the shifting of stresses to AS through UIV.

Figure 1 A and B. Standard technique
The rods are secured at UIV (T2) by placing and tightening of the setscrew. Cantilever reduction and compression of the screws at upper foundation in this case results with distraction between UIV (T2) and adjacent upper vertebrae (T1). Distractive force may weaken ligaments and facet joint capsule and may cause subluxation of facet joint between UIV and adjacent upper vertebrae, which may end up with PJK.

Figure 2 A and B. Modified technique
The rods are placed at UIV (T2) but not tightened and left free. As there are no forces applied to UIV (T2) during Cantilever reduction and Compression maneuvers, less or no stresses are created in between UIV (T2) and adjacent upper vertebrae (T1) (Fig. 2A). The rods are secured at UIV after the Cantilever and Compression maneuvers are completed (Fig. 2B).



313. Bending X-Rays vs. Traction X-Ray under General Anesthesia (TRuGA) for Evaluation of Flexibility of Curves and Prediction of Correction in Patients with Adult Idiopathic Scoliosis: Which is Better?

Levent Ulusoy; Sinan Kahraman; Meric Enercan; Alauddin Kochai; Tunay Sanli, MA; Cagatay Ozturk, MD; Ahmet Alanay; Azmi Hamzaoglu, MD
Turkey

Summary: TRuGA reflects the flexibility rates better than than traditional x-rays in adult idiopathic scoliosis.

Introduction: Bending x-rays (BXR) are traditionally used for evaluation of flexibility in patients with adolescent idiopathic scoliosis. There are few studies reporting traction x-ray under general anesthesia (TRUGA) may be a better alternative to BXR in AIS patients. There are no studies so far comparing both techniques in adult idiopathic scoliosis (AduIS), which may reflect different intrinsic curve characteristics. The aim of this study was to compare BXR with TRuGA in patients with AduIS.

Methods: 40 patients with AduIS who were operated by pedicle screw posterior instrumentation and have had both preoperative BXR and TRuGA were included in this study. Traction x-ray was taken under general anesthesia after induction and before positioning the patient. The flexibility rate obtained by each method at proximal thoracic (PT), Main thoracic (MT) and Thoracolumbar/lumbar (TL/L) curves was compared using student's t test. A subgroup of patients with more than 60 degrees of MT curve was also evaluated. To evaluate the best method to predict the postsurgical result, the agreement between the methods and postoperative results were examined using Bland-Altman method.

Results: The average age of patients (32F, 8M) was 25 (20-50) years and average f/up was 38.6 (24-96) months. The difference between flexibility rates by

TRADITIONAL POSTER ABSTRACTS

each method was similar for PT curves (p>0.05). TRuGA demonstrated significantly more flexibility rates for MT curve (p=0.000) and more flexibility for TL/L curves which did not reach to significance (p=0.053). TRuGA also demonstrated significantly more flexibility rates for MT curves over 60° (p=0.000). TRuGA demonstrated better 95% limits of agreement with postoperative results for all PT,MT and TL/L curves when compared to BXR (table 1).

Conclusion: TRuGA demonstrates more flexibility rates for both mild and severe MT curves and provides a better agreement with the postoperative correction rates in patients with AdulS.

314. Anterior Column Realignment (ACR) For Focal Kyphotic Spinal Deformity Using a Lateral Transpsoas Interbody Approach and ALL Release

Behrooz A. Akbarnia, MD; Gregory M. Mundis, MD; Payam Moazzaz, MD; Nima Kabirian, MD; Ramin Bagheri, MD; Robert K. Eastlack, MD; Jeff Pawelek
USA

Summary: Patients who underwent the less invasive Anterior Column Realignment (ACR) for treatment of focal kyphotic spinal deformity had similar degree of sagittal deformity correction and incidence of surgical complications compared to traditional corrective techniques.

Introduction: Spinal sagittal imbalance can adversely affect the long-term outcome of spinal deformity surgery. The purpose of this study was to evaluate the safety of a new technique of Anterior Column Realignment (ACR) using a lateral transpsoas interbody approach with ALL release for correction of focal kyphotic deformity.

Methods: Retrospective clinical and radiographic review of patients who underwent ACR.

Results: Seventeen consecutive patients (12 F, 5 M) had a mean age of 63 years (35-76) at surgery with a mean follow-up of 15.1 months (3-58). Fourteen of 17 (82%) had previous spine surgery and 12/17 (71%) had previous spine fusion. Twelve of the17 patients (71%) underwent the ACR procedure for adjacent segment disease. Six patients had previous posterior spinal fusions cephalad to the ACR with distal junctional kyphosis and 6 patients with previous fusions caudad to the ACR with proximal junctional kyphosis. Fifteen patients (88%) had posterior Smith-Peterson osteotomies at the level of the ACR. Mean intra-operative blood loss during the ACR and posterior procedure was 111 cc and 1484 cc, respectively. Pre-operative motion segment angle averaged 8.8° and improved to -19.4° after ACR and to -25.6° after posterior surgery. The average total correction was 37°. Lumbar lordosis improved from -11.6° to -38° after ACR and -48.8° after posterior instrumentation. 8 patients (47%) had complications, 4 patients during or after ACR procedure and 6 patients after the posterior stage. Two were neurological of which, one has resulted in persistent weakness, and one patient had vascular injury during an anterior plate removal.

Conclusion: Our study shows comparable correction and morbidities of a less invasive technique for treatment of focal kyphotic spinal deformity. Careful case selection, attention to the details of the technique and enough experience are prudent elements for a desirable outcome.

Ω315. Simultaneous Multi-Planar Loading to Quantify the Correction Potential of Ponte Osteotomies in a Cadaveric Biomechanical Model

Richard E. Bowen, MD; Sean L. Borkowski, MS; Sophia N. Sangiorgio, PhD; Juliann Kwak, MD; Anthony A. Scaduto, MD; Edward Ebramzadeh, PhD
USA

Summary: Single and multi-planar loading were applied to cadaveric full thoracic spines, and increases in ROM of up to 8.1° were measured after facetectomies, with additional 3.1° after each Ponte osteotomy, suggesting the potential of Ponte osteotomies to achieve added correction in cases of AIS.

Introduction: Although studies have quantified the increase in flexibility and ROM following destabilizing procedures, no study to date has evaluated the correction potential of surgical release under multi-planar loading, more closely simulating clinical AIS cases. We used both single plane and multi-planar loading to quantify ROM of full thoracic cadaveric spines following facetectomies and sequential Ponte osteotomies.

Methods: 10 human cadaveric thoracic spines (T1-T12) were placed an 8-DOF MTS load frame. Cyclic, pure moments (±4Nm) were applied in: flexion-extension (FE); lateral bending (LB); axial rotation (AR); FE combined with AR; and LB combined with AR. Using the MTS and an optical motion tracker, torque-rotation and total ROM were measured at all levels intact, after 9 total facetectomies (T2-T11), then after each of 4 sequential Ponte osteotomies.

Results: Under single plane loading, following 9 levels of bilateral total facetectomies, total ROM (T2-T11) increased, with a max of 6.6° in FE (all 9 facetectomies), 3.1° in LB, and 8.1° in AR (approximately 0.73°, 0.34°, 0.9° per facetectomy). Much higher per-level increases were seen after additional Ponte osteotomies, with increases in ROM following one single osteotomy of up to 2.7° in FE, 1.4° in LB, and 3.1° in AR. Under multi-planar loading, simultaneous increases were seen, of as much as 5.2°, 2.7°, and 5.4° following the facetectomies, and up to 1.4°, 1.6°, and 2.2° following a single Ponte osteotomy.

Conclusion: Each additional Ponte osteotomy provided higher per-level increases in ROM under single plane loading than total facetectomies alone. Although Ponte osteotomies have been considered primarily for sagittal plane deformities, in this study, they provided simultaneous increase in all 3 planes under multi-planar loading.

316. Incidence, Magnitude and Classification of Pedicle Screw Migration

Hazem B. Elsebaie, FRCS, MD; Hilali H. Noordeen, FRCS; Behrooz A. Akbarnia, MD
Egypt

Summary: A retrospective review of radiographs of 23 patients treated with single growing rods with a minimum of 4 distractions. We found that the change of screws position toward a more caudal direction in relation to the vertebral body after serial distractions is a frequent occurrence in the distal pedicle screws. Reviewing radiographs of these cases we could identify 3 types of pedicle screw migration.

Introduction: The change of position of the distal pedicle screws with growing rods in relation to vertebral bodies was described as "Pedicle Screws Migration"; pedicle screws are subjected to serial distractive forces pushing them down with every distraction, in addition there is continuous growth of the vertebral bodies during the treatment period; these two factors can affect the change of position of the pedicle

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screws in relation to the vertebrae during the use of growing rods. To the authors' knowledge this finding has never been studied, confirmed or quantified.

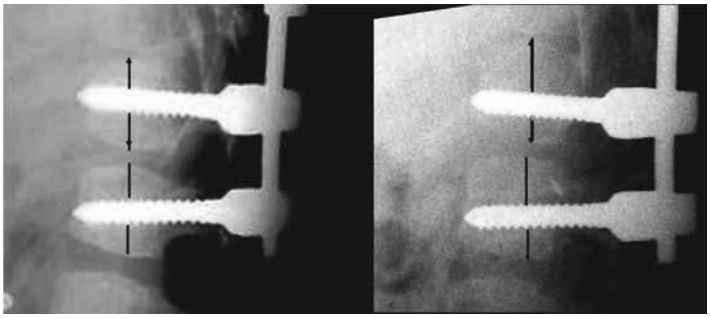
Methods: Retrospective review of the radiographs and operative notes of 23 consecutive cases of early onset scoliosis treated with single growing rods. Age at index surgery was 4y 2m to 8y 9m, the number of distractions was 4 to 11 per patient. Measurements were done on post index and latest follow up true lateral radiographs, we calculated the distance superior to the screw (SS) and the distance inferior to the screw(IS) and we had this ratio as a percentage. An increase in this percentage denoted a more caudal position; a change of less than 10 percent was considered insignificant.

Results: Seven cases were excluded because of inadequate radiographs for measurements.

Within the distal construct, measurements of the upper pedicle screw showed that: Six cases had a change of less than 10% and were considered insignificant.

Ten cases had change more than 10%:five had between 10 and 50% change, three between 50 and 100 % and two more than 100% change. We identified 3 types of migration: I. Instrumented or uninstrumented pedicles migration with growth (the screw staying at the same position in relation to the pedicle). II. Pedicle screw migration within the confinement of the pedicle with pedicle displacement. Type II: Pedicle screw migration within the confinement of the pedicle with pedicle distal elongation. Type III: Through and may be distal to the pedicle. Type III is the most common cause of screw loosening.

Conclusion: Change of screw position with time is a frequent occurrence in the distal pedicle screws with single growing rods. Pedicle screw migration can be classified in 3 basic types.



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317. Coupled Symmetry and Proportional Expansion of the Ribs through Adolescence

Richard M. Schwend, MD; Laurel C. Blakemore, MD; Behrooz A. Akbarnia, MD; Julie L. Reigrut, MS; John A. Schmidt, PhD; Complex Spine Study Group
USA

Summary: 31 pediatric specimens (722 ribs) of various ages from the Hamann-Todd Human Osteology Collection were photographed to evaluate rib growth during childhood. Costal length and projected area defined by the shape of the rib were measured. Costal length showed constant linear growth while projected area growth accelerated throughout childhood. The middle ribs 4-8 had the fastest overall growth, with the greatest growth rate seen in the projected area of ribs 7 and 8 compared to rib 1.

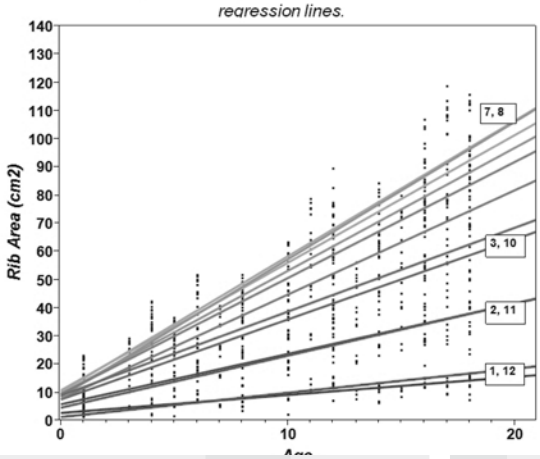
Introduction: Spinal deformity in the thoracic spine is intimately involved with rib growth and anatomy. This study describes the changing rib length and shape during childhood to gain insight into normal thoracic shape.

Methods: All ribs available for each of the 31 unaltered, normal pediatric specimens (722 total ribs) from the Hamann-Todd Human Osteology Collection were photographed in the cranial view. Rib images were calibrated and measured for outer costal length and base diameter. An estimate of the rate of costal length growth and projected area growth of each rib through adolescence were calculated based on these measurements.

Results: All ribs showed linear growth rates of costal length, with the middle ribs 4-8 growing the fastest, approximately 4 cm/year. Figure 1 shows changes in rib projected area (costal length x base diameter) over time. This figure displays paired symmetry, with ribs 1 and 12, 2 and 11, 3 and 10 showing nearly identical growth rates. The ribs of the mid thorax (ribs 4-9) show much larger growth rates with ribs 7 and 8 the growing the most. Left and right ribs showed symmetric growth. There was no acceleration of costal length growth rate during adolescence. The costal length of ribs 4-8 grows at the same rate; 2.6-2.7 times faster than rib 1. However, the projected rib area growth rate of ribs 4-8 have an increasing growth rate, with corresponding values of 5.8, 6.8, 7.1, 7.5 and 7.6 times faster than rib 1.

Conclusion: Rib length had constant growth rates with the middle ribs growing the fastest while projected area growth accelerated through adolescence. This may be attributed to the ribs acquiring the characteristic spiral pattern to form the barrel chest features of an adult human. Rib growth in specimens with scoliosis at the Hamann-Todd Collection does not follow this type of pattern. Comparing this symmetrical growth pattern in normal healthy specimens to that observed in scoliotic specimens may lead to a better understanding of this deformity.

Figure 1: *Linear regression of Projected Rib Area vs. Age. The linear growth for each rib is plotted and rib symmetry between upper and lower thorax is evident by the pairing of regression lines.*



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TRADITIONAL POSTER ABSTRACTS

318. Scoliosis in the 22Q11 Deletion Syndrome

Dino Colo, BSc; Denis S. Drummond, MD; John P. Dormans, MD; Rene M. Castelein, MD, PhD
Netherlands

Summary: The 22q11 deletion syndrome (22q11DS) is a frequently occurring multisystem disorder, in which scoliosis may also occur. In our retrospective analysis we found that 15% of these patients have a scoliosis, with 14% requiring surgery. The true prevalence may even be higher. It can represent a clinically significant problem and therefore a proactive approach towards the diagnosis and management of scoliosis in 22q11DS is recommended.

Introduction: The 22q11 deletion syndrome (22q11DS, or DiGeorge/velocardiofacial syndrome) is a frequently occurring multisystem disorder, in which scoliosis may also occur. This has thus far received little attention, probably because other associated anomalies (cardiac, psychiatric, palatal) have more severe implications for everyday functioning. The aim of this study was to determine the prevalence and characteristics of scoliosis in 22q11DS.

Methods: A total of 1067 patients (2 cohorts: CHOP/UMCU, mean age 14.1yrs, range 0.8-49), diagnosed with 22q11DS by molecular analysis, were included. The majority was first evaluated by different specialists before being assessed by an orthopaedic surgeon or paediatrician. They were retrospectively analysed for scoliosis by reviewing their clinical evaluations and assessing available radiographs of the spine.

Results: Scoliosis was reported in 15% (in the UMCU cohort 20%), with females being affected more frequently (61%). Of the patients with scoliosis, 7% received brace-treatment, 14% required surgical correction with 3/21 requiring two surgeries because of progression despite treatment. Brace treatment was ineffective in almost 50%. When reviewing the available spinal radiographs (n=92), 22% of the curve patterns did not resemble typical adolescent idiopathic scoliosis.

Conclusion: Scoliosis is a much more common feature in 22q11DS than thought and may represent a clinically significant problem. It was found in 15% of our population. Given the retrospective nature of our study, it seems likely that a number of smaller curves was missed so the true prevalence will probably even be higher. 14% of the scoliotic children has so far required one or more surgeries. Moreover, the majority of our population has not gone through their growth spurt yet and thus are at risk for developing (more severe and atypical) scoliotic curves. Curves usually seem to resemble the typical idiopathic type. A proactive approach towards the diagnosis and management of scoliosis in 22q11DS is recommended. Furthermore, awareness of the syndrome and its associated consequences/complications is of great importance for the treating orthopaedic surgeon. Based on these findings, we have initiated a prospective study.

319. Improvement of Segmental Lordosis in Transforaminal Lumbar Interbody Fusion: A Comparison of Two Techniques

John C. France, MD; James W. Rice, MD; Sanford E. Emery, MD, MBA; Scott D. Daffner, MD
USA

Summary: This study compares radiographic outcomes of two different techniques for transforaminal lumbar interbody fusion. One group of patients received a kidney-shaped allograft placed as anteriorly as possible in the disc space, while the second group received a straight PEEK cage. At least one year follow up was required. Preoperative and postoperative values for segmental lordosis, segmental coronal alignment, and disc heights were compared. Statistically significant improvment in lordosis and disc height was seen in favor of the kidney-shaped allograft.

Introduction: Transforaminal Lumbar Interbody Fusion (TLIF) was introduced as an alternative to Posterior Lumbar Interbody Fusion for treating degenerative lumbar disorders. Different variations of the original TLIF technique are employed. Several studies have investigated the clinical outcomes of TLIFs, but few have evaluated the effect of technique on radiographic outcomes. The purpose of this study was to evaluate the relationship between TLIF technique, segmental alignment, and disc height.

Methods: A total of 127 levels (in 101 patients) fused via TLIF were retrospectively reviewed. Levels were divided into two groups based on technique. Group 1 received a curved allograft placed anteriorly in the disc space. Group 2 received a straight, PEEK cage packed with bone graft or bone substitute. Rod contouring and posterior compression were performed in each group. Group 1 contained 55 levels; Group 2 had 72. Segmental lordosis (SL), disc height (DH), and segmental coronal alignment (SC) were measured on standing lumbar radiographs at the preoperative visit, day of surgery (t0), first postoperative visit (t1), one-year follow-up (t2), and last follow-up (t3). Preoperative measurements were subtracted from subsequent values, yielding correction values (deltas) for each time point (t). Mean deltas were compared between groups using the student's t-test.

Results: Both groups improved SL at all time points, but correction decreased over time. Group 1 SL delta values were 7.8(t0), 6.5(t1), 5.6(t2), and 3.9(t3) degrees. SL delta values for Group 2 were 4.0(t0), 1.8(t1), 0.9(t2), and 0.1(t3) degrees. Findings were statistically significant at all time points ($p<0.0001$). DH delta values were also greater in Group 1 versus Group 2: 5.6 vs 2.2 (t1), 4.5 vs 0.8 (t2), 3.6 vs. 0.2 (t3). Statistical significance ($p<0.0001$) was present at all time points. Comparison of coronal alignment (SC) did not reach statistical significance at any time point.

Conclusion: Both techniques effectively correct hypolordosis and loss of disc height initially, but show a loss of correction over time. Radiographic outcomes favor the curved allograft technique at all time points. Further evaluation of this data is needed to determine if clinical outcomes correlate to radiographic outcomes.

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320. Biomechanical Evaluation of Four Different Foundation Constructs Commonly Used in Growing Spine Surgery: Are Rib Anchors Comparable to Spine Anchors?

Behrooz A. Akbarnia, MD; Burt Yaszay, MD; Muharrem Yazici, MD; Nima Kabirian, MD; Kevin Strauss, ME; Diana A. Glaser, PhD; Complex Spine Study Group
USA

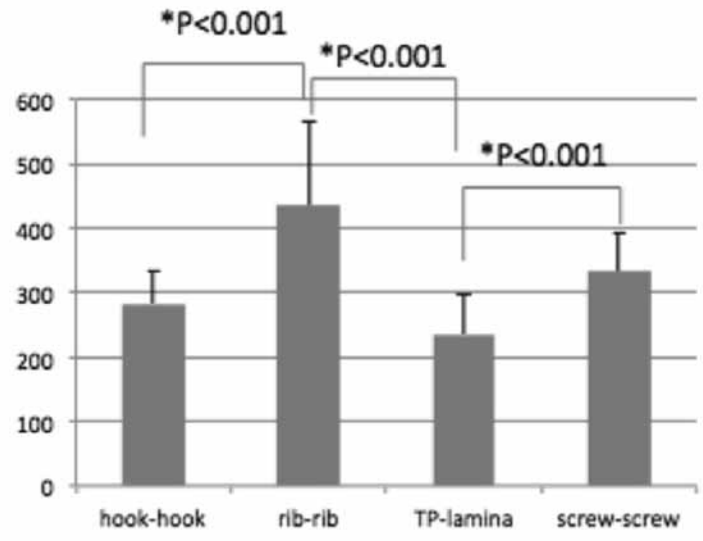
Summary: In an in-vitro, porcine study, comparing four different upper foundations, posteriorly applied loads showed Rib Hook anchors and Spine Screws failed at the highest ultimate loads. Despite having lower ultimate loads, Spine Hook anchors showed less variable results.

Introduction: In an in-vitro, porcine study, comparing four different upper foundations, posteriorly applied loads showed Rib Hook anchors and Spine Screws failed at the highest ultimate loads. Despite having lower ultimate loads, Spine Hook anchors showed less variable results.

Methods: Forty immature porcine specimens (10 per group) were instrumented with one of four bilateral proximal anchors at T5-T6. The four groups were: Screw-Screw (SS), Lamina Hook-Hook (HH), Rib Hook-Hook (RR) and Transverse Process to Lamina Hook-Hook (TPL). The entire specimen including soft tissues was kept intact except for the surgical site exposure. A unique fixture was designed to brace the specimen and provide a counter-force. The ultimate load was identified as the greatest load recorded for a construct and analyzed by a Student's t-test using the JMP 9.0 statistical package.

Results: All specimens eventually failed at the bone-anchor interface. No failures were observed in the instrumentation utilized. The mean and standard deviation of ultimate loads were measured as RR (429±133N), SS (349±89N), HH (283±48N) and TPL (236±60N). There was no statistically significant difference between each of the following construct pairs: RR/SS, SS/HH and HH/TPL (Fig.). Young's Modulus was calculated for each construct type and no statistically significant difference was determined.

Conclusion: This study showed RR and SS constructs had the greatest ultimate strengths but also greatest variability among the foundations tested. HH and TPL constructs, however, had lower ultimate strengths but were less variable. Rib based anchors may be considered as an alternative in upper foundation constructs in Growing Rod techniques.



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321. DNA-Based Prognostic Test Scores are Higher in Patients who Fail Orthotic Treatment for Adolescent Idiopathic Scoliosis

James W. Ogilvie, MD; Rakesh Chettier, MS; Lesa M. Nelson, BS; Kenneth Ward, MD
USA

Summary: In the near future, genetic tests may be developed to predict the outcome of AIS brace treatment, which could improve the delivery of medical care. Underlying genetic risks must be considered in any discussion of scoliosis treatment.

Introduction: Orthotic treatment is a common therapy for teens with adolescent idiopathic scoliosis (AIS). Published failure rates vary widely from 7% to 50% and failure may occur for a variety of reasons. No objective clinical markers or biomarkers are available to predict success. Our purpose was to correlate the success of AIS brace treatment with the results of genetic testing.

Methods: We reviewed a cohort of 207 consecutive braced AIS subjects who had an AIS prognostic test (AIS-PT) performed retrospectively. The subjects came from a wide geographic distribution and all were treated by SRS members who were unaware of the patients genetic score during treatment. Clinical course was abstracted form the patient's medical records. Mann-Whitney tests were used to determine statistical significance.

Results: In this 207 patient cohort, treating physicians considered 91 to be "brace successes" and 62 to be "brace failures"; all patients in this later group were then treated surgically. Table 1 shows that the average of age at bracing was identical and the average Cobb angle was similar in the two groups. However the AIS-PT scores were significantly lower in the subset of patients.

Conclusion: Although the DNA-based AIS-PT score was not designed to predict brace success or failure, our data show that underlying genetic factors may play an important role in response to bracing.

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Pre-Meeting Course

A Decade of Evolution in Spine Deformity Management: A Critical Appraisal of Practice Changes, Outcomes and Technology

Course Chairpersons:
Mark B. Dekutoski, MD
John R. Dimar, II, MD

Course Planning Committee:
Kamal N. Ibrahim, MD, FRCS(C), MA
Lori Ann Karol, MD
B. Stephens Richards, III, MD
Daniel J. Sucato, MD, MS

Wednesday, September 5, 2012
Sheraton Chicago Hotel & Towers
Chicago, Illinois, USA

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A DECADE OF EVOLUTION IN SPINE DEFORMITY MANAGEMENT: A CRITICAL APPRAISAL OF PRACTICE CHANGES, OUTCOMES AND TECHNOLOGY

Scoliosis Research Society • Pre-Meeting Course

Wednesday, September 5, 2012
8:00am - 3:30pm
Sheraton Chicago Hotel & Towers
Chicago, Illinois

Course Co-Chairs:
Mark B. Dekutoski, MD
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Kit M. Song, MD, MHA

Course Overview
This interactive course, presented by internationally renowned faculty, by symposia and case examples, will address a critical appraisal of practice changes, outcomes, and technology over the last decade.

Course Objectives and Outcomes
At the conclusion of this course, the learner will be able to:
- Recognize factors that may contribute to higher complication rates or risk of reoperation and incorporate pre-and peri-operative steps that help to avoid complications in spinal deformity surgery;
- Assess clinical and radiographic factors that contribute to positive or negative outcomes in spinal deformity surgery and utilize this knowledge to prevent adverse outcomes;
- Understand new techniques for the treatment of patients with Early Onset Scoliosis;
- Understand the short and long-term effect of fusion for patients with AIS using a variety of correction strategies and implants.

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

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3. On the iPhone once the QR code is centered it will automatically scan and load the webpage linked to the QR code
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   - Blackberry Messenger: Click into Blackberry Messenger and scroll down to find the option that says "scan a group barcode." The app will then give you a short tutorial how to scan your code.
   - QR Code Scanner Pro: Open the app and click the scan option. Once you have your code centered and as large as the brackets select "click to scan." The app will then pull up the URL.
5. On the iPhone: You can click on the arrow in the bottom right-hand corner to open the webpage in safari. You can also navigate the app while you are still in the Scan App.

6. On the Blackberry: Once you scan the code you will be able to navigate the entire app. To permanently save the app click on your blackberry button and select save page. A message will prompt you to save to message list-click ok. The app will save to your email. Anytime you want to revisit the app, click on the message in your email and you will automatically be linked back to the app

Lunchtime Sessions

The following symposia will take place during the lunch hour:

Breaking News: Initial Presentations from Recent SRS Grant Winners

Location: Michigan Room, Level 2
Chair: John M. Flynn, MD

The SRS Research Grants Committee presents a lunchtime symposium, giving recent grant recipients an opportunity to present and discuss the fruits of their labors. After presenting their preliminary or final results, each project will be discussed in detail. There will also be an opportunity to discuss the grant funding application process with the members of the SRS Research Grants Committee

Reaching Around the World – Global Outreach Committee

Location: Chicago 8-10, Level 4
Chair: Kenneth J. Paonessa, MD

Meet the members of the SRS Global Outreach Committee and representatives from the SRS Endorsed Sites at the Global Outreach Committee Lunchtime Symposium. If you have ever thought about volunteering your skills and knowledge in another country or want to learn about some of the current treatment of less common conditions such as Pott's disease or untreated severe scoliosis then you will find this symposium informative. During the symposium, representatives from the SRS Endorsed Sites will report on the last year's activities at some of the sites that they have volunteered at including Western and Eastern Africa, South and Central America, the Indian Subcontinent and Asia, and Eastern Europe. If you have already been involved in Global Outreach in Spinal Deformity care, this is an excellent opportunity to network with colleagues.

Scoliosis Research Society • 47th Annual Meeting • Pre-Meeting Course Agenda

A DECADE OF EVOLUTION IN SPINE DEFORMITY MANAGEMENT: A CRITICAL APPRAISAL OF PRACTICE CHANGES, OUTCOMES AND TECHNOLOGY

Wednesday, September 5, 2012

Course Co-Chairs:

Mark B. Dekutoski, MD
John R. Dimar, II, MD

Combined Morning Session		
8:00 - 9:45am	**Technical Advances in Adult & Pediatric Iliolumbar Fixation in Deformity Surgery: A Ten Year Retrospective Review** Moderators: Christopher I. Shaffrey, MD; John R. Dimar, II, MD	
8:00 - 8:05am	Welcome Remarks	*B. Stephens Richards, III, MD*
8:05 - 8:15am	A Historical Perspective on Lumbo-Pelvic Fixation	*Nathal H. Lebwohl, MD*
8:15 - 8:30am	Pediatric Neuromuscular Scoliosis: Have Surgical Techniques & Implants Changed Surgical Outcomes?	*Paul D. Sponseller, MD*
8:30 - 8:45am	High Grade Spondylolisthesis: Has Improved Iliolumbar Fixation Improved Fusion Success & Outcomes?	*Hubert Labelle, MD*
8:45 - 9:00am	Technical Advances in Adult & Pediatric Iliolumbar Fixation In Deformity Surgery: A Ten Year Retrospective Review Combined Session	*Frank J. Schwab, MD*
9:00 - 9:15am	What Evidence Exists for Fusion to the Pelvis with Iliolumbar Fixation When a L5-S1 Spondylolisthesis & AIS Co-Exist?	*Jean A. Ouellet, MD, FRCS*
9:15 - 9:30am	Debate and Case Discussion: Does Current Evidence Define When to Stop at L5 or Extended the Fusion to S1 in Adult Lumbar Scoliosis	*Moderator: Keith H. Bridwell, MD* *Panel: Jean A. Ouellet, MD, FRCS; Mark Weidenbaum, MD; Ronald A. Lehman, Jr., MD; Serena S. Hu, MD*
9:30 - 9:35am	Discussion	
9:35 - 9:45am	Audience Response Questions	
9:45 - 10:00am	Break	

Concurrent Morning Session		
	Pediatric	
10:00 - 11:30am	**Innovations in Diagnostic & Guidance Techniques in Pediatric Spinal Surgery Over the Past Decade** Moderators: Lori Ann Karol, MD; James O. Sanders, MD	
10:00 - 10:10am	After a Decade of Intense Investigation, What is the Role that Genetics Plays in the Development of Scoliosis?	*Nancy Hadley Miller, MD*
10:10 - 10:20am	Debate: The Scoliscore: Has it Proven Effective in Predicting the Progression of Scoliosis, Does it Guide Treatment Decisions and is there Quality Literature to Support its Accuracy?	*Suken A. Shah, MD; Peter O. Newton, MD*
10:20 - 10:30am	Is Bracing in AIS Still Beneficial in 2012 and Has it Reached its Maximum Development or is there Still Room for Future Improvement?	*Keith DK Luk, MD*
10:30 - 10:40am	What New Imaging and Guidance Techniques Have Been Developed Over the Past Ten Years for the Treatment of Scoliosis?	*John M. Flynn, MD*
10:40 - 10:50am	What are the Advances in Neuromonitoring Over the Past Decade and are Our Patients Safer?	*Laurel C. Blakemore, MD*

10:50 - 11:00am	What Non-Fusion Scoliosis Techniques Have Evolved for the Treatment of the Growing Spine and Have Stood the Test of Time: Growing Rods and VEPTR	*Michael G. Vitale, MD, MPH*
11:00 - 11:10am	Non—Fusion Scoliosis Techniques for Growing Spine – Modulation Methods: Evolution & Current Status	*Charles E. Johnston, MD*
11:10 - 11:25am	Case Discussion: Have Recent Corrective Techniques for the Growing Spine Shown Better Outcomes Than Those Used in 2002?	*Moderator: Lori Ann Karol, MD* *Panel: Kamal N. Ibrahim, MD, FRCS(C), MA; Michael G. Vitale, MD, MPH; Charles E. Johnston, MD; James O. Sanders, MD; Laurel C. Blakemore, MD; Richard E. McCarthy, MD*
11:25 - 11:30am	Discussion	
11:30 - 11:35am	Audience Response Questions	
11:35 - 12:45am	Lunch	

Concurrent Morning Session		
	Adult	
10:00 - 11:30am	**The Evolution of Interbody Surgery Use for the Correction of Spinal Deformity** Moderators: Keith H. Bridwell, MD; Steven M. Mardjetko, MD, FAAP	
10:00 - 10:10am	Is Structural Autograft Still the Gold Standard for Spinal Deformity Surgery?	*David W. Polly, Jr., MD*
10:10 - 10:20am	What are the Current Indications for Anterior Releases & Interbody Fusion (AIBF) in Adult Degenerative Spinal Disease & Deformity?	*John R. Dimar, II, MD*
10:20 - 10:35am	Has the PLIF Technique's Effectiveness in the Management of Spinal Deformity Fallen Out of Favor Over the Past Decade?	*Benny T. Dahl, MD, PhD, DMSc*
10:35 - 10:50am	Transformainal Lumbar Interbody Fusion (TLIF) in the Management of Deformity: Is This the Standard of Care for Posterior Approach Surgery?	*Todd J. Albert, MD*
10:50 - 11:10am	Debate: The Development, Indications and Benefits of the Lateral Interbody Spinal Approach and Implants (XLIF): What are the Indications, Effectiveness and Known Complications in Deformity Correction?	*Juan S. Uribe, MD; Justin S. Smith, MD, PhD*
11:10 - 11:25am	Round Table and Case Discussions: Which Techniques are Applicable to Correcting Adult Sagittal and Coronal Imbalance?	*Moderator: Steven M. Mardjetko, MD, FAAD* *Panel: Todd J. Albert, MD; John R. Dimar, II, MD; David W. Polly, Jr., MD; Justin S. Smith, MD, PhD*
11:25 - 11:30am	Discussion	
11:30 - 11:35am	Audience Response Questions	
11:35am - 12:45pm	Lunch	

Combined Afternoon Sessions		
1:00 - 2:00pm	**A Decade of Change in the Treatment of Pediatric & Adult Spinal Deformity: What Progress Has Been Made?** Moderators: Daniel J. Sucato, MD, MS; Richard E. McCarthy, MD	
1:00 - 1:10pm	What are the Indications for Anterior Fusion and Instrumentation for the Treatment of Pediatric Spinal Deformity in 2012?	*Firoz Miyanji, MD, FRCSC*
1:10 - 1:20pm	What are the Benefits of the Evolution of Segmental Spinal Instrumentation from Predominately Hook Constructs to Pedicle Screw Instrumentation?	*B. Stephens Richards, III, MD*
1:20 - 1:30pm	Has the Refinement of the Vertebral Column Resection Technique (VCR) Forever Changed the Approach to the Treatment of Severe Spinal Deformities in Children Over the Past Decade?	*Lawrence G. Lenke, MD*
1:30 - 1:40pm	Discussion	

1:40 - 2:00pm	Debate and Case Discussion: Has Pedicle Screw Instrumentation and VCR Replaced the Need for Multi-Stage Surgery for the Treatment of Severe Pediatric Spinal Deformity?	*Moderator: Daniel J. Sucato, MD, MS* *Panel: B. Stephens Richards, III, MD; Lawrence G. Lenke, MD; Richard E. McCarthy, MD; Firoz Miyanji, MD, FRCSC; Mark A. Erickson, MD*
2:00 - 2:05pm	Audience Response Questions	
2:05 - 2:15pm	Break	
2:15 - 4:30pm	A Review of a Decade of Change in Adult Deformity Moderators: Steven D. Glassman, MD; Joseph H. Perra, MD	
2:15 - 2:30pm	Has the Incorporation of Evidence Based Medicine Over the Past Decade Changed How We Treat Spinal Disease and Deformity?	*Sigurd H. Berven, MD*
2:30 - 2:45pm	Has the Problem of Adjacent Segment Complications Above and Below a Fusion for Degenerative Deformity Been Solved Over the Past Decade?	*Christopher I. Shaffrey, MD*
2:45 - 3:00pm	After a Decade of Use, Which of the Posterior Osteotomy Techniques has Proven Effective in Restoring Sagittal Balance at an Acceptable Complication Rate?	*Tyler R. Koski, MD*
3:00 - 3:15pm	What is the Likely Outcome of a Long Fusion to the Sacrum Now and Are the Current Techniques More Effective Than 10 Years Ago?	*Keith H. Bridwell, MD*
3:15 - 3:40pm	Debate and Case Discussion: Is Change Really Progress in the Treatment of Adult Spinal Deformity?	*Moderator: Joseph H. Perra, MD* *Panel: Sigurd H. Berven, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Alpesh A. Patel, MD*
3:40 - 3:50pm	After 10 Years of Evolution, Which Bone Graft Substitutes Have Shown Effectiveness in Spinal Fusions?	*Mark B. Dekutoski, MD*
3:50 - 4:05pm	What Are the Current Blood Replacement Strategies in 2012: What is the Role of Blood Auto-Donation, Cell Saver and Pharmacological Blood Loss Techniques?	*Charles H. Crawford, MD*
4:05 - 4:25pm	Discussion	
4:25 - 4:30pm	Audience Response Questions	

TECHNICAL ADVANCES IN ADULT & PEDIATRIC ILIOLUMBAR FIXATION IN DEFORMITY SURGERY: A TEN YEAR RETROSPECTIVE REVIEW

Moderators:
Chistopher I. Shaffrey, MD; John R. Dimar, II, MD

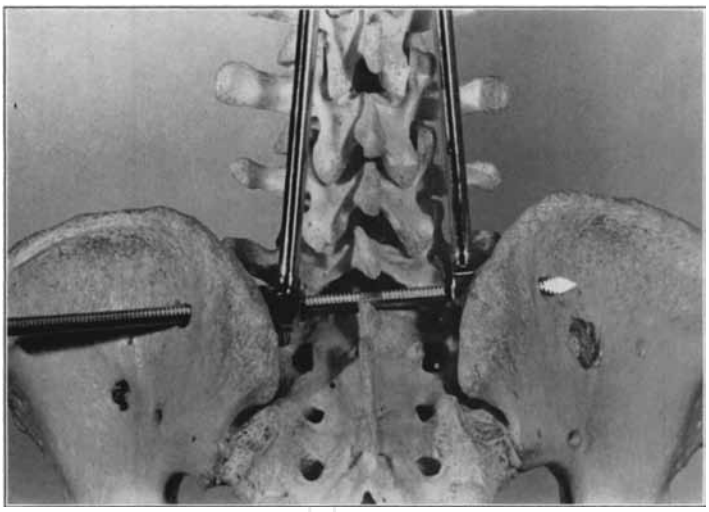
Faculty:
Nathan H. Lebwohl, MD; Paul D. Sponseller, MD; Hubert Labelle, MD; Frank J. Schwab, MD; Jean A. Ouellet, MD, FRCS; Keith H. Bridwell, MD; Mark Weidenbaum, MD; Ronald A. Lehman, MD; Serena S. Hu, MD

HISTORICAL PERSPECTIVE ON LUMBO-PELVIC FIXATION: AN ANNOTATED BIBLIOGRAPHY

Nathan Lebwohl, MD
Chief, Spinal Deformity Surgery
University of Miami
Miller School of Medicine
Miami, Florida, USA

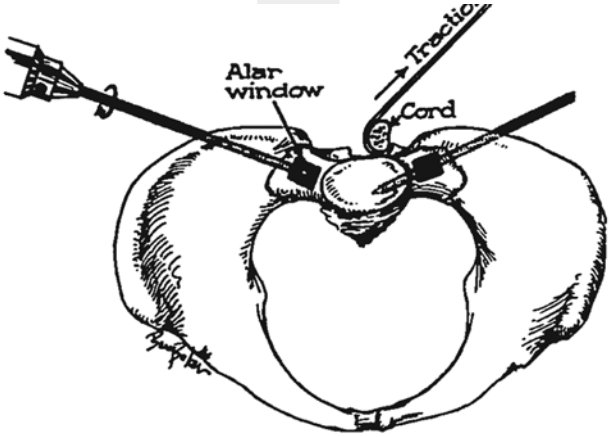
1) Harrington, P.R. Treatment of Scoliosis, Correction and Internal Fixation by Spine Instrumentation. JBJS 44a:591-610, 1962.

Paul Harrington's classic initial description of his technique for treatment of scoliosis included a photograph and brief description of the sacral bar (trans-iliac bar.) This is the first reported method for extending fixation to the lumbopelvis.



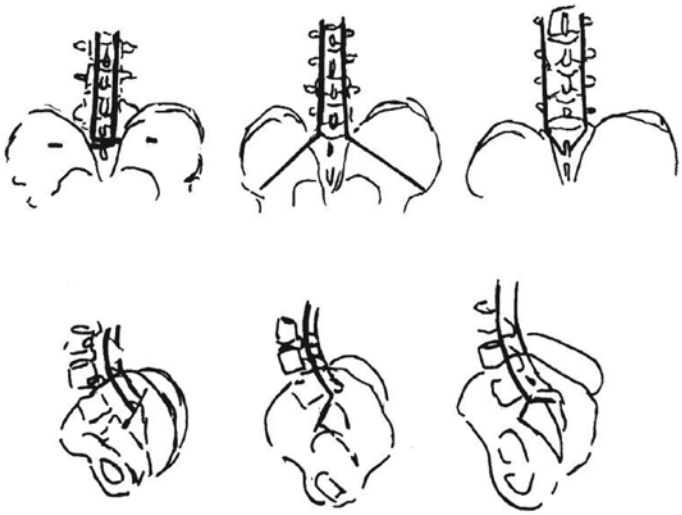
2) Harrington, P.R. and Tullos, H.S. Spondylolisthesis in Children, Observations and Surgical Treatment. CORR 79:75-84, 1971.

In addition to having the distinction of being the first to document the use of pedicle screws in the United States, this article describes the placement of an iliosacral anchor for sacral fixation.



3) Luque, E.R. Segmental Spinal Instrumentation of the Lumbar Spine. CORR 203: 126-134, 1986.

In this article Dr. Luque reviews his experience with three methods of rod fixation to the pelvis using his instrumentation system. A preference for not crossing the SI joint is stated, when no coronal deformity is present, due to problems with fixation across an unfused joint, and associated pain.



4) Allen, B.L. and Ferguson, R.L. The Galveston Technique for L Rod Instrumentation of the Scoliotic Spine. Spine 7: 276- 284, 1982.

Classic description of Galveston technique of smooth rod intrailiac fixation.

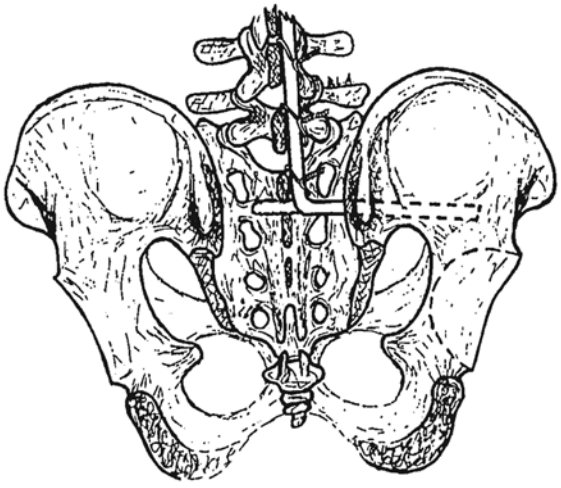
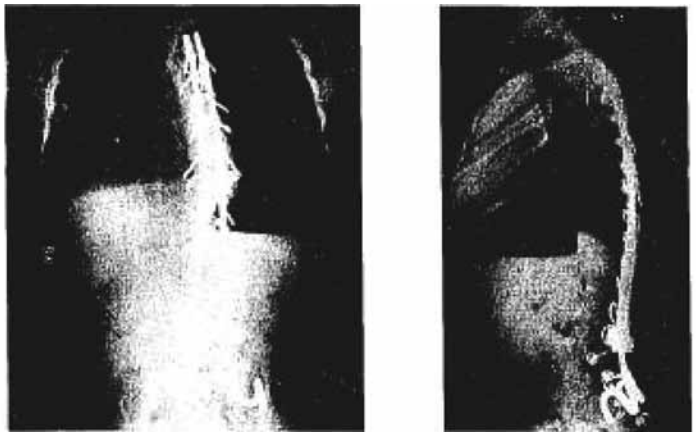


Fig 4. Proper position for pelvic fixation. Dotted portion of rod lies intraosseously along transverse bar of ilium, sacral portion passes from adjacent to SI joint at PSIS to point between first and second sacral spinous processes at which rod is directed cephalad. Note development and wiring of first sacral lamina. Spinal portion of rod is positioned as for routine technique.

5) McCarthy, R.E., Dunn, H., and McCollough, F.L., Luque Fixation to the Sacral Ala using the Dunn-McCarthy Modification. Spine 14: 281- 283, 1989.

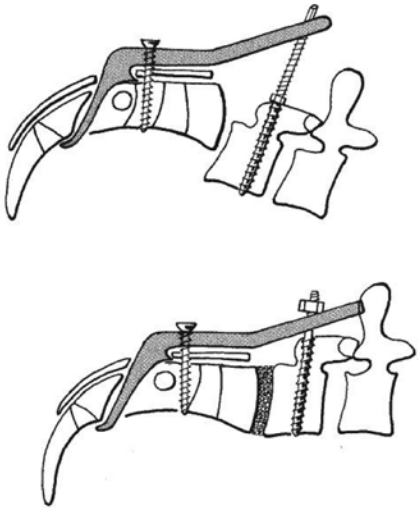
Review of initial experience of sacral fixation technique in 24 patients with neuromuscuar disease. The rod is contoured pre-operatively, based on radiographic

measurements, to engage the sacral ala. The technique can be used when the ilium is deficient due to hypoplasia or prior surgery.



6) Schollner,D. One Stage Reduction and Fusion for Spondylolisthesis. International Orthopaedics 14: 145-150, 1990.

In this paper, Dr. Schollner reviews his technique for plate fixation of the sacrum with distal fixation in the S2 foramen, providing a lever arm to resist lumbar flexion. A 27 year experience with 51 cases is reviewed.



7) Boachie-Adjei O, et al.: Management of Adult Spinal Deformity with Combined Anterior-Posterior Arthrodesis and Luque-Galveston Instrumentation. J Spinal Disorders 4:131-141, 1991.

A series of 25 patients with adult scoliosis is reported. In spite of adding anterior fusion and posterior Luque Galveston instrumentation, a 41% rate of pseudoarthrosis was found.

8) Camp JF et al. Immediate Complications of Cotrel-Dubousset Instrumentation to the Sacro-Pelvis. Spine Vol. 15, No. 9, pp. 932-41, 1990.

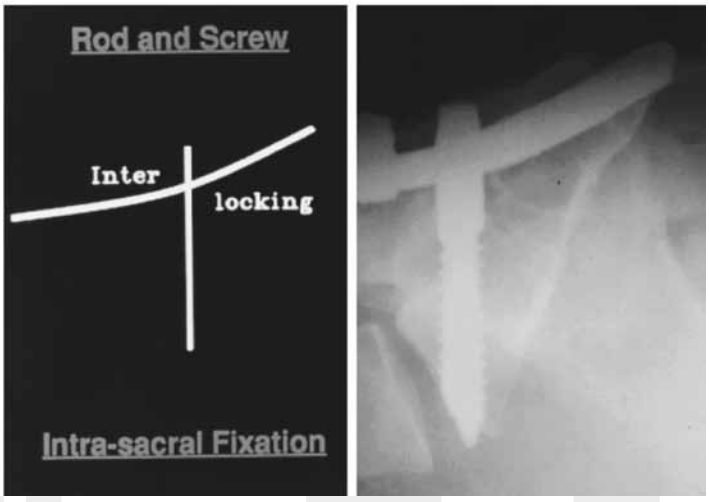
7/16 patients instrumented to the sacrum with divergent sacral screws had early hardware failure. 2/7 patients instrumented with iliosacral screws failed. No patient with Luque Galveston instrumentation had hardware failure.

9) Miladi, LT et al. Iliosacral Screw Fixation for Pelvic Obliquity in Neuromuscular Scoliosis, A Long-Term Follow-Up Study. Spine 22:1722 – 1729, 1997.

The authors review a 13 year experience in 154 patients with iliosacral screw fixation. The evolution of the CD instrumentation for this mode of fixation is reviewed.

10) Jackson RP and McManus AC. The Iliac Buttress. A Computed Tomographic Study of Sacral Anatomy. Spine 18: 1318 - 1328, 1993.

The intrasacral rod position is described along with its theoretical mechanical benefits. The concept of the iliac buttress is described, along with CT validation.



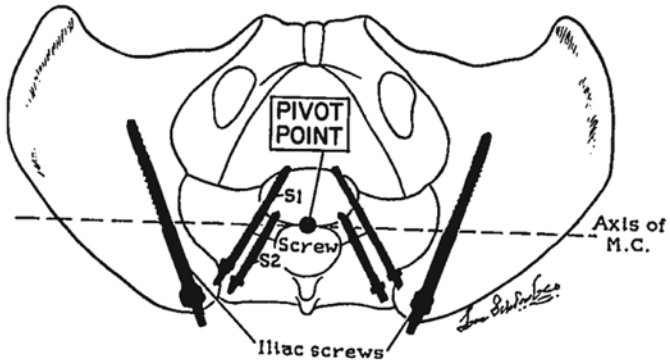
11) Kostuik, JP and Musha, Y, Extension to the Sacrum of Previous Adolescent Scoliosis Fusions in Adult Life, CORR 364: 53 – 60, 1999

The senior author describes a 21 year experience and the evolution of his technique. He advocates an anterior L5S1 transfixion screw and a transiliac bar supplementing sacral screw fixation.

12) McCord DH, et al. Biomechanical Analysis of Lumbosacral Fixation. Spine, 17: S235-S243, 1992.

In a calf spine model with load to failure testing, iliac fixation was superior to any sacral construct. The concept of a lumbosacral pivot point is

introduced. This point is located at the posterior junction of the lumbosacral disk and S1 vertebral body. The iliac fixation must extend anterior to the lumbosacral pivot point.



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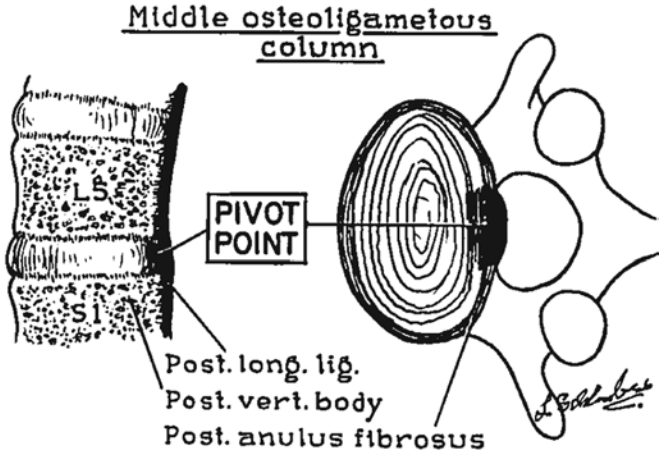

C

Notes

PEDIATRIC NEUROMUSCULAR SCOLIOSIS: HAVE SURGICAL TECHNIQUES & IMPLANTS CHANGED SURGICAL OUTCOMES?

Paul D. Sponseller, MD
Johns Hopkins University
Baltimore, Maryland, USA

1. Background
   - What has changed?
   - Decision-making
     - Benefits of PSF for CP
     - Less surgery for DMD
     - Growth-guided implants- good for SMA, ? for CP, MM
     - VEPTR for Myelokyphectomy
   - Non-Pelvic Improvements:
     - Infection prevention
     - Antifibrinolytics
2. Common Surgical Diagnoses
   - CP
   - Rett
   - Myelomeningocele
   - DMD
   - SMA, congenital myopathies
   - Friedreich
   - Spinal cord injury
   - "Unspecified" NM disorders
3. Evolution of Spino-Pelvic Fixation
   - Harrington hooks, screw
   - Galveston Rods
   - Unit rod
   - McCarthy S-Hook
   - Iliac screw
   - Jackson Technique
   - Kostuik Bar
   - Iliosacral/MW screw
   - SAI fixation
4. Goals of Iliolumbar Fixation
   - Balanced Sitting
     - Stable, enduring
   - Prevent pressure breakdown
   - Improve / prevent pain
   - reserve mobility to accomplish ADLs
     - Cath
     - Transfer
     - Rolling
     - Ambulation
   - Preserve self-image
   - Indications for surgery are further refined based upon
     - Ability to manage with brace, wheelchair
     - Self–image

Pulmonary picture
Comorbidities

It is now easier to incorporate pelvis in fusion
T2-pelvis = best deformity control
Sparing levels = adding on later!!

5. Biomechanics
Long iliac anchors projecting anterior to sacral pivot & laterally
Biomechanically strongest
Most important with Pelvic Obliquity

6. Anatomy –New knowledge: Transverse-plane pelvic asymmetry in Early-Onset NM patients
Mean 10 degrees difference
More in "windswept" patients
May affect iliac fixation
May affect apparent symmetry

7. Treatment
Posterior vs AP approach
Combined approach for NM deformity "routine" in '80's & 90's
Lonstein, Bradford, Winter
New osteotomies, fixation change everything!
Current Harms prospective CP study:
15% A&P;
mostly among larger curves (105° vs 76°)
AP Approach still preferred for:
Severe lordosis or lordoscoliosis
Especially in lumbar spine
Some Curves >90°

8. Correction Mechanics
Cantilever
Compression/distraction/derotation
More complex when major curve requires different measures
Or when very proximal, kyphotic

9. Complications

Pseudoarthrosis
Adequate distal fixation
At least 2 pairs of anchors distal to L4
Appropriate fixation in osteopenia
Adequate posterior elements?
Role of anterior fusion not routine; mainly revisions, adults

Prominence, breakdown
Use low profile implant
Adequate muscle coverage

Back-out:
Smooth rods inadequate in lumbar kyphosis
Difficult to place in hyperlordosis

Lucency
Due to inadequate fixation
Rods may not be fully in ilium

Pelvic Obliquity
Difficult to assess intra-operatively
Correction of curve may exceed pelvic obliquity
Galveston rod ensures this
Use T-square

"Crankshaft"
Rare with modern pelvic fixation and segmental spine fixation
Implants can tether growth

Effects on Gait
No detriment in CP gait studies- Miller
May affect those with weak glutei who walk without aids

10. Growth-friendly Fixation
Iliac screws best for pelvic obliquity
"sloppy fixation" (S-hooks) – best with lateral fixation – more moment

References

Lonstein JE, Akbarnia A: Operative treatment of spinal deformities in patients with cerebral palsy or mental retardation: An analysis of one hundred and seven cases. J Bone Joint Surg Am 983;65(1):43-55.

Miller A, Temple T, Miller F: Impact of orthoses on the rate of scoliosis progression in children with cerebral palsy. J Pediatr Orthop 1996;16(3):332-335.

Yazici M, Asher MA, Hardacker JW: The safety and efficacy of Isola-Galveston instrumentation and arthrodesis in the treatment of neuromuscular spinal deformities. J Bone Joint Surg Am 2000;82(4):524-543.

Benson ER, Thomson JD, Smith BG, Banta JV: Results and morbidity in a consecutive series of patients undergoing spinal fusion for neuromuscular scoliosis. Spine 1998;23(21):2308-2318.

Kalen V, Conklin MM, Sherman FC: Untreated scoliosis in severe cerebral palsy. J Pediatr Orthop 1992;12(3):337-340.

Cassidy C, Craig CL, Perry A, Karlin LI, Goldberg MJ: A reassessment of spinal stabilization in severe cerebral palsy. J Pediatr Orthop 1994;14(6):731-739.

Thomson JD, Banta JV: Scoliosis in cerebral palsy: An overview and recent results. J Pediatr Orthop B 2001; 10(1):6-9.

Watanabe K, Lenke LG, Daubs MD, et al : Is spine deformity surgery in patients with spastic cerebral palsy truly beneficial? A patient/parent evaluation. Spine 2009;34(20):2222-2232. Eighty-four patients and families of patients with cerebral palsy completed a questionnaire at an average 6 years after spine fusion. High satisfaction was reported for sitting balance (93%), cosmesis (94%), and patient quality of life (71%). Lower satisfaction was correlated with late complications, less correction of deformity, and hyperlordosis of the lumbar spine.

Jevsevar DS, Karlin LI: The relationship between preoperative nutritional status and complications after an operation for scoliosis in patients who have cerebral palsy.J Bone Joint Surg Am 1993;75(6):880-884.

McCarthy RE, Bruffett WL, McCullough FL: S rod fixation to the sacrum in patients with neuromuscular spinal deformities. Clin Orthop Relat Res 1999;364(364):26-31.

Boachie-Adjei O, Lonstein JE, Winter RB, Koop S, vanden Brink K, Denis F: Management of neuromuscular spinal deformities with Luque segmental instrumentation. J Bone Joint Surg Am 1989;71(4):548-562.

Auerbach JD, Spiegel DA, Zgonis MH, et al : The correctionof pelvic obliquity in patients with cerebral palsy and neuromuscular scoliosis: Is there a benefit of anterior release prior to posterior spinal arthrodesis? Spine 2009;34(21):E766-E774. Sixty-one patients with neuromuscular scoliosis had eitheranteroposterior or posterior-only fusion with a unit rod. The final results were comparable for curve correction and pelvic obliquity. The children with anteroposterior fusion had a larger, stiffer curve.

Shufflebarger HL, Grimm JO, Bui V, Thomson JD: Anterior and posterior spinal fusion: Staged versus sameday surgery. Spine 1991;16(8):930-933.

Banta JV: Combined anterior and posterior fusion for spinal deformity in myelomeningocele. Spine 1976) 1990;15(9):946-952.

O'Brien T, Akmakjian J, Ogin G, Eilert R: Comparison of one-stage versus two-stage A/P spinal fusion for neuromuscular scoliosis. J Pediatr Orthop 1992;12(5):610-615.

Sarwahi V, Sarwark JF, Schafer MF, et al : Standards in anterior spine surgery in pediatric patients with neuromuscular scoliosis. J Pediatr Orthop 2001;21(6):756-760.

Takeshita K, Lenke LG, Bridwell KH, Kim YJ, Sides B, Hensley M: Analysis of patients with nonambulatory neuromuscular scoliosis surgically treated to the pelvis with intraoperative halo-femoral traction. Spine 2006;31(20):2381-2385. In a retrospective review, 20 of 40 patients with neuromuscular scoliosis and pelvic obliquity had intraoperative halo-femoral traction. The selection criteria were not controlled. A larger correction of the lumbar curve and a greater correction of the pelvic obliquity were found in the patients with halo-femoral traction.

Whitaker C, Burton DC, Asher M: Treatment of selected NM patients with posterior instrumentation and arthrodesis ending with lumbar pedicle screw anchorage. Spine 2000;25(18):2312-2318.

Shapiro F, Zurakowski D, Sethna NF: Tranexamic acid diminishes intraoperative blood loss and transfusion in spinal fusions for DMD scoliosis.Spine 2007;32(20):2278-2283. 56 patients with DMDwere evaluated for blood loss during spine fusion.36 patients did not receive tranexamic acid, and 20 did. The mean blood loss for the patients receiving tranexamic acid was 1,944 mL; mean blood loss for the other patients was 3,382 mL.

Modi HN, Hong JY, Mehta SS, et al : Surgical correction and fusion using posterior-only pedicle screw construct for neuropathic scoliosis in patients with CP: A three-year follow-up study. Spine 2009;34(11):1167-1175. The average curve correction was 56% and the average pelvic obliquity was 43% in patients with cerebral palsy. The overall rate of complications was 32%, of which most were pulmonary.

Allen BL Jr , Ferguson RL: L-rod instrumentation for scoliosis in cerebral palsy. J Pediatr Orthop 1982;2(1):87-96.

Chang TL, Sponseller PD, Kebaish KM, Fishman EK:Low profile pelvic fixation: Anatomic parameters for sacral alar-iliac fixation versus traditional iliac fixation.Spine 2009;34(5):436-440. A method is described for inserting long iliac screws through a sacral starting point that is deep under a midline muscle flap and in line with other spinal anchors

Lipton GE, Miller F, Dabney KW, Altiok H, Bachrach SJ: Factors predicting postoperative complications following spinal fusions in children with CP. J Spinal Disord 1999;12(3):197-205.

Yazici M, Asher MA: Freeze-dried allograft for PSF in patients with neuromuscular spinal deformities. Spine 1997;22(13):1467-1471.

Sponseller PD, LaPorte DM, Hungerford MW, Eck K,Bridwell KH, Lenke LG: Deep wound infections after neuromuscular scoliosis surgery: A multicenter study of risk factors and treatment outcomes. Spine2000;25(19):2461-2466.

Hatlen T, Song K, Shurtleff D, Duguay S: Contributory factors to postoperative spinal fusion complications for children with myelomeningocele. Spine 2010;35(13):1294-1299.

Sponseller PD, Shah SA, Abel MF, Newton PO, Letko L, Marks M: Infection rate after spine surgery in CP is high and impairs results. Clin Orthop Relat Res 2010;468(3):711-716.

Jones KB, Sponseller PD, Shindle MK, McCarthy ML:Longitudinal parental perceptions of spinal fusion for NM Spine deformity in patients with totally involved CP. J Pediatr Orthop 2003;23(2):143-149.

NOTES

HIGH GRADE SPONDYLOLISTHESIS: HAS IMPROVED ILIOLUMBAR FIXATION IMPROVED FUSION SUCCESS & OUTCOMES?

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Intro

This is a difficult question to answer since there is no level I or II evidence available in the literature on this topic, only multiple retrospective case series with sometimes conflicting results. Therefore, the surgical management of high-grade spondylolisthesis (HGS) remains controversial and we are unfortunately still limited to expert opinions on this question. In 2007, Transfeldt and Mehbod[1] reviewed the available literature in an attempt to formulate evidence-based recommendations for the surgical treatment of HGS in the pediatric population. Through an electronic database search and published literature cross-reference, appropriate studies were identified and assigned the appropriate level of evidence. They found no level I or II evidence, the best evidence being 5 retrospective comparative studies comparing fusion in situ to reduction and fusion. Pseudarthrosis rates were decreased by performing an instrumented reduction with a fusion. However, there was no significant difference in a clinical outcome of patients treated in situ versus reduction. They were thus not able to formulate clear guidelines for treatment of HGS based on the best evidence available in the published literature. A review of the literature since then tells us that this conclusion is still valid and that more evidence is needed before a definite answer can be given.

Therefore, the 2 old debates: "To reduce or not to reduce?" and "To instrument or not to instrument?" are still hot topics for HGS and the following discussion should be considered as my "expert" opinion on this subject based on a literature review and on my past experience as Chair of the Spondylo section of the Spinal Deformity Study Group over the past decade.

Has anything changed in the last decade?

The situation a decade ago could be summarized as follows: many retrospective studies supported in situ fusion as the gold standard of treatment, with goods result in most cases, but there was also evidence of cases with inadequate outcome and continued progression with pseudarthrosis rates up to 50% in some series. On the other hand, many different techniques of surgical correction & instrumentation had been reported and recommended, with fairly high rates of associated complications, including instrument failures and neurologic deficits in up to 30% of patients.

What has changed since then? First, there has been an improved understanding of sagittal spino-pelvic balance in normal and pathological conditions: this has fostered a renewed interest and rationale for reduction in HGS when sagittal balance is compromised, therefore requiring the use of instrumentation coupled to fusion, and shifting the pendulum towards instrumentation, reduction and 360º fusion for HGS. Second, there has been a more generalized use of pedicle screws, a more liberal use of TLIF and PLIF with cages, especially in the pediatric orthopedic community, and there have been improvements in spino-pelvic methods of fixation with iliac screws, iliosacral screws, lumbo-sacral or trans-sacral screws, etc. All these new techniques coupled to new methods of L5-S1 reduction have also shifted the pendulum towards instrumentation, reduction and 360º fusion for HGS. What is the evidence that this shift has improved outcomes? Let's examine the question with respect to the 2 old debates.

To reduce or not to reduce?

After a successful Pre-Meeting Course on spondylolisthesis at the Scoliosis Research Society's 36th Annual Meeting in Quebec City, the SRS published a focus issue of *Spine* in 2005 on this topic. The summary statement[2] made the following observations:

"Global sagittal plane alignment is important in both adult and pediatric patients with spondylolisthesis. In patients with high-grade developmental spondylolisthesis, this has provided a compelling rationale to reduce and realign the spondylolisthesis deformity, thus restoring global spinal balance and improving the biomechanical environment for fusion. Decisions on whether to perform a reduction should be individualized and should take into consideration the extent and location of neural compression, sagittal balance, and posterior element dysplasia. In particular, reduction should be given strong consideration in pediatric patients with high-grade developmental spondylolisthesis and significant lumbosacral kyphosis. Circumferential fusion with instrumentation is recommended when a reduction is performed."

Indeed, one of the most significant changes in HGS over the past decade has been our better understanding of sagittal spino-pelvic alignment and in particular of pelvic shape and morphology, which have been shown to significantly influence spino-pelvic balance of the human trunk in normal and pathological conditions. This finding has important implications for the evaluation and treatment of HGS and has fostered a renewed interest in the radiologic evaluation of spino-pelvic balance in this condition. Pelvic morphology is best measured with pelvic incidence (PI), an angle introduced by Duval-Beaupère et al[3] and defined as the angle between the line perpendicular to the upper sacral end plate and the line joining the middle of the upper sacral end plate and the hip axis (Fig. 1). In contrast to PI, the **pelvic tilt (PT)** and **sacral slope (SS)** measure the orientation of the sacro-pelvis in the sagittal plane. SS is defined as the angle between the sacral end plate and the horizontal line, whereas PT is defined as the angle between the vertical line and the line joining the middle of the sacral end plate and the hip axis (Fig. 2).

The pelvic shape determines the position of the sacral endplate. The spine reacts to this position by adapting through lumbar lordosis, the amount of lordosis increasing as the sacral slope increases in order to balance the trunk in the upright position. Pelvic incidence, sacral slope, pelvic tilt, and lumbar lordosis are found to be significantly greater in subjects with HGS, while thoracic kyphosis is significantly lower when compared to a reference population. Furthermore, the differences between the two populations increase in a direct linear fashion as the severity of the spondylolisthesis increases, suggesting that pelvic anatomy is intimately linked to the development of HGS[4]. Hresko et al[5] identified two subgroups of patients: balanced versus unbalanced pelvis (Fig. 3). The "balanced" group includes patients standing with a high SS and a low PT, a posture similar to normal individuals with high PI, whereas the "unbalanced" group includes patients standing with a retroverted pelvis and a vertical sacrum, corresponding to a low SS and a high PT. In HGS, sacro-pelvic morphology is thus abnormal and, combined with the presence of a local lumbosacral deformity and dysplasia, it can result in an abnormal sacro-pelvic orientation and a disturbed global balance.

Recently, the Spinal Deformity Study Group has proposed a classification system[6] of HGS (Fig. 3), based on spino-pelvic alignment: three types are found. Each subject is first classified as having a balanced or an unbalanced sacro-pelvis using PI and SS values and the nomogram provided by Hresko et al5. When SS > PT and values are located above the threshold line, the subject is classified as high SS/low PT. On the other hand, when SS < PT and values are located below the threshold line, the subject is classified as low SS/high PT. Next, spino-pelvic balance is determined using the C7 plumb line. If this line falls over or behind the femoral heads, the spine is balanced, while if it lies in front of the femoral heads, the spine is unbalanced.

While the need for reduction in the surgical treatment of spondylolisthesis is still debated, five recent studies provide some insight for the decision-making process. In a recent literature review, Agabegi and Fischgrund[7] concluded that the need for reduction is controversial and is mostly indicated for patients with significant lumbosacral kyphosis and sagittal imbalance. Hresko et al[5] stated that the failure to analyze sacro-pelvic balance and therefore to distinguish between a balanced and an unbalanced sacro-pelvis could account for the variability found in the past literature regarding the outcome of reduction for HGS. Accordingly, they suggest that reduction techniques might preferably be considered in types 5 and 6 with an unbalanced sacro-pelvis. Mac-Thiong et al[8] also suggested attempting reduction of HGS in types 5 and 6 with an unbalanced sacro-pelvis since these patients present with an abnormal spino-pelvic balance, as compared to the normal population. In a retrospective multi-center study analysis of spino-pelvic alignment after surgical instrumentation and correction of 73 subjects with high grade slips, Labelle et al[9] have shown that while sacro-pelvic shape (PI) is unaffected by attempts at surgical reduction, proper repositioning of L5 over S1 significantly improves sacro-pelvic balance and the shape of the lumbar spine in HGS. Their results also emphasize the importance of subdividing subjects with HGS into types 4, 5 and 6, and further support the contention that reduction techniques might preferably be considered for types 5 and 6 of the classification. More recently, Martiniani et al[10] concluded, in a retrospective study of 16 HGS, that the analysis of the spino-pelvic sagittal balance allows to identify two types of HGS: the balanced deformities, which do not need reduction, and the unbalanced deformities, in which correction is needed.

In summary, the proposed classification[6] emphasizes that subjects with L5-S1 HGS are a heterogeneous group with various adaptations of their posture and that clinicians

need to keep this fact in mind for evaluation and treatment (Figure 4). Although level I and II outcome studies are needed before a definitive treatment algorithm can be established for each subtype, it is suggested that for subjects with a type 4 spino-pelvic alignment, forceful attempts at reduction of the deformity may not be required and that simple instrumentation and fusion after postural reduction may be sufficient to maintain adequate sagittal alignment. For subjects with type 5 posture, reduction and realignment procedures should preferably be attempted, but in cases with minimal lumbo-sacral kyphosis, instrumentation and fusion after postural reduction may also be sufficient to achieve adequate sagittal alignment, since spinal alignment is maintained. Reduction and realignment procedures would appear mandatory in type 6 deformities where sagittal alignment is severely disturbed.

To instrument or not to instrument?

A review of the literature indicates that almost all articles on HGS published in the past decade report on instrumentation ± reduction of HGS. The only reports discussing in situ fusion without instrumentation come from one institution[11] and are long term results of cases done prior to this

decade, thus indicating a clear shift of the balance towards instrumentation in HGS over the past decade. Many articles support the contention that a 360° fusion is superior to posterolateral fusion in HGS, with a decreased incidence of pseudarthrosis[11,12,13,19]. In their recent literature review on spondylolisthesis, Agabegi and Fischgrund7 concluded that achieving a circumferential fusion is associated with a higher fusion rate and has become more common, especially with high-grade slips, leading to improved functional outcomes and reduction in pain. There is also evidence that the use of L5-S1 pedicle screws coupled to TLIF/PLIF with anterior L5-S1 support provide satisfactory results with solid fusion, as demonstrated by the cases series of Harms[14] and Shufflebarger[15], although isolated cases of S1-S2 stress fractures have been reported with this mono-segmental approach.

To avoid this complication and to improve fusion rates and outcomes, posterior spino-pelvic fixation coupled to L5-S1 anterior support by PLIF/TLIF and circumferential fusion has been recommended by most authors[13,16,17,18,19,29,30].

A variety of techniques for achieving reduction and/or fusion and to decrease the risk of neurological complications have been recommended, including Magerl's external fixator[19], sacral dome resection[20], transsacral graft[21], transdiscal screws[22], dowel fibular strut grafts[23], Ilizarov external fixation[27] and Jackson's intrasacral fixation[28].

Various modes of fixation have also been recommended to achieve fusion and or maintain reduction, including iliac screws[13], custom-made canulated screws[24], ilio-sacral screws[25], transsacral strut grafting[26], and transsacral screws[16].

SRS morbidity reports[32,33] still demonstrate a fairly high number of complications after instrumentation ± reduction in HGS. In cases done in 200732, the occurrence of new neurological deficit after surgery was the most common complication, seen in 11.5% of patients. Performance of an osteotomy was associated with a higher incidence of new neurological deficits in both adult and pediatric groups. Although most of the new neurological deficits improved over follow-up, 10% had no improvement. In the 10,242 cases reported[33], there were 945 complications (9.2%) in 813 patients (7.9%).

Conclusions:

Over the past decade, the pendulum has clearly shifted towards instrumentation, reduction/partial reduction & circumferential fusion in HGS. The indications for reduction have been more clearly defined based on an improved understanding of sagittal spino-pelvic balance, the need for a 360° fusion has been demonstrated and lumbo-sacro-iliac instrumentation techniques have become more popular. The majority of the procedures are done through a posterior approach. These new practice changes have gradually replaced the gold standard of postero-lateral in situ fusion without instrumentation for HGS. Unfortunately, although there is ample level IV evidence to support these new trends and changes, there is still no level I or II evidence to support this evolution in spine deformity management for HGS.

Figure 1

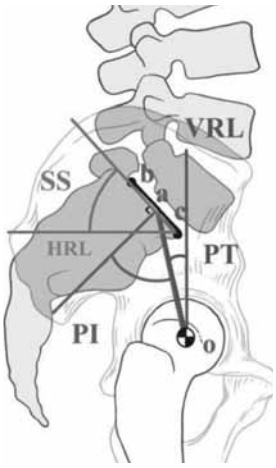


Figure 2

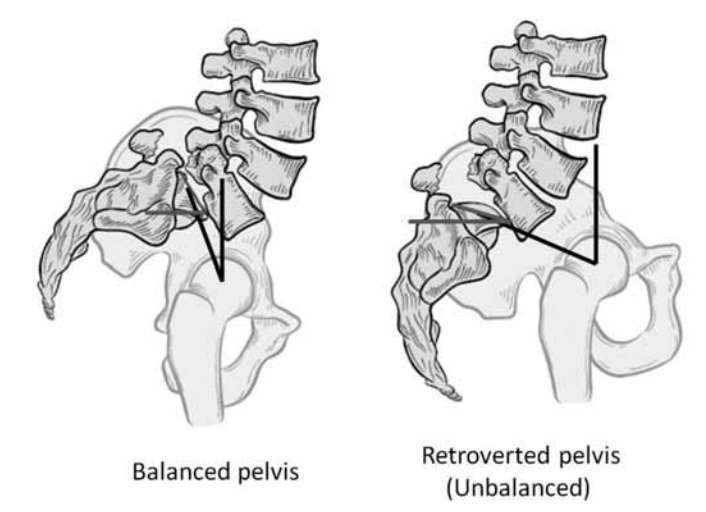


Figure 3

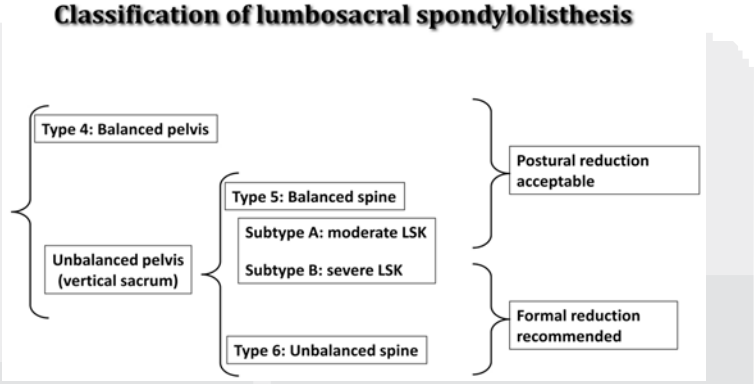
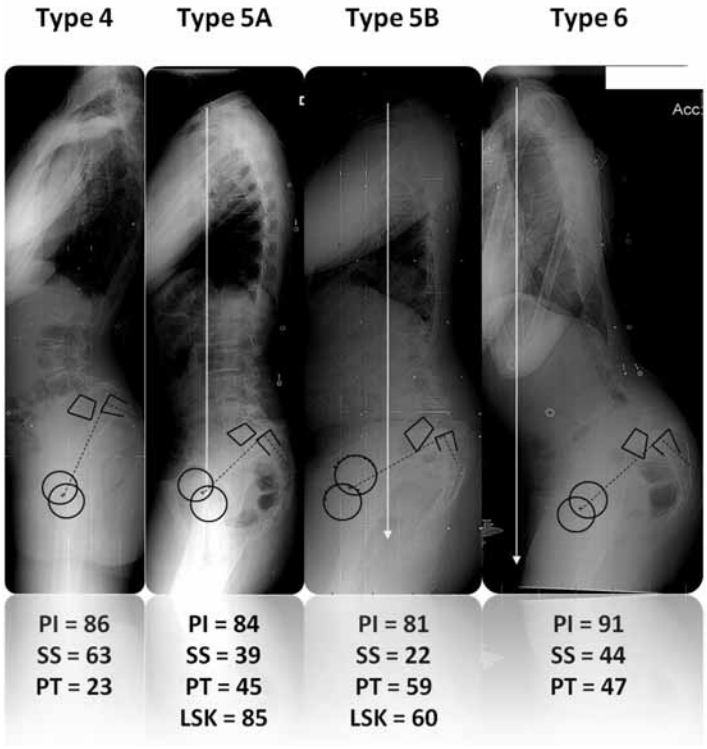


Figure 4



References:

1. Transfeldt EE, Mehbod AA, Evidence-based medicine analysis of isthmic spondylolisthesis treatment including reduction versus fusion in situ for high-grade slips. Spine (Phila Pa 1976). 2007 Sep 1;32(19 Suppl):S126-9.
2. Mardjetko S, Albert T, Andersson G, Bridwell K, DeWald C, Gaines R, Geck M, Hammerberg K, Herkowitz H, Kwon B, Labelle H, Lubicky J, McAfee P, Ogilvie J, Shufflebarger H, Whitesides T. Spine/SRS Spondylolisthesis Summary Statement. Spine 2005, 30(6 Suppl):S3
3. Legaye J, Duval-Beaupère G, Hecquet J, et al. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 1998;7:99-103
4. Labelle H, Roussouly P, Berthonnaud E, et al. The importance of spinopelvic balance in L5–S1 developmental spondylolisthesis: a review of pertinent radiologic measurements. Spine 2005; 30(suppl): 27–34.
5. Hresko MT, Labelle H, Roussouly P, Berthonnaud E. Classification of High Grade Spondylolistheses Based on Pelvic Version and Spinal Balance: Possible Rationale for Reduction. Spine, 2007, 32(20):2208–2213
6. Labelle H, Mac-Thiong JM, Roussouly P. Spino-pelvic sagittal balance of spondylolisthesis: a review and classification. Eur Spine J. 2011 Sep; 20(5):641-6.
7. Agabegi SS, Fischgrund JS. Contemporary management of isthmic spondylolisthesis: pediatric and adult. Spine J. 2010 Jun;10(6):530-43. Epub 2010 Apr 8.
8. Mac-Thiong JM, Labelle H, Wang Z, de Guise JA, Postural model of sagittal spino-pelvic balance and its relevance for lumbosacral developmental spondylolisthesis. Spine, 2008 33(21):2316–2325
9. Labelle H, Roussouly P, Chopin D, Berthonnaud E, Hresko T, O'Brien M. Spino-pelvic alignment after surgical correction for developmental spondylolisthesis, Eur Spine J, 2008 17:1170–1176
10. Martiniani M, Lamartina C, Specchia N. "In situ" fusion or reduction in high-grade high dysplastic developmental spondylolisthesis (HDSS). Eur Spine J. 2012 May;21 Suppl 1:S134-40. Epub 2012 Mar 14.
11. Helenius I, Remes V, Poussa M, Uninstrumented in situ fusion for high-grade childhood and adolescent isthmic spondylolisthesis: long-term outcome. Surgical technique , J Bone Joint Surg Am. 2008 Mar;90 Suppl 2 Pt 1:145-52.
12. Laursen M, Thomsen K, Eiskjaer SP, Hansen ES, Bünger CE.J, Functional outcome after partial reduction and 360 degree fusion in grade III-V spondylolisthesis in adolescent and adult patients. Spinal Disord. 1999 Aug;12(4):300-6.
13. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C, Minimum 5-year analysis of L5-S1 fusion using sacropelvic fixation for spinal deformity. Spine. 2006;31(3):303-8.
14. Ruf M, Koch H, Melcher RP, Harms J, Anatomic reduction and monosegmental fusion in high-grade developmental spondylolisthesis. Spine. 2006 Feb 1;31(3):269-74.
15. Shufflebarger HL, Geck MJ. High-grade isthmic dysplastic spondylolisthesis: monosegmental surgical treatment. Spine (Phila Pa 1976). 2005 30(6 Suppl):S42-8.
16. Lakshmanan P, Ahuja S, Lewis M et al. Transsacral screw fixation for high-grade spondylolisthesis, Spine J. 2009 Dec;9(12):1024-9.
17. Goyal N, Wimberley DW, Hyatt A, Zeiller S, Vaccaro AR, Hilibrand AS, Albert TJ. Radiographic and clinical outcomes after instrumented reduction and transforaminal lumbar interbody fusion of mid and high-grade isthmic spondylolisthesis. J Spinal Disord Tech. 2009 Jul;22(5):321-7.
18. Rodriguez-Olaverri JC et al. Comparing the clinical and radiological outcomes of pedicular transvertebral screw fixation of the lumbosacral spine in spondylolisthesis versus unilateral transforaminal lumbar interbody fusion (TLIF) with posterior fixation using anterior cages. Spine, 2008 Aug 15;33(18):1977-81.
19. Karampalis C, Grevitt M, Shafafy M, Webb J. High-grade spondylolisthesis: gradual reduction using Magerl's external fixator followed by circumferential fusion technique and long-term results. Eur Spine J. 2012 May;21 Suppl 2:S200-6.
20. Min K, Liebscher T, Rothenfluh D. Sacral dome resection and single-stage posterior reduction in the treatment of high-grade high dysplastic spondylolisthesis in adolescents and young adults. Eur Spine J. 2011 Jul 29. [Epub ahead of print]
21. Milewski MD, Whang PG, Grauer JN. A novel technique for preparing an allograft fibula for use as a transsacral graft as treatment for high-grade spondylolisthesis.Am J Orthop. 2011;40(3):130-3, 138.
22. François J, Lauweryns P, Fabry G, Treatment of high-grade spondylolisthesis by posterior lumbosacral transfixation with transdiscal screws: surgical technique and preliminary results in four cases. Acta Orthop Belg. 2005 Jun;71(3):334-41.
23. Hanson DS, Bridwell KH, Rhee JM, Lenke LG. Dowel fibular strut grafts for high-grade dysplastic isthmic spondylolisthesis. Spine. 2002;27(18):1982-8.
24. Bollini G, Jouve JL, Launay F, Glard Y, Jacopin S, Blondel B.High-grade child spondylolisthesis: A custom-made canulated screw to treat the so-called double instability. Orthop Traumatol Surg Res. 2011 Feb 25. [Epub ahead of print]
25. Sailhan F, Gollogly S, Roussouly P, The radiographic results and neurologic complications of instrumented reduction and fusion of high-grade spondylolisthesis without decompression of the neural elements: a retrospective review of 44 patients. Spine. 2006, 31(2):161-9.
26. Sasso RC, Shively KD, Reilly TM, Transvertebral Transsacral strut grafting for high-grade isthmic spondylolisthesis L5-S1 with fibular allograft. J Spinal Disord Tech. 2008, 21(5):328-33
27. Doita M, Uno K, Maeno K, Shimomura T, Nishida K, Fujioka H, Kurosaka M. Two-stage decompression, reduction, and interbody fusion for lumbosacral spondyloptosis through a posterior approach using Ilizarov external fixation. J Neurosurg Spine. 2008 Feb;8(2):186-92.
28. Ilharreborde B, Fitoussi F, Morel E, Bensahel H, Penneçot GF, Mazda K. Jackson's intrasacral fixation in the management of high-grade isthmic spondylolisthesis. J Pediatr Orthop B. 2007;16(1):16-8.
29. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C. Minimum 5-year analysis of L5-S1 fusion using sacropelvic fixation (bilateral S1 and iliac screws) for spinal deformity. Spine. 2006;31(3):303-8.
30. DeWald CJ, Vartabedian JE, Rodts MF, Hammerberg KW. Evaluation and management of high-grade spondylolisthesis in adults. Spine. 2005;30(6 Suppl):S49-59.
31. Boachie-Adjei O, Do T, Rawlins BA. Partial lumbosacral kyphosis reduction, decompression, and posterior lumbosacral transfixation in high-grade isthmic spondylolisthesis. Spine, 2002;27(6):E161-8.

32. Kasliwal MK et al. Short-term Complications Associated With Surgery for High-Grade Spondylolisthesis in Adults and Pediatric Patients: A Report From the Scoliosis Research Society Morbidity and Mortality Database. Neurosurgery. 2012, 71(1):109-16

33. Sansur CA, et al. Morbidity and mortality in the surgical treatment of 10,242 adults with spondylolisthesis. J Neurosurg Spine. 2010;13(5):589-93

NOTES

TECHNICAL ADVANCES IN ADULT & PEDIATRIC ILIOLUMBAR FIXATION IN DEFORMITY SURGERY: A TEN YEAR RETROSPECTIVE REVIEW COMBINED SESSION

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TITLE

Iliolumbar Fixation in the Treatment of Adult Spinal Deformity, Spinal Stenosis & Failed Low Back Surgery: Does it Improve Outcomes & Fusion Rates?

AUTHORS

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ILIOLUMBAR FIXATION : Historical overview leading to solutions in the adult population

In 1948, Cleveland published the first review of non-union related to fusion of the lumbo-sacral spine. The study reviewed 647 patients (Primary and Revision) with non-instrumented fusions for adult lumbosacral fusion; 33 % had nonunion of L5-S1

In the beginning of the 1960's, Harrington (1962) published the first study on corrective instrumentated fusion of pediatric spinal deformity. This study included patients with poliomyelitis, paraplegia and adolescent idiopathic scoliosis (AIS). The paper suggested the need for sacral fixation, describing a 'Sacral Bar' to increase the strength and stability of fusion and lead to better correction of deformity.

At the end of the 1970's, Luque and Cardoso described their technique for segmental spinal instrumentation (1977) including the Luque method of instrumentation for correction of scoliosis in patients who had overcome poliomyelitis n=40, or AIS n=25.

In 1982, 1984 and 1987, Allen & Ferguson described their results with the Luque Galveston Technique (NM, post polio patients with Iliac fixation by bent rod). This technique then became the gold standard for treatment of neuromuscular scoliosis or cerebral palsy.

In 1990, Jackson (1990) developed a technique for intra-sacral rod fixation. The results of this technique published by Lharreborde et al were centered on neuromuscular cases and pelvic obliquity. This report found no cases of pseudarthrosis at L5-S1 and reported good clinical and radiological results. Jackson noted occasional radiolucent lines surrounding the intra-sacral rod on post op imaging but specified that perfection in this technique was difficult to achieve.

In 1992, Farcy et al reviewed 28 patients who previously underwent surgery for adult spinal deformity with iliosacral fixation. Ninety five percent of patients displayed radiographic evidence of fusion, with only three requiring removal of iliosacral screws before 2 year follow up. In 1999, Arlet et al confirmed the benefits of illio-sacral constructs using the AO Universal Spine System to obtain a "Maximum Width fixation."

WHAT HAVE WE LEARNED OVER THE LAST 10 YEARS?

A review of publications over the past decade reveals literature which can be grouped into two categories: biomechanical studies and clinical outcomes studies.

Biomechanical Studies

Cunningham, in 2002 compared different lumbo-sacral constructs and demonstrated that instrumentation involving iliac screw and anterior support was superior to iliac screws or interbody cage alone. It was concluded that iliac screws are better than anterior support alone for protecting against pull-out of S1 screws.

In 2003, Schwend reported iliac screws are 3 times stronger than Galveston rods and described the "Pylon" concept of pelvic anchorage.

Clinical Outcomes & Fusion

In 2002, Enemi compared outcomes and complications in 3 groups of patients: Group 1 was Luque-Galvestone technique; Group 2 was bicortical sacral screws and Group 3 was Sacral screws and Iliac Screws. He concluded that the rate of complications in the Luque Galveston group was too high and recommended that surgeons no longer use this technique. There was a high rate of removal of iliac screws due to pain. There was no difference found between primary and revision cases in this population.

In 2006, Kim has evaluated the risk factors for spinal nonunion and reported 24% of pseudarthrosis in the setting of adult spinal deformity; 10,4% at the lumbosacral level. The main risk factors were age, incomplete sacropelvic fixation, hip arthritis, thoracolumbar kyphosis and thoraco-lumbar approach (as compared to paramedian approach)

In 2006, Tsuchiya studied lumbosacral fusion with a combination of bilateral sacral screws and iliac fixation, reporting clinical outcome with 5 to 10 years follow up. He studied 2 groups the first with high grade spondylolisthesis, and the second involving ASD with long fusion extending up to the thoracic spine. The study found 92.5% fusion rate with 5 cases of nonunion at L5-S1 asociated with rod breakage between L5-S1 or screw failure at L4-L5, 3 from the spondylolisthesis group and 2 from the ASD group. Three of the patients with nonunion had no anterior support. 4 of the 5 patients with nonunion had revision, 3 of 4 having solid fusion at final followup. Of 67 patients, 33 had iliac screws removed at final follow up, due to breakage, loosening or rod failure at that level. For high-grade spondylolisthesis and long ASD fusions, iliac screws were found to be effective at protecting the sacral screws from failure.

In 2010, Kasten reported the long-term results of iliac fixation in the setting of adult spinal deformity and found 15% Pseudarthrosis after long fusions to sacrum. He reported over 54% of patient with at least one complication. He noted 7.7% of iliac screws were removed at follow up due to pain. 78% of patients who had screw removal reported that they were satisfied with their procedure at final follow up.

More recently, Harimaya (2011) reviewed 33 patients with failed spinal fusion and fixation at L5-S1. 21 of 33 patients had revision surgery prior to the review and 33% of the patients with revision procedures were diagnosed with further pseudarthrosis subsequent to the secondary procedure. Harimaya described a high rate of rod breakage and screw loosening. He confirmed that iliac screws with anterior support protect sacral screws from pull out but that revision of pseudoarthrosis at the lumbo-sacral junction remained a challenge for surgeons.

In 2012, O'Shaughnessy evaluated the removal of symptomatic iliac screws. He studied 395 Patients with 2-year follow up after surgery. He concluded that if there is a solid fusion removal should be considered after 2 years of follow up as many of these patients symptoms will subside. 24(6.1%) patients had either bilateral or unilateral removal of iliac screws 78.3% of the patient were improved and 91.7% were satisfied with the operation and would do it again.

CURRENT STATE OF THE ART (Evolution in iliac fixation)

After a review of the literature we find that there is limited high quality data regarding iliac fixation in the setting of adult spinal deformity. However, the biomechanical considerations of instrumentation are important given that an optimal construct is necessary for fusion. Iliac screws, particularly when combined with interbody support appears to offer the highest rates of fusion and can help avert catastrophic failures of instrumentation.

It is critical to note that sagittal alignment is a key parameter which drives clinical outcomes in the setting of ASD. Therefore, it stands to reason that optimal instrumentation to permit fusion in a desired spino-pelvic alignment is essential for good outcomes. From that perspective, iliac fixation can be highly recommended when combined with proper pre-operative planning and execution of alignment goals. A brief summary of spino-pelvic alignment goals is as follows:

- SVA <5cm,
- Pelvic Tilt <25°,
- Pelvic Incidence = Lumbar Lordosis ± 10°.

NEWER APPROACHES TO SPINO-PELVIC FIXATION

In 2009, Harrop described an anatomic approach for iliac screw fixation and described this technique as creating less dead space, less vascular insult to soft tissue and involving less bone resection for placement of the screws. The iliac screws are aligned with spinal instrumentation and do not need connectors.

Several authors (Nottmeier and O'Brien, 2010) described alternative approaches to iliac fixation through an S2 approach. These reports describe an anatomic safe zone. Screws of up to 90 mm length without connectors can be placed by direct visualization or with the help of fluoroscopy. The proposed S2 alar sacro-iliac screws apparently do not lead to damage of the SI joint. The proposed approach may be an alternative to consider but long-term follow up is lacking.

In 2010, Yu BS. Compared single iliac screws per side with a technique involving dual iliac screw per side determining that a dual construct is superior to a single screw/side construct. The double screw construct was more effective at preventing screw pull out, however, the biomechanical tests were applied are following sacrectomy and therefore, the 4 screw technique may be best suited for select high complexity cases.

CURRENT INDICATION FOR ILIO-LUMBAR FIXATION

Fusion

Long fusion over L3 should be protected by an iliac fixation construct

Deformity

All major deformity with global malalignment should be protected with iliac fixation to ensure maintenance of key spino-pelvic parameters (SVA, PT, PI – LL offset)

Instability

High grade spondylolisthesis (Grade 3 or greater) will most likely requires a construct including iliac fixation

Anchorage Concerns

Iliac fixation should be considered for patients with poor bone quality and in cases of revision surgery for pseudarthrosis.

CONCLUSION

The history of ilio-lumbar fixation began in the area of neuromuscular spinal deformity and was heavily focused on addressing pelvic obliquity. The published literature over the last deaced addressing clinical issues surrounding iliac fixation is largely retrospective with no randomized trials and minimal prospective data focusing on patients with ASD.

However, one can conclude that long fusions in the setting of ASD should include iliac fixation to optimize realignment and fusion success. The noted increase in the use of iliac fixation relating to operative treatment of ASD reflects findings from mechanical studies and increasing appreciation of the key principles in obtaining and maintaining ideal spino-pelvic alignment for improved outcomes.

Bibliography References:

1. Allen BL Jr, Ferguson RL (1982) The galveston technique for l rod instrumentation of the scoliotic spine. Spine (Phila Pa 1976) 7(3):276–84
2. Allen BL Jr, Ferguson RL (1984) The galveston technique of pelvic fixation with l-rod instrumentation of the spine. Spine (Phila Pa 1976) 9(4):388–94
3. Allen BL Jr, Ferguson RL (1988) A 1988 perspective on the galveston technique of pelvic fixation. Orthop Clin North Am 19(2):409–18
4. Arlet V, Marchesi D, Papin P, Aebi M (1999) The 'mw' sacropelvic construct: an enhanced fixation of the lumbosacral junction in neuromuscular pelvic obliquity. Eur Spine J 8(3):229–31
5. Cleveland M, Bosworth DM, Thompson FR (1948) Pseudarthrosis in the lumbosacral spine. J Bone Joint Surg Am 30A(2):302–12
6. Cunningham BW, Lewis SJ, Long J, Dmitriev AE, Linville DA, Bridwell KH (2002) Biomechanical evaluation of lumbosacral reconstruction techniques for spondy- lolisthesis: an in vitro porcine model. Spine (Phila Pa 1976) 27(21):2321–7,
7. Emami A, Deviren V, Berven S, Smith JA, Hu SS, Bradford DS (2002) Outcome and complications of long fusions to the sacrum in adult spine deformity: luque- galveston, combined iliac and sacral screws, and sacral fixation. Spine (Phila Pa 1976) 27(7):776–86
8. Farcy JP, Weidenbaum M, Michelsen CB, Hoeltzel DA, Athanasiou KA (1987) A comparative biomechanical study of spinal fixation using cotrel-dubousset instru- mentation. Spine (Phila Pa 1976) 12(9):877–81
9. Harimaya K, Mishiro T, Lenke LG, Bridwell KH, Koester LA, Sides BA (2011) Etiology and revision surgical strategies in failed lumbosacral fixation of adult spinal deformity constructs. Spine (Phila Pa 1976) 36(20):1701–10, DOI 10.1097/ BRS.0b013e3182257eaf
10. Harrington PR (1962) Treatment of scoliosis. correction and internal fixation by spine instrumentation. J Bone Joint Surg Am 44-A:591–610

11. Harrop JS, Jeyamohan SB, Sharan A, Ratliff J, Vaccaro AR (2009) Iliac bolt fixation: an anatomic approach. J Spinal Disord Tech 22(8):541–4, DOI 10.1097/ BSD.0b013e31818da3e2
12. Ilharreborde B, Hoffmann E, Tavakoli S, Queinnec S, Fitoussi F, Presedo A, Penne ϖot GF, Mazda K (2009) Intrasacral rod fixation for pediatric long spinal fusion: results of a prospective study with a minimum 5-year follow-up. J Pediatr Orthop 29(6):594–601, DOI 10.1097/ BPO.0b013e3181b2b403
13. Kasten MD, Rao LA, Priest B (2010) Long-term results of iliac wing fixation below extensive fusions in ambulatory adult patients with spinal disorders. J Spinal Disord Tech 23(7):e37–42, DOI 10.1097/BSD.0b013e3181cc8e7f
14. Kim YJ, Bridwell KH, Lenke LG, Rhim S, Cheh G (2006) Pseudarthrosis in long adult spinal deformity instrumentation and fusion to the sacrum: prevalence and risk factor analysis of 144 cases. Spine (Phila Pa 1976) 31(20):2329–36, DOI 10. 1097/01. brs.0000238968.82799.d9
15. Luque ER (1982) Segmental spinal instrumentation for correction of scoliosis. Clin Orthop Relat Res (163):192–8
16. Nottmeier EW, Pirris SM, Balseiro S, Fenton D (2010) Three-dimensional image- guided placement of s2 alar screws to adjunct or salvage lumbosacral fixation. Spine J 10(7):595–601, DOI 10.1016/j.spinee.2010.03.023
17. O'Brien JR, Yu WD, Bhatnagar R, Sponseller P, Kebaish KM (2009) An anatomic study of the s2 iliac technique for lumbopelvic screw placement. Spine (Phila Pa 1976) 34(12):E439–42, DOI 10.1097/BRS.0b013e3181a4e3e4
18. Oshaughnessy BA, Lenke LG, Bridwell KH, Cho W, Zebala LP, Chang MS, Auer- bach JD, Crawford CH, Koester LA (2012) Should symptomatic iliac screws be electively removed in adult spinal deformity patients fused to the sacrum? Spine (Phila Pa 1976) 37(13):1175–81, DOI 10.1097/BRS.0b013e3182426970
19. Schwend RM, Sluyters R, Najdzionek J (2003) The pylon concept of pelvic an- chorage for spinal instrumentation in the human cadaver. Spine (Phila Pa 1976) 28(6):542–7, DOI 10.1097/01.BRS.0000049925.58996.66
20. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C (2006) Minimum 5-year analysis of l5-s1 fusion using sacropelvic fixation (bilateral s1 and iliac screws) for spinal deformity. Spine (Phila Pa 1976) 31(3):303–8, DOI 10.1097/ 01.brs.0000197193.81296.f1
21. Yu BS, Zhuang XM, Zheng ZM, Li ZM, Wang TP, Lu WW (2010) Biomechanical advantages of dual over single iliac screws in lumbo-iliac fixation construct. Eur Spine J 19(7):1121–8, DOI 10.1007/s00586-010-1343-8
22. Zahi R, Vialle R, Abelin K, Mary P, Khouri N, Damsin JP (2010) Spinopelvic fixation with iliosacral screws in neuromuscular spinal deformities: results in a prospective cohort of 62 patients. Childs Nerv Syst 26(1):81–6, DOI 10.1007/ s00381-009-0966-8

NOTES

WHAT EVIDENCE EXISTS FOR FUSION TO THE PELVIS WITH ILIOLUMBAR FIXATION WHEN A L5-S1 SPONDYLOISTHESIS & AIS CO-EXIST? - LITTLE TO NONE

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Adolescent Idiopathic Scoliosis (AIS) and spondylolisthesis have been well known to be associated with each other in 15% - 48% of cases[1-3]. However, the etiology of the co-existence of these two deformities is not that well understood. Spondylolisthesis may contribute to or be responsible for scoliosis via muscular spasm, irritation, and rotation of slipping "olisthetic" verterba[1, 2]. It is more commonly associated with lumbar scoliosis than with thoracic or thoracolumbar curves. Three main types of scoliosis occur with spondylolisthesis[1, 3, 4]:

1. diopathic Scoliosis in patients with a positive family history and a curve of the upper spine (Thoracic or Thoracolumbar):
   - This curve is unlikely to be related with the spondylolisthesis.
   - 6.2% of idiopathic scoliosis patients have co-existing spondylolisthesis [1-3, 5]
   - Treat the spondylolisthesis and scoliosis curve independent of each other [5]
2. Scoliosis, usually lumbar, induced by irritation and muscle spasm because of the spondylolisthesis (Sciatic scoliosis):
   - Generally no rotation of pedicles[1, 2]
   - Scoliosis curve Cobb angle usually not severe enough to warrant surgery
   - If treated before spine deformity becomes structural, the treatment of muscle spasm or spondylolisthesis can reduce or resolve the scoliosis[1, 2, 5]
3. Scoliosis associated with an asymmetric olisthetic defect:
   - This can cause rotatory deformity of the spine above due to the asymmetric foundation
   - Scoliotic lumbar curve shows more rotation than is expected from an equivalent AIS curve[1]
   - The maximal rotation is at the olisthetic vertebra instead of the apical vertebra
   - Just addressing the spondylolisthesis in these cases may not address the scoliosis because[1, 2]:
     i. fixation of the spondylolisthesis does not address the asymmetry of the foundation and hence does not help in correction of the scoliosis
     ii. the scoliosis could be purely idiopathic and mostly independent of the spondylolisthesis
   - Lumbar curves showing high Cobb angles should be considered as purely idiopathic, in which the spondylolisthesis has a minor contribution.
   - These cases require addressing the spondylolisthesis independently from the scoliosis.
     i. Treat spondylolisthesis if symptomatic[1, 2]
     ii. Treat scoliosis only if curve of surgical magnitude[1, 5]
     iii. Extended fusion to pelvis only if spondylolisthesis symptomatic[1, 2, 6] or spondylolisthesis of Meyerding Grade IV[1]

iv. Goldstein et al[5]in 1976 had advocated extension to the sacrum if the scoliosis required surgical treatment whether or not the spondylolisthesis was symptomatic. However, this claim was only supported by individual cases instead of a series of patients.

Many authors believe that the two conditions should be treated separately even if they co-exist[1, 2, 7]. Crostelli et al[1] reported on 25 patients with a mean 5.3 y follow-up that had AIS associated with an asymptomatic spondylolisthesis (Meyerding Grades I-III) in which they treated only the scoliosis by instrumented arthrodesis, they did not observe worsening of the spondylolisthesis. However, they recommend extending the fusion to the pelvis if the spondylolisthesis is of Meyerding grade IV because the arthrodesis would put stress on a kyphotic, highly unstable area.

In summary, the treatment for scoliosis and spondylolisthesis should be separate. In patients undergoing lumbar spinal arthrodesis for scoliosis, the fusion should be extended to the pelvis if they have a symptomatic spondylolisthesis or if the spondylolisthesis is of Meyerding Grade IV.

Summary Algorithm for Treatment of Scoliosis in Patients with Co-existing Spondylolisthesis:

1. Scoliosis of the upper spine (thoracic or thoracolumbar) in patients with positive family history of scoliosis and classic curve pattern (lordoscoliosis)

   Treat scoliosis and spondylolisthesis separately pending presentation:

   A. Treat spondylolisthesis if symptomatic & follow scoliosis
      - Keep in mind that olesthetic curves can be severe hence address spondy first and see what the scoliosis does (case 1 below)

   B. Treat scoliosis once curves reach of surgical magnitude & follow spondy as it may become symptomatic (case 2 below)
      - Keep in mind to leave as many non-fused segments as possible between the fusion and the spondy allowing stress dissipation from the spondy

2. Small Cobb scoliosis of Lumbar spine purely associated with spasm due to symptomatic spondylolisthesis
   A. If scoliotic curve is flexible treat only spondylolesthesis, spontaneous correction of lumbar curve should occur
   B. If lumbar curve structural and significant may need to treat both scoliosis and spondylolesthesis with extension to pelvis
      - One can stage surgeries to see outcome of spondy surgery
3. Scoliosis of lumbar spine with olisthetic scoliosis due to asymmetric slip

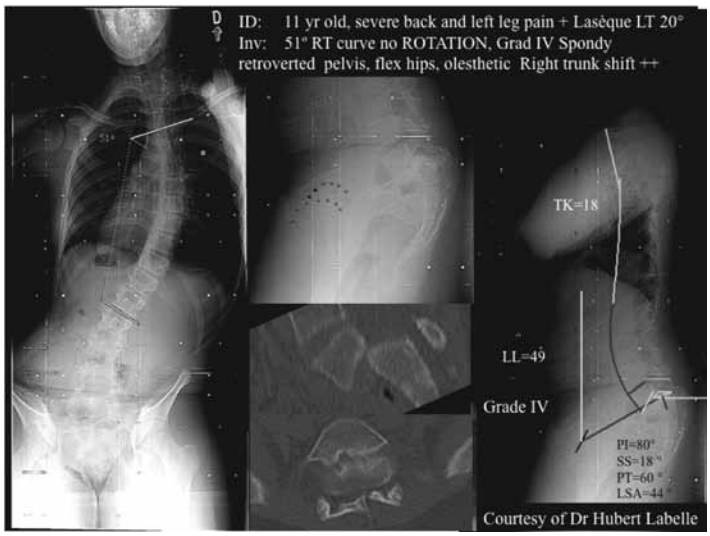
   Treat scoliosis and spondylolisthesis separately:

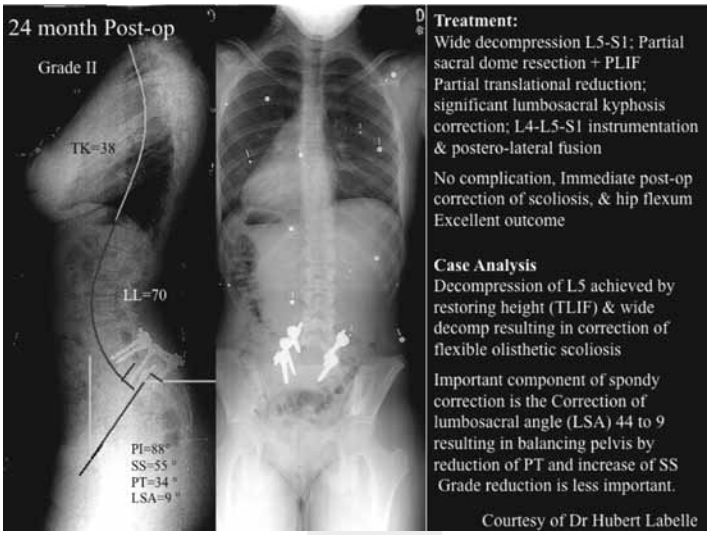
   A. Treat spondylolisthesis if symptomatic
   B. Treat scoliosis only if curve of surgical magnitude
      - Extended fusion to pelvis if spondylolisthesis of Meyerding Grade IV

REFERENCES

1. Crostelli, M. and O. Mazza, AIS and spondylolisthesis. Eur Spine J, 2012.
2. Pneumaticos, S.G. and S.I. Esses, Scoliosis associated with lumbar spondylolisthesis: a case presentation and review of the literature. Spine J, 2003. 3(4): p. 321-4.
3. Seitsalo, S., K. Osterman, and M. Poussa, Scoliosis associated with lumbar spondylolisthesis. A clinical survey of 190 young patients. Spine (Phila Pa 1976), 1988. 13(8): p. 899-904.
4. McPhee, I.B. and J.P. O'Brien, Scoliosis in symptomatic spondylolisthesis. J Bone Joint Surg Br, 1980. 62-B(2): p. 155-7.
5. Goldstein, L.A., P.W. Haake, J.R. Devanny, et al., Guidelines for the management of lumbosacral spondylolisthesis associated with scoliosis. Clin Orthop Relat Res, 1976(117): p. 135-48.
6. Fisk, J.R., J.H. Moe, and R.B. Winter, Scoliosis, spondylolysis, and spondylolisthesis. Their relationship as reviewed in 539 patients. Spine (Phila Pa 1976), 1978. 3(3): p. 234-45.
7. Arlet, V., P. Rigault, J.P. Padovani, et al., [Scoliosis, spondylolysis and lumbosacral spondylolisthesis. A study of their association apropos of 82 cases in children and adolescents]. Rev Chir Orthop Reparatrice Appar Mot, 1990. 76(2): p. 118-27.

Case 1:





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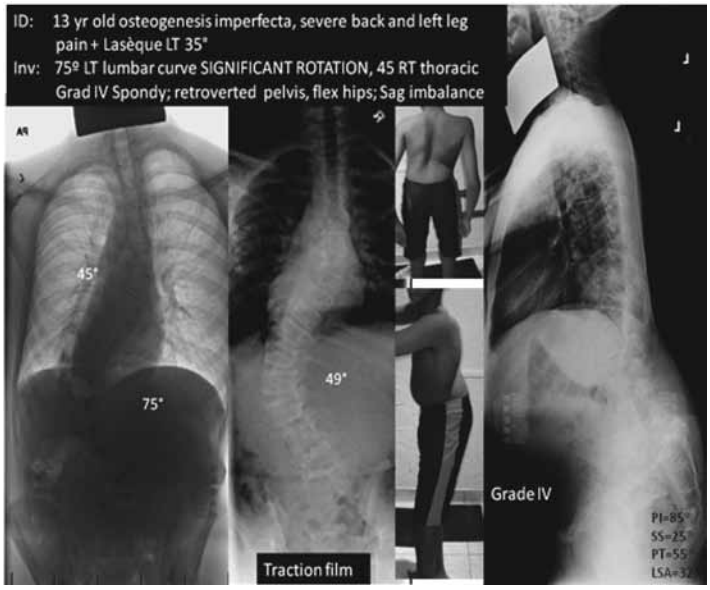

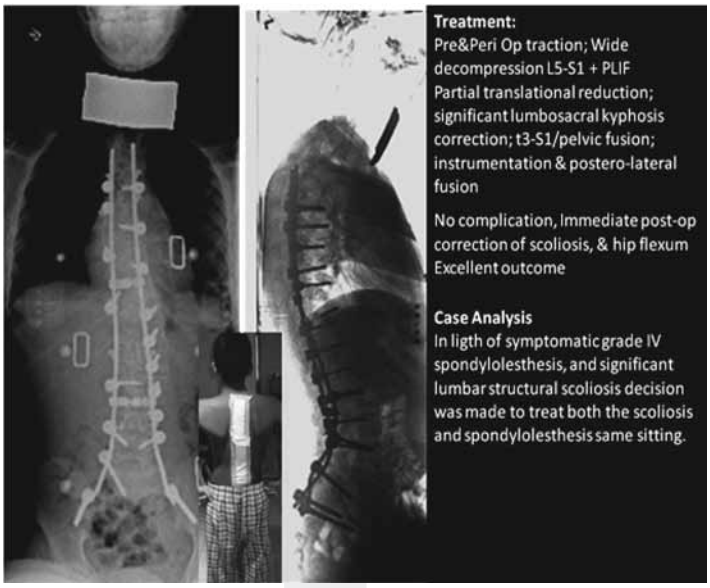

Notes

DEBATE AND CASE DISCUSSION 1: DOES CURRENT EVIDENCE DEFINE WHEN TO STOP AT L5 OR EXTENDED THE FUSION TO S1 IN ADULT LUMBAR SCOLIOSIS

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Background:

There still remains debate about whether it is better to stop a long fusion distally at L5 or the sacrum.

The problems with stopping at the sacrum are that the nonunion rate is higher and it requires additional fixation points to protect the S1 screws. There is debate about how much morbidity there is with iliac screws. Also, long fusions to the sacrum result in a longer procedure than stopping at L5 and, in the short-term, there are more complications. Circa 2005 the results were:

High Pseudarthrosis Rate With Going To The Sacrum (Circa 2005)

Kim YJ, Bridwell KH, Lenke LG, Cho K, Edwards II C, Rinella AS: Pseudarthrosis in adult spinal deformity following multisegmental instrumentation and arthrodesis. J Bone Joint Surg 2006;88(4):721-728

- **A clinical and radiographic assessment of 232 adults**
- **Prevalence of pseudarthrosis following long arthrodesis was 17%**
- **Factors found to be significantly associated were preop thoracolumbar kyphosis of >20°, age of >55 years, arthrodesis to S1 compared to L5**
- **Patients with a pseudarthrosis had lower total outcome scores on SRS questionnaire**

Results:

In the long-term, there may be more complications with stopping at L5. The L5 pedicles are big cancellous patulous pedicles that run the risk of the screws loosening and as the screws loosen, the spine will fall into some kyphosis at L4-L5 and maybe L5-S1 as well. Over the long-term there seems to be a reasonable prevalence of disc degeneration occurring at L5-S1. This subsequent disc degeneration at L5-S1 often leads to very substantial sagittal imbalance. Circa 2002 the results with stopping at L5 were:

Lots of Subsequent Breakdown at L5-S1 With Stopping At L5

Edwards C, Bridwell K, Patel A, Rinella A, Della Rocca G, Berra A, Lenke L: Thoracolumbar deformity arthrodesis to L5 in adults: The fate of the L5-S1 disc. Spine 2003;28(18):2122-2131

- **34 consecutive adult deformity patients fused from the thoracic spine to L5**
- **Subsequent L5-S1 DDD developed in 66% of patients after long adult fusions to L5**
- **Relative but not absolute protection against progressive DDD is provided by a deep-seated L5 (p=0.003)**

Some past literature has suggested that short fusions may do reasonable well at L5, meaning along the lines of T10 or T11 to L5. The risk of early breakdown at L5-S1 seems to be higher with a longer fusion from the upper thoracic spine to L5. We are only inclined to consider a long fusion to L5 and not the sacrum in a very young, very physically fit individual. Results circa 2006 were:

Better Results With Short Fusion To L5 Than Long Fusion

Kuhns CA, Bridwell KH, Lenke LG, Amor CJ, Lehman Jr RA, Buchowski JM, Edwards CC: Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc with a minimum 5-year follow-up. Spine 2007;32 (24):2771-2776

- **High percentage of patients subsequently degenerated the L5-S1 disc**
- **With degeneration of the L5-S1 disc, sagittal balance was frequently lost**
- **Prevalence of breakdown of the L5-S1 disc much greater in the "long" fusions (T4-L5) vs. the "short" fusions (T10-L5)**

Role of interbody fusions:

There is substantial variation in terms of how much anterior surgery is recommended for long fusions to L5 or the sacrum in adult deformity. I believe if you polled the SRS, you would find a reasonable percentage of members are willing to do a fusion to L5 without any interbody fusion, but going to the sacrum more surgeons are going to want to do interbody fusions at the bottom. I don't necessarily agree with this particular approach, but I do believe that is what any vote or survey of SRS members would reveal, so more surgery and surgical charges result in fusing L5-S1.

How much motion at L5-S1?

There is substantial dispute about how much motion L5-S1 contributes. Does some motion at L5-S1 facilitate gait? Does it protect the SI joints? Does it facilitate personal hygiene?

Clear indications for going to the sacrum rather than L5:

There are other considerations as well. The degree of disc degeneration at L5-S1 is a factor. If the disc is severely degenerated with accompanying spinal stenosis, spondylolisthesis or prior laminectomy, then stopping at L5 is not advisable. Stopping at L5 is a consideration if either the L5-S1 segments seems very normal or if the L5-S1 segment is hyperstable with large stabilizing osteophytes.

These are some of the important considerations with stopping at L5 or the sacrum.

The symposium will consist of four short presentations that summarize the pros and cons of stopping at L5 vs. the sacrum. Following that will be two case discussions; one where the fusion was stopped at L5 and one where the fusion was stopped at the sacrum.

References

1. Edwards C, Bridwell K, Patel A, Rinella A, Della Rocca G, Berra A, Lenke L: Thoracolumbar deformity arthrodesis to L5 in adults: The fate of the L5-S1 disc. Spine 2003;28(18):2122-2131.
2. Kim YJ, Bridwell KH, Lenke LG, Cho K, Edwards II C, Rinella AS: Pseudarthrosis in adult spinal deformity following multisegmental instrumentation and arthrodesis. J Bone Joint Surg 2006;88(4):721-728.
3. Kuhns CA, Bridwell KH, Lenke LG, Amor CJ, Lehman Jr RA, Buchowski JM, Edwards CC: Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc with a minimum 5-year follow-up. Spine 2007;32 (24):2771-2776.

Notes

DEBATE AND CASE DISCUSSION 1: DOES CURRENT EVIDENCE DEFINE WHEN TO STOP AT L5 OR WHEN TO EXTEND THE FUSION TO S1 IN ADULT LUMBAR SCOLIOSIS.

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Goals of Surgery

- Pain relief/functional improvement
- Prevent curve progression
- Restore global balance

Common Reasons for Fusion to Sacrum

- L5 Spondylolisthesis
- Prior decompression L5-S1

- Stenosis (foraminal > central/lateral recess)
- Oblique take-off at L5-S1
- Revision
- Imbalance – sagittal and/or coronal
- Severe Disc degeneration at L5-S1

Advantages of fusion to L5[1,2]
- Retain motion at lumbosacral junction
- Decrease OR time
- Reduce sacro-iliac stress
- Lower pseudarthrosis rate
- Fewer overall complications

Disadvantages of stopping at L5[3]
- Degeneration of L5-S1 disc leads to:
  - Worsening of sagittal balance
  - Pain
  - Need for revision
- Failure of fixation at L5
  - Short, cancellous, capacious, medially angled pedicles
  - L5 anterior cortex bite potentially risky

Complications of fusion to sacrum
- Howe 2011[4]– Retrospective study of 103 consecutive patients fused long to pelvis 2003-2007
  - 97% posterior only (TLIF in all but 8; 3 anterior)
  - 4% mortality!
  - 12% had at least one major medical complication (4 MI, 4 PE, 4 ARDS, 4 pneumonia, 3 ARF, 3 CVA, 1 blindness)
  - ASA score and Charlson Co-Morbidity Index[5] were associated w/medical complications but age was not
  - 17% had a **documented new persistent neurological deficit** that was still present at the final clinic visit
  - 35% underwent at least one unplanned return to the OR (infection, ASD, nonunion, etc)
  - 2.7 days in ICU, 12 days in hospital
  - **Complex spine reconstruction to the- pelvis continues to be a high-risk procedure in spite of more advanced surgery and perioperative techniques**
- Fusion to sacrum – "is of larger magnitude" and introduces higher complication rate[3]
- Edwards[6] - 27 vs. 12 matched cohorts (L5, sacrum)
  - 22 vs. 75 major complications
    - Total procedures : 1.7 vs. 2.8
    - No difference on SRS 24 outcomes
- **24% incidence of pseudo**[7]
- Implant failure due to[8]
  - High mechanical demand at L5-S1 junction
  - Wide pedicles of L5 and S1
  - Augmentation strategies – alar, S2 pedicle screws, S1 foraminal hooks, Galveston, iliac screws, anterior interbody structural support

Requirement of L5 level
- Must be L5-S1 disc must be hydrated w/retained height (younger patients)
  - Lordosis must be well preserved
  - Edwards[9] - 34 patients fused from thoracic spine to L5 followed >5 yrs
    - 61% developed DDD but only 15% required revision to sacrum
    - 88% G to E
    - Disc degeneration correlated with loss of sagittal balance
    - Loss of fixation associated w/deep seated L5
      - Deep-seated L5 provides relative but not absolute protection against progressive DDD
    - Need good overall balance
  - Brown et al[10]
    - Need good preop sag balance
    - Preserved lumbar lordo
    - Good post-op fractional curve correction
    - L5-S1 disc height preservation

Some numbers
- **LL – TK > 20°** advisable in most circumstances to achieve optimal sagittal balance[11]
- Kuhns[12] -31 patients (average age 45) fused to L5 followed 9.4 years
  - Disc degeneration graded by Weiner grad (0,1– healthy, 2-3 – degenerated)[13]
  - 69% developed subsequent advanced degeneration (SAD)
    - C7 plumb >5 in 67% SAD, but only 13% of healthy
    - 23% revised to sacrum
    - Another 19% precluded by co-morbidities
    - Risk factors
      - Long fusion
      - Circumferential lumbar fusion
      - **C7 plumb > 5 cm**
- Cho[14]
  - Retrospective study 45 patients (mean age 64) - 24 to L5 and 21 to sacrum
    - 6 segments mean; f/u 2 yrs
  - 42% (19) developed sagittal decompensation
    - preop sag imbalance - C7 plumb >6.8 cm
    - high PI (pelvic incidence) – 62° vs. 55°
  - 5 of 21 to sacrum had pseudo – 24% (80% had sag decompression)
  - 55% who had screw loosening developed SD
  - **Conclusion – Restoration of optimal LL and secure L5 fixation is necessary w/preop sagittal imbalance and high PI to prevent sagittal decompensation post op**[15,16]
- Cho[17] 2009
  - No difference in Cobb correction between L5/sacrum groups (although LL correction better in sacrum group)
  - Advanced L5-S1 DDD occurred in 58% of L5
    - Development of adjacent segment disease was not related to preop grade of disc degeneration
    - In L5 group – 9 complications (disc degeneration and screw loosening)

  - 7 of 9 showed preop sag imbalance and/or lumbar hypo-lordosis, which might be risk factors of complications at L5-S1
- **Conclusion: L5-S1 should be included in fusion even if the disc is minimally degenerated for patients with sagittal imbalance or lumbar hypo-lordosis**

General Thoughts

- Fusion to the sacrum/pelvis is associated with more complications and more revisions
- Quantitative data on un-fused discs adjacent to long fusions[18] may be useful in the future
- Guidelines in the literature continue to evolve with regard to guiding surgical decision making and functional outcomes

References

1. Polly, D.W., Jr., C.L. Hamill, and K.H. Bridwell, Debate: to fuse or not to fuse to the sacrum, the fate of the L5-S1 disc. Spine, 2006. 31(19 Suppl): p. S179-84.
2. Bridwell, K.H., C.C. Edwards, 2nd, and L.G. Lenke, The pros and cons to saving the L5-S1 motion segment in a long scoliosis fusion construct. Spine, 2003. 28(20): p. S234-42.
3. Swamy, G., S.H. Berven, and D.S. Bradford, The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis. Neurosurgery clinics of North America, 2007. 18(2): p. 281-8.
4. Howe, C.R., et al., The morbidity and mortality of fusions from the thoracic spine to the pelvis in the adult population. Spine, 2011. 36(17): p. 1397-401.
5. Charlson, M.E., et al., A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of chronic diseases, 1987. 40(5): p. 373-83.
6. Edwards, C.C., 2nd, et al., Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. Spine, 2004. 29(18): p. 1996-2005.
7. Kim, Y.J., et al., Pseudarthrosis in long adult spinal deformity instrumentation and fusion to the sacrum: prevalence and risk factor analysis of 144 cases. Spine, 2006. 31(20): p. 2329-36.
8. Harimaya, K., et al., Etiology and revision surgical strategies in failed lumbosacral fixation of adult spinal deformity constructs. Spine, 2011. 36(20): p. 1701-10.
9. Edwards, C.C., 2nd, et al., Thoracolumbar deformity arthrodesis to L5 in adults: the fate of the L5-S1 disc. Spine, 2003. 28(18): p. 2122-31.
10. Brown, K.M., S.C. Ludwig, and D.E. Gelb, Radiographic predictors of outcome after long fusion to L5 in adult scoliosis. Journal of spinal disorders & techniques, 2004. 17(5): p. 358-66.
11. Kim, Y.J., et al., An analysis of sagittal spinal alignment following long adult lumbar instrumentation and fusion to L5 or S1: can we predict ideal lumbar lordosis? Spine, 2006. 31(20): p. 2343-52.
12. Kuhns, C.A., et al., Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc, minimum 5-year follow-up. Spine, 2007. 32(24): p. 2771-6.
13. Weiner, D.K., et al., Does radiographic osteoarthritis correlate with flexibility of the lumbar spine? Journal of the American Geriatrics Society, 1994. 42(3): p. 257-63.
14. Cho, K.J., et al., Risk factors of sagittal decompensation after long posterior instrumentation and fusion for degenerative lumbar scoliosis. Spine, 2010. 35(17): p. 1595-601.
15. Roussouly, P. and J.L. Pinheiro-Franco, Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 2011. 20 Suppl 5: p. 609-18.
16. Roussouly, P. and C. Nnadi, Sagittal plane deformity: an overview of interpretation and management. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 2010. 19(11): p. 1824-36.
17. Cho, K.J., et al., Arthrodesis to L5 versus S1 in long instrumentation and fusion for degenerative lumbar scoliosis. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 2009. 18(4): p. 531-7.
18. Auerbach, J.D., et al., Quantification of intradiscal pressures below thoracolumbar spinal fusion constructs: is there evidence to support "saving a level?". Spine, 2012. 37(5): p. 359-66.

Notes

DEBATE AND CASE DISCUSSION 1: DOES CURRENT EVIDENCE DEFINE WHEN TO STOP AT L5 OR EXTEND THE FUSION TO S1 IN ADULT LUMBAR SCOLIOSIS?

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BACKGROUND: Adult lumbar scoliosis (Cobb angle > 10°) is a common disorder with reported prevalence that increases steadily after the age of 50[1-3] and appears to be more prevalent and more severe in women[1,2,4-10]. Studies have reported prevalence of scoliosis in adults of up to 60% - 68%[1,11]. Adult scoliosis is commonly symptomatic and is associated with degenerative changes of the lumbar spine such as degenerative disc disease, spinal stenosis, spondylolisthesis, lateral listhesis, rotatory subluxation, lumbar hypolordosis and coronal and sagittal imbalance[1]. The L3 level followed by L2 is the common location for the apex of the lumbar scoliosis curves and the L3-L4 junction is the most commonly involved level in lateral listhesis[1,12,13].

The relationship between the magnitude of deformity and the severity and existence of symptoms has not been clearly established[1,2]. However, adults with scoliosis report significantly higher pain, functional impairment and effect on quality of life than those without scoliosis[1-3]. In adults with scoliosis, sagittal balance[14] has the most significant impact on pain, function and progression of deformity compared to other radiographic parameters. Patients most often choose surgery because of pain, impairment of walking ability and function and appearance due to deformity. Studies have favored operative treatment versus non-operative for symptomatic patients with adult scoliosis[12,15-18]. Depending on the type of pathology and symptoms, the main goal of surgery is to achieve spinal balance, spinal stabilization, and neural decompression. All of which have led to quantifiable improvement in patient's self-assessment of health status. The challenge when treating adult lumbar scoliosis is determining the

extent of surgery required: decompression alone, limited fusion, and long fusion. Due to lack of conclusive evidence supporting the different options and a high percentage of associated peri-operative complications of 39% - 78%[4-6,9,10,17,18], the perioperative plan needs to be thorough and established in conjunction with the patient and their expectations. For patients requiring long fusion into the lumbar spine, the question then remains whether to stop the fusion at L5 or to extend the fusion to S1 and the pelvis. There are certain indications that are well accepted for extension of fusion to S1 and the pelvis. These include: Spondylolisthesis at L5-S1, previous decompression at L5-S1, stenosis at L5-S1, fixed obliquity of the L5-S1 motion segment, incomplete correction of global sagittal balance and advanced and symptomatic degenerative changes at L5-S1[4,5,13,19-21]. However, for patients who do not meet those criteria and have a relatively healthy L5-S1 motion segment, typically younger patients with good bone stock, the decision to choose whether to stop the fusion at L5 or to extend to S1/pelvis remains controversial[4,5,13,19-22]. Like any controversial topic, there are several pros and cons (Table 1 and Table 2) to both these approaches, some of these arguments are supported by literature while others are anecdotal or theoretical concerns based on expert opinions. Short of compelling evidence, we abide by the AO motto that "life is motion, motion is life" and advocate stopping fusions at the L5 vertebra, thereby sparing the L5-S1 motion segment in patients with a health L5/S1 disc, and spinal deformities in which surgeons are expected to achieve spinal balance. This handout provides a summary of the relevant literature guiding surgeons as to the pros and cons of the two options (Table 1 and Table 2).

OBJECTIVES: To evaluate the evidence found in the literature in patients undergoing long fusion (for adult lumbar scoliosis) stopping at L5 versus those with fusion extending to S1. We opted to look at specific quantifiable outcomes which could influence surgeons decisions: complications rates surgical time, surgical blood loss, functional status, pseudarthrosis rate, revision surgery rate, loss of deformity correction, degeneration at L5-S1, rate of hip/sacroiliac (SI) joint degeneration.

RESULTS: We identified 7 studies meeting criteria to be included in this report Table 3. The evidence level for the studies is defined according to Evidence Based Spine Journal Guidelines (http://www. Aospine.org/ebsj). At first glance, the evidence levels remain weak. Results in the tables are reported as either Mean, Mean ± SD or Mean (range).

Evaluation of peri-operative parameters and Complications (Table 3): Cho et al[4] were the only ones to directly compare surgical times (L5 group:220 ± 47 min, S1 group: 229 ± 65 min) and blood loss (L5 group: 2754 ± 1195ml, S1 group: 2938 ± 1923 ml) of the two groups. They found no statistically significant differences between the two groups. They attributed this to the fact that they excluded patients from the sacral fusion group that underwent iliac screw fixation in addition to the S1 screws, suggesting that the higher complication rates reported in other studies were due to addition of the iliac screws if the number of levels fused were similar. Charosky et al[17] in their retrospective analysis of 306 patients identified extension of fusion to the sacrum, augmented with iliac fixation, as a risk factor for peri-operative complications (P = 0.001, Odds ratio: 3.66). Edwards et al[5] also reported a higher rate of peri-operative complications in patients fused to the sacrum versus those fused to L5. Their group also had augmentation of the sacral fixation with iliac screws and anterior column support.

Deformity correction and maintenance: There was no difference in the Coronal plan Cobb angles pre-op and post-op between the two groups reported by Cho et al[4]. They also showed no statistically significant difference in the pre-op and post-op lumbar lordosis of the two groups. However, they showed a statistically significant difference (P = 0.03) in post-op maintenance of Lumbar lordosis between the two groups. The loss of correction of lumbar lordosis was more in the L5 group. This was attributed to progression of degeneration at L5-S1 causing decrease in lordosis across the L5-S1 segment that changed in the L5 group from -7.2° pre-op to -2.1° at final visit.

For correction in the sagittal plane, Cho et al[4] found no significant difference between the two groups. On the contrary, Edwards et al[5] reported a higher loss of correction of sagittal balance for the cohort that had fusion stopped at L5 compared to the ones where the fusion was extended to S1. Loss of L5-S1 disc lordosis was again suggested to be associated with the loss of sagittal balance in the group where fusion was stopped at L5[5].

Subsequent advanced L5-S1 and Sacroiliac joint degeneration: Stopping the fusion at L5 has been shown in multiple studies to lead to subsequent advanced disc degeneration at L5-S1 after long lumbar fusion to L5[4,5,8,18] with an incidence of 58% - 69%. However, this progression of degeneration has not been shown to be related to the level of degeneration present at L5-S1 pre-operatively[4,18]. Cho et al[4] reported that it is more likely in patients with preoperative sagittal imbalance (> 5cm) and lumbar hypolordosis (< 30°). The presence or absence of a deep seated L5 segment (pedicles of L5 below the intercrestal line) also does not appear to have an effect on subsequent advanced degeneration as reported by Eck et al [18]. Another factor that appears to be important in causing subsequent advanced degeneration at L5-S1 is the length of the fusion, with longer fusions having a higher incidence of degeneration[8]. It is also worth mentioning that post-op subsequent advances L5-S1 degeneration

predisposes to, but does not equate to, symptomatology or need for revision surgery in the studies[4,5,8]. However, longer follow-up of 10-20 years may be needed to properly establish that relationship.

Disc degeneration was graded according to the modified Weiner scale as introduced by Edwards et al[5].Ohtori et al [4] reported no incidence of SI joint degeneration after a minimum 3 y follow-up in patients fused to the sacrum. Eck et al[18] also reported on patients with fusion to the sacrum that showed no evidence of SI joint degeneration after a minimum follow-up of 2 y.

Pseudarthrosis: For patients with extension of fusion to S1, development of pseudarthrosis is a major risk post-op with rates between 19 – 42%[5-7,9]. This rate, however, does decrease with augmentation of the sacral fusion with iliac screws[10,17] and perhaps even more with complete sacropelvic fixation using bilateral bicortical S1 scews, bilateral iliac screws and anterior column support at L5-S1. Weistroffer et al[9] report a pseudarthrosis rate of 24% of patients with long fusion to the. Interestingly they also noted that only 25% of those pseudarthrosis were detected within the 2 year follow-up period. They noted no difference in pseudarthrosis rate between patients with or without augmentation with iliac fixation[9].

Functional Outcomes: Two studies[4,5] showed no statistically significant difference in functional outcome scores between the groups at final follow-up. Cho et al[4] showed significant improvement from pre-op to final post-op in both groups. Ohtori et al[10] only published on the L5 group also showing significant improvement from pre-op to final post-op. There is also a concern that extending the fusion to S1 would alter gait mechanics. However, this has not been proven. In fact, Engsberg et al[23] showed that there was no difference in the gait of the patients regardless of fusion to L5 or to S1.

Revision Surgery Rate: The studies show that there is a significant revision rate in both groups. However, no studies report a higher revision rate for the L5 group even with a known high rate of subsequent L5-S1 degeneration. On the other hand, Edwards et al[5] reported statistically significant difference in revision rates between the 2 groups with the mean number of procedures of 2.8 in the S1 group compared to 1.7 in the L5 group. However, revision fusion to the sacrum may include smaller surgeries like removal of symptomatic iliac screws or revising implants for L5-S1 pseudarthrosis with addition of BMPs[19].

DISCUSSION: In the studies looking at fusion stopping at L5 versus extending to S1 there were no differences in terms of surgical time, blood loss and complications if the fusion to the sacrum was not augmented with iliac screws and/or anterior column support. However, when the fusion to the sacrum is augmented there is a higher rate of complications that is statistically significant compared to the group with fusions stopping at L5. Patients with fusion extending to the sacrum also have a significantly higher rate of revision surgery compared to those with fusion stopping at L5 and exhibit a significant rate of pseudarthrosis of between 19% - 42%. There is a higher rate of loss of sagittal balance and lordosis correction in the patients where the fusion is stopped at L5 compared to those with fusion extending to the sacrum. This appears to be related to the high rate (58% - 69%) of development of subsequent L5-S1 disc degeneration in these patients that leads to loss of lordosis at the L5-S1 disc. This subsequent disc degeneration does not appear to be related to the pre-op status of the disc or to the existence of a deep seated L5. Nevertheless, presence of subsequent disc degeneration predisposes to, but does not guarantee, having symptoms or requiring revision surgery. However, longer term follow-up may be needed to establish that relationship. Based on these findings, we advocate stopping the fusion at L5 in patients with "healthy" pre-op L5-S1 disc. We must emphasize again the importance of involving the patient in this decision and making them aware of the risk for revision surgery. However, stopping the fusion at L5 carries a risk of revision surgery that is not higher than that in patients fused to the sacrum and also allows for sparing of the L5-S1 motion segment.

REFERENCES

1. Kilshaw, M., et al., Abnormalities of the lumbar spine in the coronal plane on plain abdominal radiographs. Eur Spine J, 2011. 20(3): p. 429-33.
2. Urrutia, J., et al., The impact of lumbar scoliosis on pain, function and health-related quality of life in postmenopausal women. Eur Spine J, 2011. 20(12): p. 2223-7.
3. Kebaish, K.M., et al., Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. Spine (Phila Pa 1976), 2011. 36(9): p. 731-6.
4. Cho, K.J., et al., Arthrodesis to L5 versus S1 in long instrumentation and fusion for degenerative lumbar scoliosis. Eur Spine J, 2009. 18(4): p. 531-7.
5. Edwards, C.C., 2nd, et al., Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. Spine (Phila Pa 1976), 2004. 29(18): p. 1996-2005.
6. Emami, A., et al., Outcome and complications of long fusions to the sacrum in adult spine deformity: luque-galveston, combined iliac and sacral screws, and sacral fixation. Spine (Phila Pa 1976), 2002. 27(7): p. 776-86.
7. Kostuik, J.P. and B.B. Hall, Spinal fusions to the sacrum in adults with scoliosis. Spine (Phila Pa 1976), 1983. 8(5): p. 489-500.
8. Kuhns, C.A., et al., Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc, minimum 5-year follow-up. Spine (Phila Pa 1976), 2007. 32(24): p. 2771-6.
9. Weistroffer, J.K., et al., Complications in long fusions to the sacrum for adult scoliosis: minimum five-year analysis of fifty patients. Spine (Phila Pa 1976), 2008. 33(13): p. 1478-83.
10. Ohtori, S., et al., Clinical incidence of sacroiliac joint arthritis and pain after sacropelvic fixation for spinal deformity. Yonsei Med J, 2012. 53(2): p. 416-21.
11. Schwab, F., et al., A lumbar classification of scoliosis in the adult patient: preliminary approach. Spine (Phila Pa 1976), 2005. 30(14): p. 1670-3.
12. Liu, W., et al., The clinical features and surgical treatment of degenerative lumbar scoliosis: a review of 112 patients. Orthop Surg, 2009. 1(3): p. 176-83.
13. Bridwell, K.H., C.C. Edwards, 2nd, and L.G. Lenke, The pros and cons to saving the L5-S1 motion segment in a long scoliosis fusion construct. Spine (Phila Pa 1976), 2003. 28(20): p. S234-42.
14. Kim, Y.J., et al., An analysis of sagittal spinal alignment following long adult lumbar instrumentation and fusion to L5 or S1: can we predict ideal lumbar lordosis? Spine (Phila Pa 1976), 2006. 31(20): p. 2343-52.
15. Seo, J.Y., et al., Risk of progression of degenerative lumbar scoliosis. J Neurosurg Spine, 2011. 15(5): p. 558-66.
16. Wang, M.Y., PLIF for the treatment of adult spinal deformity. Acta Neurochir (Wien), 2011. 153(3): p. 557.
17. Charosky, S., et al., Complications and risk factors of primary adult scoliosis surgery: a multicenter study of 306 patients. Spine (Phila Pa 1976), 2012. 37(8): p. 693-700.
18. Eck, K.R., et al., Complications and results of long adult deformity fusions down to l4, l5, and the sacrum. Spine (Phila Pa 1976), 2001. 26(9): p. E182-92.
19. Polly, D.W., Jr., C.L. Hamill, and K.H. Bridwell, Debate: to fuse or not to fuse to the sacrum, the fate of the L5-S1 disc. Spine (Phila Pa 1976), 2006. 31(19 Suppl): p. S179-84.
20. Horton, W.C., R.T. Holt, and D.S. Muldowny, Controversy. Fusion of L5-S1 in adult scoliosis. Spine (Phila Pa 1976), 1996. 21(21): p. 2520-2.
21. Swamy, G., S.H. Berven, and D.S. Bradford, The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis. Neurosurg Clin N Am, 2007. 18(2): p. 281-8.
22. Cho, K.J., et al., Short fusion versus long fusion for degenerative lumbar scoliosis. Eur Spine J, 2008. 17(5): p. 650-6.
23. Engsberg, J.R., et al., Prospective comparison of gait and trunk range of motion in adolescents with idiopathic thoracic scoliosis undergoing anterior or posterior spinal fusion. Spine (Phila Pa 1976), 2003. 28(17): p. 1993-2000.

Table 1: Pros and cons of stopping the fusion at L5

Pros of stopping the fusion at L5	Cons to stopping fusion at L5
Preservation of the L5-S1 motion segment[4,18,19].	Possible loss of deformity correction over time with less reliable maintenance of sagittal balance[4,5,18-20].
Shorter surgery reducing the magnitude of the operation[19].	Degeneration at L5-S1 causing worsening of pain and function[4,5,18,20].
Fewer perioperative complications[5,17].	Less reliable maintenance of functional and pain improvement[18,20].
Decreased incidence of pseudarthrosis[4,5,19].	Need for revision surgery with extension to the sacrum[4,5,19,20].
Protect sacroiliac and hip joints.	

Table 2: Pros and Cons to extending the fusion to S1

Pros of extending the fusion to S1	Cons to extending the fusion to S1
Lower rate of revision surgeries[20].	Longer surgeries with more blood loss[19].
More reliable maintenance of functional and pain improvement[18].	Loss of motion at lumbosacral motion segment, resulting in altering gait mechanics[4,19].
Reliable maintenance of deformity correction[4,5,18-20].	Higher rate of peri-operative complications[5,17].
	Higher rate of pseudarthrosis[4,5,17,19,20].
	Incidence of symptomatic iliac screws[19].
	Higher rate of sacroiliac and hip joint arthritis.

Table 3: Characteristics of studies included & complications reported

Author	Study Design (Evidence Level)	Demographics	Interventions	Follow-up	Complications
Cho et al[4] (2009)	Retrospective Cohort (II)	**L5 group:** -N: 24 -Age: 63.6 ± 6.3 y **S1 group:** -N: 21 -Age: 65.6 ± 6.8 y	**L5 group:** fusion to L5 **S1 group:** fusion to S1 (excluded patients with iliac screw fixation)	Minimum: 2 y Mean ±SD: 3.5 ± 1.7 y	**L5 group:** Instrumentation: 4; Distal segment disease: 4; Proximal segment disease: 5; Peri-operative Medical: 7 **S1 group:** Instrumentation Failure: 5; Proximal segment disease: 5; Peri-operative Medical: 8 *P* **NS**
Ohtori et al[10] (2012)	Prospective Cohort (III)	**S1 group:** -N: 20 -Male:Female: 12:8 -Age: 66± 7.0	**S1 group only:** fusion to S1	Minimum: 3 y Mean (range): 3.4 (3-4) y	**S1 group:** Deep infection: 2; Adjacent level compression; racture: 3
Edwards et al[5] (2004)	Retrospective Matched Cohort (II)	**L5 group:** -N: 28 -Age: 44 (20 – 61) y **S1 group:** -N = 12 -Age: 44 (27 – 77) y	**L5 group:** fusion to L5 **S1 group:** fusion to S1	Minimum: 2 y Mean (range): 4.8 (2 – 14.3) y	**L5 group:** Distal transition syndrome: 4; Proximal transition syndrome: 1; Post-operative radiculopathy: 1; Loss of fixation: 1; Non-union: 1 **S1 group:** Proximal transition syndrome: 1; Perioperative Medical: 4; Non-union: 5 Infection: 2; Coronal imbalance: 1 ***P*** = 0.02
Kuhns et al[8] (2007)	Retrospective Cohort (III)	**L5 group:** -N: 31 -Age: 45 (20 – 62) y -Male:Female: 3:28	**L5 group only:** fusion to L5	Minimum: 5 y Mean (range): 9.4 (5-20.1) y	NR
Kostuik et al[7] (1983)	Retrospective Cohort (III)	**S1 group:** -N: 45 -Age: 44.3 y	**S1 group only:** fusion to the sacrum		NR
Weistroffer et al[9] (2008)	Retrospective Cohort (III)	**S1 group:** -N: 50 -Age: 54 (18 – 72) y	**S1 group only:** fusion to sacrum from T10 or higher	Minimum: 5 y Mean: 9.7 (5-26) y	**S1 group:** Wound infections: 8 Dural tears: 5; Perioperative medical: 8; Painful instrumentation: 11; Implant loosening or failure: 9
Emami et al[6] (2002)	Retrospective Cohort (III)	**S1 group:** -N: 54 -Age: 54.9 (25 – 77) y	**S1 group only:** fusion from T11 or above to the sacrum	Minimum: 2 y Mean: 57 months	**S1 group:** Dural tears: 6; Infection: 4; Epidural hematoma: 1; Symptomatic instrumentation: 9; Cauda equine: 1; Periop medical: 8
Charosky et al[17] (2012)	Retrospective Cohort (IV), Combined results of all treatment groups report, not separated by type of intervention	N: 306 Age: 63 (50 – 83) Male:Female:52:254 **Fusion to sacrum:** N = 134	**Anterior only surgery:** 30 **Posterior only surgery:** 221 **Anterior + posterior surgery:** 55	Minimum: 1 y Mean: 54 ± 30 months	**Total:** 175 for 119 patients (39%) : Peri-op Medical: 13.7%, infection: 5.2%, Neurologic: 7.5%, Mechanical (deformity/pseudarthrosis/instrumentation failure): 24% **Risk Factors:** High pre-op CIRS > 4.2, Number of segments fused > 4, Fusion to sacrum, PSO, PT > 23°

CIRS indicates Cumulative Illness Rating Scale; P, P Value; PSO, Pedicle Subtracting Osteotomy; PT, Pelvic Tilt; NR, Not reported; NS, Not significant (P > 0.05)

Notes

DEBATE AND CASE DISCUSSION 1: FATE OF FUSING TO L5 OR THE SACRUM/ILIUM: DO WE HAVE ENOUGH INFORMATION

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Considerations for Stopping at L5

1. Preserve L5-S1 Disc if Healthy
2. Decrease known risk of pseudarthrosis at L5-S1 with fusion to ilium
3. Shorter surgery with less dissection and implant issues
4. Patulous pedicles at L5 leading to implant issues or/and loss of correction

Considerations to Fuse to Sacrum/Ilium

1. Better restoration of sagittal balance
2. Known long-term degeneration/SAD of L5-S1
3. Highest risk of pseudarthrosis at L5-S1 Kim et al ~19%
4. If previous decompression of L5
5. Spondylolysis or lysis at L5
6. Preoperative advanced disc degeneration

Weiber Radiographic Scoring System for Osteoarthritis of Lumbosacral Spine Disc

Score	Description
0	No degeneration
1	Mild degen, <25% narrowing, small spur formation, no gas or eburnation; no listhesis
2	Moderate degen; 25-75% narrowing, moderate spurring and eburnation; ≤ 3mm listhesis; no Gas
3	Advanced degen; large spur formation; listhesis > 5mm, gas present

Edwards et al reported SAD developing at L5-S1 in 61% of patients at 5.6 yr of FU

Kuhns et al reported rate of SAD in 72% with avg FU of 9.4 years

The main finding between minimum 2-yr FU and subsequent 5-yr FU was no only further degeneration of the L5-S1 segment, but most importantly the development of increasingly positive sagittal balance.

Potential risk factors for development of SAD included:

1. Long fusions extending into the upper thoracic spine down to L5
2. Circumferential fusions in caudal lumbar spine.
3. 28% of patients with "short fusions" (t8-12 down to L5) developed SAD
4. 72% of patients with "long fusions" (T1-7 down to L5) demonstrated SAD

Surgical Considerations if Extending Down to Sacrum

1. Bicortical or Tricortical Fixation of S1
2. Anterior Interbody support via ALIF or TLIF
3. Iliac screws or S2-Alar Screws to protect S1 screws
4. Plenty of autogenous/allograft bone
5. Consideration of Biologics

Case Example

56 degrees Left TL/L (L1-L4) Curve with Back and leg pain

L3-4 stenosis by CT Myelogram

Normal Thoracic Kyphosis

Pt also with Left T11/12 Large Calcified Disc by Myelogram

Patient Assessment

1. Patient with Back and Leg pain
2. ? Extension to thoracic spine
3. ? How far caudal to extend
4. Good overall sagittal balance
5. ? Caudal disc assessement
    a. L5-S1 Disc Weiber 2/3

Dilemma

1. PSF from T3-L5
2. PSF from T3-ilium
3. PSF from T10-L5
4. PSF from T10-Ilium
5. ? TLIF L4/5 and L5/S1
6. ? ALIF L4-5 and L5-S1
7. Limited Decompression L4-5 $\pm$ TLIF or PLF

Why Fuse to L5 versus S1

1. If you believe the L5-S1 Disc is completely normal
2. If you are concerned about pseudoarthrosis

Why fusing to S1/Ilium is Best in this case

1. Because of the Cobb angle and end vertebrae (in addition to the T11/12 Disc herniation), normal sagittal alignment and normal thoracic kyphosis…. best decision is a T10-ilium with T11/12 discectomy/decompression through the pedicle with L3/4 decompression and TLIF at L4/5 and L5-S1 with iliac fixation or S2-iliac screws
2. Reason L5 will eventually fail
    a. L5-S1 Disc will degenerate precipitously over time
    b. Pt will likely develop stenotic symptoms over time
    c. Pt will likely "pitch forward" over time

References

1. Kuhns CA, Bridwell KH, Lenke LG, Amor C, Lehman RA, Buchowski JM, Edwards C 2nd, Christine B. Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc: minimum 5-year follow-up. Spine (Phila Pa 1976). 2007 Nov 15;32(24):2771-6.
2. Edwards CC 2nd, Bridwell KH, Patel A, Rinella AS, Berra A, Lenke LG. Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. Spine (Phila Pa 1976). 2004 Sep 15;29(18):1996-2005.
3. Harimaya K, Mishiro T, Lenke LG, Bridwell KH, Koester LA, Sides BA Review: Etiology and revision surgical strategies in failed lumbosacral fixation of adult spinal deformityconstructs. Spine (Phila Pa 1976). 2011 Sep 15;36(20):1701-10.
4. Swamy G, Berven SH, Bradford DS. The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis. Neurosurg Clin N Am. 2007 Apr;18(2):281-8.12.
5. Edwards CC 2nd, Bridwell KH, Patel A, Rinella AS, Jung Kim Y, Berra AB, Della Rocca GJ, Lenke LG. Thoracolumbar deformity arthrodesis to L5 in adults: the fate of the L5-S1 disc. Spine (Phila Pa 1976). 2003 Sep 15;28(18):2122-31.
6. Eck KR, Bridwell KH, Ungacta FF, Riew KD, Lapp MA, Lenke LG, Baldus C, Blanke K. Complications and results of long adult deformity fusions down to l4, l5, and the sacrum. Spine (Phila Pa 1976). 2001 May 1;26(9):E182-92.

Notes

Concurrent Morning Session - Pediatric

INNOVATIONS IN DIAGNOSTIC & GUIDANCE TECHNIQUES IN PEDIATRIC SPINAL SURGERY OVER THE PAST DECADE

Moderators:
Lori Ann Karol, MD; James O. Sanders, MD

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AFTER A DECADE OF INTENSE INVESTIGATION, WHAT IS THE ROLE THAT GENETICS PLAYS IN THE DEVELOPMENT OF SCOLIOSIS?

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Outline:

A. Overview of genetic etiology of disease

B. Evolution of Methods of study

   a. Molecular advancements

   b. Statistical Approaches

C. Idiopathic scoliosis: a complex genetic disease – where are we?

A. Genetic basis of disease

Initial epidemiological approach

Population versus family observation to establish genetic basis

Twin Studies

Genetic mode of heritability

Candidate gene 'causation'

Family-based studies

One gene – major effect

Gene targets

Extracellular matrix

Endocrine

Struggle to define phenotype – concominant issue

Etiology - factors causing the condition

Pathogenesis – mode of origin of a condition

Pathomechanism – sequence of events in the evolution of its structural and functional changes of a condition

Recognition of spatial-temporal aspects of embryological development as potentially playing a role as both factors of initiation and factors for progression of idiopathic scoliosis

B. Advances in molecular medicine – parallel our understanding of complex genetic disease

1. Candidate gene

Can isolate genetic product (for example, type 3 collagen)

Define a family with a strong phenotype

Trace the genetic product within the members of the family and relate to phenotype

Early studies in which DNA sequence 'known', can isolate the DNA sequences as opposed to the genetic product and trace within family

2. Genome-wide scanning with microsatellite markers

Knowledge of DNA genetic sequences such as common repeats, enzyme cleavage points, which in and of themselves are 'innocent' but also have variation from individual to individual.

As knowledge grew, density increased, so that one could detect them approximately one per 8-10 centimorgans (a length along a chromosome).
**length is important due to chances of recombination during meiosis

KEY POINT: DENSITY OF MARKERS

Statistical Analysis – primarily LINKAGE analysis directed at looking at shared alleles at a marker locus (chromosomal area with a number of genes) in family data.

Advantage: high power to detect loci with alleles that have a large effect size, for example, alleles that make a large contribution to risk of a disease. Note that these are rare variants with large effect, both for simple Mendelaian disease and complex disease.

Strategy is feasible with much less dense set of markers than we are accustomed to today, and can detect co-segregation of markers over a much larger range or area

Disadvantage: alleles with a large effect size tend to be rare in the general population AND rare variants are COMMON in the general population

Examples: Cystic fibrosis (CFTR); Huntington disease (HTT)
Breast ca (BRCA1 and BRCA2)

3. Genome wide scanning with statistical association studies (GWAS)

Further knowledge of genomic sequence has led to identifying variation at the single nucleotide level (SNP).

Commonly refers to a population-based study of unrelated individuals with high-density SNP panels in case-control or cohort study designs.

Varying density on a 'chip' - density has a statistical level of 'diminishing returns'

Statistical Analysis: association studies of populations of unrelated individuals

Advantages: designed to have high power to detect common alleles which tend to have a small effect size upon the disease or trait
Ease of obtaining population-based samples of unrelated individuals, focus on categorical disease, and simplicity of analysis

Disadvantage: common alleles of small effect for complex traits many times do not explain a large proportion of disease risk or variation of the trait.
SNPs included in a GWAS chip are usually relatively common, not 'rare' because rare variants within a population based study will frequently be removed during data cleaning as potentially 'not real', technical error.

KEY POINT: STUDY DESIGN - FAMILY OR POPULATION-BASED

4. Next generation sequencing
   Technology has advanced to DNA sequencing techniques that make it feasible to sequence all exons or whole genomes of a reasonably large number of individuals

   Statistical Analysis: can be population or family based approach

   Combine sequencing methods with linkage and/or association techniques to identify causal variants with a large effect size

   Focus has now advanced to the specific identification of common or rare sequence variants (SVs)

   Advantages: ability to detect sequence variant whether it is common or rare.

   Disadvantages: Rare causal variants with large effect size will be difficult to detect in population based studies unless population is extremely large.

   Examples: Charcot Marie tooth variants and familial hypercholesterolemia

5. Timeline for understanding genetics of a complex genetic disease
   Example: breast cancer
   Importance of replication of findings in independent laboratories

C. Idiopathic scoliosis: a complex genetic disease – where are we?
   1. Candidate genes analysis with families
   2. Linkage analysis with families
   3. GWAS analysis with familial/sporadic populations

References:

Bailey-Wilson, J et al. Linkage Analysis in the Next-Generation Sequencing Era. Human Heredity 2011; 72:228.

Simpson CL et al., Old lessons learned anew: family based methods for detecting genes responsible for quantitative and qualitative in the genetic analysis workshop. BMC Proceedsing 2011, 5 S83.

Hall JM Linkage of early –onset familial breast cancer to chr 17q21. Science 1990:250:1684

Walsh T et al. Detection of inherited mutations for breast and ovarian cancer . Proc Natl Acad Scie USA 2010:107:12629.

Notes

DEBATE 2: THE SCOLIOSCORE: INNOVATIONS IN DIAGNOSTIC & GUIDANCE TECHNIQUES IN PEDIATRIC SPINAL SURGERY OVER THE PAST DECADE

ETIOLOGY AND IMAGING

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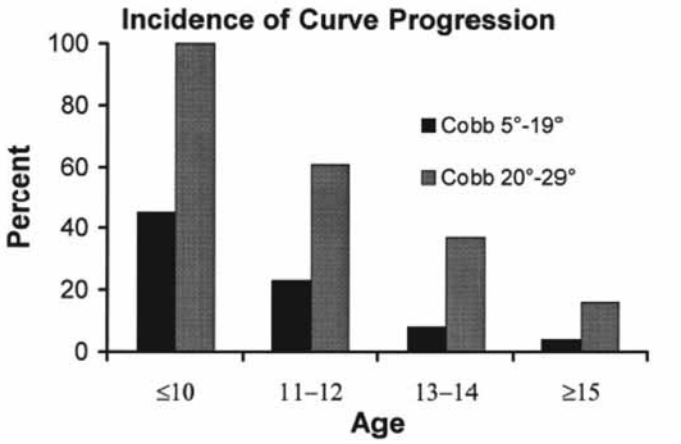
Prognostic Genetic Testing for AIS: Scoliscore™

Is AIS Genetic?

- Complex genetic disorder
  - High prevalence and extreme variability
- Environmental factors
- Specific mode of genetic inheritance?
  - Genetic loci
- Kinship coefficient is strong
- Progression to severe curve is more genetic than having mild scoliosis

Determining Who will Progress is the Clinical Challenge

- Almost impossible at the earliest stages
- Cobb angle, Risser, age are always changing
- Lonstein & Carlson Criteria, JBJS-A 1984



…but it has its limitations

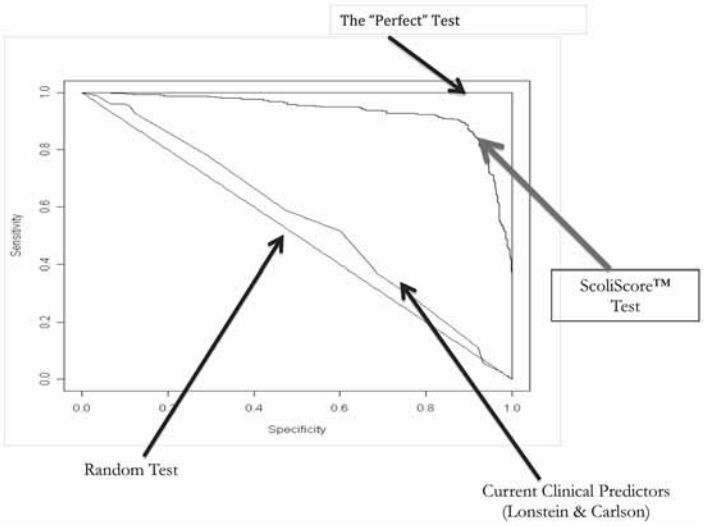
- Current observation treatment algorithm involves X-rays every 4-6 months
  - Clinical exam, time away from school, work, $$$
  - Many of these patients will not progress to need treatment
- Identification of those at risk and customization of treatment is needed

Development of a Prognostic Genetic Test for AIS

- Saliva based test
- Genome-wide association study
- DNA marker panel (53 SNPs) predicts likelihood of progression to a severe curve by skeletal maturity
- Indications for use:
  - Diagnosis – Adolescent Idiopathic Scoliosis
  - Age Range – 9-13 years of age Gender – Females and Males

- Races/Ethnicities – Caucasian (insufficient data for AA, Hispanics), not indicated for Asians
- Curve Type – Mild Curve (10- 25°Cobb Angle)

- Reports a score (incorp Cobb angle) 1-200
- Receiver / Operating Characteristic (ROC) Curve



AIS Prognostic Test: Impact

- AIS predictive test could eliminate inefficiencies in the mild scoliosis group at great individual and aggregate savings.
  - High negative predictive value
- Personalized, evidence based treatment
- Pre-symptomatic identification of patients at highest risk offers possibilities for novel treatments.

Validation of Scoliscore™

- Ward K, et al., Spine (31) 2010
  - Validation in 3 patient cohorts show that low risk scores have a NPV of 99%
  - School screening population, high acuity spine practice, AIS male cohort
  - Low risk (1-50), Intermediate risk (51-180), High risk (181-200)

Preliminary External Data

- Shah SA, et al., POSNA 2012, IMAST 2012
  - 234 patients tested prospectively, consecutively
  - Avg age = 11.8 yrs
  - Avg Cobb = 16.8° (10-25°)
  - Scoliscore™: Low risk (46%), Intermediate risk (48%), High risk (6%)
  - Low risk group
    - 46% of our patients (instead of 75% of a school screening population)
    - Smaller curves at presentation
    - Longer period between f/u and x-ray
    - Lower incidence of bracing
    - Different than those proportions previously described
- Roye BD, et al., SRS 2011, Spine 2012
  - 91 patients tested
  - Assigned a "clinical risk" score (L&C) and compared to Scoliscore™
  - Scoliscore™: Low risk (36%), Intermediate risk (55%), High risk (9%)
  - Clinical risk scores: Low risk (2%), Intermediate risk (51%), High risk (47%)
  - Only 25% of patients were in the same risk category using both systems
  - Positive correlation with Scoliscore™ and Cobb angle ($r=0.581$, $p<0.001$)
  - Scoliscore™ provides unique information to traditional predictors of AIS progression

Frequently Asked Questions

- What is the significance of an Intermediate Risk Score?
  - Direct correlation of risk of progression to a moderate curve
- How much does it cost?
  - $2950 and most are covered by insurance
- I have a Low risk patient who progressed, now what?
  - MRI, genetics consult, history…does the patient really have AIS?

References:

Lonstein JE, Carlson JM. The prediction of curve progression in untreated idiopathic scoliosis during growth. J Bone Joint Surg Am, 1061-71, 1984.

Ogilvie J, Braun J, Argyle V, et al. The search for idiopathic scoliosis genes. Spine 31, 679-81, 2006.

Roye BD, Wright M, Williams B, et al. Does Scoliscore provide more information than traditional clinical estimates of curve progression? Spine [Epub ahead of print] 2012.

Shah SA, Yorgova P, Neiss GI, Gabos PG, Bowen JR. Preliminary experience with clinical use of a DNA prognostic test for adolescent idiopathic scoliosis, presented at the 19th International Meeting on Advanced Spine Techniques, Istanbul, Turkey, 2012.

Ward K, Ogilvie J, Singleton M, et al. Validation of DNA-based prognostic testing to predict spinal curve progression in adolescent idiopathic scoliosis. Spine 35, E1455-64, 2010.

Ward K, Ogilvie J, Argyle V, et al. Polygenic inheritance of adolescent idiopathic scoliosis : a study of extended families in Utah. Am J Med Genet A, 1178-88, 2010.

Notes

DEBATE 2: THE SCOLISCORE: HAS IT PROVEN EFFECTIVE IN PREDICTING THE PROGRESSION OF SCOLIOSIS, DOES IT GUIDE TREATMENT DECISIONS AND IS THERE QUALITY LITERATURE TO SUPPORT ITS ACCURACY?

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Debate: The Scoliscore: Has it Proven Effective in Predicting the Progression of Scoliosis, Does it Guide Treatment Decisions and is there Quality Literature to Support its Accuracy?

Scoliosis is a Genetic Condition

Predictive test for Progression of AIS developed by Axial Biotech
- Saliva based
- 53 DNA marker panel
- Clinical trials completed (6500 patients)

Indications:
- Caucasian Females
- Age 9-13
- Cobb angle 10-25 degrees

Predicts progression to a "severe" curve, >40 degrees
- Low risk score: <50
- Intermediate risk score: 50-180
- High risk score: >180

How to Use the Information
- Low risk: less frequent follow-up xrays/exams
- High risk: possibly earlier intervention

Questions:

Has it Proven Effective in Predicting the Progression of Scoliosis? Sort of…but only for those who won't progress…which is most.
- 2-4% of curves progress to surgery
- 96-98% of patients don't progress
- Negative Predictive Value of test is reported as 99% (CI 95-100%)

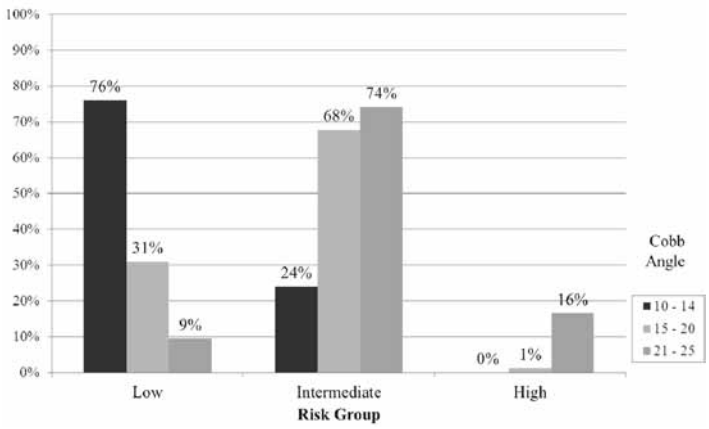
Table 3. Clinical Validation of AIS-PT Performance (Using Cutpoint of 40)

Cohort	No. Subjects	2 × 2 Tables AIS-PT	Severe	Mild/Moderate	NPV (95% CI)	No. Subjects Scored as Low Risk (%)
Screening	277	41–200	8	93	100% (99%–100%)	64%
		1–40	0	176		
Spine surgery practice (high acuity)	257	41–200	26	98	99% (95%–100%)	52%
		1–40	2	131		
Male (high acuity)	163	41–200	15	46	97% (93%–99%)	63%
		1–40	3	99		

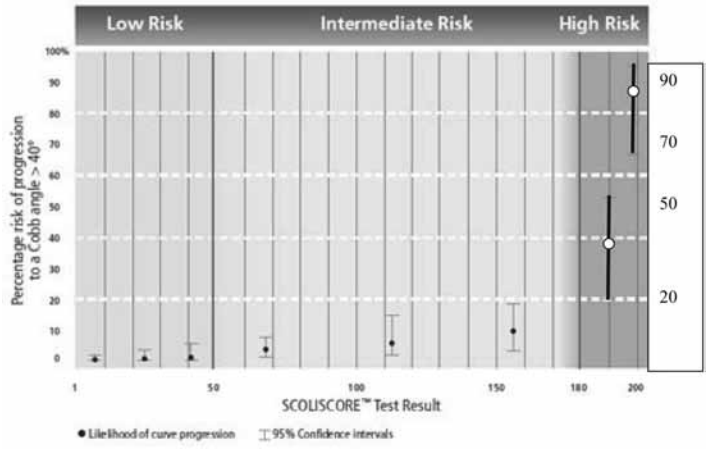
NPV indicates negative predictive value; 95% CI, 95% confidence intervals; AIS-PT indicates adolescent idiopathic scoliosis prognostic test.

Does it Guide Treatment Decisions? I don't think so…6-12 months of time and an xray is cheaper and much more helpful.

Curves 21-25 deg rarely get low risk score (might save them a brace?), Low risk means low risk of progression to surgery…but could progress up to 40 deg.



Maybe High risk patients should be treated early… NO
High risk is not very high (Score of 190, risk 20-50%).
Positive Predictive Value is low (8-21%).



Is there Quality Literature to Support its Accuracy? NO

SPINE Volume 35, Number 25, pp E1455–E1464
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Validation of DNA-Based Prognostic Testing to Predict Spinal Curve Progression in Adolescent Idiopathic Scoliosis

Kenneth Ward, MD,* James W. Ogilvie, MD,* Marc V. Singleton, MS,* Rakesh Chettier, MS,* Gordon Engler, MD,† and Lesa M. Nelson, BS*

3 Cohorts studied as intended use populations
- 227 low risk females representing screening cohort
- 257 higher risk females from referral centers
- 163 high risk males

Low risk scores, <41 (out of 200 max) had NPV of 100%, 99% and 97%

Spine Publish Ahead of Print
DOI: 10.1097/BRS.0b013e31825eb605

Does ScoliScore™ Provide More Information Than Traditional Clinical Estimates Of Curve Progression?

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Frequency of Scores do not match those intended by the Axial. Too few get the low scores they should, too many get high scores they shouldn't.

Distribution of ScoliScores		Intended Use Distribution from Axial	
Low	36%	Low	75%
Intermediate	55%	Intermediate	24%
High	9%	High	1%

1/3 of the Score is related to the Cobb magnitude, 2/3 related to genetics

Additional references:

Letters to the Editor

Dobbs and Gurnett, SPINE Volume 36, Number 15, p 1257, 2011

Grant and Dormans, SPINE Volume 36, Number 15, pp 1258–1259, 2011

Technical Monograph: http://www.scoliscore.com/portals/12/resources/ScoliScoreTechMono_12.pdf

Notes

IS BRACING IN AIS STILL BENEFICIAL IN 2012 AND HAS IT REACHED ITS MAXIMUM DEVELOPMENT OR IS THERE STILL ROOM FOR FUTURE IMPROVEMENT?

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Outline

1. Rationale for bracing
2. Evidence for/against bracing
3. Summary and limitations
4. Room for future improvement
5. Conclusions

1. Rationale for bracing
   - Generally agreed the etiology of AIS is genetic. Natural history is that some curves may progress during the adolescent growth spurt. No single predictor can determine which curve will progress and by how much. Prediction of progression is based on a combination of parameters including skeletal maturity, menarche status, curve type, curve magnitude at diagnosis, predicted body height etc.
   - Reason for bracing: "This is for curves between 25-40 degrees in growing children to prevent further progression of the curve while growth of the spine remains." - SRS
   - Treatment options other than bracing: observation/no treatment, surgery.
   - Clinical difficulties with bracing: selection of patients, compliance, psychosocial effect, QOL, etc. Effectiveness of bracing still controversial.
2. Evidence for/against bracing
   - Comparing bracing with observation
     i. For
        1. SRS prospective, non-RCT, multicenter study (Nachemson 1995)
        2. Surgical rate lower in braced patients between 20-39 degrees. (Lonstein 1994)
        3. Surgical rate 14.1% for braced and 28.1% for non-intervention. (Murayama 2011)
        4. Psychological effects only transient. (Noonan 1997)

     ii. Against
        1. Bracing surgical rate 23% vs 22% with observation (Dolan 2007)
        2. No significant difference, bracing probably unnecessary in majority of patients. (Miller 1984)
   - Comparing between full-time and part-time bracing
     i. Full time bracing better than part time bracing, better than natural history (Rowe 1997, Katz 2001, Jarvis 2008, Lee 2012)
   - Meta-analysis
     i. 92% no progression in braced group, vs 49% in untreated group (Rowe 1997)
     ii. 74% vs 34% success rate between braced and non-braced (Negrini, Cochrane review 2010)
     iii. Brace effective in the long term. QOL comparable to normal. (Murayama 2008)
3. Summary and limitations

   Literature in general supportive of bracing though evidence is weak. Brace more effective for smaller curves but not for >45 degrees. Full time is better than part time. Evidence in favor of hard versus elastic braces is also low.

   High variability in the conduct of clinical trials. Difficult to monitor compliance to bracing and non-adherence to protocol. RCT very difficult if not impossible. (Dolan 2008). Braces cannot be concealed. Two ongoing RCTs in US and Netherlands already facing failure of recruitment. (Bunge 2008, Dolan 2008, Weinstein 2009).

4. Room for future improvement
    - Evidence based medicine
        i. Conventional RCT
        ii. Alternative methods (Fong)
    - Standardize outcome definitions, in addition to Cobb angles.
    - Improve brace compliance and effect
        i. Hard versus flexible braces
        ii. Pressure sensors for monitoring both compliance and fitting (Chan 2012)
        iii. 'Smart' pressure pads (Culik 2011)
5. Conclusions
    - Bracing is still beneficial
    - However quality of present evidence is low
    - There is still ample room for future development
    - Will positively affect the value of scoliosis screening

References:

Bunge EM, Habbema JDF, de Konig HJ (2009). A randomised controlled trial on the effectiveness of bracing patients with idiopathic scoliosis; failure to include patients and lessons to be learnt. Idiopathic Scoliosis: Evaluation and Treatment:47–60.

Chan A, Lou E, Hill D, Faulkner G. (2012) Design and validation of transducers to measure interface force distribution in a spinal orthosis. Med Eng Phys. 18.

Culik J, Marik I, Cerny P. (2011) Treatment of children scoliosis by corrective brace with regulated force effect. J Musculoskelet Neuronal Interact. 11(2):203-7.

Dolan LA, Weinstein SL (2007). Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Spine; 32(19 Suppl):S91–S100.

Dolan, L. A., V. Sabesan, S. L. Weinstein and K. F. Spratt (2008) Preference assessment of recruitment into a randomized trial for adolescent idiopathic scoliosis." J Bone Joint Surg Am, 90(12): 2594-2605.

Daniel Y. T. Fong, Kenneth M. C. Cheung, Yat-wa Wong, Wai-Yuen Cheung, Idy C. Y. Fu, Evelyn E. Kuong, K. C. Mak, Michael To, Keith D. K. Luk. Is there a better alternative to a randomized control design for assessing the efficacy and effectiveness of bracing in AIS? (unpublished data) (Spine 2012)

Jarvis, J., S. Garbedian and G. Swamy (2008). Juvenile idiopathic scoliosis: the effectiveness of part-time bracing. Spine, 33(10): 1074-1078.

Katz, D. E.; Durrani, A. (2001). Factors that influence outcome in bracing large curves in patients with adolescent idiopathic scoliosis. Spine, 26(21):2354-2361.

Lee, C. S., C. J. Hwang, D. J. Kim, J. H. Kim, Y. T. Kim, M. Y. Lee, S. J. Yoon and D. H. Lee (2012). "Effectiveness of the Charleston Night-time Bending Brace in the Treatment of Adolescent Idiopathic Scoliosis." J Pediatr Orthop 32(4): 368-372.

Lonstein, J. E. and R. B. Winter (1994). "The Milwaukee brace for the treatment of adolescent idiopathic scoliosis. A review of one thousand and twenty patients." J Bone Joint Surg Am 76(8): 1207-1221.

M2 Maruyama, T. (2008). "Bracing adolescent idiopathic scoliosis: a systematic review of the literature of effective conservative treatment looking for end results 5 years after weaning." Disabil Rehabil 30(10): 786-791.

Maruyama T, Grivas TB, Kaspiris A (2011) SYSTEMATIC REVIEW Effectiveness and outcomes of brace treatment: A systematic review Physiotherapy Theory and Practice, 27(1):26–42.

Miller, J. A.; Nachemson, A. L.; and Schultz, A. B. (1984). Effectiveness of braces in mild idiopathic scoliosis. Spine, 9:632-635.

Nachemson, A.; Peterson, L. E and members of the Brace Study Group of the Scoliosis Research Society(1995): Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. J. Bone and Joint Surg., 77-A: 815-822.

Negrini S, Minozzi S, Bettany-Saltikov J, Zaina F, Chockalingam N, Grivas TB, Kotwicki T, Maruyama T, Romano M, Vasiliadis ES (2010). Braces for idiopathic scoliosis in adolescents (Review) Issue 1. http://www.thecochranelibrary.com

Noonan, K. J., L. A. Dolan, W. C. Jacobson and S. L. Weinstein (1997). "Long-term psychosocial characteristics of patients treated for idiopathic scoliosis." J Pediatr Orthop 17(6): 712-717.

Rowe, D. E.; Bernstein, S.M.; Riddick, M. F.; Adler, F.; Emans, J. B.; Gardner-Bonneau, D (1997). A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. JBJS, 79A-5:664-674.

Scoliosis Research Society Brace Mannual. http://www.srs.org/professionals/education_materials/SRS_bracing_manual/section1.pdf

Weinstein SL, Dolan L. Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST). http://clinicaltrials.gov/ct2/show/NCT00448448 2009. (Unpublished data)

Notes

WHAT NEW IMAGING AND GUIDANCE TECHNIQUES HAVE BEEN DEVELOPED OVER THE PAST TEN YEARS FOR THE TREATMENT OF SCOLIOSIS?

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In the operating room: imaging for safe placement of implants

Pedicle screw misplacement using conventional method (available a decade ago)

Lehman, Lenke et al Spine 2007–107/1023 (10.5%) had "significant mediolateral pedicle wall violations"
Smorgick et al J Spinal Disord Tech 2005–12.5% misplaced, 2 on aorta
Sarlak et al. Eur Spine J 2009–185/1797 (10%) thoracic misplaced
Amaral SRS 2011:Risking viscera: only 2.2% of screws, but 25% of patients

The evolution to image guided navigation for pediatric deformity surgery

Advantages of CT image guided navigation
- reveals axial deformity, as well as sagittal coronal planes
- screw length and diameter can be optimized
- fast and efficient, after initial learning curve
- fewer misplaced screws compared to freehand/C-arm technique

Disadvantages of CT image guided navigation

- cost
- radiation
- learning curve

Current evidence regarding image guided navigation

Current technique

Summary: CT image guided navigation in spine deformity surgery today is where neurologic monitoring was 20 years ago (there were concerns about cost, reliability, safety, and general availability of neurologic monitoring). Image guide navigation will soon be as much a standard of safe spine deformity surgery as neurologic monitoring is today.

In the clinic: reducing radiation and gaining more information

Efforts to reduce radiographs and radiation

Digital imaging

Attempts to use surface topography to follow scoliosis progression

EOS

- advantages
- disadvantages

References

1. Flynn JM, Sakai DS. Improving safety in spinal deformity surgery: advances in navigation and neurologic monitoring. Eur Spine J. 2012 May 22.
2. Ughwanogho E, Patel NM, Baldwin KD, Sampson NR, Flynn JM Computed tomography-guided navigation of thoracic pedicle screws for adolescent idiopathic scoliosis results in more accurate placement and less screw removal. Spine (Phila Pa 1976). 2012 Apr 15;37(8):E473-8.
3. Koivukangas T, Katisko JP, Koivukangas JP. Technical accuracy of an O-arm registered surgical navigator. Conf Proc IEEE Eng Med Biol Soc. 2011;2011:2148-51.
4. Sanborn MR, Thawani JP, Whitmore RG, Shmulevich M, Hardy B, Benedetto C, Malhotra NR, Marcotte P, Welch WC, Dante S, Stein SC. Cost-effectiveness of confirmatory techniques for the placement of lumbar pedicle screws.Neurosurg Focus. 2012 Jul;33(1):E12.
5. .Larson AN, Santos ER, Polly DW Jr, Ledonio CG, Sembrano JN, Mielke CH, Guidera KJ. Pediatric pedicle screw placement using intraoperative computed tomography and 3-dimensional image-guided navigation Spine (Phila Pa 1976). 2012 Feb 1;37(3):E188-94.
6. Bledsoe JM, Fenton D, Fogelson JL, Nottmeier EW. Accuracy of upper thoracic pedicle screw placement using three-dimensional image guidance. Spine J 2009: 817-821
7. DiGioia AM, Jaramaz B, Colgan BD. Computer Assisted Orthopaedic Surgery – Image Guided and Robotic Assistive Technologies. Clinic Orthop Relat Resear 1998;354: 8-16
8. Gebhard FT, Kraus MD, Scheider E, et al. Does Computer-Assisted Spine Surgery Reduce Intraoperative Radiation Doses? Spine 2006;31(17):2024-2027
9. Holly LT, Foley KT. Image Guidance in Spine Surgery. Orthop Clin N Am 2007;38:451-461.
10. Lehman RA, Lenke LG, Keeler KA, et al. Computed Tomography Evaluation of Pedicle Screws Placed in the Pediatric Deformed Spine Over an 8-Year Period. Spine 2007;32(24): 2679-2684
11. Lehman RA, Sasso RC, Helgeson MD, et al. Accuracy of Intraoperative Plain Radiographs to Detect Violations of Intralaminar Screws Placed Into the C2 Vertebrae. Spine 2007;32(26): 3036-3040
12. Mirza SK, Wiggins GC, Kuntz C, et al. Accuracy of Thoracic Vertebral Body Screw Placement Using Standard Fluoroscopy, Fluoroscopic Image Guidance, and Computed Tomographic Image Guidance. Spine 2003;28(4): 402-413
13. Nottmeier EW, Seemer W, Young PM. Placement of thoracolumbar pedicle screws using three-dimensional image guidance: experience in a large patient cohort. J Neurosurg Spine 2009;10: 33-39
14. Rampersaud YR, Foley KT, Shen AC, et al. Radiation Exposure to the Spine Surgeon During Fluoroscopically Assisted Pedicle Screw Insertion. Spine 2000;25(20):2637-2645
15. Slomczykowski M, Roberto M, Scheneeberger P, et al. Radiation Dose for Pedicle Screw Insertion – Fluoroscopic Method Versus Computer-Assisted Surgery. Spine 1999;24(10):975-983

Notes

WHAT ARE THE ADVANCES IN NEUROMONITORING OVER THE PAST DECADE AND ARE OUR PATIENTS SAFER?

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Spinal Deformity Surgery in 2012

- More powerful ways to correct deformity
- More aggressive surgical techniques
- Complex medical legal climate
- Changing expectations of patients/society

Our neuromonitoring standard of care has changed:

- Wake-up test
- Somatosensory evoked potentials
- Multimodal monitoring
- Multimodal monitoring with TceMEP's and H reflex

Neurological monitoring evolution — Why?

Wake-up test

- Too little– test of gross function
- Too late — delay after surgical maneuver

Somatosensory evoked potentials

- Too little– does not test motor function
- Too late — delay after surgical maneuver
- Unreliable: false + and false –
- Highly sensitive to inhalational anesthetics

Transcranial Electric Motor Evoked Potentials (tceMEP) Facts

- Site of mediation:
  - corticospinal tract (CST)
  - spinal interneurons
  - anterior horn cells
  - alpha motor-neurons
- Technically more challenging than SSEPs TIVA
- Identifies inadequate spinal cord perfusion pressure

Has our level of safety improved?

Schwartz et al JBJS 2007

- SSEP monitoring alone carries risk of false negative
- No false positives, no false negatives with tceMEP
- SSEP changes often lag behind tceMEP changes (average= 5 minutes)
- Prolonged hypotension predisposes the cord to neurologic insult
- tceMEPs are a more rapid and sensitive method of detecting an impending neurologic deficit

Vitale et al JBJS 2010

- 162 pts, 151 successfully monitored
- 12 true electrophysicial event, higher in pts with cardiopulmonary cormorbidity
- 8- correction
- 2-hypotension
- 2 cord trauma (1 PS)
- 2/12 postop neuro deficit

Thuet et al Spine 2010

- 23 yr retrospective 3436 pediatric pts
- 2.2% potential neurologic deficits
- Seven patients (0.2%) false-negative - neurologic deficits undetected by neuromonitoring.
- CONCLUSION: The combined use SSEP's, TcMEP's, DNEP's, and EMG monitoring allowed accurate detection of permanent neurologic status in 99.6% of 3436 patients
- Intervention reduced the total number of permanent neurologic injuries to 6 (0.17%).

Osteotomies: Cheh et al Spine 2008

- Review of 42 pediatric thoracic kyphosis osteotomy cases
- 9 (21%)complete loss NMEP data with normal SSEP's, with return to normal in 8-20 min.
- One false negative, no permanent neuro deficits
- Interventions=raise MAP>80mmHg, reduce correction, correct saggital translation, possibly bigger cage or more decompression IMMEDIATELY.

CONCLUSION:

Data supports the use of current neuromonitoring techniques combining SSEP's, TcMEP's, DNEP's, and EMG monitoring. This has allowed intervention and reductioin in the number of intraoperative neurologic injuries during spinal deformity surgery. The use of more aggressive correction techniques including spinal osteotomies requires the use of these modalities.

REFERENCES

Cheh G et al. Loss of Spinal Cord Monitoring Signals in Children During Thoracic Kyphosis Correction With Spinal Osteotomy: Why Does It Occur and What Should You Do? Spine 2008; 33(10):1093–1099.

Fehlings MG et al. The Evidence for Intraoperative Neurophysiological Monitoring in Spine Surgery: Does It Make a Difference? Spine 2010; 35(9): S37–S46.

Lenke LG et al. Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res. 2010;468(3):687-99.

Lewis SJ et al. Neurophysiological changes in deformity correction of adolescent idiopathic scoliosis with intraoperative skull-femoral traction. Spine 2011; 36(20):1627-38.

Pastorelli F et al. The prevention of neural complications in the surgical treatment of scoliosis: the role of the neurophysiological intraoperative monitoring. Eur Spine J. 2011; 20:S105-14.

Schwartz DM et al. Neurophysiological detection of impending spinal cord injury during scoliosis surgery. J Bone Joint Surg Am. 2007;89(11):2440-9.

Schwartz DM et al. Transcranial electric motor evoked potential monitoring during spine surgery: is it safe? Spine 2011; 36(13):1046-9.

Thuet ED et al. Validity and reliability of intraoperative monitoring in pediatric spinal deformity surgery: a 23-year experience of 3436 surgical cases. Spine 2010; 35(20):1880-6.

Vitale MG et al.Risk factors for spinal cord injury during surgery for spinal deformity. J Bone Joint Surg Am. 2010;92(1):64-71.

Notes

WHAT NON-FUSION SCOLIOSIS TECHNIQUES HAVE EVOLVED FOR THE TREATMENT OF THE GROWING SPINE AND HAVE STOOD THE TEST OF TIME: GROWING RODS AND VEPTR

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Early onset scoliosis (EOS) is typically defined as a three-dimensional spine and chest wall deformity presenting in children under the age of 9. In contrast to scoliosis developing in adolescence, EOS is often associated with abnormal anatomy or disease and is roughly categorized as idiopathic, congenital, neuromuscular, or syndromic[1,2]. Children with EOS may suffer from significant morbidity and severely shortened life expectancy[2]. Morbidity is largely secondary to the devastating effects of the deformity on the developing lungs and thorax, as the growth velocities of thoracic and lumbar vertebrae are usually greatest during the first 5 years of life[3,4]. Campbell et al., described the thoracic insufficiency syndrome (TIS), as the inability for the thorax to support normal respiration and lung growth[5]. In children with EOS, this phenomenon can be attributed to the presence of chest wall abnormalities such as fused ribs and hemivertebrae; as a result of spasticity or weakness secondary to neuromuscular disease; or following surgery, such as early spinal fusion or procedures involving thoracotomy.

In years past, spinal fusion with metal rods was thought to be the gold standard surgical treatment for all children with significant scoliosis, even the skeletally immature[6]. Over time, it was observed that patients fused at a very young age experienced severe impairment in pulmonary function and early mortality due to growth arrest in the thoracic spine[7–10]. With this knowledge, spine surgeons have established that the goals of therapy in EOS should be to facilitate continued growth of the spine while slowing or halting the progression of a malignant curvature[11].

Treatment options in patients with EOS have proven to be extremely variable given the many different etiologies and available methods of correction and/or stalling progression. Nonsurgical methods include bracing, casting, halo traction, and physical therapy, while operative treatment includes non-fusion techniques such as growth distraction, growth guiding, and growth modulating methods[1] (Skaggs paper on different EOS surgeries). As evidence in the field is lacking, choice of intervention is largely dependent on the practitioner's experience in treating patients with certain similar characteristics as well as his/her skill and comfort with a particular method.

Harrington is credited as being the first to perform insertion of a single subcutaneous rod without fusion, which has inspired several variations since[6,12]. While this approach certainly reduced Cobb angle and preserved growth potential to some degree, complications occurred at an unacceptable rate.

Akbarnia et al presented their experience with a dual-growing rod method that achieved appreciable correction of deformity and permitted T1-S1 growth that nearly equaled that of normal spines[13]the growing rod techniques have used a single rod and the reported results have been variable. There has been no published study exclusively on the results of dual growing rod technique for early-onset scoliosis. METHODS: From 1993 to 2001, 23 patients underwent dual growing rod procedures using pediatric Isola instrumentation and tandem connectors. Diagnoses included infantile and juvenile idiopathic scoliosis, congenital, neuromuscular, and other etiologies. All had curve progression over 10 degrees following unsuccessful bracing or casting. Of 189 total procedures within the treatment period, 151 were lengthenings with an average of 6.6 lengthenings per patient. Analysis included age at initial surgery and final fusion (if applicable. The growing rods require multiple lengthening surgeries to maintain correction and keep up with the growth of the spine. This is believed to stimulate vertebral growth, but the repeated manipulations predispose to a significant complication rate. There is great variability and little evidence to support optimal intervals for lengthening procedures.

Campbell's research on TIS brought to light the cardiopulmonary ramifications of severe scoliosis and chest wall abnormalities. In 2003, Campbell presented the technique of expansion thoracoplasty with a Vertical Expandable Prosthetic Titanium Rib (VEPTR)[14,15]. This device is FDA approved for treating patients with TIS secondary to rib abnormalities and thoracogenic scoliosis. However, due to its capacity for modifications, experienced surgeons have applied the VEPTR to patients across all etiologies of spinal deformity. The VEPTR procedure is certainly not without complications and the issue of frequency of lengthening procedures remains unanswered.

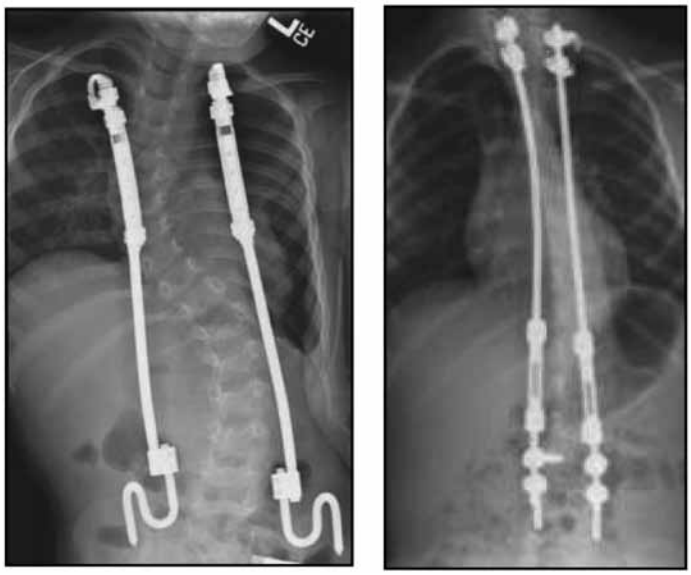

Figure 1. (a) Bilateral VEPTR rib-to-pelvis construct. (b) Dual spine-based growing rods.

Due to the lack of high level of evidence work, the complexities of these young patients and the ongoing developments with growing systems have led to significant variability in the surgical decision-making and management of EOS, which was further illustrated by Vitale et al[16]. Such variability in opinion, if reflective of actual decision making, raises concerns about the quality of care of patients with early onset scoliosis. It also further highlights the need for organization of Level I and II multicenter studies to rigorously compare various treatment modalities in this heterogeneous and challenging group of patients.

Members of the CWSDSG and the GSSG have collaborated on several parallel projects with a goal of improving the research infrastructure within the field of EOS.

Four research priorities were identified:

1. To establish a patient-based outcome measure of quality of life (QOL) in EOS.
2. To identify areas of equipoise amongst pediatric spine surgeons in the management of EOS, setting the stage for clinical trials and other high-level evidence studies.
3. To develop a classification system to facilitate communication between providers, improve management, and guide future research in the field of EOS
4. To build an effective, experienced group of researchers spanning both study groups who are invested in contributing to a prospective study in this area.

Having made significant progress in achieving the previous aims, the study group applied for and was awarded an OREF grant in 2010/2011 to fund a clinical trial-planning meeting. The EOS Clinical Trial Planning meeting at ICEOS 2011 enabled discussion amongst group members to decide which clinical question was most pressing to pursue in a prospective study. It was decided that a study comparing the safety and effectiveness of growing rods with spine or rib based proximal anchors would substantially inform management decisions in the future and improve care for these young patients.

A retrospective pilot study reviewing data collected from the CWSDSG and GSSG registries was performed to analyze characteristics of patients treated with spine-based distraction rods and those treated with rib-based growing rods. The initial results of this retrospective review can be found in the tables below.

Table 1. Demographics of Patients with EOS, age 2-10 years old

TOTAL	**N = 809**
Cobb >50	**N = 702**
Distraction method:	
Spine-based	N = 408
Rib-based	**N = 276**
Other treatment	**N = 18**

Etiology	**N (%)**
Idiopathic	157 (19.4%)
Congenital/structural	259 (32.0%)
Syndromic	180 (22.2%)
Low tone NM	157 (19.4%)
High tone NM	4 (0.005%)
Cerebral Palsy	43 (0.053%)

Table 2. Children with Cobb >50 treated with spine or rib-based construct

	Spine-based (N=408)		**Rib-based (N=276)**
	Mean (S.D.)		Mean (S.D.)
Pre-Implant Cobb	78.29 (+/-18.08)		77.63 (+/- 17.13)
Post-Implant Cobb*	42.42 (+/-15.78)		55.13 (+/-17.83)
% Correction	45%		29%

**immediate post-op visit*

Table 3. Incidence of Complications

	Spine-based (N=408)		Rib-based (N=276)
	Total (per patient)		Total (per patient)
Complications	429 (1.05)		172 (0.62)
Unplanned procedures	254 (0.62)		N/A

809 subjects total from both registries, aged 2-10 years old were identified. Subjects were recruited between 2002 and 2012. Approximately one-third of the analyzed subjects were classified as having Congenital/Structural scoliosis, with the remaining two-thirds being roughly divided between Idiopathic, Syndromic, and Neuromuscular. The significantly larger number of spine-based versus rib-based procedures is indicative of the latter being a relatively novel procedure; we expect to observe a smaller gap in the prospective trial as more surgeons have adopted rib-based methods into their repertoire. Spine-based growing rods achieved greater correction from pre-op to immediate post-implant surgery than rib-based (45% vs. 29%). The rate of complications in patients treated with spine-based growing rods was significantly greater than with rib-based constructs.

The goal of the prospective study is to gain a better understanding of the benefits and pitfalls associated with the two methods of distraction. A future aim to facilitate future research would be to create a centralized, national EOS database, through a combined effort of the CWSDSG and GSSG. This will help to guide optimal care for EOS patients and may serve as a blueprint for similar organizing efforts in other fields of medicine.

References

1. Akbarnia B a. Management themes in early onset scoliosis. J Bone Joint Surg Am. 2007;89 Suppl 1:42-54 OD - 2007/02/03. Available at: internal-pdf://akbarnia2007-3549508608/Akbarnia2007.pdf. Accessed March 30, 2011.
2. Lonstein JE. Scoliosis: surgical versus nonsurgical treatment. Clinical orthopaedics and related research. 2006;443(443):248-59. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16462448. Accessed November 28, 2010.
3. Dimeglio A. Growth of the Spine Before Age 5 Years. Journal of Pediatric Orthopaedics Part B. 1993;(1):102-107.
4. Emery JL, Mithal A. The number of alveoli in the terminal respiratory unit of man during late intrauterine life and childhood. Arch Dis Child. 1960;35:544-7 OD - 1960/12/01. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=13726619.
5. Campbell RM, Smith MD, Mayes TC, et al. The characteristics of thoracic insufficiency syndrome associated with fused ribs and congenital scoliosis. J Bone Joint Surg Am. 2003;85-A(3):399-408 OD - 2003/03/15. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12637423.
6. Moe JH, Kharrat K, Winter RB, Cummine JL. Harrington instrumentation without fusion plus external orthotic support for the treatment of difficult curvature problems in young children. Clinical orthopaedics and related research. 1984;(185):35-45. Available at: http://www.ncbi.nlm.nih.gov/pubmed/6705397. Accessed April 5, 2011.
7. Campbell RM. The Characteristics of Thoracic Insufficiency Syndrome Congenital Scoliosis. Journal Of Bone And Joint Surgery. 2003;85-A(3):399-408.
8. 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):1091-6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/1411763. Accessed April 5, 2011.
9. Vitale MG, Matsumoto H, Bye MR, et al. A retrospective cohort study of pulmonary function, radiographic measures, and quality of life in children with congenital scoliosis: an evaluation of patient outcomes after early spinal fusion. Spine. 2008;33(11):1242-9. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18469699. Accessed February 17, 2012.
10. Karol L a, Johnston C, Mladenov K, et al. Pulmonary function following early thoracic fusion in non-neuromuscular scoliosis. The Journal of bone and joint surgery. American volume. 2008;90(6):1272-81. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18519321. Accessed October 26, 2010.

11. Mehlman CT, Wall EJ. Re: Klemme WR, et al. Hemivertebral excision for congenital scoliosis in very young children. J Pediatr Orthop 2001;21:761-764. J Pediatr Orthop. 2003;23(2):273-4 OD - 2003/02/27. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12604965.
12. Harrington PR. Treatment of scoliosis. Correction and internal fixation by spine instrumentation. J Bone Joint Surg Am. 1962;44-A(2):591-610 OD - 1962/06/01. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11861739.
13. Akbarnia BA, Marks DS, Boachie-Adjei O, Thompson AG, Asher MA. Dual growing rod technique for the treatment of progressive early-onset scoliosis: a multicenter study. Spine. 2005;30(17 Suppl):S46-57 OD - 2005/09/03. Available at: http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&DbFrom=pubmed&Cmd=Link&LinkName=pubmed_pubmed&LinkReadableName=Related Articles&IdsFromResult=16138066&ordinalpos=3&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_RVDocSum.
14. Campbell RM, Smith MD, Hell-Vocke AK. Expansion thoracoplasty: the surgical technique of opening-wedge thoracostomy. Surgical technique. The Journal of bone and joint surgery. American volume. 2004;86-A Suppl:51-64. Available at: http://www.ncbi.nlm.nih.gov/pubmed/14996922.
15. Hell AK, Campbell RM, Hefti F. [New treatment concept for children with thoracic insufficiency syndrome due to congenital spine deformity]. Klin Padiatr. 2005;217(5):268-73 OD - 2005/09/17. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16167273.
16. Vitale MG, Gomez JA, Matsumoto H, Roye DP. Variability of expert opinion in treatment of early-onset scoliosis. Clinical orthopaedics and related research. 2011;469(5):1317-22. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3069263&tool=pmcentrez&rendertype=abstract. Accessed July 19, 2011.

Notes

NON — FUSION SCOLIOSIS TECHNIQUES FOR GROWING SPINE – MODULATION METHODS: EVOLUTION & CURRENT STATUS

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I. Why modulate?
   1. Avoid morbidity of serial, multiple interventions (distraction- based techniques)
   2. Gradual correction/stablization of scoliosis prevents / improves extrinsic chest wall deformity (windswept thorax)
   3. Preserve motion / disc and facet function, preserve growth (EOS patients)

II. Basic Biomechanics / Hueter-Volkmann

Scoliosis progression intimately related to ↓ growth on concavity → vertebral wedging → more compressive inhibition → more progression
"Vicious Cycle" (Roaf, Stokes/Aronsson)
0.1 MPa stress – compression or distraction → "dramatic effect on longitudinal endochondral growth" (Aronsson 2011) [≈1 MPa force → growth arrest Bylski-Austrow 2001]

A. Classic experiment – rat tail vertebra, external fixator (Mente/Aronsson 1997,'99)
   1. Impose scoliosis + concave compression → vertebral wedging, asymmetric growth with concave inhibition
   2. Reverse loading -> wedging corrected 100%
   3. Remove loading -> wedging corrected 36%
   4. Supports simultaneous distraction of concavity while compressing convexity if feasible Confirmed histologically – chondrocyte cell height and zone of hypertrophy enlarge/ narrow under influence of distraction/compression (Stokes 2002, Apte 1994, Bylski-Austrow 2009)

B. Implant effect on Hueter-Volkmann stress asymmetry
   – FEM model of 28^0 R thor curve in 13 yo female (Driscoll 2011)

   Stress across concave apex = 0.60 MPa , convex = 0.12 – asymmetric load 0.48 MPa

   Flexible tether applied -> concave = 0.53 MPa, convex 0.30 – asymmetric load 0.23

   Shape memory staple applied -> concave 0.55 MPa, convex 0.22 – asymmetric load 0.33

   Conclusion: tether increases convex compression, more reduction in stress asymmetry

C. Next question – what happens to motion segment (disc/facets) subjected to modulating forces ?
   1. ROM restriction

   – nitinol staples -> relatively minimal – "may not be clinically relevant" (2 deg or less /motion segment in lat. bend compared to intact spine, less in axial rotation or flex/ext) + very minimal effect on ROM of adjacent non-stapled segments (Puttlitz 2007)

   – tether construct flexibility > staple(2/disc) in axial rot; tether stiffer> staples in lat bend away, extension (Glaser 2012)

   – tether restricts lateral bend away when in place, but normal motion returns on removal (Newton 2005)

   2. Disc health vs degeneration

   Hunt (2010) – 6 month disc space instrumented.

   Cell density, cell apoptosis: staple = tether < control, including adjacent disc (in spite of much more deformity in tethered discs – see III A. below). No change H_2O or GAG content.

   Upasani,/ Newton (2011) – 6 month tethering, relatively mild

deformity with wedging + rotation (see III A. below). Disc wedging "reversal" – wider on side of tether (?)

MRI + histology -> preservation of cell density, H_2O + GAG content in nucleus pulp.; changes in annulus content w/o fiber injury/tea = metabolic response to compressive loads produced by tether

Chay/Patel/Schwab (2012) – 16-20 week anterior corrective tether of 50^0 porcine curve -> no histologic evidence of growth cartilage injury, only decreased proliferative zone and cell height changes

III. Experimental efficacy

A. Creation of deformity by anterior vertebral body implants across end plate/physis/disc

1. Historical – Naclas & Borden 1951 – based on Blount staples for long bones
2. Newton (2002,05) bovine flexible tether/screw anchors, plowing and migration problems
3. Wall (2005) – porcine "staple hemiepiphyseodesis" staple/screw device (for stability) 7 vertebrae/ 6 pairs physes -> 22.4^0 mean / 8 weeks
4. Newton (2008) – porcine flexible tether/screw anchors . 4 vertebrae/ 3 pairs physes -> 13^0 / 6 mos; 30^0 / 12 mos. ; 13^0 kyphosis
5. Johnston/Zhang (unpubl) – porcine flexible tether/screw anchors. 6 vertebrae/ 5 pairs physes -> 55^0 / 7 mos.
6. Hunt (2010) – caprine, nitinol staples vs. flexible tether. 6 vertebrae / 5 pairs physes -> 6.5^0 staple vs. 41.0^0 tether / 6 mos.

B. Correction of experimental deformity by anterior implants – does ability to create deformity by modulation = ability to correct a deformity ?

1. Braun (2006) – caprine deformity/ asymmetric posterior flexible tether combined with concave rib tether + convex rib resection -> 76^0 scoliosis/ -41^0 lordosis/ 8 weeks tethering;
   then treated / followed x 12-16 weeks (final):
   group 1 (no rx) -> 97^0 scoliosis, -61^0 lordosis
   group 2 (nitinol staple) -> ipo 76^0/-34^0, final 94^0/-49^0
   group 3 (flexible tether) -> ipo 62^0/-37^0, final 70^0/-59^0
2. Patel,Schwab, Lafage (2012 unpubl) – porcine deformity 2^0 asymmetric posterior flexible tether unilateral spine + concave ribs -> ≈ 50^0 scoliosis / 6-7 weeks ; then treated by tether release (TR) vs. convex corrective tether (AC) x 16 weeks
   group TR preop 46^0 -> ipo 45^0-> final 45^0 no effect on sagittal curve
   group AC preop 45^0-> ipo 35^0 -> final 24^0 no effect on sagittal plane

Summary of experimental studies

1. Tether constructs produce more severe deformity > staples in undeformed spine
   - probably longer lever arm, restriction of lat bend motion away
   - staples "loosen" in bone with motion -> lose compression ?
   - unplowed screw anchors produce more compression over time -> more effective corrective capability ??
2. Staples = "rigid" disc fixation construct, tethers = "flexible" . However, no histologic or biochemical evidence of disc or physeal irreversible injury.
   Note: 6 month time period of construct implantation probably not equivalent to clinical application
3. Correction of experimentally created curves
   Tethers appear superior (Braun 2006, Schwab 2012), especially in larger curves

IV. Clinical

A. Vertebral body stapling

1. Memory-metal (Nitinol) staples (Betz 2010;Lavelle 2011)
   – Based on historical experimental curve creation and predicted increased bone stability when tines clamp down when transformed
   – Technique (thoracoscopic) standardized since 2002 as alternative to bracing in JIS/AIS with: R ≤ 1, Sanders digital stage ≤ 4, Th curve < 35^0, L curve < 40^0
   – Results 2010 Average age 9.4 yr, 26 Th curves, 15 L. Mean f/u 3.2 yr (2-5.3)

Outcomes: curves within 10^0 of preop = unchanged Unchanged + Improved
curves decreased ≥ 10^0 = improved = "Success"

Th curves < 35^0 –> 78% success ; if curve < 20^0 on 1st upright Xray -> 86% success ; if curve ≥ 20^0 on 1st xray -> 52% success

Th curves > 35^0 -> 75% progressed > 50^0 35^0 statistically signf cutoff

Th hypokyphosis (<10^0) improved in 4/7

L curves < 45^0 -> 87% success

Modulation (gradual correction/overcorrection) definitely seen, especially in <8 yr patients

2. Limits of nitinol stapling (Oleary 2011)
   – 11 patients, mean age 7, multiple dx's, f/u 22 months
   – preop curve 68^0 (25-105) -> ipo 45^0 (24-88) -> final 69^0 (36-107); 8/11 with 80^0 residual curve -> additional surgery
   – majority of curves progressed despite stapling, due to initial curve magnitude and underlying dx (N-M, congenital, paralytic, myelo)

Take-home Conclusion: stapling works < 35^0 non-neuro, non-congenital [same indication for brace wear] ; 68^0 curves too large

3. Staple/screw device (Wall) – currently starting FDA IDE study

Indications: AIS ≥ 10 yr; single Th curve (lenke 1A,1B), 25-40^0, endoscopic insertion,TRC open, RO

B. Flexible anterior tethering

1. Indications (Lenke AAOS 2012)
   – infantile / young juvenile idiopathic; also syndromic, neuromuscular (??) – 25-45^0+ , normal or hypokyphotic Th spine apex mid-lower Th levels
   – "custom" implant
2. case report (Crawford 2010)
   – 8 yo male, progressive curve to 40^0 despite bracing
   – anterior T6-12 flexible tether -> ipo 25^0

– subsequent gradual correction to -6^0 over 5 years, no change in sagittal alignment

3. Other off label/offshore examples – Dynesys, Singapore

C. Growth Guidance techniques
1. "Shilla" (McCarthy 2011)

Technique : hyper-correction of apex deformity, incl anterior release, over 3-5 segments with dual pedicle screws

– sliding screws at end vertebrae, allowing "guided" growth away from fused apex

– sliding screws inserted extraperiosteal transmuscular, avoid spontaneous fusion

Indication – larger curves (40-115^0, mean 77^0), multiple dx's incl syndromes (Marfan, arthrogryposis, SMA, skel dyspl). Mean age 6.5 yr (23 mo – 11 yr).

Results : Initial 10 patients (> 2 yr f/u) – required estimated 49 less procedures than GR's 5 yr results – to be reported at 2012 SRS

2. Luque Trolley (Ouellet 2011)
–fixed proximal and distal anchors (screws, hooks) at end vertebrae
– sliding anchors in apical segments (sublaminar wires, "gliding" screws"), placed through minimal muscular "windows"
–dual rods overlapping in apical area, correction by cantilver/ lateral translation

Results:

5 cases, mean age 6.5 yr, dx's : IIS, N-M, Prader-Willi.

Curve correction 60^0 preop -> 21^0 ipo -> 31^0 at 4.5 yr f/u.

4/5 cases "grew" mean 3 cm (1.7-4.8) = 63% (12-100%) predicted spine length achieved

2 cases revised because of outgrowing rod overlap. Further update 2012 SRS

References

Roaf R. Vertebral growth and its mechanical control. JBJS 42-B: 40, 1960

Aronsson DD & Stokes IAF. Nonfusion treatment of adolescent idiopathic scoliosis by growth modulation and remodeling. J Pediatr Orthop 31:S99, 2011

Mente PL, Stokes IA, Spence H et al. Progression of vertebral wedging in an asymmetrically loaded rat tail model. Spine 22: 1292, 1997

Mente PL, Aronsson DD, Stokes IA et al. Mechanical modulation of growth for the correction of vertebral wedge deformities. J Orthop Res 17: 518, 1999

Stokes IA, Mente PL, Iatridis JC et al. Enlargement of growth plate condrocytes modulated by sustained mechanical loading. JBJS 84-A:1842, 2002

Apte SS, Kenwright J. Physeal distraction and cell proliferation in the growth plate. JBJS 76-B: 837, 1994

Bylski-Austrow DI, Wall EJ, Rupert MP et al. Growth plate forces in adolescent human knees: radiographic and mechanical study of epiphyseal staples. J Pediatr Orthop 21:817,2001

Bylski-Austrow DI, Wall EJ, Glos DL et al. Spinal hemiepiphyseodesis decreases size of vertebral growth plate hypertrophic zone and cells. JBJS 91-A:584, 2009

Puttlitz CM, Masaru F, Barkley A et al. A Biomechanical assessment of thoracic spine stapling. Spine 32:766, 2007

Driscoll M, Aubin C-E, Moreau A et al. Biomechanical comparison of fusionless growth modulation corrective techniques in pediatric scoliosis. Med Biol Eng Comput 2011; DOI 10.1007/ s11517-011-0801-8

Wall EJ, Bylski-Austrow DI, Kolata RJ et al. Endoscopic mechanical spinal hemiepiphyseodesis modifies spine growth. Spine 30: 1148, 2005

Hunt KJ, Braun JT, Christensen BA. The effect of two clinically relevant fusionless scoliosis implant strategies on the health of the intervertebral disc. Spine 35: 371, 2010

Glaser DA, Nandipati C, Nunn T et al. Biomechanics of Two Fusionless Scoliosis Correction Implant Strategies- Rigid Staple vs. Flexible Tether. 78th AAOS Feb 2011, San Diego, CA

Newton PO, Faro FD, Farnsworth CL, et al. Multilevel spinal growth modulation with an anterolateral flexible tether in an immature bovine model. Spine 2005;30:2608.

Newton PO, Upasani W, Farnsworth CL et al. Spinal growth modulation with use of a tether in an immature porcine model. JBJS 90-A: 2695, 2008

Upasani VV, Farnsworth CL, Chambers RC et al. Intervertebral disc health preservation after six months of spinal growth modulation. JBJS 93-A: 1408, 2011

Chay E, Patel A, Ungar B et al. Impact of unilateral tethering on the histology of the growth plate in an established porcine model for thoracic scoliosis. Spine 2012; 37: E883

O'Leary PT, Sturm PF, Hammerberg KW et al. Convex hemiepiphyseodesis. Spine 2011; 36:1579

Crawford CH, Lenke LG. Growth modulation by means of anterior tethering resulting in progressive correction of juvenile idiopathic scoliosis: a case report. JBJS 2010; 92-A:202

Ouellet J. Modern Luque trolley, a self-growing rod technique. Clin Orthop Relat Res 2011; 469:1356

McCarthy RE. Growth guided instrumentation: Shilla procedure. In Akbarnia BA et al (eds). The Growing Spine. Springer-Verlag, Berlin Heidelberg 2011. P. 593

Notes

CASE DISCUSSION 1: HAVE RECENT CORRECTIVE TECHNIQUES FOR THE GROWING SPINE SHOWN BETTER OUTCOMES THAN THOSE USED IN 2002?

Moderator: Lori Anne Karol, MD
Panel: Kamal N. Ibrahim, MD, FRCS(c), MA; Michael G. Vitale, MD, MPH; Charles E. Johnston, MD; James O. Sanders, MD; Laurel C. Blakemore, MD; Richard E. McCarthy, MD

Case #1:
6yo female with "chromosomal abnormality"
Hx seizures
Ambulatory with normal neuro exam except "cortically blind"
Presented with scoliosis age 5
Thoracic curve progressed to 60 degrees age 6

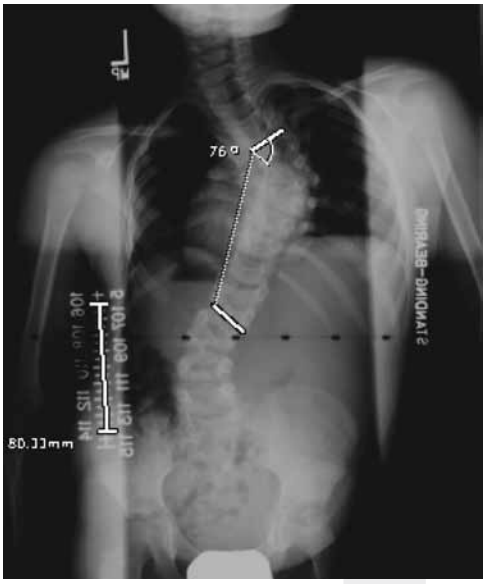
What to do?
Surgery? Growing rod vs definitive?
Casting? Has already rejected brace and progressed?
Radiograph at age 18…

Case 2:
31 mos female with 51 degree thoracic curve
Hx of torticollis
"Scoliosis with lateral gaze palsy"
78 degrees age 5
Surgery? Growing rod vs definitive?
Casting? Has already rejected brace and progressed?
Radiograph at age 12 Risser 4

Case 2 radiograph age 5

Case 3:
7 mo female with 44 deg congenital thoracic scoliosis
Age 4 78 deg (documented progression) with 12 cm chest
Surgery? What type?
Radiograph age 11


age 7Mo



age 4y

Notes

CASE DISCUSSION 1: GROWING RODS FOR EARLY ONSET SCOLIOSIS – HAS A DECADE MADE A DIFFERENCE?

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Focus:
In this talk, we are focusing on growing rod type constructs, important issues surrounding their use, and will not discuss vertebral body stapling or growth modifying tethers.

Problems with Surgical treatment of the growing spine:
Growth stoppage: By the early 1970's it was recognized[1,2] that instrumentation and fusion of young spines stopped their growth which they though was probably not beneficial. Later studies confirmed problems with early fusion causing pulmonary restriction and poor appearance[2], and Campbell, et al [3,4] , subsequently described the thoracic insufficiency syndrome (TIS) as short, restricted chests unable to accommodate adult pulmonary needs.

Crankshaft: Prior to Dubousset's more complete description[5], several authors between 1979 and 1983[6-8] described increasing rotation with deterioration of the spinal alignment following posterior fusion for scoliosis developing as the patient went through their growth spurts.

A brief historical tour:
In the late 1950's and early 1960's, Harrington developed the first successful spinal instrumentation[9]. His earliest procedures were done without fusion and had a high rate of instrumentation failure leading him to supplement the instrumentation with a fusion, which subsequently created modern spinal deformity treatment.

About the same time, James[10] identified a course of treatment for early onset scoliosis persisting to this day – keep the spine growing while controlling the curve with what ever means you have (he had casts and the Milwaukee brace) until age 10, and then do a definitive fusion.

The current basic concept in managing early onset scoliosis in most centers is to marry these two concepts by using bracing, casting, or instrumentation without fusion so the spine can gain sufficient length to prevents pulmonary problems associated with fusion before age 10, after which a formal fusion is done if the curve magnitude warrants[2,6].

Development of Techniques:
1977 – first growing rods reported[11] with non-fusion Harrington rod protected by a Milwaukee brace and recommended fusion of the superior and inferior levels 6 months prior to placement of the rod.

1978 – Moe[12] presented his first cases of subcutaneous Harrington rodding with periodic lengthening and Milwaukee brace protection until later definitive fusion.

1979 – Segmental wiring without a fusion (the Luque trolley) was described[13]. Roaf"s previously described anterior/posterior convex epiphyseodesis[14] was soon added to the Luque trolley and later to other forms of growing instrumentation[15-17].

1993 – McCarthy and McCullough reported the first dual growing rods using pediatric CD or TSRH instrumentation[18].

1995 – An automated lengthening rod was reported (beagles)[19].

2000 – First SRS presentation of the vertical expandable prosthetic titanium rib (VEPTR) [3].

2002 – Akbarnia, et al[20], presented an exhibit which was presented as a podium presentation the following year[21] on 38 patients treated with dual growing rods with 44 month follow up and favorable results.

2004 – VEPTR approved as an HDE by the FDA for TIS and has become a mainstay in complex congenital scoliosis.

"Problems, Difficulties, and Complications": Most early reports of growing instrumentation were very optimistic with very few complications[11,12,15,16,22-28], but rod failure and cutout were discussed [25,29,30]. The Luque trolley had more difficulties reported earlier compared to other techniques including spontaneous fusion and infection[13,31-33]. The largest series of Harrington instrumentation without fusion found hook failure, rod fracture, skin breakdown and septicemia. They also reported one death from a rod reinsertion entering the chest.

Growth Obtained Reports of the spine growing 3.8-5.4 cm, but what stage of growth this represents is uncertain. The Iowa experience expressed discouragement with the complications compared to the growth gained[34]. Among the Luque trolley, those treated with anterior/posterior hemiepiphyseodesis had the most favorable results in terms of length and curve maintenance.

2003-2012:
Since 2002, the major changes have been primarily modifications of the prior devices with pedicle screws, more purchase points, and even magnetically controlled growing rods[35]. Techniques in the ascendency include the earlier described dual growing rod technique, the VEPTR, and Rick McCarthy's growth guidance or Shilla technique. The Shilla[36-37] or growth guidance technique is an extension of the Luque trolley concept except that it is performed with MIS techniques with an open apical fusion.

Results over the past decade:
Probably the single greatest improvement in our treatment of early onset scoliosis is not the specific treatments themselves, but the realization that without long-term prospective studies, we cannot determine the role of the various available methods. To this end, at least two longitudinal databases have been developed, the Growing Spine Study Group (GSSG) and the Chest Wall and Spinal Deformity Group (CWSDSG). While mining data from these is subject to selection bias for specific treatments, and type II statistical error, we now have the ability to perform level 3 therapeutic studies, and, if the data is both accurately recorded and enrollment is consecutive, more accurately evaluate complications.

Complications:
The GSSG database[38] has confirmed the high complication rate of prior studies and found that the more lengthenings, the higher complication rate. They also identified less complications with dual submuscular rods than single or subcutaneous rods. VEPTR complication rates are similar[39-41].

Length Gained:
Dual growing rods have better growth gained than single rods and single rods with apical fusion. Length improvement is improved best with more frequent (6 month or less) lengthenings compared to longer intervals[42]. Lengthening becomes progressively more difficult with subsequent lengthening often providing only 3 to 4 years of effective lengthening[43-44].

Originally thought to be only a problem with the Luque trolley[45-46], spontaneous

fusion also occurs very frequently with growing rods[47] and also appears to occur in those with VEPTR like constructs[48]. The Shilla technique's outcomes have not been published, but a variant with clinical experience in 5 patients looked promising in a recent retrospective study[49].

So, what hath a decade wrought?

We have 3 growing rod techniques – VEPTR, "Growth guidance", and growing rods.

Surgical Techniques:

1. Complications with all techniques are frustratingly frequent and increase the longer a device is implanted.
2. Anchors are better including both claws and pedicle screws.
3. Apical fusion does not appear to help in growing rod constructs except perhaps in the Shilla where it is mandatory.
4. More frequent lengthenings appear beneficial in length gained, but more lengthenings also results in more complications.
5. If you are using growing rods, dual submuscular growing rods appear better than other techniques in preventing wound problems.

Biological problems:

1. Unfortunately we do not any good evidence equating how much length must be gained to obtain good long-term pulmonary function.
2. Should we continue to lengthen until age 10 and then fuse?
3. Does this philosophy optimize outcome?
4. Are the complications worth the end result?
5. Can we eliminate the complications with mechanical improvements (Phoenix, etc)?
6. The law of diminishing returns is real and means you can often get 3-4 years of effective lengthening.
7. Remember, no matter how promising a new technique looks, it is not truly tested until you have prospective, well-collected data to maturity.
8. It is unlikely we will ever get prospective randomized studies in this disorder, but prospective comparative studies designed to minimize bias are certainly possible.

Summary:

Our constructs have become more stable over the past decade, but the complication rate with growing constructs is frustratingly high, and our understanding of the biology remains poor, and our mechanical treatments may not address the underlying issues. One of the most important advances is the recognition that we cannot make good decisions without prospective comparative studies.

Philosophically, are we still going the right direction by combining the concepts of JIP James and Paul Harrington? Most importantly, what do we need to do to understand this heterogeneous group of patients with early onset scoliosis so we can provide the most effective treatments in the future?

References:

1. Letts RM, et al. Fusion of the scoliotic spine in young children. ClinOrthop. 1974:136-45.
2. Goldberg CJ, et al. Respiratory function and cosmesis at maturity in infantile-onset scoliosis. Spine. 2003:2397-406.
3. Campbell RM, et al. The Treatment of Thoracic Insufficiency Syndrome Associated with Fused Ribs and Scoliosis. SRS; Conference
4. Campbell RM, Jr., et al. The characteristics of thoracic insufficiency syndrome associated with fused ribs and congenital scoliosis. J Bone Joint Surg Am. 2003:399-408.
5. Dubousset J, et al. The crankshaft phenomenon. Journal of Pediatric Orthopedics. 1989:541-50.
6. McMaster MJ, et al. The management of progressive infantile idiopathic scoliosis. J Bone Joint Surg Br. 1979:36-42.
7. Hefti FL, et al. The effect of the adolescent growth spurt on early posterior spinal fusion in infantile and juvenile idiopathic scoliosis. J Bone Joint Surg Br. 1983:247-54.
8. Mehta MH, et al. Progression of Vertebral Rotation Following Spinal Fusion in Idiopathic Scoliosis. SRS; Conference
9. Harrington P. Treatment of Scoliosis: Correction and Internal Fixation by Spine Instrumentation. J Bone Joint Surg Am. 1962:591-634.
10. James JIP, et al. Infantile structural scoliosis. Journal of Bone & Joint Surgery - British Volume. 1959:719-35.
11. Marchetti PG, et al. "End Fusions in the treatment of some progressing or severe scoliosis in childhood or early adolescence. SRS; Conference
12. Moe JH, et al. Harrington Instrumentation Without Fusion Combined With The Milwaukee Brace For Ifficult Scoliosis Problems In Young Children. SRS; Conference
13. Luque ER, et al. Segmental Instrumentation in Growing Children. SRS; Conference
14. Roaf R. Vertebral growth and its mechanical control. J Bone Joint Surg Br. 1960:40-59.
15. Patterson JF, et al. Operative Treatment of Infantile and Juvenile Scoliosis: An Analysis of Curve Correction and a New Approach to Estimate Growth of the Instrumented Segment of the Spine. SRS; Conference
16. Grivas T, et al. Progressive Infantile Idiopathic Scoliosis: A Comparison Of Three Methods And The Derotation Of A Combined Procedure. SRS; Conference
17. Patterson JF, et al. The operative treatment of progressive early onset scoliosis. A preliminary report. Spine (Phila Pa 1976). 1990:809-15.
18. McCarthy RE, et al. Growing Instrumentation for Scoliosis. SRS; Conference
19. Takaso M, et al. A Newly Designed Spinal Instrumentation For Scoliosis In Young Children - A Preliminary Investigation Of Remote Control Growing -Rod System. SRS; Conference
20. Akbarnia BA, et al. Dual Rod Posterior Instrumentation Without Fusion For The Treatment Of Progressive Early Onset Scoliosis: A Multicenter Study - Exhibit. SRS; Conference
21. Akbarnia BA, et al. Dual Rod Posterior Instrumentation Without Fusion for the Treatment of Progressive Early Onset Scoliosis: A Multicenter Study. SRS; Conference
22. Fister JS, et al. Scoliosis Correction and Preservation of Spinal Growth. SRS Conference
23. Piggott H. Scoliosis in the young child. Proceedings of the Royal Society of Medicine. 1974:205-6.
24. Taylor JF, et al. Costodesis and contralateral rib release in the management of progressive scoliosis. Acta Orthop Scand. 1983:603-12.
25. Moe JH, et al. Harrington instrumentation without fusion plus external orthotic support for the treatment of difficult curvature problems in young children. Clin Orthop Relat Res. 1984:35-45.
26. Andrew T, et al. Growth arrest for progressive scoliosis. Combined anterior and posterior fusion of the convexity. J Bone Joint Surg Br. 1985:193-7.
27. Crawford A. Management of Severe Spinal Deformities Presenting Under 3 Years of Age. SRS; Conference
28. Piggott H. Growth modification in the treatment of scoliosis. Orthopedics. 1987:945-52.
29. O'Brien J F, et al. Instrumentation Without Fusion-A Clinical Experience Of Sixteen Cases. SRS; Conference
30. Zaraycki D, et al. Operative Treatment of Infantile and Juvenile Scoliosis by Harrington-Luque Technique Without Fusion. SRS - Poster; Conference
31. Luque ER. Paralytic scoliosis in growing children. Clin Orthop Relat Res. 1982:202-9.
32. Mardjetko S, et al. The Luque Trolley Revisited: Review Of 9 Cases Requiring Revision. SRS; Conference
33. Zembo MM, et al. Successful Use Of "Luque Trolley" To Preserve Trunk Growth In Children With Paralytic Spinal Deformity. SRS; Conference

34. Mineiro J, et al. Subcutaneous rodding for progressive spinal curvatures: early results. J Pediatr Orthop. 2002:290-5.
35. Cheung KM, et al. Magnetically controlled growing rods for severe spinal curvature in young children: a prospective case series. Lancet. 2012:1967-74.
36. McCarthy RE, et al. Shilla Growing Rods in a Caprine Animal Model: A Pilot Study. Clinical Orthopaedics and Related Research®. 2009:705-10.
37. McCarthy RE, et al. Shilla growing rods in a caprine animal model: a pilot study. Clin Orthop Relat Res. 2010:705-10.
38. Bess S, et al. Complications of growing-rod treatment for early-onset scoliosis: analysis of one hundred and forty patients. J Bone Joint Surg Am. 2010:2533-43.
39. Akbarnia BA, et al. Complications of growth-sparing surgery in early onset scoliosis. Spine (Phila Pa 1976). 2010:2193-204.
40. Sankar WN, et al. Comparison of complications among growing spinal implants. Spine (Phila Pa 1976). 2010:2091-6.
41. Latalski M, et al. Problems and complications in VEPTR-based treatment. Ortop Traumatol Rehabil. 2011:449-55.
42. Akbarnia BA, et al. Dual growing rod technique followed for three to eleven years until final fusion: the effect of frequency of lengthening. Spine (Phila Pa 1976). 2008:984-90.
43. Sankar WN, et al. Lengthening of dual growing rods and the law of diminishing returns. Spine (Phila Pa 1976). 2011:806-9.
44. Noordeen HM, et al. In vivo distraction force and length measurements of growing rods: which factors influence the ability to lengthen? Spine (Phila Pa 1976). 2011:2299-303.
45. Mardjetko SM, et al. The Luque trolley revisited. Review of nine cases requiring revision. Spine. 1992:582-9.
46. Fisk JR, et al. Spontaneous fusion in scoliosis after instrumentation without arthrodesis. Journal of Pediatric Orthopedics. 1995:182-6.
47. Cahill PJ, et al. Autofusion in the immature spine treated with growing rods. Spine (Phila Pa 1976). 2010:E1199-203.
48. Yilgor C, et al. Is Expansion Thoracoplasty a Safe Procedure for Mobility and Growth Potential of the Spine? Spontaneous Fusion After Multiple Chest Distractions in Young Children. Journal of Pediatric Orthopaedics. 2012:483-9 10.1097/BPO.0b013e318257d3a9.
49. Ouellet J. Surgical technique: modern Luque trolley, a self-growing rod technique. Clin Orthop Relat Res. 2011:1356-67.

Notes

Concurrent Morning Session - Adult

THE EVOLUTION OF INTERBODY SURGERY USE FOR THE CORRECTION OF SPINAL DEFORMITY

Moderators:

Keith H. Bridwell, MD; Steven M. Mardjetko, MD, FAAP

Faculty:

David W. Polly, Jr., MD; John R. Dimar, II, MD; Todd J. Albert, MD; Juan S. Uribe, MD; Benny T. Dahl, MD, PhD, DMSc; Justin S. Smith, MD, PhD

IS STRUCTURAL AUTOGRAFT STILL THE GOLD STANDARD FOR SPINAL DEFORMITY SURGERY?

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Autograft structural
Sources
- Iliac crest
- Rib
- Fibula
- Other?

Autograft non-structural
- As above
- Local bone

Other sources
- Allograft
- Bone graft extenders
- Bone graft substitutes

Structural support alternatives
- Metal
- Plastic
- Bioglass
- Others

What is the goal of the graft?
- Fusion
- Maintenance of correction

What is 'gold standard'
- Best practice- best result
- Most common
- Other?

Literature based standard
Pub Med 6/15/12
'bone graft source for spine' 67 results
'bone graft and spine deformity' 339 results

Database standard
- Cannot obtain the specific data from HCUP or NIS through public access
- Various commercial databases exist
- Data obtained from Pearl Diver commercial data base

			2006	2007	2008	2009	2010	Total
Private Payer Deformity Procedures		Total deformity procedure volumes	1,430	1,506	1,400	1,286	1,254	**6,876**
Private Payer with Graft								
	20930	Allograft, morselized	528	625	617	569	603	**2,942**
	20931	Allograft, structural	62	79	86	55	38	**320**
	20936	Autograft for spine surgery only	635	726	679	608	600	**3,248**
	20938	Autograft for spine surgery only structural	36	24	*	*	16	**89**
Medicare Deformity Procedures		Total deformity procedure volumes	189	214	199	176	196	**974**
Medicare with Graft								
	20930	Allograft, morselized	37	42	63	53	66	**261**
	20931	Allograft, structural	43	27	23	20	*	**121**
	20936	Autograft for spine surgery only	55	82	97	68	67	**369**
	20938	Autograft for spine surgery only structural	*	*	*	*	*	**21**

Within the limitations of this data set only 89/6,876 private payer cases was structural autograft used, and in only 21/974 Medicare cases was it used.

So in the United States clearly structural autograft is NOT the gold standard.

References

1: Arner JW, Daffner SD. Bone graft extenders and substitutes in the thoracolumbar spine. Am J Orthop (Belle Mead NJ). 2012 May;41(5):230-5. PubMed PMID: 22715441.

2: Cabraja M, Kroppenstedt S. Bone grafting and substitutes in spine surgery. J Neurosurg Sci. 2012 Jun;56(2):87-95. PubMed PMID: 22617171.

3: Al Saleh KA, Tougas CA, Roffey DM, Wai EK. Osteoconductive Bone Graft Extenders in Posterolateral Thoracolumbar Spinal Fusion: A Systematic Review. Spine (Phila Pa 1976). 2012 Mar 13. [Epub ahead of print] PubMed PMID: 22414999.

4: Hu MW, Liu ZL, Zhou Y, Shu Y, Chen CL, Yuan X. Posterior lumbar interbody fusion using spinous process and laminae. J Bone Joint Surg Br. 2012 Mar;94(3):373-7. PubMed PMID: 22371546.

5: Lewis SJ, Kulkarni AG, Rampersaud YR, Jhaveri S, Quraishi N, Bacon SA, Magana SP. Posterior column reconstruction with autologous rib graft after en bloc tumor excision. Spine (Phila Pa 1976). 2012 Feb 15;37(4):346-50. PubMed PMID: 22333929.

6: Kang J, An H, Hilibrand A, Yoon ST, Kavanagh E, Boden S. Grafton and local bone have comparable outcomes to iliac crest bone in instrumented single-level lumbar fusions. Spine (Phila Pa 1976). 2012 May 20;37(12):1083-91. PubMed PMID: 22076647.

7: Sathira-Angkura V, Kunakornsawat S, Assawachutithamrong B, Tungsiripat R. Two-year outcome of hydroxyapatite mixed with autogenous bone marrow and local bone graft for posterolateral lumbar fusion. J Med Assoc Thai. 2011 Sep;94(9):1096-103. PubMed PMID: 21970199.

8: Sundararaj GD, Amritanand R, Venkatesh K, Arockiaraj J. The use of titanium mesh cages in the reconstruction of anterior column defects in active spinal infections: can we rest the crest? Asian Spine J. 2011 Sep;5(3):155-61. Epub 2011 Aug 12. PubMed PMID: 21892387; PubMed Central PMCID: PMC3159063.

9: Carragee EJ, Comer GC, Smith MW. Local bone graft harvesting and volumes in posterolateral lumbar fusion: a technical report. Spine J. 2011 Jun;11(6):540-4. PubMed PMID: 21729803.

10: Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: emerging safety concerns and lessons learned. Spine J. 2011 Jun;11(6):471-91. Review. PubMed PMID: 21729796.

11: Hart RA, Daniels AH, Bahney T, Tesar J, Sales JR, Bay B. Relationship of donor variables and graft dimension on biomechanical performance of femoral ring allograft. J Orthop Res. 2011 Dec;29(12):1840-5. doi: 10.1002/jor.21459. Epub 2011 May 16. PubMed PMID: 21590719.

12: Abdullah KG, Steinmetz MP, Benzel EC, Mroz TE. The state of lumbar fusion extenders. Spine (Phila Pa 1976). 2011 Sep 15;36(20):E1328-34. Review. PubMed PMID: 21358468.

13: Burkus JK, Gornet MF, Glassman SD, Slosar PJ, Rosner MK, Deckey JE, Nowak J, Hatcher BM. Blood serum antibody analysis and long-term follow-up of patients treated with recombinant human bone morphogenetic protein-2 in the lumbar spine. Spine (Phila Pa 1976). 2011 Dec 1;36(25):2158-67. PubMed PMID: 21325990.

14: Lad SP, Nathan JK, Boakye M. Trends in the use of bone morphogenetic protein as a substitute to autologous iliac crest bone grafting for spinal fusion procedures in the United States. Spine (Phila Pa 1976). 2011 Feb 15;36(4):E274-81. PubMed PMID: 21304362.

15: Knox JB, Dai JM 3rd, Orchowski J. Osteolysis in transforaminal lumbar interbody fusion with bone morphogenetic protein-2. Spine (Phila Pa 1976). 2011 Apr 15;36(8):672-6. PubMed PMID: 21217443.

16: Ohtori S, Suzuki M, Koshi T, Takaso M, Yamashita M, Yamauchi K, Inoue G, Suzuki M, Orita S, Eguchi Y, Ochiai N, Kishida S, Kuniyoshi K, Nakamura J, Aoki Y, Ishikawa T, Arai G, Miyagi M, Kamoda H, Toyone T, Takahashi K. Single-level instrumented posterolateral fusion of the lumbar spine with a local bone graft versus an iliac crest bone graft: a prospective, randomized study with a 2-year follow-up. Eur Spine J. 2011 Apr;20(4):635-9. Epub 2010 Dec 17. PubMed PMID: 21165658; PubMed Central PMCID: PMC3065607.

17: Glassman SD, Howard J, Dimar J, Sweet A, Wilson G, Carreon L. Complications with recombinant human bone morphogenic protein-2 in posterolateral spine fusion: a consecutive series of 1037 cases. Spine (Phila Pa 1976). 2011 Oct 15;36(22):1849-54. PubMed PMID: 20838369.

18: Ploumis A, Albert TJ, Brown Z, Mehbod AA, Transfeldt EE. Healos graft carrier with bone marrow aspirate instead of allograft as adjunct to local autograft for posterolateral fusion in degenerative lumbar scoliosis: a minimum 2-year follow-up study. J Neurosurg Spine. 2010 Aug;13(2):211-5. PubMed PMID: 20672956.

19: Betz RR, Lavelle WF, Samdani AF. Bone grafting options in children. Spine (Phila Pa 1976). 2010 Aug 1;35(17):1648-54. Review. PubMed PMID: 20628337.

20: Rihn JA, Kirkpatrick K, Albert TJ. Graft options in posterolateral and posterior interbody lumbar fusion. Spine (Phila Pa 1976). 2010 Aug 1;35(17):1629-39. Review. PubMed PMID: 20628336.

21: Andersen T, Christensen FB, Langdahl BL, Ernst C, Fruensgaard S, Ostergaard J, Andersen JL, Rasmussen S, Niedermann B, Høy K, Helmig P, Holm R, Lindblad BE, Hansen ES, Egund N, Bünger C. Fusion mass bone quality after uninstrumented spinal fusion in older patients. Eur Spine J. 2010 Dec;19(12):2200-8. Epub 2010 Apr 29. PubMed PMID: 20429017; PubMed Central PMCID: PMC2997208.

22: Shah SA, Borkhuu B, Littleton AG, Keller MS, Kuester V, Dodge GR. Can a bone marrow-based graft replacement result in similar fusion rates as rib autograft in anterior interbody fusion procedures for adolescent thoracolumbar scoliosis? J Spinal Disord Tech. 2010 Feb;23(1):57-62. PubMed PMID: 20084031.

23: Lehman RA Jr, Dmitriev AE, Cardoso MJ, Helgeson MD, Christensen CL, Raymond JW, Eckel TT, Riew KD. Effect of teriparatide [rhPTH(1,34)] and calcitonin on intertransverse process fusion in a rabbit model. Spine (Phila Pa 1976). 2010 Jan 15;35(2):146-52. PubMed PMID: 20081509.

24: Agarwal R, Williams K, Umscheid CA, Welch WC. Osteoinductive bone graft substitutes for lumbar fusion: a systematic review. J Neurosurg Spine. 2009 Dec;11(6):729-40. Review. PubMed PMID: 19951027.

25: Maeda T, Buchowski JM, Kim YJ, Mishiro T, Bridwell KH. Long adult spinal deformity fusion to the sacrum using rhBMP-2 versus autogenous iliac crest bone graft. Spine (Phila Pa 1976). 2009 Sep 15;34(20):2205-12. PubMed PMID: 19752707.

26: Dusseldorp JR, Mobbs RJ. Iliac crest reconstruction to reduce donor-site morbidity: technical note. Eur Spine J. 2009 Sep;18(9):1386-90. Epub 2009 Aug 4. PubMed PMID: 19653014; PubMed Central PMCID: PMC2899541.

27: Ha KY, Lee JS, Kim KW. Bone graft volumetric changes and clinical outcomes after instrumented lumbar or lumbosacral fusion: a prospective cohort study with a five-year follow-up. Spine (Phila Pa 1976). 2009 Jul 15;34(16):1663-8. PubMed PMID: 19561561.

28: Kim DH, Rhim R, Li L, Martha J, Swaim BH, Banco RJ, Jenis LG, Tromanhauser SG. Prospective study of iliac crest bone graft harvest site pain and morbidity. Spine J. 2009 Nov;9(11):886-92. Epub 2009 Jun 18. PubMed PMID: 19540168.

29: Nassr A, Khan MH, Ali MH, Espiritu MT, Hanks SE, Lee JY, Donaldson WF, Kang JD. Donor-site complications of autogenous nonvascularized fibula strut graft harvest for anterior cervical corpectomy and fusion surgery: experience with 163 consecutive cases. Spine J. 2009 Nov;9(11):893-8. Epub 2009 Jun 13. PubMed PMID: 19525152.

30: Glassman SD, Polly DW, Bono CM, Burkus K, Dimar JR. Outcome of lumbar arthrodesis in patients sixty-five years of age or older. J Bone Joint Surg Am. 2009 Apr;91(4):783-90. PubMed PMID: 19339561.

31: Alt V, Chhabra A, Franke J, Cuche M, Schnettler R, Le Huec JC. An economic analysis of using rhBMP-2 for lumbar fusion in Germany, France and UK from a societal perspective. Eur Spine J. 2009 Jun;18(6):800-6. Epub 2009 Mar 20. PubMed PMID: 19301041; PubMed Central PMCID: PMC2899669.

32: Carreon LY, Glassman SD, Djurasovic M, Campbell MJ, Puno RM, Johnson JR, Dimar JR 2nd. RhBMP-2 versus iliac crest bone graft for lumbar spine fusion in patients over 60 years of age: a cost-utility study. Spine (Phila Pa 1976). 2009 Feb 1;34(3):238-43. PubMed PMID: 19179918.

33: Vaccaro AR, Lawrence JP, Patel T, Katz LD, Anderson DG, Fischgrund JS, Krop J, Fehlings MG, Wong D. The safety and efficacy of OP-1 (rhBMP-7) as a replacement for iliac crest autograft in posterolateral lumbar arthrodesis: a long-term (>4 years) pivotal study. Spine (Phila Pa 1976). 2008 Dec 15;33(26):2850-62. PubMed PMID: 19092614.

34: Glassman SD, Carreon LY, Djurasovic M, Campbell MJ, Puno RM, Johnson JR, Dimar JR. RhBMP-2 versus iliac crest bone graft for lumbar spine fusion: a randomized, controlled trial in patients over sixty years of age. Spine (Phila Pa1976). 2008 Dec 15;33(26):2843-9. PubMed PMID: 19092613.

35: Glassman SD, Polly DW, Bono CM, Burkus K, Dimar JR. Outcome of lumbar arthrodesis in patients sixty-five years of age or older. J Bone Joint Surg Am. 2009 Apr;91(4):783-90. PubMed PMID: 19339561.

36: Dhawan A, Kuklo TR, Polly DW Jr. Analysis of iliac crest bone grafting process measures. Am J Orthop (Belle Mead NJ). 2006 Jul;35(7):322-6. PubMed PMID: 16927657.

37: Bojescul JA, Polly DW Jr, Kuklo TR, Allen TW, Wieand KE. Backfill for iliac-crest donor sites: a prospective, randomized study of coralline hydroxyapatite. Am J Orthop (Belle Mead NJ). 2005 Aug;34(8):377-82. PubMed PMID: 16187727.

38: Polly DW Jr, Ackerman SJ, Shaffrey CI, Ogilvie JW, Wang JC, Stralka SW, Mafilios MS, Heim SE, Sandhu HS. A cost analysis of bone morphogenetic protein versus autogenous iliac crest bone graft in single-level anterior lumbar fusion. Orthopedics. 2003 Oct;26(10):1027-37. PubMed PMID: 14577525.

39: Ackerman SJ, Mafilios MS, Polly DW Jr. Economic evaluation of bone morphogenetic protein versus autogenous iliac crest bone graft in single-level anterior lumbar fusion: an evidence-based modeling approach. Spine (Phila Pa 1976). 2002 Aug 15;27(16 Suppl 1):S94-9. PubMed PMID: 12205426.

40: Klemme WR, Cunningham BW, Polly LD DW Jr. Microradiographic and histopathologic findings in a human cage explant after two-level corpectomy: a case report. Spine (Phila Pa 1976). 2002 Jan 1;27(1):E15-7. PubMed PMID: 11805653

Notes

WHAT ARE THE CURRENT INDICATIONS FOR ANTERIOR INTERBODY FUSION (AIBF) IN SPINAL DEFORMITY & PATHOLOGY?

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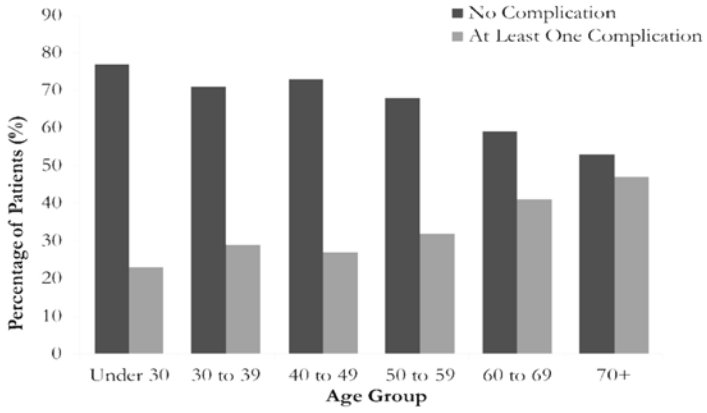
1. When the *Pathology Demands* Direct Visualization of the Anterior Vertebral Column (1): * *High Priority Diagnosis*
   - Tumor*
   - Infection*– T.B., Pyogenic
   - Thoracic HNP
   - Scoliosis - Ant. Release of Discs & Ligaments
     - Congenital Hemi-Vertebrae Resection (2)
     - Prevent Crankshaft Phenomenon
   - Scheuermann's Kyphosis
   - Trauma* – Burst Fracture, SCI
   - Pseudarthrosis* – Previous PSF Failure
   - Discogenic Low Back Pain
   - Previous Decompression with Resection of Posterior Elements
2. Indications for the Anterior Approach in Deformity Surgery:
   - For Direct Decompression
   - For Anterior Structural Support
   - To Release of Tethering Structures
   - For Growth Arrest
   - To Apply Anterior Instrumentation
   - To Improve Fusion Success
3. Benefits of Anterior Surgery in Deformity:
   - Increased Fusion Rates (Particularly When Combined With PSF)
   - Load Support – Decreased Stress on Posterior Implants
   - Restoration of Lordosis
     - Especially at L4/5 to L5/S1 (67% of Total Lordosis at These Levels)
   - Correction of Deformity
     - Scoliosis or Spondylolisthesis
   - Eliminate Pain Generator: The Disc Space
   - Restoration of Sagittal & Coronal Balance
4. General Advantages of Anterior Surgery:
   - Less Muscle Trauma (Muscle Splitting)
   - Reduced Blood Loss in Stand Alone AIBF
   - Reduced OR Time in Stand Alone AIBF
   - Better Visualization of the Disc Space
     - More Thorough Discectomy
     - More Fusion Surface Area
     - Wider Endplate Footprint for Interbody Graft or Implant
   - Improved Fusion Rates
5. Biomechanical Benefits:
   - Improved Area for Grafting
   - Wider Footprint for Interbody Implant When Compared To PLIFs/TLIFs
   - Adds Significant Stability to the Overall Construct
     - Particularly When Combined with Anterior Instrumentation Where it Increases Stiffness & Decreases Screw Strain
     - Screw Strength Dependent on Triangulation, Position in the Body, Bi-cortical Fixation, & Concurrent Bone Staple: All Increase Fixation Strength & the Biomechanical Strength of the Fixation/ Construct
6. Disadvantages Anterior Surgery:
   - Need for an Approach Surgeon
   - Significant Need for Vascular Expertise
   - ↑OR Time & Blood Loss When Combined with a Posterior Procedure (3,4)
   - Abdominal Hernia (Technique Dependent) (5)
   - Scarring of Anterior Structures Impedes any Future Surgery
   - Risk of Postoperative Ileus
   - Retrograde Ejaculation in Reproductive Males
7. <u>Complications of Anterior Surgery:</u>
   - Vascular Injuries
   - Lymphatic Injuries
   - Neurologic Injuries
   - Spleen & Liver Contusion
   - Bowel Laceration
   - Ureter Injury
   - Abdominal Wall Hernias/ Pain
   - Hematoma
   - Infection
   - Thromboembolic Disease (TED) – Right Sided Approaches (6)
   - Pulmonary Degradation – Thoracotomies (7)

8. Complication Rates in the Literature (8,9)
   - Louisville 1992: 447 Patients: 31% (140 Patients) Had Complications
     - Minor Complications -11% (47)
     - Major Complications - 24% (109)
   - Minneapolis 1995:11.5% (141/1223) Anterior Surgery Only:
     - Post-thoracotomy Pain Syndrome – 9.2% (61)
     - Pleural Effusion – 3% (20)
     - Wound Infection [Superficial] – 1% (12)
     - Pneumothorax – 1% (12)
     - Abdominal Hernia – 1% (11)
     - Wound Infection [Deep] - .5% (7)
     - Impotence & Retrograde Ejaculation – 1.3% (5)
     - Aortic Injury – 08% (1)

*Studies Concluded Anterior Surgery Has Acceptable Complications

Complications: Adult Deformity Study Group: 2006

The Impact of Perioperative Complications on Clinical Outcomes in Adult Deformity Surge Glassman, Hamil, Bridwell, Schwab, Berven, Dimowe, Spine 2007



Prospective, Multicenter Adult Deformity Database

Major Complications:	Minor Complications:
- SCI	- CSF Leak
- DVT	- Skin Problems
- Deep Infection	- Seroma
- Anterior Vascular Complications*	

Outcome Measures: SF-12, ODI, SRS-22, NRS for Leg/Back Pain

Results: Comparing 3 Groups:

No Complications vs. Minor vs. Major Complications

- Significant Improvement of all Outcomes at 1 year Post-op in all 3 Groups Except the SF-12
- SF-12 Deteriorated 2.1 Points in the Major Group Compared to the Minor Group Which Improved 4.2 Points

*Not All Major Complication's Long Term Effects are Equal

For Example: Laceration of the Renal Artery During an Anterior Approach to the Spine Causing Long Term Kidney Failure.

9. Available Anterior Approaches: May be Left or Right Sided
   - L5-S1 Trans-abdominal Interbody Approach
   - Anterior Lateral Lumbar Retroperitoneal Approach - Muscle Splitting or Trans-muscular
     - Regional - Single Level
     - Extensile - Multilevel
   - L3-S1 Para-median Retroperitoneal Trans-rectus Approach
   - Thoracolumbar (Thoracotomy) Approach
     - Thoracolumbar Junction - T10/11 to L2/3
     - Extensile Approach – T10/11 to L5/S1
   - Thoracotomy (open or Thoracoscopic [10]) (– T3/4 to T10/11
   - Trans-sternal or Trapdoor Anterior Thoracotomy – T1/2 to T3/4
   - OLIF – Open Lateral Interbody Fusion (Approach)
10. Anterior Surgical Techniques Considerations:
    - Annulotomy
      - Wide Enough for Graft
    - Elevate Disc From the Endplates
    - Thorough Discectomy
      - Leave Lateral Annulus to Prevent Expulsion of the Cage/Graft
    - Proper Endplate preparation
      - Remove All of the Nucleus/Soft Tissue
    - Bone Graft/Cage Placement – Centered on the Outer Third of the Endplate Where it is Strongest
11. Bone Graft Materials:
    - Autograft
      - Cancellous ICBG
      - Tri-cortical ICBG
    - Allograft
      - Structural Such as Femoral Rings
      - Bone Dowels (Threaded)
      - Humeral Shaft
      - Compressed Cancellous
    - Biologics
12. Synthetic Cages (11):
    Cylindrical Cages (Screw In)
    Titanium Mesh Cages (12)
    PEEK Cages
      - Laterally Placed Interbody Cages (DLIF, XLIF)
      - Anteriorly Placed Round/Oval Cages
      - Laterally. Anteriorly Placed Stacked Cages

    Carbon Fiber Cages
    Metal Expandable Cages
      - Cage Placement & Configuration
        - Degree of Lordosis
        - Diameter & Geometry
        - Material Viscoelasticity Considerations
        - Radiographic Visualization
        - Impedance of Fusion Evaluation
13. Anterior Instrumentation: Numerous Systems Available (13)

Bibliography:

1. Denis F, Anterior Surgery for Scoliosis, Clinical Orthopedics & Related Research, No. 300, p 38-44, 1994

2. Song KS, Chang BS, Yoem JS, Lee JH, Park KW, Lee CK, Surgical Treatment of Severe Angular Kyphosis with Myelopathy: Anterior & Posterior Approach with Pedicle Screw Instrumentation, Spine, Vol. 33, No. 11, pp. 1229-1235, 2008

3. Good CR, Lenke LG, Bridwell KH, O'Leary PT, Pichelmann MA, Keeler KA, Baldus CR, Koester LA., Can posterior-only surgery provide similar radiographic and clinical results as combined anterior (thoracotomy/thoracoabdominal)/posterior approaches for adult scoliosis?, Spine (Phila Pa 1976). 2010 Jan 15;35(2):210-8.

4. Pateder DB, Kebaish KM, Cascio BM, Neubaeur P, Matusz DM, Kostuik JP. Posterior only versus combined anterior and posterior approaches to lumbar scoliosis in adults: a radiographic analysis. Spine (Phila Pa 1976). 2007 Jun 15;32(14):1551-4. (Simultaneous Cases Have the Same Complications as Posterior Only)

5. Kim YB, Lenke LG, Kim YJ, Kim YW, Blanke K, Stobbs G, Bridwell KH. The morbidity of an anterior thoracolumbar approach: adult spinal deformity patients with greater than five-year follow-up. 14. Spine (Phila Pa 1976). 2009 Apr 15; 34(8):822-6.

6. Piasecki DP, Poynton AR, Mintz DN, Roh JS, Peterson MG, Rawlins BA, Charles G. Boachie-Adjei O.Thromboembolic disease after combined anterior/posterior reconstruction for adult spinal deformity: a prospective cohort study using magnetic resonance venography. Spine (Phila Pa 1976). 2008 Mar 15;33(6):668-72.

7. Lonner BS, Auerbach JD, Estreicher MB, Betz RR, Crawford AH, Lenke LG, Newton PO., Pulmonary function changes after various anterior approaches in the treatment of adolescent idiopathic scoliosis., J Spinal Disord Tech. 2009 Dec;22(8):551-8.

8. McDonnell MF, Glassman SD, Dimar JR 2nd, Puno RM, Johnson JR, Perioperative complications of anterior procedures on the spine. J Bone Joint Surg Am. 1996 Jun;78 (6):839-47.

9. Faciszewski T, Winter RB, Lonstein JE, Denis F, Johnson L, The Surgical & Medical Perioperative Complications of Anterior Spinal Fusion Surgery in the Thoracic & Lumbar Spine in Adults. A Review of 1223 Procedures, Spine (Phila Pa 1976). 1995 Jul 15;20(14):1592-9.

10. Izatt MT, Adam CJ, Labrom RD, Askin GN., The relationship between deformity correction and clinical outcomes after thoracoscopic scoliosis surgery: a prospective series of one hundred patients., Spine (Phila Pa 1976). 2010 Dec 15;35(26):E1577-85.

11. Arts MP, Peul WC., Vertebral body replacement systems with expandable cages in the treatment of various spinal pathologies: a prospectively followed case series of 60 patients., Neurosurgery. 2008 Sep;63(3):537-44; discussion 544-5.

12. Lenke LG, Bridwell K. , Mesh Cages in Idiopathic Scoliosis in Adolescents, Clin Orthop Relat Res, 2002 Jan:(394):98-108

13. Maurice B., Anterior Instrumentation (Dual Screws Single Rod System) for the Surgical Treatment of Idiopathic Scoliosis in the Lumbar Area: A Prospective Study on 33 Adolescents & Young Adults, Based on a New System of Classification. Eur Spine J. 2012 May 30. [Epub ahead of print] (Case of Operative 30° Curve)

Notes

HAS THE PLIF TECHNIQUE´S EFFECTIVENESS IN THE MANAGEMENT OF SPINAL DEFORMITY FALLEN OUT OF FAVOR OVER THE PAST DECADE?

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A) Definitions
- Deformity
- Intercorporal fusion

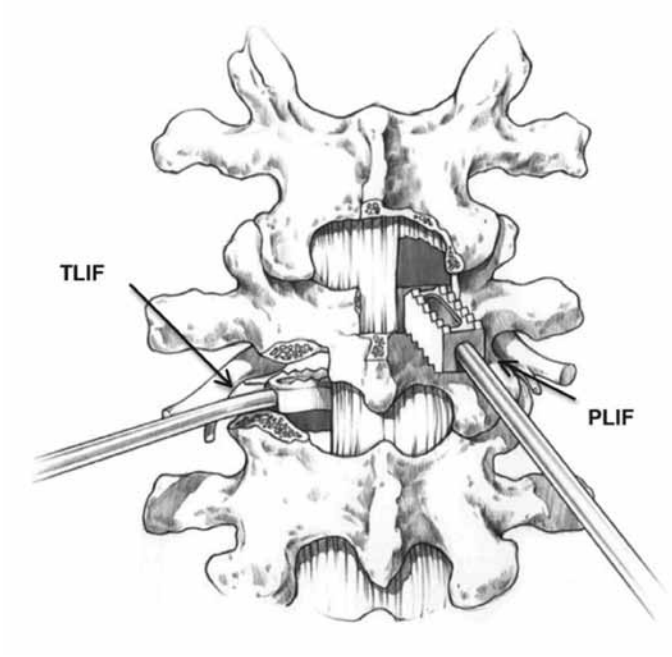
B) Surgical questions
- Special considerations in deformity surgery
- Advantages and drawbacks with the PLIF technique
- PLIF alternative

C) Conclusions and key points

A) Definitions

Deformity
- An established definition exists for adolescent idiopathic scoliosis (AIS). Various definitions have been suggested for adult spinal deformities (ASD); most recently the Scoliosis Research Society – Schwab Adult Spinal Deformity Classification (Schwab et al. 2012).
- 60% in the older population is estimated to have ASD
- Assessment of HRQL using SF-36, ODI, EQ-5D and SRS-22 shows that radiographic parameters correlated with HRQL.
- Previous trauma or spine surgery is often seen in patients with ASD.

Intercorporal fusion
- In combination with posterior fusion often termed "circumferential fusion" or "360-fusion".
- Cloward first described intercorporal fusion in 1953 in patients with lumbar disc herniation. Since this was before the era of the pedicle screw it was a stand-alone technique.
- Several principles of intercorporal fusion now exists including TLIF (transforaminal lumbar interbody fusion), XLIF (extreme lateral interbody fusion) and GO-LIF (guided oblique interbody fusion).
- The objective of intercorporal fusion
  - Restoration of disc height
  - Anterior vertebral support
  - Increased lordosis
  - Increased spinal stability
  - Improved fusion mass
  - Prevention of sagittal imbalance
- PLIF is characterized by:
  - Extension of hemilaminectomy
  - Preservation of facet joint
  - Retraction of the dural sac



B) Surgical questions

What are the surgical advantages of using the PLIF technique?

- Minimally invasive option
- Avoiding hypogastric plexus
- Avoiding great vessels

Furthermore, "non-surgical" factors, such as reimbursement issues, availability of an access surgeon may play a role.

Complications from PLIF

The PLIF technique is associated with the same complications as the TLIF technique. These include:

- Dural tears
- Hardware migration
- Neural palsy
- Radiculopathy
- Motor deficit
- Infection

In the largest studies the overall rate of neurologic complications has been reported to be approximately 7% with up to 3% sustaining permanent motor deficit.

Specific challenges with the PLIF technique in spinal deformity surgery

A considerable number of patients undergoing surgery for an adult spinal deformity have had previous spine surgery. Furthermore, these patients are often elderly having a number of co-morbidities. Therefore, factors like the length of the procedure and blood loss become increasingly relevant. Consequently, a pedicle subtraction osteotomy or a vertebral columna resection may be a better alternative than PLIF to correct a deformity, since multiple PLIF´s can be time consuming and limited to the lower lumbar region. Other factors of relevance are sural scar tissue and fusion mass from previous spine surgery

C) Conclusions and key points

The majority of studies describing results after using the PLIF technique focus on patients with lumbar degenerative scoliosis.

A surprisingly large number of these studies do not include spinopelvic parameters in the pre- and postoperative radiographic evaluation.

There is limited evidence that the complication rate is affected by the choice of PLIF or TLIF, and most comparative studies have been performed on patients with chronic low back pain without deformities.

Increasing evidence supports that long standing radiographs, including the spinopelvic junction, are imperative in the surgical evaluation of patients with spinal deformities.

References

Cloward RB: The treatment of ruptured intervertebral discs by vertebral body fusion: Indications, operative technique, after care. J Neurosurg 1953;10:154-168

Okuda et al. Surgical complications of posterior lumbar interbody fusion with total facetectomy in 251 patients. J Neurosurg Spine 2006;4:304-309

Pateder et al. Posterior Only Versus Combined Anterior and Posterior Approaches to Lumbar Scoliosis in Adults. Spine 2007;32:1551–1554

Schwab et al. Scoliosis Research Society—Schwab Adult Spinal Deformity Classification. A Validation Study. Spine 2012;37:1077–1082

Schwab et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine (Phila Pa 1976) 2005;30:1082–5

Tsai et al. Functional outcome analysis: instrumented posterior lumbar interbody fusion for degenerative lumbar scoliosis. Acta Neurochir (2011)153:547–555

Notes

TRANSFORMAINAL LUMBAR INTERBODY FUSION (TLIF) IN THE MANAGEMENT OF DEFORMITY: IS THIS THE STANDARD OF CARE FOR POSTERIOR APPROACH SURGERY?

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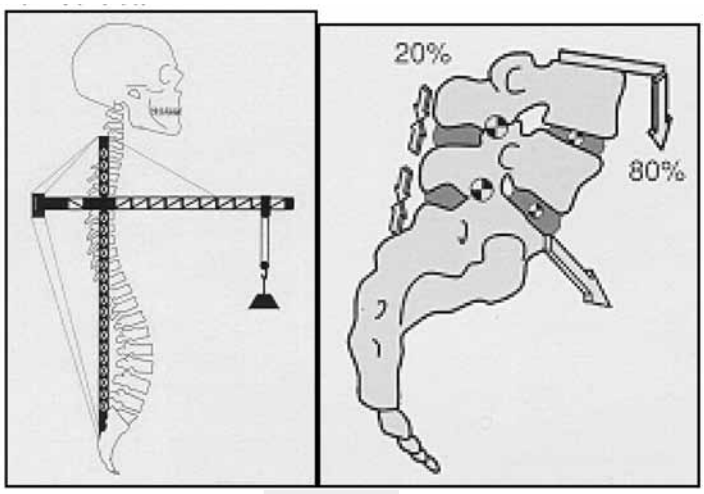
I. ANATOMY
  A. Biomechanics – Interbody Load Sharing –
    a. "Without adequate anterior column support-physiologic loads will exceed the bending strength of any pedicle based system" (Cunningham, Spine 1993)
    b. 80/20 relationship between the vertebral body & the posterior elements
    c. Surgical Goals: Restore Physiologic Lordosis
    d. Increase Construct Stability - Tension Band Restoration
    e. Disk Space/Foraminal Volume
    f. Pain Generator



II. INDICATIONS FOR INTERBODY SUPPORT
  A. Spondylolisthesis
  B. Degenerative Disc Disease
  C. Scoliosis
  D. Pseudarthrosis
  E. Failed Laminectomies
  F. Junctional Degeneration

III. INTERBODY TECHNIQUES & APPROACHES
  A. Techniques
    a. ALIF
      i. Pros:
        1. Fast
        2. ↓EBL
        3. Sagittal balance
        4. ↓ASD
      ii. Cons:
        1. Vascular laceration
        2. Visceral Injury (ureter/kidney/bladder)
        3. Ileus
        4. Retrograde ejaculation
        5. DVT
        6. Cost
        7. Adhesions
        8. Sympathectomy Effect
        9. Hernia
        10 Muscular Atony
        11. Infection
    b. Posterior: TLIF & PLIF
      i. Pros (over ALIF):
        1. Allows for direct neural decompression
          a. Exposure does double duty
        2. Allows advantages of pedicle fixation
          a. Enhanced stability
          b. Deformity correction
        3. Complication risk tradeoff:
          a. Vascular, Retrograde Ejaculation (ALIF) vs. Neural (TLIF)
        4. No approach surgeon needed
        5. Excision of disk fragments
        6. Less expensive than 360^0 fusion
      ii. Cons:
        1. Dural tear
        2. Injury to nerves
          a. Cylindrical Cages – up to 30% neural injury
          b. Impacted Devices – 3-10%
        3. ASD
      iii. TLIF Advantages over PLIF
        1. Less neuropraxia
        2. Less dural injury
        3. Revisions are easier
      iv. TLIF Contraindications
        1. Osteoporotic vertebrae
        2. Vertebral body fracture
        3. No neural compression
        4. Significant kyphosis?
    c. Far Lateral
      i. Pros:
        1. Large Graft (Surface Area, Height)
        2. Approach tolerated better than conventional anterior lumbar approaches
        3. Foraminal Indirect Decompression
        4. Apophyseal Bone Footprint

ii. Cons:
Lumbar Plexus
Setup
Radiation
Cost

B. Approaches
a. OPEN
b. MINI-OPEN
c. LAPARASCOPIC
d. MIS
e. STAND-ALONE
f. 270°
g. 360°

IV. TLIF
A. Ideal Patient – Young males with 1-2 level interbody indication, foraminal stenosis with no more than moderate disk space collapse.
a. Poor ALIF candidates
i. Prior anterior surgery
ii. Calcified Vasculature
iii. Young males
B. Indications
a. I/II degenerative/isthmic spondylolisthesis
b. Scoliosis - Lumbosacral fixation
i. Long segment fusion
ii. Fixation strength
iii. 360 degree fusion
c. Postlaminectomy Instability
d. Adjacent Segment Disease
e. High pseudoarthrosis risk
i. Previous failed fusion
ii. Smoker
C. Limitations –
a. High Grade Slips
b. Marked Disk Collapse
c. Severe Bilateral Scar
D. Principles
a. TLIF converts distraction to compression!
i. ↑ interbody height
ii. ↑ lordosis (kyphosis -> lordosis)
iii. Biomechanical Advantage
iv. Graft under compression
v. Ability to correct deformity / Spondy

V. OUTCOMES
A. Sagittal Correction
a. Can we induce lordosis with TLIF?
i. *Yson, JNS Spine, 2012*
1. 42 pts (57 levels) – retrospective case series
2. Technique: Bilateral facetectomies with TLIF + post compression
3. Mean prop alignment 8.1
4. Mean preop alignment 8.1°
5. Mean Postop alignment 15.3°(7.2° correction)
6. L5-S1 largest gain in lordosis/level (10.1°)
7. ↑ correction with multilevel (9.8 vs 5.2°)
ii. *Ould-Slimane, Eur Sp J, 2012*
1. 45 pts – 58.4yo (+/-9.6) - 35.1 (+/-4.1)m F/U
2. 13/45 (29%) – globally + sagittal balance
3. 32/45 (71%) – globally balanced but ↑PT(>20°)
4. Compensatory retroverted pelvis
5. PT reduced to normal postop (<20°) –> p<0.01
6. Global balance not significantly altered (p=0.07)
7. Conclusion: Posterior 1-level circumferential fusion can reduce pelvic compensation though might not correct global sagittal imbalance

b. TLIF & SPONDYLOLISTHESIS
i. ALIF vs TLIF - Hsieh, JNS Sp, 2007
1. 1st comparative retrospective cohort (degen/isthmic spondy)
2. N=32 ALIF with perc screws, N=25 open TLIF
3. Radiographic Results: ALIF is superior
4. ↑18.5% For Ht (TLIF ↓0.4%)
5. ↑local disk angle 8.3° & LL 6.2° (TLIF ↓0.1° & 2.1°)
6. BUT No diff in clinical & fxn outcomes between both groups at 2y F/u.
ii. Recnik, JSDT, 2011
1. 32 pts isthmic spondy – 12-60 m F/U
2. Retrospective case series
3. Initial Postop:
a. ↓Slip (p<0.001)
b. ↑post disk space ht (p=0.002)
4. No change in segmental lordosis (p=0.811)
5. Final f/u
a. ↑Slip (p=0.002) ↓PDSH & SL (p<0.001)
6. Conclusion: Rod contouring & anterior cage placement allow slip reduction & SL correction
iii. MIS-TLIF vs mini-ALIF+perc screws - Kim, JSDT, 2009
1. Retrospective cohort
2. N=48 mTLIF, N=46 mALIF with perc screws
3. Conclusions:
a. No diff in clinical & fxn outcomes in both groups
b. Significant ↓VAS leg/back & ODI scores (p<0.001)
c. Fusion: 95.8% (ALIF) vs 92.3% (TLIF)
d. ALIF better radiographically - signif ↑ Disk Ht, segmental & whole lordosis (p<0.05)
4. Similar Findings as prior open comparative study.

c. DEGEN SCOLIOSIS:
i. TLIF vs ALIF- *Crandall, Spine, 2009*
1. Prospective NR case series - 40 pts – 38 (24-68) m F/U
2. Avg 7 level post instrumentation (n=20 ALIF/TLIF)

3. Matched preop coronal/sagittal deformity/balance
4. Outcomes
   a. CT eval for fusion @ 1year
   b. VAS & ODI similar signif improvements ($p<0.0019$)
5. Deformity Correction similar (70%) both groups
6. Complications:
   a. ALIF: 4NU, 5 Adj Level Fx, 5 ASD, 3 infxn, 1 footdrop = 8 reoperations
   b. TLIF: 2NU, 2 Adj Level Fx, 3 ASD, 1 infxn, 1 footdrop = 2 reops
7. Conclusion: Both ALIF & TLIF allow effective deformity correction in degen scoliosis with fewer reops in TLIF.

ii. MIS TLIF & Posterior Instrumentation for Degen Scoli – *Scheufler, Nsurg, 2010*
1. Retrospective case series – NO SIGNIF SAGITTAL IMBALANCE (preop SVA 32mm -> postop 8mm)
2. 30 pts – age 64-88yo - 19.6 m F/U
3. Adult Degen Scoli (Avg Preop Cor Cobb 44.8° (25-85°)
4. Technique: MIS unilateral TLIF/decomp + 3-8 segment posterior instrumentation + rhBMP-2 with intraop-CT v flouro
5. 90% segment fusion
6. Postop ↓ Cobb to 31.7° , LL ↑ +8.8° -> -36°
7. Avg surgeon XRT: 0.025 mSv (flouro) vs 0mSv (iCT)
8. Conclusion: Intraop CT can eliminate XRT, ↓ screw compls in pts with NORMAL SVA

d. COMPLICATIONS
i. Neural Injury
1. 0-7% incidence
2. Etiology: Traction ischemia
3. ↑ in MIS-TLIF vs. open
   a. Vaidya, JSDT, 2008
   b. Dhall, JNS Sp, 2008
4. Pain > Numbness/Weakness
5. No defined recovery timeline
6. Tx: Nonop

ii. Implant Migration
1. Unremitting postop leg/back pain
   a. Foraminal compression > cauda (migrated PLIF cage)
2. ↑ Bioabsorbable vs Carbon-fiber cages
3. Etiology:
   a. Overaggressive endplate preparation
   b. Incorrect sizing
   c. Poor positioning
   d. BMP / Postoperative Osteolysis – 31% requiring revisions
      i. *Vaidya, JSDT, 2008*
4. Tx: Prevention, Upsize cage or remove

iii. TLIF & rh-BMP2
1. rhBMP-2 (Infuse®) - FDA approved for 1-level L4-S1 ALIF with metal cages only
2. >85% "off-label" use
3. Reports 92-100% fusion
4. Carragee reports 10-50% complication rates
   a. *Spine J, 2011*
5. PRMCT with rh-BMP-2 vs ICBG auto in TLIF
   a. Begun in August 2011
   b. Pending data

iv. BMP Heterotopic Ossification
1. HO - Ectopic bone formation in spinal canal or neuroforamen
2. Reports vary on incidence & implications – *Chen, JNS Sp, 2010*
3. Symptomatic patients – few but poor results in literature with revision decompression and HO removal
4. Treatment:
   a. Prevention –" BARRIER TECHNIQUE" – Fibrin glue sealant -
   b. No strong supporting evidence

v. BMP Radiculitis
1. Diagnosis of exclusion – acute or delayed presentation
2. No real classification system
   a. Compressive (HO) vs Non-compressive
3. Postulated due to BMP inflammatory response
   a. *Dimitriev, Spine J, 2011*
4. 14% (BMP) vs 3% (ICBG)
5. Barrier technique - ↓ 20->4% with BMP
   a. *Rihn, Spine J, 2009*
6. Prevention:
   a. BMP placement anteriorly (contained)
   b. Small dose
   c. Fibrin sealants

vi. BMP Osteolysis
1. Excessive bone resorption - Giannoudis, Osteopor Int, 2007
   a. BMP-Osteoclast activation
   b. Dose-dependent
2. 54-100% incidence
3. Postulated to not affect rate of fusion
4. ~16% associated with subsidence
   a. *McClellan, JSDT, 2006*
   b. *Meisel, Eur Sp J, 2008*
5. Up to 31% revision rate
   a. Implant Migration
      i. *Helgeson, Spine J, 2011*
      ii. *Vaidya, JSDT, 2008*

e. MIS TLIF
   i. No Class I data for MIS over open TLIF
   ii. II/III Demonstrate improved short-term outcomes:
      1. ↓ EBL, narcotics, hospital stay
   iii. Some data suggest equivalent long-term outcomes
      1. *Peng, Spine, 2009*

VI. TECHNICAL TIPS
   A. Use lateral film / Dilators ® disc orientation
   B. Establish Lordosis
      a. Anterior cage placement
      b. Jackson table, or.
      c. Extend hips for rod placement
   C. Protect (monitor?) exiting root
   D. Minimize BMP complications
      a. Avoidance vs Barrier Technique

VII. TLIF PITFALLS
   A. Subsidence – aggressive endplate prep, BMP
   B. Neural Injury – DRG, Traction, BMP
   C. Inadequate debridement or access
      a. Anterior disc space
      b. Posterior vertebral osteophytes
   D. Cyclic loading of pedicle screws
      a. Use lamina spreader
   E. BMP-associated HO, radiculitis, osteolysis

REFERENCES

1. Cunningham BW, Sefter JC, Shono Y, McAfee PC: Static and cyclical biomechanical analysis of pedicle screw spinal constructs. *Spine* (Phila Pa 1976). 1993 Sep 15;18(12):1677-88.
2. Yson SC, Santos ER, Sembrano JN, Polly DW Jr: Segmental lumbar sagittal correction after bilateral transforaminal lumbar interbody fusion. *J Neurosurg Spine*. 2012 May 11. [Epub ahead of print]
3. Ould-Slimane M, Lenoir T, Dauzac C, Rillardon L, Hoffmann E, Guigui P, Ilharreborde B: Influence of transforaminal lumbar interbody fusion procedures on spinal and pelvic parameters of sagittal balance. *Eur Spine J*. 2012 Jun;21(6):1200-6.
4. Hsieh PC, Koski TR, O'Shaughnessy BA, Sugrue P, Salehi S, Ondra S, Liu JC: Anterior lumbar interbody fusion in comparison with transforaminal lumbar interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance. *J Neurosurg Spine*. 2007 Oct;7(4):379-86.
5. Recnik G, Košak R, Vengust R: Influencing Segmental Balance in Isthmic Spondylolisthesis using Transforaminal Lumbar Interbody Fusion. *J Spinal Disord Tech*. 2011 Dec 5.
6. Kim JS, Kang BU, Lee SH, Jung B, Choi YG, Jeon SH, Lee HY: Mini-transforaminal lumbar interbody fusion versus anterior lumbar interbody fusion augmented by percutaneous pedicle screw fixation: a comparison of surgical outcomes in adult low-grade isthmic spondylolisthesis. *J Spinal Disord Tech*. 2009 Apr;22(2):114-21.
7. Crandall DG, Revella J: Transforaminal lumbar interbody fusion versus anterior lumbar interbody fusion as an adjunct to posterior instrumented correction of degenerative lumbar scoliosis: three year clinical and radiographic outcomes. *Spine* (Phila Pa 1976). 2009 Sep 15;34(20):2126-33.
8. Scheufler KM, Cyron D, Dohmen H, Eckardt A: Less invasive surgical correction of adult degenerative scoliosis, part I: technique and radiographic results. *Neurosurgery*. 2010 Sep;67(3):696-710.
9. Scheufler KM, Cyron D, Dohmen H, Eckardt A: Less invasive surgical correction of adult degenerative scoliosis. Part II: Complications and clinical outcome. *Neurosurgery*. 2010 Dec;67(6):1609-21; discussion 1621.
10. Vaidya R: Transforaminal interbody fusion and the "off label" use of recombinant human bone morphogenetic protein-2. *Spine J*. 2009 Aug;9(8):667-9. No abstract available.
11. Vaidya R, Sethi A, Bartol S, Jacobson M, Coe C, Craig JG. Complications in the use of rhBMP-2 in PEEK cages for interbody spinal fusions. *Spine J*. 2009.
12. Dhall SS, Wang MY, Mummaneni PV: Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up. *J Neurosurg Spine*. 2008 Dec;9(6):560-5.
13. Carragee EJ, Hurwitz EL, Weiner BK: A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: Emerging safety concerns and lessons learned. *Spine J* 2011;11(6):471-491.
14. Chen NF, Smith ZA, Stiner E, Armin S, Sheikh H, Khoo LT: Symptomatic ectopic bone formation after off-label use of recombinant human bone morphogenetic protein-2 in transforaminal lumbar interbody fusion. *J Neurosurg Spine* 2010;12(1):40-46.
15. Dmitriev AE, Lehman RA Jr, Symes AJ: Bone morphogenetic protein-2 and spinal arthrodesis: The basic science perspective on protein interaction with the nervous system. *Spine J* 2011;11(6): 500-505.
16. Rihn JA, Patel R, Makda J, et al: Complications associated with single-level transforaminal lumbar interbody fusion. *Spine J* 2009;9(8):623-629.
17. Giannoudis PV, Kanakaris NK, Einhorn TA: Interaction of bone morphogenetic proteins with cells of the osteoclast lineage: Review of the existing evidence. *Osteoporos Int* 2007;18(12):1565-1581.
18. McClellan JW, Mulconrey DS, Forbes RJ, Fullmer N: Vertebral bone resorption after transforaminal lumbar interbody fusion with bone morphogenetic protein (rhBMP-2). *J Spinal Disord Tech* 2006; 19(7):483-486.
19. Meisel HJ, Schnöring M, Hohaus C, et al: Posterior lumbar interbody fusion using rhBMP-2. Eur *Spine J* 2008; 17(12):1735-1744.
20. Helgeson MD, Lehman RA Jr, Patzkowski JC, Dmitriev AE, Rosner MK, Mack AW: Adjacent vertebral body osteolysis with bone morphogenetic protein use in transforaminal lumbar interbody fusion. *Spine J* 2011;11(6): 507-510.
21. Peng CW, Yue WM, Poh SY, Yeo W, Tan SB: Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. *Spine* (Phila Pa 1976) 2009; 34(13):1385-1389.

Notes

DEBATE 3: THE DEVELOPMENT, INDICATIONS & BENEFITS OF THE LATERAL INTERBODY SPINAL APPROACH AND IMPLANTS: WHAT ARE THE INDICATIONS, EFFECTIVENESS IN DEFORMITY CORRECTION & KNOWN COMPLICATIONS? WHAT ARE THE BENEFITS OF THE LATERAL APPROACH?

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Minimally invasive spine surgery (MIS) was initially developed to address morbidity associated with traditional open spinal surgery. Over the last decade, the application of MIS techniques continues to evolve and expand. The confluence of commercially available devices, advanced surgeon training, and modern intraoperative imaging techniques has accelerated this development. MIS techniques have been implemented in the treatment of more difficult and complex pathologies including adult degenerative scoliosis (ADS). The prevalence of ADS has increased due to the increase in life expectancy (Anand, et al 2010. Dakwar, et al., 2010). The traditional surgical correction of ADS incorporates extensive open spinal mobilization and then reconstruction with long multilevel implants and may confer significant morbidity. Controversy remains over the role of MIS in these patients. Less invasive techniques have the potential for muscle mass preservation and decreased physiological stress, blood loss, narcotic use and length of hospital stay. However, MIS techniques have their own set of challenges and complications. Difficulties related to MIS correction of ADS are especially associated with its steep learning curve and technical limitations. A full understanding of the fundamentals of spinal deformity correction, three-dimensional spinal anatomy and the technical limitations of the MIS instrumentation systems are prerequisites for successful outcomes.

The lateral interbody fusion (MIS LIF) as an option for the surgical treatment of ADS can be used either alone or combined with other techniques such as posterior interbody fusions, anterior column release, and/or posterior percutaneous instrumentation. The MIS LIF should be considered in hybrid constructs incorporating traditional posterior osteotomies. The MIS decision making process includes a thorough analysis of clinical and radiographic parameters to establish benchmark surgical objectives which includes decompression and restoration of spinal balance

MIS LIF Indications on ASD:

Stand Alone: Mild deformity (10-30 degrees coronal cobb angle), Advanced age, multiple comorbities, no osteoporosis, Sagittal and coronal balance.

MIS LIF with posterior instrumentation (percutaneous): Coronal balance, Sagittal balance, No fractional curve, Osteopenia

MIS LIF and/or anterior longitudinal ligament release, Facetectomy, Posterior instrumentation (percutaneous): (10-40 degrees coronal cobb), Sagittal unbalance < 9cm SVA, PT 20-30.

MIS LIF with posterior open osteotomies (Hybrid configuration), posterior pedicle screws: Significant deformity (> 40 degrees coronal cobb), Coronal unbalance, Fractional curve, Sagittal unbalance, > 9 cm, PT >30.

MIS LIF

The MIS LIF is a safe alternative to traditional open procedures. An adaptation of an endoscopic lateral transpsoas approach to lumbar fusion, this technique has many advantages. With the lateral approach the risk of thecal sac injury, arachnoiditis, and CSF fistulae from manipulation is minimal compared to posterior approaches. Furthermore, the risk of vascular injury is also minimal compared to the traditional anterior approach. Other advantages include indirect canal and foraminal decompression through the placement of a large interbody graft that covers the majority of available endplate, less tissue trauma, decreased blood loss, shorter operating times, less wound issues, earlier mobilization, and maintenance of the stabilizing posterior ligamentous complexes and tension bands.(Ozgur et al., 2010., Rodgers et al., 2010). There is a known learning curve partly because the lateral approach introduces anatomical challenges to surgeons who are more familiar with open posterior or anterior approaches. The skill set required is dependent on surgeon experience and detailed understanding of regional anatomy

Complications

As with any operation, there will always be a risk of complications that underscores the importance of meticulous attention to detail throughout the perioperative period (Knight, et al., 2009). Complications can arise from the result of inadequate preoperative planning; For instance, neurovascular structures may be in the way of the intended exposure, which may preclude a safe corridor for operating. Close attention to preoperative MRI's can help avoid such complication. In addition, suboptimal patient positioning, particularly at L4/5 disc space, can increased risk of postoperative motor or sensory deficits (Tormenti et al., 2010).

Numbness, paresthesia, and weakness

The lateral retroperitoneal transpsoas approach is a technique that can be challenging since it is a non-traditional approach for many spine surgeons who are more accustomed to a posterior approach. Hence, it does have a learning curve, and the skill at which it is performed is very dependent on experience with the regional anatomy and with the approach itself. . Real-time EMG monitoring is critical to minimize the chance of motor nerve injury (Uribe, et al., 2010). However, sensory nerves cannot be monitored, thereby leaving them susceptible to iatrogenic injury if there is not a thorough understanding of the regional anatomy.

Nerve injuries can lead to motor and sensory deficits, with the highest rates with L4/5 interbody approaches. The current literature is inconsistent with its reporting of postoperative "thigh" symptoms, which could range from numbness, paresthesias, dysesthesias, or weakness. Because of this, an overall rate of "thigh complications" ranging from 0.7% - 62.7% must be considered with a fair degree of caution (Knight, et al., 2009; Cummock, et al., 2011; Rodgers, et al., 2011).

The rate of paresthesias following MIS LIF can range from 0.7% to 30% (Bergey, et al., 2004; Knight, et al., 2009; Cummock, et al., 2011; Rodgers, et al., 2011), while the rate of numbness has been reported as 8.3% - 42.4% (Dakwar, et al., 2010; Cummock, et al., 2011; Pimenta, et al., 2011). Commonly affected nerves include the genitofemoral, lateral femoral cutaneous, and anterior femoral cutaneous nerves. It is important to distinguish between the different dermatomes of these sensory nerves on the postoperative examination, and not to simply report that a patient has "thigh pain" or "numbness". Reports of motor weakness from femoral nerve injury have also varied in the literature, ranging from 3.4% - 23.7% (Knight, et al., 2009; Cummock, et al., 2011; Pimenta, et al., 2011). It is important to realize that most motor and sensory deficits are transient and do recover;

with 50% recovery at 90 days, and 90% recovery at 1 year in some series (Cummock, et al., 2011). This may be a result of the muscles and nerves recovering from manipulation, inflammation, and irritation during the operation. As a result, it is advisable to fully disclose to patients preoperatively that there is a chance of motor or sensory deficit following the operation, but that the vast majority of cases are transient in nature.

Abdominal wall paresis

Abdominal wall paresis, also referred to as a "pseudohernia", has been identified as a potential complication of the MIS lateral approach (Dakwar, et al., 2011). The mechanism is attributed to iatrogenic nerve injury during the initial dissection of the abdominal wall. Consequences include denervation, paresis, and bulging of the anterior abdominal wall. Associated signs and symptoms include swelling, pain, hyperesthesia, or other sensory abnormalities. If suspected, it is important to rule out a true abdominal hernia in these instances. In many cases, spontaneous recovery can occur.

Spinal implants related complications

There have been few reports of complications attributed to the device implanted such as the interbody cage or lateral plate. Recently, Dua et al. reported a 15% rate of spinal device related complications based off a series of 13 patients (Dua, et al., 2010). These cases consisted of two atraumatic coronal plane fractures at L4/5 in the first six weeks of the postoperative period. A review of our own series has demonstrated a device related complications rate of 5.9% in a series of 101 consecutive cases (Le, et al., 2011). The complications included three hardware failures and three vertebral body fractures. All cases were atraumatic. All cases presented with recurrent back pain except one, which was identified incidentally. All devices failures involved a dislodged lateral plate and lock nut(s). The mechanism is unclear, but may involve cage subsidence with a fixed angle screw, , a stress riser in the area of stress concentration, violation of the endplate during preparation or screw insertion, or malplacement of the hardware lock nuts (Disch, et al., 2008; Dua, et al., 2010; Le, et al., 2011).

Subsidence

As with any technique used for lumbar fusion, subsidence of the cage can occur at one or both endplates. The subsequent progressive deformity and compression of neural elements can lead to a loss of indirect decompression and reduced chance of successful fusion and possible reoperation (Closkey, et al., 1993; Kozak, et al., 1994).

In a study that included 140 patients and 238 levels fused in the lumbar spine with a mean follow-up of 9.6 months, we have recently found subsidence to be present in 14.3% of the cases and in 8.8% of the total levels fused (Le, et al., 2011). Only 2.1% of the patients had symptomatic subsidence, however. Subsidence appears to correlate with construct length. The most important finding, however, was that there was a 14.1% rate of subsidence with smaller 18 mm cages versus only 1.9% with larger 22 mm cages, leading to the conclusion that the largest interbody cage should be used whenever feasible.

Rhabdomyolysis

Rhabdomyolysis is a rare, but known, complication of spinal surgery. In severe cases, acute renal failure may result. The first cases of rhabdomyolysis and acute renal failure recently been reported following MIS LIF (Dakwar, et al., 2011). This potential complication should be suspected in appropriate cases especially in morbidly obese patients and in procedures associated with prolonged operative times.

MIS LIF and Sagittal balance

The minimally-invasive lateral transpsoas approach to the lumbar spine provides an alternative method for lumbar interbody fusion and spinal deformity correction. (Anand, et al 2010. Dakwar, et al., 2010). The contribution to global lumbar lordosis provided by the MIS lateral approach, however, has not been well quantified (Acosta, et al., 2011). From a theoretical standpoint, anterior-based procedures have been described favorably in the ability to better correct deformities . This is due to the relatively greater role the anterior column(primary weight-bearing column) plays in contributing to and also correcting coronal, sagittal, and rotatory deformities. The potential increase in global lumbar lordosis provided by large interbody implants in a conventional lateral interbody fusion procedure is limited by routine retention of the anterior longitudinal ligament. The minimally-invasive lateral transpsoas approach, in particular, has been shown to demonstrate good radiographic and clinical outcomes in short and mid-term follow up, preserving preoperative segmental lordosis without promoting loss of sagittal global balance. However, in the case where there is a fixed sagittal imbalance, the MIS lateral transpsoas approach may not adequately restore lordosis without release of the anterior longitudinal ligament (Dakwar et al, 2010).

Selective sectioning of the ALL using MIS techniques is feasible during the lateral retroperitoneal transpsoas approach as the current and other authors have shown (Uribe et al, 2012 JNS spine on press). Anterior longitudinal ligament release using the MIS lateral trans-psoas approach provides an alternative to both anterior lumbar interbody fusion and posterior osteotomies for the restoration of segmental lordosis. Placement of increasingly lordotic lateral interbody cages leads to a mean progressive increase in segmental lordosis of 11.6° and resulted in generally equivalent lordosis restoration to reports of SPO alone (Uribe et al., 2012 JNS spine on press). The specific utility of ALL release and MIS lateral deformity correction will be better understood as more experience is gained with this approach through clinical application.

Conclusions and key points

The retroperitoneal transpsoas approach, for adult degenerative scoliosis, is a safe and effective alternative to traditional posterior open lumbar techniques. As with most minimally invasive techniques, there is a learning curve to be overcome in order to minimize the risk of iatrogenic nerve injuries. An integral aspect of this curve is to always be aware of the regional anatomy encountered. Small technical variations can result in dramatic changes in patient outcome due to the proximity of the lumbosacral plexus. Directional t-EMG can help guide the surgeon and alert of any critical distances from surrounding motor nerves specially at the lower lumbar levels. Even with this, transient sensory deficits and, on occasion, weakness may occur. Therefore it is important to discuss this potential with surgical candidates preoperatively.

Using this technique, coronal Cobb angles can be improved. However, the effects on sagittal Cobb angles, such as with lumbar lordosis and the overall global sagittal balance, have not been as well established. In the case where there is a fixed sagittal imbalance, the MIS lateral transpsoas approach may not adequately restore lordosis without release of the anterior longitudinal ligament or incorporating traditional posterior osteotomies.

References

Anand, N., Rosemann, R., Khalsa, B., & Baron, E.M. (2010). "Mid-term to long-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis." Neurosurg Focus 28(3): E6.

Cummock, M.D., Vanni, S., Levi, A.D., Yu, Y., & Wang, M.Y. (2011). "An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion." J Neurosurg Spine 15(1): 11-18.

Dakwar, E., Cardona, R.F., Smith, D.A., & Uribe, J.S. (2010). "Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis." Neurosurg Focus 28(3): E8.

Dakwar, E., Le, T.V., Baaj, A.A., Le, A.X., Smith, W.D., Akbarnia, B.A., & Uribe, J.S. (2011). "Abdominal wall paresis as a complication of minimally invasive lateral transpsoas interbody fusion." Neurosurg Focus 31(4): E18.

Dakwar, E., Rifkin, S.I., Volcan, I.J., Goodrich, J.A., & Uribe, J.S. (2011). "Rhabdomyolysis and acute renal failure following minimally invasive spine surgery: report of 5 cases." J Neurosurg Spine 14(6): 785-788.

Dakwar, E., Vale, F.L., & Uribe, J.S. (2011). "Trajectory of the main sensory and motor branches of the lumbar plexus outside the psoas muscle related to the lateral retroperitoneal transpsoas approach." J Neurosurg Spine 14(2): 290-295.

Dua, K., Kepler, C.K., Huang, R.C., & Marchenko, A. (2010). "Vertebral body fracture after anterolateral instrumentation and interbody fusion in two osteoporotic patients."Spine J 10(9): e11-15.

Knight, R.Q., Schwaegler, P., Hanscom, D., & Roh, J. (2009). "Direct lateral lumbar interbody fusion for degenerative conditions: early complication profile." J Spinal Disord Tech 22(1): 34-37.

Le, T.V., Baaj, A.A., Dakwar, E., Burkett, C.J., Murray, G., Smith, D.A., & Uribe, J.S. (2011). "Subsidence of PEEK Intervertebral Cages in Minimally Invasive Lateral Retroperitoneal Transpsoas Lumbar Interbody Fusion." Spine (Phila Pa 1976

Le, T.V., Smith, D.A., Greenberg, M.S., Dakwar, E., Baaj, A.A., & Uribe, J.S. (2011). "Complications of lateral plating in the minimally invasive lateal transpsoas approach." J Neurosurg Spine

Mundis, G.M., Akbarnia, B.A., & Phillips, F.M. (2010). "Adult deformity correction through minimally invasive lateral approach techniques." Spine (Phila Pa 1976) 35(26 Suppl): S312-321.

Ozgur, B.M., Aryan, H. E., Pimenta, L., & Taylor, W.R. (2006). "Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion." Spine J 6(4): 435-443.

Rodgers, W.B., Gerber, E.J., & Patterson, J. (2011). "Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases." Spine (Phila Pa 1976) 36(1): 26-32.

Tormenti, M.J., Maserati, M.B., Bonfield, C. M., Okonkwo, D.O., & Kanter, A.S. (2010). "Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation." Neurosurg Focus 28(3): E7.

Uribe, J. S., Arredondo, N., Dakwar, E., & Vale, F. L. (2010). "Defining the safe working zones using the minimally invasive lateral retroperitoneal transpsoas approach: an anatomical study." J Neurosurg Spine 13(2): 260-266.

Uribe, J.S., Vale, F.L., & Dakwar, E. (2010). "Electromyographic monitoring and its anatomical implications in minimally invasive spine surgery." Spine (Phila Pa 1976) 35(26 Suppl): S368-374

Wang, M.Y., & Mummaneni, P.V. (2010). "Minimally invasive surgery for thoracolumbar spinal deformity: initial clinical experience with clinical and radiographic outcomes." Neurosurg Focus 28(3): E9.

Youssef, J.A., McAfee, P.C., Patty, C.A., Raley, E., DeBauche, S., Shucosky, E., & Chotikul, L. (2010). "Minimally invasive surgery: lateral approach interbody fusion: results and review." Spine (Phila Pa 1976) 35(26 Suppl): S302-311.

Notes

DEBATE 3: THE DEVELOPMENT, INDICATIONS, AND BENEFITS OF THE LATERAL INTERBODY SPINAL APPROACH AND IMPLANTS: WHAT ARE THE INDICATIONS, EFFECTIVENESS, AND KNOWN COMPLICATIONS IN DEFORMITY CORRECTION?

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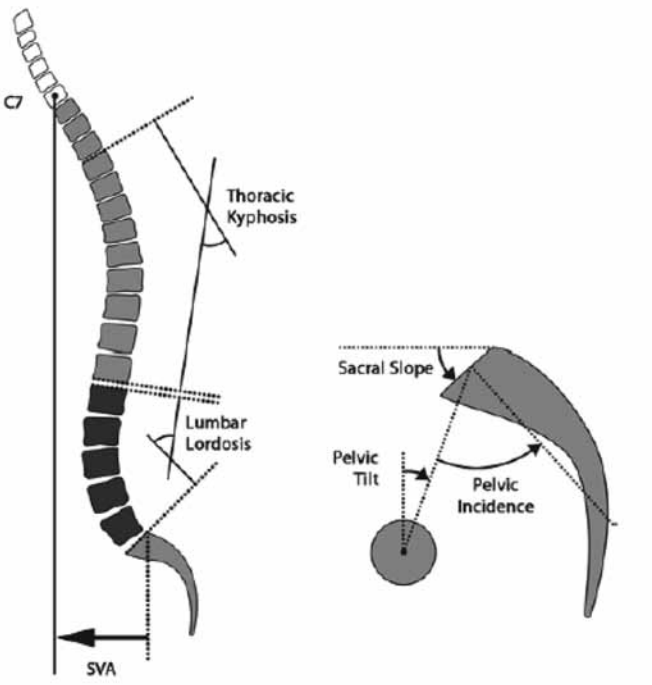
Key Points

1. Factors impacting adult deformity surgery outcomes
   A. Primary
      - improvement of neurological symptoms
      - sagittal spinal alignment
      - improvement of pelvic tilt
   B. Secondary
      - complications
      - coronal alignment
      - fusion success
2. Achieving or at least maintaining sagittal spino-pelvic alignment has been shown to be very important for good clinical outcomes for adults with scoliosis.
   A. In a landmark study from Glassman et al. (Spine 30:682-8, 2005), radiographic measures were correlated with health-related quality of life measures in 298 adults with spinal deformity, including 172 with no prior surgery and 126 with prior surgery. Positive sagittal malalignment was the most reliable predictor of clinical symptoms in both patient groups.
   B. Lafage et al. (Spine 34:E599-606, 2009) assessed 300 radiographic parameters in 125 adult spinal deformity patients (operative and non-operative) and correlated these with measures of health-related quality of life. The top 3 radiographic parameters that correlated with outcome

were all sagittal alignment parameters (not coronal alignment or coronal Cobb angle).



1. The most important parameter was the degree of mismatch between the lumbar lordosis (LL) and the pelvic incidence (PI) (PI-LL mismatch)
2. The second most important parameter was the sagittal spinal alignment (sagittal vertical axis; SVA)
3. The third most important parameter was the pelvic tilt (PT)

3. Many clinical reports are available in the literature that describe outcomes for adult spinal deformity surgery based on traditional instrumentation approaches that are not based on lateral interbody implants. Searching for relevant terms pulls at least 100 articles in Medline. For example:

Smith JS, Kasliwal, MK, Crawford A, Shaffrey CI. Outcomes, expectations, and complications overview for the surgical treatment of adult and pediatric spinal deformity. Spine Deformity. In press.

Smith JS, Shaffrey CI, Glassman S, Berven S, Hamill C, Horton W, Ondra S, Schwab F, Sansur CA, Bridwell K. Risk-benefit assessment of surgery for adult scoliosis: an analysis based on patient age. Spine 36(10):817-824, 2011.

Bridwell KH, Baldus C, Berven S, Edwards C 2nd, Glassman S, Hamill C, Horton W, Lenke LG, Ondra S, Schwab F, Shaffrey C, Wooten D. Changes in radiographic and clinical outcomes with primary treatment of adult spinal deformity surgeries from two years to three- to five-years follow-up. Spine 35(2):1849-54, 2010.

Smith JS, Shaffrey CI, Berven S, Glassman S, Hamill C, Horton W, Ondra S, Schwab F, Fu KG, Bridwell K. Operative versus conservative treatment of leg pain in adults with scoliosis: A retrospective review of a prospective multicenter database with two-year follow-up. Spine 34(16):1693-1698, 2009.

Bridwell KH, Glassman S, Horton W, Shaffrey C, Schwab F, Zebala LP, Lenke LG, Hilton JF, Shainline M, Baldus C, Wooten D. Does treatment (non-operative and operative) improve the two-year quality of life in patients with adult symptomatic lumbar scoliosis: a prospective multicenter evidence-based medicine study. Spine 34(20):2171-8, 2009.

Smith JS, Shaffrey CI, Berven S, Glassman S, Hamill C, Horton W, Ondra S, Schwab F, Shainline M, Fu KG, Bridwell K. Improvement of back pain with operative and nonoperative treatment in adults with scoliosis. Neurosurgery 65(1):86-94, 2009.

4. A search of Medline for minimally invasive adult deformity manuscripts with relevant search terms only identifies 6 manuscripts.
   A. Anand N, Baron EM, Thaiyananthan G, Goldstein TB. Minimally invasive multilevel percutaneous correction and fusion for adult lumbar degenerative scoliosis. J Spinal Disord Tech, 21(7):459-467, 2008.
      1. Prospective evaluation of 12 consecutive patients who have had lateral lumbar interbody fusions and minimally invasive percutaneous correction of adult lumbar degenerative scoliosis
      2. Ages ranged from 50-85 (mean 72.8)
      3. Mean number of levels operated was 3.5 (range 2-8)
      4. Very short follow-up (mean of 75 days)
      5. Mean surgical time for anterior procedures was 4.3 hours and for percutaneous posterior screws was 3.9 hours
      6. Mean length of hospital stay was 8.6 days
      7. 3 patients had thigh pain that resolved in 6 weeks
      8. Mean pre-op coronal Cobb angle was 18.9 degrees and post-op was 6.2 degrees
      9. ??SRS, ODI, actual sagittal balance, pelvic parameters, fusion status
   B. Wang MY, Mummaneni PV. Minimally invasive surgery for thoracolumbar spinal deformity: initial clinical experience with clinical and radiographic outcomes. Neurosurg Focus 28(3):E9, 2010.
      1. Retrospective study of 23 patients with adult degenerative scoliosis treated with lateral interbody fusions and percutaneous posterior screws
      2. Mean preoperative Cobb angle was 31.4 degrees and post-op was 11.5 degrees
      3. Mean blood loss was 477 ml and operative time was 401 minutes
      4. Mean follow-up time was 13.4 months (range 6-34 months)
      5. Complications included 2 returns to the OR (CSF leakage and instrumentation pullout)
      6. 30.4% had new thigh numbness, dysesthesias, pain, or weakness
      7. Lumbar lordosis increased by mean of 8 degrees
      8. ??SRS, ODI, actual sagittal balance, or impact on pelvic parameters
   C. Tormenti MJ, Maserati MB, Bonfield CM, Okonkwo DO, Kanter AS. Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation. Neurosurg Focus 28(3):E7, 2010.
      1. Retrospective review of 8 patients treated with combined transpsoas and posterior open pedicle screw placement for correction of degenerative scoliosis

2. No follow-up length indicated
3. Median pre-op coronal Cobb angle 38.5 degrees; 70.2% mean correction post-op
4. Mean lumbar lordosis decreased from pre-op (47.3 degrees) to post-op (40.4 degrees)

M. J. Tormenti et al.

TABLE 3: Preoperative and postoperative radiographic parameters for combined and posterior-only approaches

Case No.	Coronal Cobb Angle		AVT		Lumbar Lordosis	
	Preop (°)	Postop (°)	Preop (cm)	Postop (cm)	Preop (°)	Postop (°)
combined approach						
1	26	7	2.8	1.7	84	43
2	41	4	1.9	1.1	69	45
3	39	24	3.7	3.2	79	40
4	38	16	2.5	1.9	50	46
5	18	2	1.2	0	37	39
6	48	8	5.7	2.4	22	41
7	80	46	10.0	4.0	2	38
8	21	0	1.0	0	35	42
posterior-only approach						
1	17	14	2.0	1.3	26	37
2	10	2	0	0	44	43
3	25	18	4.2	1.9	31	36
4	21	8	2.5	1.2	19	35

5. 2 patients (25%) had new post-op motor deficit and this persisted in 1 at last follow-up
6. Sensory symptoms occurred in 6 patients (75%) and persisted in 5 of the 6 (83%) at last follow-up
7. One additional patient had a bowel injury during lateral transpsoas and required emergent laparotomy/bowel resection and underwent posterior-only correction 6 months later. Thus 2/9 (22%) bowel injury rate.

TABLE 5: Complications arising from the combined approach for deformity correction with XLIF in 8 patients

Complication	No. of Patients
bowel perforation	1
infection/meningitis	1
postop sensory radiculopathy	6
postop motor radiculopathy	2
pleural effusion necessitating chest tube placement	2
intraop hemodynamic instability	1
pulmonary embolism	1
ileus	1
durotomy (during posterior stage)	1

D. Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. Neurosurg Focus 28(3):E8, 2010.
   1. Retrospectively reviewed a prospectively acquired database of 25 patients with adult degenerative deformity treated with transpsoas approach
   2. Mean follow-up 11 months (range 3-20 months)
   3. Mean blood loss was 53 ml per level
   4. Average length of stay was 6.2 days
   5. Mean operative time was 108 minutes per level
   6. Perioperative complications included a patient with rhabdomyolysis requiring temporary hemodialysis, an asymptomatic subsidence, and a patient with asymptomatic instrumentation failure
   7. 3 patients (12%) had transient postoperative thigh numbness
   8. Mean ODI improved from 53.6% to 29.9% at last follow-up
   9. ??sagittal balance or impact on pelvic parameters

E. Anand N, Roseman R, Khalsa B, Baron EM. Mid-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis. Neurosurg Focus 28(3):E6, 2010.
   1. Retrospective review of 28 adults with scoliosis treated with lateral interbodies and percutaneous pedicle screws
   2. Mean follow-up 22 months (range 13-37 months)
   3. 100% fusion rate
   4. Mean SF-36: 56 -> 62; Mean ODI: 39 -> 7
   5. Mean Cobb angle: 22 degrees -> 7 degrees
   6. No sagittal alignment or pelvic parameters presented

F. Isaacs RE, Hyde J, Goodrich JA, Rodgers WB, Phillips FM. A prospective, nonrandomized, multicenter evaluation of extreme lateral interbody fusion for the treatment of adult degenerative scoliosis. Spine 35(26S):S322-30, 2010.
   1. Prospective, non-randomized, multicenter study of 107 adult degenerative scoliosis patients treated with lateral interbody +/- posterior instrumentation (open or MIS)
   2. Mean pre-op coronal Cobb angle 24 degrees
   3. Mean of 4 spinal levels fused
   4. 36 patients (33.6%) had some evidence of weakness post-op
   5. No clinical outcomes provided
   6. No sagittal alignment or pelvic parameters presented

5. Other published studies that do not primarily focus on deformity provide insight into the complications and limitations of the transpsoas approach

A. Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY. An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion. J Neurosurg Spine 15:11-18, 2011.
   1. Retrospective review of 59 consecutive patients treated with lateral interbody fusion for mixed pathologies
   2. 62.7% had new thigh symptoms post-op
      a. burning, aching, stabbing pain (39%) (15.5% @ 3 mos)
      b. numbness (42.4%) (24.1% @ 3mos)
      c. paresthesias (11.9%) (5.6% @ 3 mos)
      d. weakness (23.7%) (11.3% @ 3 mos)

B. Sofianos DA, Briseno MR, Abrams J, Patel AA. Complications of the lateral transpsoas approach for lumbar interbody arthrodesis. Clin Orthop Relat Res 470:1621-32, 2012.
   1. Retrospective review of 45 consecutive patients treated with lateral interbody fusion for mixed pathologies
   2. 40% complication rate
   3. Iliopsoas weakness in 22.2%
      a. also quadriceps weakness in 6.7%
      b. also foot drop in 2.2%
   4. Anterior thigh hypesthesia in 17.8%
      - did NOT resolve in 7/8 patients at mean 9 months follow-up

C. Acosta FL, Liu J, Slimack N, Moller D, Fessler R, Koski T. Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar spine disease in adults: a radiographic study. J Neurosurg Spine 15:92-6, 2011.
   1. Retrospective review of 36 consecutive patients treated with lateral interbody fusion for mixed pathologies
   2. Included 8 degenerative scoliosis patients
   3. Lateral interbody fusion increased sagittal Cobb angle at the level of the instrumentation but did not improve regional lumbar lordosis or global sagittal alignment

Patient with Adult Scoliosis

Multiple LIFs

Open/Traditional Posterior Instrumentation	Percutaneous Posterior Instrumentation
• Facet releases/osteotomies	• Limited facet releases/osteotomies
• Decompress	• Limited decompression
• Sagittal realignment	• Limited sagittal realignment
• No longer "MIS"	• Decreased short-term complications?
• What purpose do the interbody grafts serve?	• Impact on outcome?
• Increased cost (>$10,000/level)	• Increased cost (>$10,000/level)

Notes

Combined Afternoon Session

A DECADE OF CHANGE IN THE TREATMENT OF PEDIATRIC AND ADULT SPINAL DEFORMITY: WHAT PROGRESS HAS BEEN MADE?

Moderators:
Daniel J. Sucato, MD, MS; Richard E. McCarthy, MD

Faculty:
Firoz Miyanji, MD, FRCSC; B. Stephens Richards, III, MD; Lawrence G. Lenke, MD; Mark A. Erickson, MD; Richard E. McCarthy, MD

WHAT ARE THE INDICATIONS FOR ANTERIOR FUSION AND INSTRUMENTATION FOR THE TREATMENT OF PEDIATRIC SPINAL DEFORMITY IN 2012?

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Clinical Assistant Professor, Department of Orthopedics, UBC

Most Common "Classic" Indications Include:

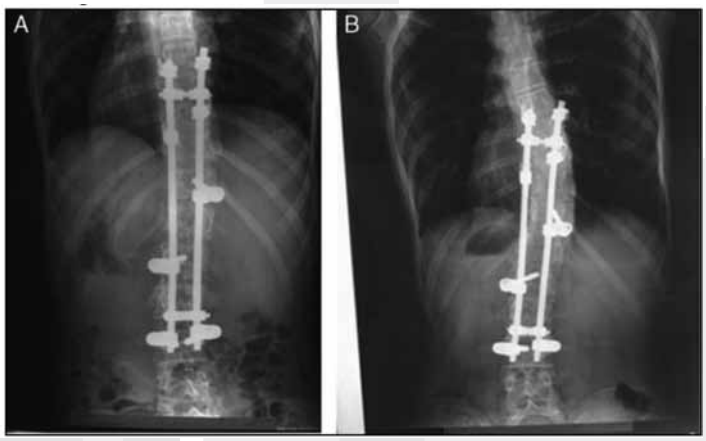
1. Prevention of Crankshaft Phenomenon.
   - Definition:
     - Evidence of solid fusion
     - No evidence of adding-on
     - Increase in vertebral rotation and progression of coronal deformity >= 10 degrees
   - Risk Factors:
     - Age <13
     - Risser < 1
     - Open Triradiate cartilage
     - Pre peak-height velocity

Historical data and review of crankshaft phenomenon really described with Harrington, CD, and Luque posterior systems

- Minimal risk of crankshaft in patients Risser 0 and *closed* triradiates; in patients with *open* triradiates 43% had crankshaft - Sanders JO et al. Posterior arthrodesis and instrumentation in the immature (Risser-grade-0) spine in idiopathic scoliosis. JBJS Am. 1995
- 37.5% documented proof of crankshaft with *open* triradiates; patients with *closed* triradiates had no progression; open triradiates not an absolute prognosticator of crankshaft but clear association - Hamill CL et al. Posterior arthrodesis in the skeletally immature patient. Assessing the risk for crankshaft: Is an open triradiate cartilage the answer? Spine 1997.

Risk of Crankshaft with modern posterior pedicle screw instrumentation increasingly challenged:

The Effect of Differing Spinal Fusion Instrumentation on the Occurrence of Postoperative Crankshaft Phenomenon in Adolescent Idiopathic Scoliosis
Tao, Fenghua MD et al *J Spinal Disord Tech.* 2010



Variable*	Consecutive (n = 22)	Hybrid (n = 21)	Interval (n = 24)	P
Cobb angle (degrees)				
Preoperation → Postoperation	−40 (−42, −36)†	−39 (−44, −34)†	−40 (−42, −35)†	0.965
Postoperation → Last follow-up	2 (1, 2)	4 (2, 10)‡	2 (1.5, 4)	0.001‖
AVR (degrees)				
Preoperation → Postoperation	−12 (−16, −9)†	−10 (−12, −7)†	−11 (−13, −9)†	0.214
Postoperation → Last follow-up	1 (0, 1)	3 (2, 5)‡	2 (1, 3)	<0.001‖
AVT (cm)				
Preoperation → Postoperation	−3.2 (−3.4, −2.6)†	−3.1 (−3.2, −2.6)†	−3.1 (−3.4, −2.5)†	0.380
Postoperation → Last follow-up	0.2 (0.1, 0.2)	0.7 (0.5, 0.8)‡	0.3 (0.3, 0.4)	<0.001‖
RVAD (cm)				
Pre-operation → Post-operation	−12 (−13, −9)†	−11 (−12, −9)†	−11 (−16, −9)†	0.490
Postoperation → Last follow-up	0.2 (0.1, 0.2)	0.7 (0.5, 0.8)‡	0.3 (0.3, 0.4)	<0.001‖
TS (cm)				
Preoperation → Postoperation	−1.2 (−1.4, −0.9)†	−1.3 (−1.3, −1.1)†	−1.1 (−1.5, −1)†	0.745
Postoperation → Last follow-up	0.3 (0.2, 0.3)‡	0.5 (0.5, 0.6)‡	0.3 (0.2, 0.3)‡	<0.001‖

*Data are expressed as median (Q1,Q3).
† Indicates a significantly different within-the-group change between the preoperation and the postoperation ($P < 0.0167$).
‡ Indicates a significantly different within-the-group change between the postoperation and the last follow-up ($P < 0.0167$).
‖ Indicates the change from preoperation to postoperation, or postoperation to the last follow-up was significantly different among groups ($P < 0.05$).
AVR indicates apical vertebral rotation; AVT, apical vertebral transposition; RVAD, rib vertebral angle difference; TS, trunk shift.

TABLE 2. Change in Clinical Characteristics From Preoperation to Postoperation, and From Postoperation to the Last Follow-up by Instrumentation Group

- Comparison of occurrence of crankshaft in patients who underwent hybrid, consecutive pedicle screws or interval pedicle screw instrumentation
- Crankshaft defined as: Cobb angle progression >10 degrees, RVAD > 10 degrees, AVR > 5 degrees
- *Patient population: CA > 40 pre-op, Risser 0,* Open Triradiates, 2 year follow-up, Risser 4 at final follow-up
- Significant difference in occurrence of crankshaft between the groups with *all* cases occurring in the hybrid instrumentation group (33%) and *no* crankshaft cases in pedicle screw groups

Others have reported similar results, albeit smaller series:

- In juvenile idiopathic curves of Risser 0 patients with open triradiate cartilages, routine combined anterior fusion to prevent crankshaft may not be warranted by posterior segmental pedicle screw instrumentation. (7 patients with 5 year follow-up) - Juvenile idiopathic scoliosis treated with posterior arthrodesis and segmental pedicle screw instrumentation before the age of 9 years: a 5-year follow-up. Sarlak A Yet al. Scoliosis 2009.
- Bone grafting together with rigid pedicle screw fixation prevented growth of the anterior column in *immature canines*. The crankshaft phenomenon did not occur in cases in which pedicle screw fixation was applied - Overpowering the crankshaft mechanism. The effect of posterior spinal fusion with and without stiff transpedicular fixation on anterior spinal column growth in immature canines. Kioschos HC et al. Spine1996.
- 7 of 18 patients had open triradiates, no significant crankshaft with stiff, segmental posterior instrumentation; concomitant anterior arthrodesis not required in patients as young as 10 - Scoliosis correction maintenance in skeletally immature patients with idiopathic scoliosis. Is anterior fusion really necessary? Burton DC et al. Spine 2000

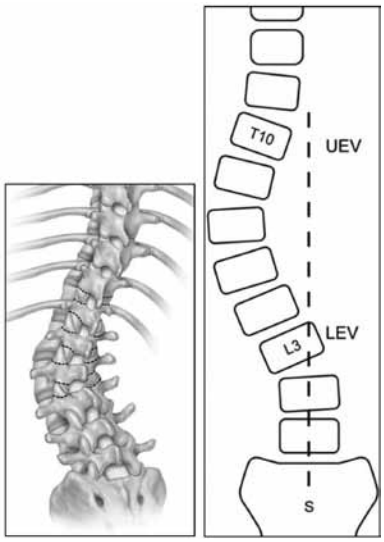
Increasing body of literature challenging previous concerns of crankshaft phenomenon using modern posterior only pedicle-screw constructs, and therefore anterior surgery for prevention of crankshaft is becoming increasingly limited.

2. Saving Distal Fusion Levels and Better Correction in Lenke 5 Curves.
   - Challenges of deformity surgery still remain at the expense of potential motion
   - Long-term follow-up studies have stressed the importance of fusing as few lumbar segments as possible because of the increased incidence of low back pain in patients with fusions extending into the lumbar spine
   - When comparing anterior instrumentation to posterior constructs, anterior instrumentation has shown the advantage of saving an average of 1.2 – 3.5 levels.[6,7]

- Fundamental principle when treating Lenke 5 thoracolumbar/lumbar curves; however real significance controversial and depends on where fusion ends. Number of authors suggest fusion above L3 does not have negative impact on lumber disc health and degeneration.[4,7,8]

More recently with advances in pedicle screw for deformity and wide posterior release procedures / Pontes, anterior spinal fusion is becoming increasingly debatable in this setting:

- Lenke 5, 3C, 6 curves showed average correction 80% with posterior only approach; lumbar lordosis normalized; Note: Average number of levels fused **not** stated - The posterior approach for lumbar and thoracolumbar adolescent idiopathic scoliosis: posterior shortening and pedicle screws. Shufflebarger HL et al. *Spine 2004.*
- Significantly better curve correction, less loss of correction over time, and shorter hospital stay for Lenke 5C curves done posteriorly compared to anterior but **again** difference in extent of arthrodesis between 2 groups not clearly reported. - Comparison of surgical treatment in Lenke 5C adolescent idiopathic scoliosis: anterior dual rod versus posterior pedicle fixation surgery: a comparison of two practices. Geck MJ, et al. *Spine 2009*



- Shorter OR time, hospital stay in posterior group, *however clearly noted that anterior surgery truly saved one motion segment compared to posterior.* Frontal and sagittal plane correction comparable in both groups - Comparison of segmental pedicle screw instrumentation versus anterior instrumentation in adolescent idiopathic thoracolumbar and lumbar scoliosis. Hee HTet al. Spine 2007.
- Curve correction and SRS-24 comparable in both groups; *however fusion length on average 1.7 segments caudal in posterior pedicle screw group* compared to anterior - Patient-based outcomes analysis of patients with single torsion thoracolumbar - lumbar scoliosis treated with anterior or posterior instrumentation: an average 5- to 9-year follow-up study. Burton DC et al. *Spine 2002.*
- No statistical difference in curve correction between 2 groups, *however fusion level shorter in anterior group by one segment on average.* Shorter OR time and hospital stay in posterior group - Comparison of selective anterior versus posterior screw instrumentation in Lenke5C adolescent idiopathic scoliosis. Li M et al. Spine 2009.
- Prospective Study reporting *shorter fusion by 1 segment*, less cost and surgical trauma *in anterior group* compared to posterior pedicle screw-based group - Anterior spinal fusion versus posterior spinal fusion for moderate lumbar/thoracolumbar adolescent idiopathic scoliosis: a prospective study. Wang Y et al.*Spine 2008.*

Despite advances in posterior instrumentation and fusion techniques, literature still supports that anterior surgery for Lenke 5 thoracolumbar/lumbar curves saves distal fusion levels.

Anterior spinal fusion in setting of thoracolumbar/lumbar curves also has long-term follow-up studies showing favorable patient-reported functional outcomes and stable deformity correction; similar long-term studies for pedicle-screw based constructs in this setting are lacking.[16]

3. Release of Large, Stiff Curves to Improve Flexibility and Correction:
Definition of large, stiff curve variable in literature and optimal indication for anterior release in this setting remains unclear:

- Some authors have "suggested" anterior release for curves of 60, 70, 100 degrees and others for curves > 40 degrees on fulcrum bending.[10,11,12]
- Meta-analysis noted most series using thoracoscopic anterior releases, Cobb angle *averaged 65 degrees* and even patients with Cobb angle of *42 degrees* have been released - Anterior thoracoscopic spine release in deformity surgery: a meat-analysis and review. Arlet V. Eur Spine J. 2000
- Lenke published most strict criteria - Anterior endoscopic discectomy and fusion for adolescent idiopathic scoliosis. Lenke LG. Spine 2003.
  - CA >= 75 degrees with decreased curve flexibility: side-bending films >= 50 degrees.
  - Severe thoracic lordosis or kyphosis

To date literature has only roughly estimated improvement offered by anterior release with very limited data assessing results after an anterior release in AIS:

- Little effect on severe scoliosis - The effect of anterior spinal release on severe adolescent idiopathic scoliosis. Wang YP et al. Zhonghua Wai Ke Za Zhi. 2004.
- Thoracic anterior release improves spinal flexibility (39% up to 54%) as shown by fulcrum bending xrays (5 patients); average 71 degree cobb angle improved to 33 degrees after release on fulcrum-bend xray - In-vivo demonstration of the effectiveness of thoracoscopic anterior release using the fulcrum-bending radiograph: a report of five cases Cheung KM et al. Eur Spine J. 2006.
- Traction xrays pre and post anterior release showed a mean 6% flexibility change or 5.5 degrees in improvement in Cobb angle; therefore amount of correction achieved averaged 1 degree / segment which was marginal - Is anterior release effective to increase flexibility in idiopathic thoracic scoliosis? Assessment by traction films. Hempfing A et al. Eur Spine J. 2007.

Proponents of pedicle-screw constructs continue to challenge role of anterior release in setting of large, stiff deformity:

- Is anterior release necessary in severe scoliosis treated by posterior segmental pedicle screw fixation? Suk SI et al. Eur Spine J. 2007

  Retrospective review of curves >= 70 degrees corrected on average 65% (79 degrees to 28 degrees) with pedicle screw posterior only procedure; authors concluded that severe curves 70-105 degrees with flexibility >= 25% can be treated without anterior release
  Note: *Curve flexibility was 44.5 – 64 %*
- Thoracic adolescent idiopathic scoliosis curves between 70 degrees and 100 degrees: is anterior release necessary? Luhmann SJ et al. Spine 2005.

  Retrospective review of curves 70-100 degrees; anterior-posterior group better coronal plane correction than posterior hook construct group but

comparable to posterior screw construct group; sagittal plane kyphosis restoration better in anterior-posterior group; anterior group improved curve correction by 14%

Note: Posterior pedicle screw group *more flexible* and anterior-posterior group's posterior construct was hook/hybrid so not direct comparison

- Anterior/posterior spinal instrumentation versus posterior instrumentation alone for the treatment of adolescent idiopathic scoliotic curves more than 90 degrees. Dobbs MB et al. Spine 2006

  Retrospective review of curves > 90 degrees treated either by anterior-posterior instrumentation and fusion or posterior instrumentation with screws alone showed equivalent outcomes

  Note: Anterior-posterior group had hook/hybrid constructs and not all pedicle screws, like posterior only group.

Some recent trends further challenging role of anterior release in setting of large, stiff curves include use of intra-operative halo-femoral traction.

- Strong halo-femoral traction with wide posterior spinal release and three dimensional spinal correction for the treatment of severe adolescent idiopathic scoliosis. Zhang HQ et al. Chin Med J (Engl). 2012

  Prospective Study in which rigid curves (>= 80 degrees with less than 35% flexibility) treated with halo-femoral traction and posterior only approach compared to anterior- posterior procedure showed better SRS-22, comparable curve correction, shorter OR time, blood loss, and hospital stay.

Indication criteria for anterior release in setting of large, stiff curves remains to be determined and certainly in more recent years has been on the decline in most centers.

4. Maintenance of Sagittal Plane:

One of the primary advantages of anterior spinal instrumentation and fusion has been its ability to restore thoracic kyphosis in AIS. A number of studies have reported this advantage over posterior only constructs.

- 81% of patients with pre-op hypokyphosis corrected to normal compared to only 40% of posterior group - Comparison of anterior and posterior instrumentation for correction of adolescent thoracic idiopathic scoliosis. Betz RR et al. Spine1999.
- Posterior spinal fusion with pedicle screws showed further loss of thoracic kyphosis and may cause/aggravate proximal junctional kyphosis - Proximal junctional kyphosis in AIS after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. Kim YJ et al. Spine 2007.
- Anterior approach was minimally kyphogenic; however posterior instrumentation produced a lordogenic trend which became more pronounced over time - Sagittal plane analysis of AIS. Rhee JM et al. Spine 2002.
- Hypokyphosis following open instrumented anterior spinal fusion corrected on average 7 degrees with further improvement up to 2 years, and no further significant change at 5 years post-op - Adolescent idiopathic scoliosis treated with open instrumented anterior spinal fusion: 5 year follow-up. Tis JE et al. Spine 2009.
- Anterior spinal fusion noted to be best method to restore thoracic kyphosis when compared to posterior approaches using hooks/hybrid constructs. - Restoration of thoracic kyphosis after operative treatment of adolescent idiopathic scoliosis: a multicenter comparison of three surgical approaches. Sucato DJ et al. Spine 2008.

Concerns with sagittal plane following anterior procedures:

- Patients with pre-op sagittal measurement of >=20 degrees is at potential risk for post-op hyperkyphosis of > 40 degrees.
- Risser 0 patients have shown in some studies to progress to excessive kyphosis following anterior spinal fusion.[13]
- Others have noted some progression of kyphosis up to 2 years post-op but kyphosis did not fall outside normal range of 10-40 degrees possibly secondary to incorporation of structural interbody grafts.

5. Other Indications:
   a) Spontaneous Correction of Non-Structural Curves:
      - Lumbar curve spontaneously reduced predictably post selective anterior spinal fusion for Lenke 1C and 2C curves; and correction stayed or improved over 2 years post-op. - Spontaneous lumbar curve correction in selective anterior instrumentation and fusion of idiopathic thoracic scoliosis of Lenke type C. Liljenqvist U et al. Eur Spine J. 2012 Apr.
      - Significant spontaneous correction of thoracolumbar/lumbar curves post open anterior instrumentation and fusion with maintenance of correction - Adolescent idiopathic scoliosis treated with open instrumented anterior spinal fusion: 5 year follow-up. Tis JE et al. Spine 2009.
      - Significant better correction of *proximal thoracic curve* also noted by number of authors following anterior spinal fusion as compared to posterior procedures (up to 39%).[14,15]

Posterior pedicle screw construct proponents have also reported similar data with limited followup and more distal fusions

- 15% *more* spontaneous correction of thoracolumbar/lumbar curves when using pedicle screws versus open anterior spinal fusion however limited follow-up and pedicle screw group required 1.2 additional levels of fusion; spontaneous correction of proximal thoracic curve however *better* in anterior group - Radiographic outcomes of anterior spinal fusion versus posterior spinal fusion with thoracic pedicle screws for treatment of Lenke Type I adolescent idiopathic scoliosis curves. Potter BK et al. Spine 2005.
- 93% correction of non-structural lumbar curve with posterior pedicle screws – ?follow-up - Determination of distal fusion level with segmental pedicle screw fixation in single thoracic idiopathic scoliosis. Suk et al. Spine 2003.

   b) Absence of posterior elements and/or compromised substrate:
      - Setting of meningomyelocele, neurofibromatosis, Marfan syndrome

Some emerging data favoring posterior-only approach with pedicle screw fixation for Marfan syndrome - Surgical treatment of scoliosis associated with Marfan syndrome by using posterior-only instrumentation. Li ZC et al. JPO B. 2011.

   c) Severe pediatric deformity:
      - Patients with severe deformity, particularly lordo-scoliosis and global – advantage is ability to do multiple peri-apical hemivertebrectomies in addition to discectomies if needed while still maintaining "relative" stability of spinal column; disadvantage is potential pulmonary insult

More recent VCR techniques are challenging need for anterior procedures, however potential for major complications are reported. [17,18]

References

1. Dubousset J, Herring JA, Shufflebarger H. The crankshaft phenomenon. JPO 1989.
2. Hefti FL et al. The effect of the adolescent growth spurt on early posterior spinal fusion in infantile and juvenile idiopathic scoliosis. JBJS Br. 1983
3. Lapinsky AS et al. Preventing the crankshaft phenomenon by combining anterior fusion with posterior instrumentation. Does it work? Spine 1995.
4. Connolly PJ et al . Adolescent idiopathic scoliosis. Long-term effect of instrumentation extending to the lumbar spine.J Bone Joint Surg Am. 1995
5. Franić M, Kovac V. Anterior instrumentation for correction of adolescent thoracic idiopathic scoliosis: historic prospective study. Croat Med J. 2006 A
6. Betz RR et al. Comparison of anterior and posterior instrumentation for correction of adolescent thoracic idiopathic scoliosis. Spine 1999.
7. Cochran T et al. Long-term anatomic and functional changes in patients with adolescent idiopathic scoliosis treated by Harrington rod fusion. Spine 1983.
8. Edgar MA et al. Long-term follow-up of fused and unfused idiopathic scoliosis. J Bone Joint Surg Br. 1988.
9. Potter BK et al. Radiographic outcomes of anterior spinal fusion versus posterior spinal fusion with thoracic pedicle screws for treatment of Lenke Type I adolescent idiopathic scoliosis curves. Spine 2005.
10. Bridwell K. Surgical treatment of idiopathic adolescent scoliosis. Spine. 1999
11. Niemeyer T, Freeman BJ, Grevitt MP, et al. Anterior thoracoscopic surgery followed by posterior instrumentation and fusion in spinal deformity. Eur Spine J. 2000
12. Waisman M, Saute M. Thoracoscopic spine release before posterior instrumentation in scoliosis. Clin Orthop. 1999.
13. D'Andrea LP et al. The effect of continued posterior spinal growth on sagittal contour in patients treated by anterior instrumentation for idiopathic scoliosis. Spine 2000.
14. Yong MR et al. Secondary Curve Behaviour in Lenke Type 1C Adolescent Idiopathic Scoliosis Following Thoracoscopic Selective Anterior Thoracic Fusion. Spine 2012.
15. Kuklo TR et al. Spontaneous proximal thoracic curve correction after isolated fusion of the main thoracic curve in adolescent idiopathic scoliosis. Spine 2001.
16. Derek MK et al. Long-term outcomes of anterior spinal fusion with instrumentation for thoracolumbar and lumbar curves in AIS. Spine 2010.
17. Lenke LG et al. Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res 2010.
18. Sponseller PD et al. Vetebral column resection in children with neuromuscular spine deformity. Spine Publish Ahead of Print.

Notes

WHAT ARE THE BENEFITS OF THE EVOLUTION OF SEGMENTAL SPINAL INSTRUMENTATION FROM PREDOMINATELY HOOK CONSTRUCTS TO PEDICLE SCREW INSTRUMENTATION?

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The Transition from hooks to screws[33,51]

2003 Richards/Lenke Debate – [44]

Benefits of using pedicle screw constructs

1) Improved coronal correction of thoracic and lumbar curves[22,23,31,33,37]
   a. Selective fusion of thoracic curves with "C" modifier may result in better balance[12]
   b. In larger thoracic curves (>70^0-90^0), the use of PSF-only, without the need for anterior release[10,13,38]
   c. Correction exceeds anterior thoracic instrumentation/fusion[40]
2) Improved axial plane correction[1,15]
   a. Direct Vertebral Derotation[30]
   b. Monaxial screws superior to multiaxial screws[7,25]
3) Increased correction in TL curves allows alternative to anterior spinal instrumentation/fusion[14,16,49,57,58]
4) Versatility - The opportunity for more aggressive correction of complex spinal deformities
   a. Dr Lenke - Vertebral Column Resections

How safe are pedicle screws to insert?

1) CT and MRI anatomic studies
   a. Pedicle Anatomy in spinal deformity[6,9,26,35,39,47]
   b. Aorta Anatomy in spinal deformity[24,36,50,53]
2) Multiple Reports on Free hand techniques
   a. Systematic Review – 94.9% accuracy in pediatric patients, more effective than hooks[27]
   b. Individual reports –Accurate (88-90%), reliable, safe[4,5,19,21,22,32,45,46,48,51,52]
3) Can safety of pedicle screw insertion be further improved?
   a. Navigation[42,54]
   b. C-arm[28,29]
   c. Electrical[3,8]
   d. Learning curve[45,46]

What are the Limitations/Problems?

1) Sagittal Plane
   a. Thoracic hypokyphosis[41,55]
   b. Releases and increased rod stiffness helpful (Suk)
2) Proximal Junctional Kyphosis[17,20,43]
   a. Consider transition to hook at uppermost level
3) Change in implant position in the vertebra (plow) during powerful correction maneuvers[56]
4) Malpositioned screws[11,18,34]
5) Expense

How do we proceed in the foreseeable future?

1) Optimizing implant density in pedicle screw constructs in AIS
   a. Dr. Aubin – Strategy variability[2]
   b. MIMO 2012 – Minimal implants maximum outcome
2) Improvements in sagittal plane curve correction
3) Adaptations for complex osteotomies
   a. Dr Lenke – VCR's

References

1. Asghar, J., Samdani, A.F., Pahys, J.M., et al.: "Computed tomography evaluation of rotation correction in adolescent idiopathic scoliosis: a comparison of an all pedicle screw construct versus a hook-rod system." Spine 34(8): 804-807, 2009.
2. Aubin, C.E., Labelle, H. and Ciolofan, O.C.: "Variability of spinal instrumentation configurations in adolescent idiopathic scoliosis." Eur Spine J 16(1): 57-64, 2007.
3. Bai, Y.S., Niu, Y.F., Chen, Z.Q., et al.: "Comparison of the Pedicle Screws Placement Between Electronic Conductivity Device and Normal Pedicle Finder in Posterior Surgery of Scoliosis." J Spinal Disord Tech, 2012.
4. Belmont, P.J., Jr., Klemme, W.R., Dhawan, A., et al.: "In vivo accuracy of thoracic pedicle screws." Spine 26(21): 2340-2346, 2001.
5. Belmont, P.J., Jr., Klemme, W.R., Robinson, M., et al.: "Accuracy of thoracic pedicle screws in patients with and without coronal plane spinal deformities." Spine 27(14): 1558-1566, 2002.
6. Catan, H., Buluc, L., Anik, Y., et al.: "Pedicle morphology of the thoracic spine in preadolescent idiopathic scoliosis: magnetic resonance supported analysis." Eur Spine J 16(8): 1203-1208, 2007.
7. Dalal, A., Upasani, V.V., Bastrom, T.P., et al.: "Apical vertebral rotation in adolescent idiopathic scoliosis: comparison of uniplanar and polyaxial pedicle screws." J Spinal Disord Tech 24(4): 251-257, 2010.
8. de Blas, G., Barrios, C., Regidor, I., et al.: "Safe pedicle screw placement in thoracic scoliotic curves using t-EMG: stimulation threshold variability at concavity and convexity in apex segments." Spine 37(6): E387-395, 2011.
9. Dhawan, A., Klemme, W.R. and Polly, D.W., Jr.: "Thoracic pedicle screws: comparison of start points and trajectories." Spine 33(24): 2675-2681, 2008.
10. Di Silvestre, M., Bakaloudis, G., Lolli, F., et al.: "Posterior fusion only for thoracic adolescent idiopathic scoliosis of more than 80 degrees: pedicle screws versus hybrid instrumentation." Eur Spine J 17(10): 1336-1349, 2008.
11. Di Silvestre, M., Parisini, P., Lolli, F., et al.: "Complications of thoracic pedicle screws in scoliosis treatment." Spine 32(15): 1655-1661, 2007.
12. Dobbs, M.B., Lenke, L.G., Kim, Y.J., et al.: "Selective posterior thoracic fusions for adolescent idiopathic scoliosis: comparison of hooks versus pedicle screws." Spine 31(20): 2400-2404, 2006.
13. Dobbs, M.B., Lenke, L.G., Kim, Y.J., et al.: "Anterior/posterior spinal instrumentation versus posterior instrumentation alone for the treatment of adolescent idiopathic scoliotic curves more than 90 degrees." Spine 31(20): 2386-2391, 2006.
14. Erickson, M.A., Kuklo, T. R., Emans, J.B., et al.: "Prospective Analysis Comparing Anterior vs. Posterior Approach for Treatment of Thoracolumbar Idiopathic Scoliosis: Paper #1 " Spine 10(Affiliated Society Meeting Abstracts): 53, 2009.
15. Fu, G., Kawakami, N., Goto, M., et al.: "Comparison of vertebral rotation corrected by different techniques and anchors in surgical treatment of adolescent thoracic idiopathic scoliosis." J Spinal Disord Tech 22(3): 182-189, 2009.
16. Geck, M.J., Rinella, A., Hawthorne, D., et al.: "Comparison of surgical treatment in Lenke 5C adolescent idiopathic scoliosis: anterior dual rod versus posterior pedicle fixation surgery: a comparison of two practices." Spine 34(18): 1942-1951, 2009.
17. Helgeson, M.D., Shah, S.A., Newton, P.O., et al.: "Evaluation of proximal junctional kyphosis in adolescent idiopathic scoliosis following pedicle screw, hook, or hybrid instrumentation." Spine 35(2): 177-181, 2011.
18. Hicks, J.M., Singla, A., Shen, F.H., et al.: "Complications of pedicle screw fixation in scoliosis surgery: a systematic review." Spine 35(11): E465-470, 2010.
19. Karapinar, L., Erel, N., Ozturk, H., et al.: "Pedicle screw placement with a free hand technique in thoracolumbar spine: is it safe?" J Spinal Disord Tech 21(1): 63-67, 2008.
20. Kim, Y.J., Lenke, L.G., Bridwell, K. H., et al.: "Proximal junctional kyphosis in adolescent idiopathic scoliosis after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases." Spine 32(24): 2731-2738, 2007.
21. Kim, Y.J., Lenke, L.G., Cheh, G., et al.: "Evaluation of pedicle screw placement in the deformed spine using intraoperative plain radiographs: a comparison with computerized tomography." Spine 30(18): 2084-2088, 2005.
22. Kim, Y.J., Lenke, L.G., Cho, S.K., et al.: "Comparative analysis of pedicle screw versus hook instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis." Spine 29(18): 2040-2048, 2004.
23. Kim, Y.J., Lenke, L.G., Kim, J., et al.: "Comparative analysis of pedicle screw versus hybrid instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis." Spine 31(3): 291-298, 2006.
24. Kuklo, T.R., Lehman, R.A., Jr. and Lenke, L.G.: "Structures at risk following anterior instrumented spinal fusion for thoracic adolescent idiopathic scoliosis." J Spinal Disord Tech 18 Suppl: S58-64, 2005.
25. Kuklo, T.R., Potter, B.K., Polly, D.W., Jr., et al.: "Monaxial versus multiaxial thoracic pedicle screws in the correction of adolescent idiopathic scoliosis." Spine 30(18): 2113-2120, 2005.
26. Kuraishi, S., Takahashi, J., Hirabayashi, H., et al.: "Pedicle Morphology Using Computed Tomography-based Navigation System in Adolescent Idiopathic Scoliosis." J Spinal Disord Tech, 2011.
27. Ledonio, C.G., Polly, D.W., Jr., Vitale, M.G., et al.: "Pediatric pedicle screws: comparative effectiveness and safety: a systematic literature review from the Scoliosis Research Society and the Pediatric Orthopaedic Society of North America task force." J Bone Joint Surg Am 93(13): 1227-1234, 2011.
28. Lee, C.S., Kim, M.J., Ahn, Y.J., et al.: "Thoracic pedicle screw insertion in scoliosis using posteroanterior C-arm rotation method." J Spinal Disord Tech 20(1): 66-71, 2007.
29. Lee, C.S., Park, S.A., Hwang, C.J., et al.: "A novel method of screw placement for extremely small thoracic pedicles in scoliosis." Spine 36(16): E1112-1116, 2011.
30. Lee, S.M., Suk, S.I. and Chung, E.R.: "Direct vertebral rotation: a new technique of three-dimensional deformity correction with segmental pedicle screw fixation in adolescent idiopathic scoliosis." Spine 29(3): 343-349, 2004.
31. Lehman, R.A., Jr., Lenke, L.G., Keeler, K.A., et al.: "Operative treatment of adolescent idiopathic scoliosis with posterior pedicle screw-only constructs: minimum three-year follow-up of one hundred fourteen cases." Spine 33(14): 1598-1604, 2008.
32. Lehman, R.A., Jr., Lenke, L.G., Keeler, K.A., et al.: "Computed tomography evaluation of pedicle screws placed in the pediatric deformed spine over an 8-year period." Spine 32(24): 2679-2684, 2007.
33. Liljenqvist, U., Lepsien, U., Hackenberg, L., et al.: "Comparative analysis of pedicle screw and hook instrumentation in posterior correction and fusion of idiopathic thoracic scoliosis." Eur Spine J 11(4): 336-343, 2002.
34. Liljenqvist, U.R., Halm, H.F. and Link, T.M.: "Pedicle screw instrumentation of the thoracic spine in idiopathic scoliosis." Spine 22(19): 2239-2245, 1997.
35. Liljenqvist, U.R., Link, T.M. and Halm, H.F.: "Morphometric analysis of thoracic and lumbar vertebrae in idiopathic scoliosis." Spine 25(10): 1247-1253, 2000.
36. Liu, J., Shen, J., Zhang, J., et al.: "The position of the aorta relative to the spine for pedicle screw placement in the correction of idiopathic scoliosis." J Spinal Disord Tech 25(4): E82-86, 2012.
37. Luhmann, S.J., Lenke, L.G., Erickson, M., et al.: "Correction of moderate (<70 degrees) Lenke 1A and 2A curve patterns: comparison of hybrid and all-pedicle screw systems at 2-year follow-up." J Pediatr Orthop 32(3): 253-258, 2012.

38. Luhmann, S.J., Lenke, L.G., Kim, Y.J., et al.: "Thoracic adolescent idiopathic scoliosis curves between 70 degrees and 100 degrees: is anterior release necessary?" Spine 30(18): 2061-2067, 2005.

39. O'Brien, M.F., Lenke, L.G., Mardjetko, S., et al.: "Pedicle morphology in thoracic adolescent idiopathic scoliosis: is pedicle fixation an anatomically viable technique?" Spine 25(18): 2285-2293, 2000.

40. Potter, B.K., Kuklo, T.R. and Lenke, L.G.: "Radiographic outcomes of anterior spinal fusion versus posterior spinal fusion with thoracic pedicle screws for treatment of Lenke Type I adolescent idiopathic scoliosis curves." Spine 30(16): 1859-1866, 2005.

41. Qiu, Y., Zhu, F., Wang, B., et al.: "Comparison of surgical outcomes of lenke type 1 idiopathic scoliosis: vertebral coplanar alignment versus derotation technique." J Spinal Disord Tech 24(8): 492-499, 2011.

42. Rajasekaran, S., Vidyadhara, S., Ramesh, P., et al.: "Randomized clinical study to compare the accuracy of navigated and non-navigated thoracic pedicle screws in deformity correction surgeries." Spine 32(2): E56-64, 2007.

43. Rhee, J.M., Bridwell, K.H., Won, D.S., et al.: "Sagittal plane analysis of adolescent idiopathic scoliosis: the effect of anterior versus posterior instrumentation." Spine 27(21): 2350-2356, 2002.

44. Richards, S.: "Debate: Resolved, a 55 degrees right thoracic adolescent idiopathic scoliotic curve should be treated by posterior spinal fusion and segmental instrumentation using thoracic pedicle screws: Con: Thoracic pedicle screws are not needed to treat a 55 degrees right thoracic adolescent idiopathic scoliosis." J Pediatr Orthop 24(3): 334-337; discussion 337-338, 340-331, 2004.

45. Samdani, A.F., Ranade, A., Saldanha, V., et al.: "Learning curve for placement of thoracic pedicle screws in the deformed spine." Neurosurgery 66(2): 290-294; discussion 294-295, 2010.

46. Samdani, A.F., Ranade, A., Sciubba, D.M., et al.: "Accuracy of free-hand placement of thoracic pedicle screws in adolescent idiopathic scoliosis: how much of a difference does surgeon experience make?" Eur Spine J 19(1): 91-95, 2009.

47. Sarlak, A.Y., Buluc, L., Sarisoy, H.T., et al.: "Placement of pedicle screws in thoracic idiopathic scoliosis: a magnetic resonance imaging analysis of screw placement relative to structures at risk." Eur Spine J 17(5): 657-662, 2008.

48. Sarlak, A.Y., Tosun, B., Atmaca, H., et al.: "Evaluation of thoracic pedicle screw placement in adolescent idiopathic scoliosis." Eur Spine J 18(12): 1892-1897, 2009.

49. Shufflebarger, H.L., Geck, M.J. and Clark, C.E.: "The posterior approach for lumbar and thoracolumbar adolescent idiopathic scoliosis: posterior shortening and pedicle screws." Spine 29(3): 269-276; discussion 276, 2004.

50. Sucato, D.J. and Duchene, C.: "The position of the aorta relative to the spine: a comparison of patients with and without idiopathic scoliosis." J Bone Joint Surg Am 85-A(8): 1461-1469, 2003.

51. Suk, S.I., Kim, W.J., Lee, S.M., et al.: "Thoracic pedicle screw fixation in spinal deformities: are they really safe?" Spine 26(18): 2049-2057, 2001.

52. Takeshita, K., Maruyama, T., Chikuda, H., et al.: "Diameter, length, and direction of pedicle screws for scoliotic spine: analysis by multiplanar reconstruction of computed tomography." Spine 34(8): 798-803, 2009.

53. Takeshita, K., Maruyama, T., Ono, T., et al.: "New parameters to represent the position of the aorta relative to the spine for pedicle screw placement." Eur Spine J 19(5): 815-820, 2010.

54. Ughwanogho, E., Patel, N.M., Baldwin, K.D., et al.: "Computed tomography-guided navigation of thoracic pedicle screws for adolescent idiopathic scoliosis results in more accurate placement and less screw removal." Spine 37(8): E473-478, 2011.

55. Vora, V., Crawford, A., Babekhir, N., et al.: "A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: myth or reality." Spine 32(17): 1869-1874, 2007.

56. Wagner, M.R., Flores, J.B., Sanpera, I., et al.: "Aortic abutment after direct vertebral rotation: plowing of pedicle screws." Spine 36(3): 243-247, 2011.

57. Wang, Y., Fei, Q., Qiu, G., et al.: "Anterior spinal fusion versus posterior spinal fusion for moderate lumbar/thoracolumbar adolescent idiopathic scoliosis: a prospective study." Spine 33(20): 2166-2172, 2008.

58. Zhan, S.Q., Chang, Y.B., Zeng, S.X., et al.: "[Comparison of surgical treatment in single thoracolumbar-lumbar adolescent idiopathic scoliosis: anterior versus posterior surgery]." Zhonghua Wai Ke Za Zhi 48(6): 419-422, 2010.

Notes

HAS THE REFINEMENT OF THE VERTEBRAL COLUMN RESECTION TECHNIQUE (VCR) FOREVER CHANGED THE APPROACH TO THE TREATMENT OF SEVERE SPINAL DEFORMITIES OVER THE PAST DECADE?

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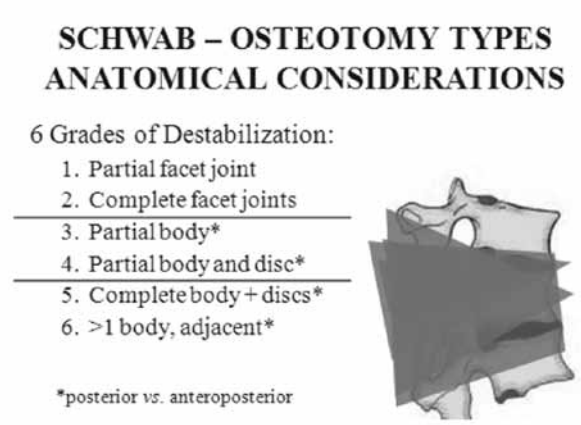
I. INTRODUCTION/TERMINOLOGY

a.



b. Fox VCR Study Group Definition:
"3-column circumferential vertebral osteotomy creating a segmental defect with sufficient instability to require provisional instrumentation

PRE-MEETING COURSE

c. Indications
   i. Pathology dependent
      1. Type of deformity (scoliosis, kyphosis, lordosis)
      2. Coronal/sagittal/combined imbalance
      3. Curve magnitude
      4. Stiffness (preop & intraop)
      5. Bone Density (proxy for PS purchase)
   ii. Surgeon dependent
      1. Operative goals
      2. Surgeon experience/comfort level (PSOs, Post HV excision, costotransversectomy approach)
   iii. Risk dependent
      1. Minimization
      2. Avoid complications

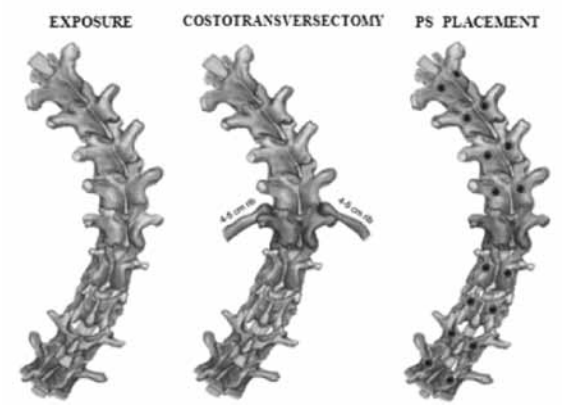
d, Contraindications
   i. VCR → "stuck dura" dorsally and/or ventrally from prior decompression/posterior interbody fusion
   ii. Unfamiliar with technique
   iii. Lack of SCM (?) During the procedure (↑ risk!)

e. Preoperative Planning
   i. Complete radiographic evaluation
   ii. Total spine MRI
   iii. 3D CT scan ± actual model
   iv. Pulmonary/nutrition analyses
   v. Cardiac/anesthesia clearance

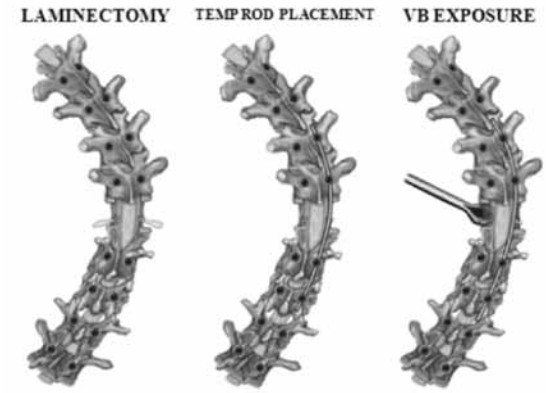
II. SPECIFIC INDICATIONS/TECHNIQUES

a. Posterior VCR
   i. Procedure of "last resort"
   ii. Severe & stiff deformities/autofused spinal columns
   iii. For primary IS → "spine on chest wall" x-rays
   iv. Marked kyphoscoliosis/lordoscoliosis
   v. Performed primarily in thoracic/TL region
   vi. Resection of all posterior elements, facet joints ↑/↓, pedicles, nearly all vertebral body and discs ↑/↓
   vii. Tremendous correction ability as spine is disarticulated at apex & proximal/distal limbs slowly brought together
   viii. Performed via staged anterior/posterior approaches or posterior-only (in single or staged fashion)

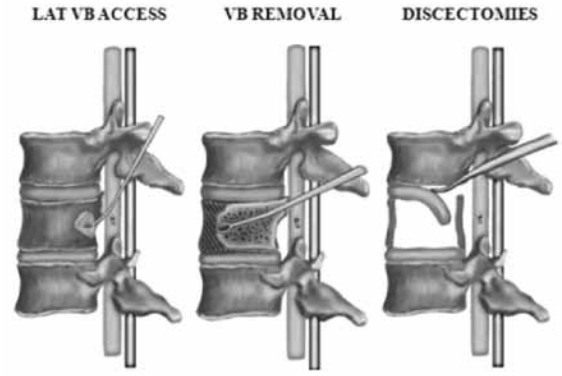
b. Surgical Technique
   i. Exposure, costotransversectomy, pedicle screw placement



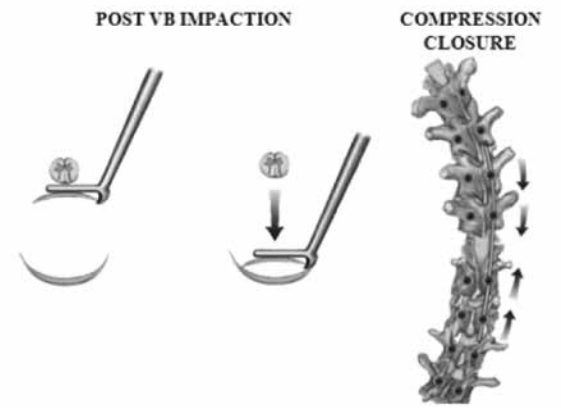
   ii. Laminectomy, temporary rod placement, vertebral body exposure



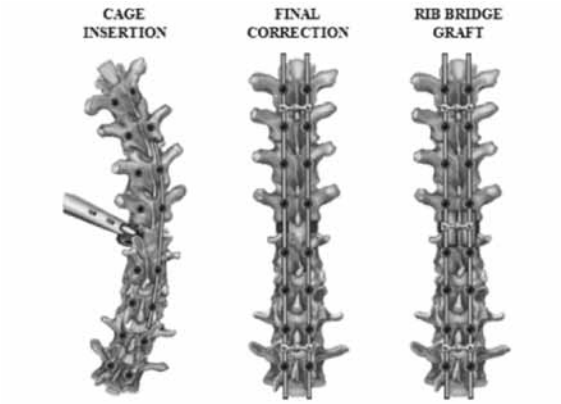
   iii. Lateral vertebral body access and removal, discectomies



iv. Posterior vertebral body impaction, compression closure



V. Anterior cage insertion, final correction, placement of rib pieces over laminar defect



III. OUTCOMES

a. VCR (data from multicenter pediatric VCR "Fox" Consortium) Multicenter analysis of 147 consecutive vertebral column resections for severe pediatric spinal deformity. SRS Annual Meeting, Kyoto, Japan, September 2010

i. Complications

1. 86/147 (59%) total complications
2. 68/147 (46%) intraop
   a. 39/147(26.5%) SCM loss or actual neuro deficit
   b. 33/147(22.4%) EBL >2L
3. 43/147 = 29% postop
   a. 21/147(14.3%) respiratory
   b. 7/147 (4.8%) infections

ii. No intraop/postop deaths

b. Neurologic Highest Risk (data from Myelopathic Patients Who Lack SCM Data Have the Highest Risk of Spinal Cord Deficits following Posterior VCR Surgery. SRS Annual Meeting, Kyoto, Japan, September 2010)

i. Postop Neuro Status

1. 138 pts./8yrs
2. 112 with intraop SCM same as preop
3. 4/26 without intraop SCM – (15%) transient paraplegia

ii. Characteristics

1. 3 KS & 1 AK – +116.3°
2. Apex proximal to mid-thoracic – T2-7
3. 3 prior ASF w/segmental vessel ligation
4. All preop neuro status acute, progressive myelopathy

iii. F/U Neuro Status

Age	VCR level(s)	Dx	Secondary Dx	Preop	Postop	F/U
7.7	T6-7	KS	SED	Myelopathy	Paraplegia	Ambulatory in brace
12.8	T5-6	KS	Infant onset scoliosis	Myelopathy	Paraplegia	Ambulatory w/assistance
15.9	T4	KS	Congenital KS	Myelopathy	Paraplegia	Ambulatory
32.6	T2-3	AK	Cervicothoracic syringomyelia	Myelopathy	Paraplegia	Spastic but ambulatory w/assistance

All 4 pts. Regained LE motor function and 4/4 ambulatory

c. Benefit of SCM – multicenter pediatric VCR "Fox" Consortium

i. Prompt response to SCM changes

1. 147 pts./7 surgeons
2. 39/147 (27%) critical change/SCM loss or failed WUT
3. 19 pts. (13%) worsening neuro status immediate postop
4. 1 permanent neuro decline

d. Intraop SCM reliability (data from Can Intraoperative Spine Cord Monitoring Reliably Help Prevent Paraplegia during Posterior VCR Surgery? SRS Annual Meeting, Louisville, KY, September 2011)

i. Loss of SCM data

1. 15/90 pts, either lost (n=13) or had degraded data to meet warning criteria (n=2)
2. All 15 SCM data returned following prompt intervention
3. All woke with intact LE function! ("SCM SAVES")

IV. Summary

a. Challenging but safe
b. Simultaneous and circumferential control/access to spinal column/cord
c. Use of SCM, especially some form of motor tract monitoring essential to minimize neuro complications
d. Beneficial alternative to circumferential approach providing dramatic radiographic/clinical correction
e. Current state-of-the-art for severe, stiff pediatric/adult deformity, however, is technically challenging and associated with potentially major neurologic & non-neurologic complications
f. "Forever" is a long time and certainly less invasive & safer means of deformity correction will be developed in the future!

Bibliography

1. Lenke LG, O'Leary PT, Bridwell KH, et al. Posterior vertebral column resection (VCR) for severe pediatric deformity: Minimum 2-year follow-up of 35 consecutive patients. Spine 2009;34(20):2213-21.
2. Lenke LG, Sides BA, Koester LA, et al. Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res 2010;468(3):687-99.
3. Lenke LG. Posterior vertebral column resection (VCR). In: Lenke LG, ed. Scoliosis Research Society e-Text Spinal Deformity. www.srs.org 2011.
4. Suk SI, Chung ER, Kim JH, et al. Posterior vertebral column resection for severe rigid scoliosis. Spine 2005;30(14):1682-7.
5. Suk SI, Kim JH, Kim WJ, et al. Posterior vertebral column resection for severe spinal deformities. Spine 2002;27(21):2374-82.
6. Suk SI, Chung ER, Lee SM, et al. Posterior vertebral column resection in fixed lumbosacral deformity. Spine 2005;30(23):E703-10.
7. Boachie-Adjei O. Role and technique of eggshell osteotomies and vertebral column resections in the treatment of fixed sagittal imbalance. Instr Course Lect 2006;55:583-9.
8. Lenke LG, Newton PO, Sucato DJ, et al. Multicenter analysis of 147 consecutive vertebral column resections for severe pediatric spinal deformity. Paper #90, Scoliosis Research Society 45th Annual Meeting, Kyoto, Japan, September 21-24, 2010.
9. Dorward I, Lenke LG. Osteotomies in the posterior-only treatment of complex adult spinal deformity: a comparative review. Neurosurg Focus 2010;28(3):E4
10. Powers A, O'Shaughnessy BA, Lenke LG. Posterior thoracic osteotomy (vertebrectomy). In: Wang JC, ed. Advanced Reconstruction: Spine. Rosemont, IL: AAOS & NASS, Instructional Course Lecture 58, Rosemont, IL: AAOS (in press August 2011)
11. Cho SK, Lenke LG, Bolon S, et al. Myelopathic patients who lack intraoperative spinal cord monitoring data have the highest rate of spinal cord deficits following posterior VCR surgery. Paper #60, Scoliosis Research Society 45th Annual Meeting, Kyoto, Japan, September 21-24, 2010.
12. Cho SK, Lenke LG, Bolon S, et al. Can intraoperative spinal cord monitoring reliably help prevent paraplegia during posterior VCR surgery? Paper #41, Scoliosis Research Society 46th Annual Meeting, Louisville, KY, September 14-17, 2011.

Notes

DEBATE AND CASE DISCUSSION 4: HAS PEDICLE SCREW INSTRUMENTATION AND VCR REPLACED THE NEED FOR MULTI-STAGE SURGERY FOR THE TREATMENT OF SEVERE PEDIATRIC SPINAL DEFORMITY?

Moderator: Daniel J. Sucato MD MS
Panelists: B. Stephens Richards, III, MD; Lawrence G. Lenke, MD
Richard E. McCarthy, MD; Firoz Miyanji, MD, FRCSC; Mark A. Erickson, MD

Severe Pediatric Spinal Deformity

- Definition
  - A spine and chest wall condition that results in significant coronal, sagittal and/or axial plane deformities that may warrant advanced surgical techniques to correct the deformity and improve the overall functional outcome of the patient.
- Characteristics
  - Three dimensional deformity of the spine and chest-
  - Often previous surgery with associated fused segments of the spine ± ribs
  - Often congenital or the deformity begins as early onset scoliosis curve
  - Poor Pulmonary function
  - Short trunk
  - Often associated with an underlying syndrome

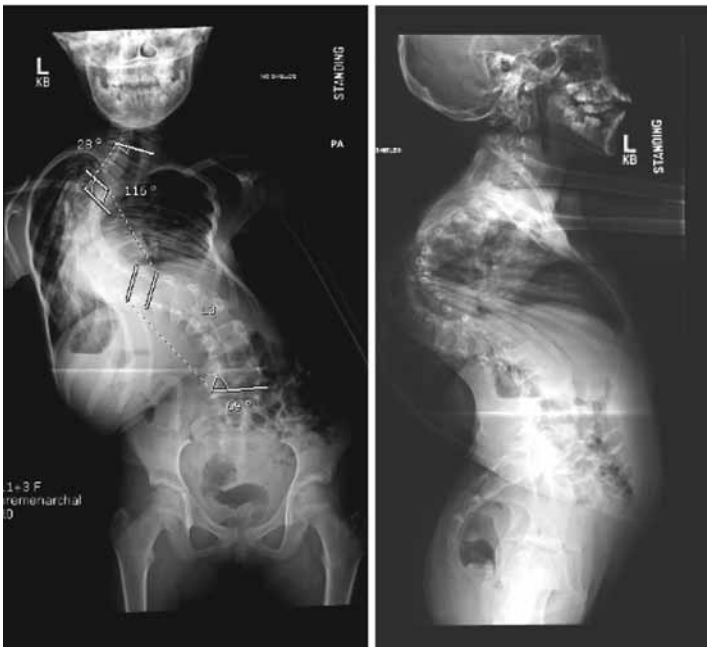
Treatment Options

- Preoperative
  - Traction
    - Types
      - Stand-alone technique
      - In combination with anterior or posterior releases
      - Temporary internal traction
    - Advantages
      - Safe stressing of the spinal cord: Patient reported neurologic monitoring
      - Well-tolerated
      - Improves pulmonary function
      - Improved spine and trunk deformity
    - Diadvantages
      - Time-consuming
      - Challenging at some institutions
      - Requires halo with subsequent visible scars
- Intraoperative
  - Use of segmental instrumentation
    - Pedicle screws standard today
    - Often challenging with severe spine deformity since pedicles can be small
  - Anterior releases (Thoracoscopic or Open)
    - Advantages
      - Effective, safe and straightforward technique
    - Disadvantages
      - Adds surgical time, repositioning
      - Detrimental effect on PFT's (?)
      - May require general surgeon (?)

- Complete facetectomies (Ponte style or Smith Petersen)
  - Advantages
    - Straightforward technique
    - Effective to a certain degree
  - Disadvantages
    - Best for global deformity over multiple segments
    - Effectiveness for severe deformity is questionable
    - Does not address the chest wall deformity
- Decancellation
  - Advantages
    - Improved correction compared to SPO or Ponte
    - Can be done at multiple segments for more global deformity
    - Less risks compared to true VCR
  - Disadvantages
    - Less correction than VCR
    - Does not address chest wall deformity
    - Little data in the literature for severe spine deformity
- Verterbal Column Resection (VCR)
  - Advantages
    - Enormous potential for correction
      - Cosmetic: life-changing event
      - Trunk height and subsequent Pulmonary function
    - Addresses spine and chest deformity
    - All posterior approach works well
  - Disadvantages
    - Significant Risks
      - Neurologic risk- 35% incidence of critical intraoperative neuro changes and ~2-3% risk for postoperative neuro deficits
      - Blood loss
    - Ideal only for local deformity (difficult to do multiple VCR at more than one location)

Case Discussion

- 11+3 you premenarchal female
- No Past medical history and no previous surgeries
- PE- Neurologically normal including abdominal reflexes
- Radigraphs- No evidence of congenital abnormalities
- MRI- NO neural axis abnormalities



References

1. Anderson, A.L., et al., The effect of posterior thoracic spine anatomical structures on motion segment flexion stiffness. Spine, 2009. 34(5): p. 441-446.
2. Geck, M.J., et al., The Ponte procedure: posterior only treatment of Scheuermann's kyphosis using segmental posterior shortening and pedicle screw instrumentation. Journal Of Spinal Disorders & Techniques, 2007. 20(8): p. 586-593.
3. Ponte, A., F. Gebbia, and F. Eliseo, Nonoperative treatment of adolescent hyperkyphosis: A 30 year experience in over 3000 patients. Orthop Trans, 1990. 14: p. 766.
4. Sponseller, P.D., et al., The use of traction in the treatment of severe spinal deformity. Spine, 2008. 33(21): p. 2305-2309.
5. Sucato, D.J., et al., Prone thoracoscopic release does not adversely affect pulmonary function when added to a posterior spinal fusion for severe spine deformity. Spine, 2009. 34(8): p. 771-8.
6. Bridwell, K.H., Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. Spine, 2006. 31(19 Suppl): p. S171-8.
7. Kim, K.-T., K.-J. Park, and J.-H. Lee, Osteotomy of the spine to correct the spinal deformity. Asian Spine Journal, 2009. 3(2): p. 113-123.

8. Suh, S.W., et al., Posterior multilevel vertebral osteotomy for correction of severe and rigid neuromuscular scoliosis: a preliminary study. Spine, 2009. 34(12): p. 1315-1320.
9. Lenke, L.G., et al., Posterior vertebral column resection for severe pediatric deformity: minimum two-year follow-up of thirty-five consecutive patients. Spine, 2009. 34(20): p. 2213-2221.
10. Suk, S.I., et al., Posterior vertebral column resection for severe rigid scoliosis. Spine, 2005. 30(14): p. 1682-7.
11. Suk, S.I., et al., Posterior vertebral column resection for severe spinal deformities. Spine, 2002. 27(21): p. 2374-82.
12. Wang, Y., et al., Posterior-only multilevel modified vertebral column resection for extremely severe Pott's kyphotic deformity. European Spine Journal: Official Publication Of The European Spine Society, The European Spinal Deformity Society, And The European Section Of The Cervical Spine Research Society, 2009. 18(10): p. 1436-1441.
13. Sucato, D., et al., Prompt Response to Critical IONM Changes Avoids Permanent Neurologic Deficit in Vertebral Column Resection Surgery for Severe Spinal Deformity, in Scoliosi Research Society. 2010: Kyoto, Japan.
14. O'Shaughnessy, B.A., T.R. Koski, and S.L. Ondra, Reversal of neurologic deterioration after vertebral column resection by spinal cord untethering and duraplasty. Spine, 2008. 33(2): p. E50-4.
15. Boachie-Adjei, O., Role and technique of eggshell osteotomies and vertebral column resections in the treatment of fixed sagittal imbalance. Instructional Course Lectures, 2006. 55: p. 583-589.
16. Diab, M.G., J.M. Franzone, and M.G. Vitale, The role of posterior spinal osteotomies in pediatric spinal deformity surgery: indications and operative technique. Journal Of Pediatric Orthopedics. 31(1 Suppl): p. S88-S98.
17. Boachie-Adjei, O. and D.S. Bradford, Vertebral column resection and arthrodesis for complex spinal deformities. Journal Of Spinal Disorders, 1991. 4(2): p. 193-202.
18. Smith, J.S., V.Y. Wang, and C.P. Ames, Vertebral column resection for rigid spinal deformity. Neurosurgery, 2008. 63(3 Suppl): p. 177-182.
19. Bradford, D.S. and C.B. Tribus, Vertebral column resection for the treatment of rigid coronal decompensation. Spine, 1997. 22(14): p. 1590-1599.
20. Buchowski, J.M., D.L. Skaggs, and P.D. Sponseller, Temporary internal distraction as an aid to correction of severe scoliosis. Surgical technique. The Journal Of Bone And Joint Surgery. American Volume, 2007. 89 Suppl 2 Pt.2: p. 297-309.
21. Burton, D.C., et al., The treatment of large (>70 degrees) thoracic idiopathic scoliosis curves with posterior instrumentation and arthrodesis: when is anterior release indicated? Spine, 2005. 30(17 (Electronic)): p. 1979-1984.
22. Dobbs, M.B., et al., Anterior/posterior spinal instrumentation versus posterior instrumentation alone for the treatment of adolescent idiopathic scoliotic curves more than 90 degrees. Spine, 2006. 31(20): p. 2386-91.
23. Newton, P.O., et al., The success of thoracoscopic anterior fusion in a consecutive series of 112 pediatric spinal deformity cases. Spine., 2005. 30(4): p. 392-398.
24. Niemeyer, T., et al., Anterior thoracoscopic surgery followed by posterior instrumentation and fusion in spinal deformity. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 2000. 9(6): p. 499-504.

Notes

Combined Afternoon Session

A REVIEW OF A DECADE OF CHANGE IN ADULT DEFORMITY

Moderators:

Steven D. Glassman, MD; Joseph H. Perra, MD

Faculty:

Sigurd H. Berven, MD; Christopher I. Shaffrey, MD; Tyler R. Koski, MD; Keith H. Bridwell, MD; Alpesh A. Patel, MD; Mark B. Dekutoski, MD; Charles H. Crawford, MD

HAS THE INCORPORATION OF EVIDENCE BASED MEDICINE OVER THE PAST DECADE CHANGED HOW WE TREAT SPINAL DISEASE AND DEFORMITY?

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A) Definition of Evidence-based Medicine

Evidence-based medicine is the practice of medicine as a science guided by the a critical assessment of the highest level of information available. Evidence-based medicine is characterized by consensus between practitioners rather than variability between domains, ongoing assessment of the outcomes of care, adjustment for patient-specific factors and risks, and responsiveness to the values and preferences of the individual patient.

David Sackett and Gordon Guyatt[1]:

"An attitude of "enlightened scepticism" about prevailing diagnostic, therapeutic, and prognostic technologies"

"The conscientious, explicit and judicious use of the best current evidence in making decisions about the individual patient"

Taking into account patient values

B) Foundations of Evidence-based Medicine:
- 1) Clinical outcomes research
  - a. Comparative Effectiveness
  - b. Defining Outcomes and Endpoints
- 2) Systematic reviews of the literature
  - a. Archie Cochrane
- 3) Generalizability across practices
- 4) Personalization between patients

C) Purposes of Clinical Outcomes Research
- 1) Patient Information
- 2) Empowerment of Informed Choice
- 3) Demonstrate value to Purchasers of Healthcare
  - a. Pay for performance
- 4) Quality Assurance
- 5) Surgeon Accountability
- 6) Clinical Research
  - a. Measure Effect of Treatment
  - b. Assess Efficacy of Treatment
  - c. Manage change in Treatment

D) Sources of Evidence
- 1) Personal Experience/ Audit of Practice
- 2) Traning/Eminence-based Medicine
- 3) Expert Opinion
- 4) Literature
  - a. Peer-reviewed
  - b. Non-peer-reviewed
- 5) Medical Societies
- 6) Clinical Practice Guidelines/AUC
- 7) National Institutions and Policies
  - a. Institute of Medicine
  - b. AHRQ
  - c. NICE

E) Variability in Care

The management of common spinal disorders, including spinal deformity is characterized by significant variability.

The presence of variability is a reflection of the absence of an evidence-based approach to care.

Variability in care indicts the quality of care

High quality care is characterized by consistency, uniformity and consensus

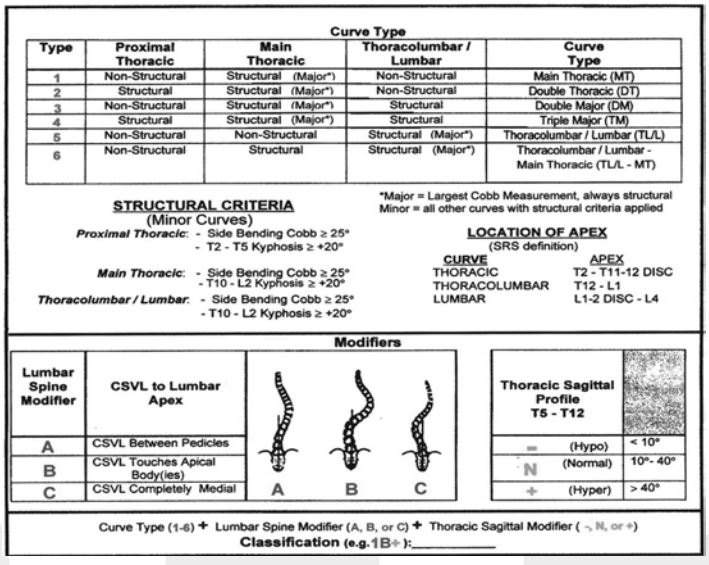
Variability is an important contributor to rising cost of care and unpredictable budgetting of care

An important goal of evidence-based medicine is to reduce variability of care

F) Evidence based Management of Adult Spinal Deformity- A Decade of Change
- 1) Classifying Adult Deformity

A comprehensive classification of scoliosis is fundamental to developing an evidence-based approach to care. The development of classifications for adult and pediatric deformity has enabled comparative research in the management of specific deformity patterns, and has provided a paradigm for consensus in clinical practices.[2]

  - a. Lenke Classification for Adolescent Deformity[3]



Curve Type

Type	Proximal Thoracic	Main Thoracic	Thoracolumbar / Lumbar	Curve Type
1	Non-Structural	Structural (Major*)	Non-Structural	Main Thoracic (MT)
2	Structural	Structural (Major*)	Non-Structural	Double Thoracic (DT)
3	Non-Structural	Structural (Major*)	Structural	Double Major (DM)
4	Structural	Structural (Major*)	Structural	Triple Major (TM)
5	Non-Structural	Non-Structural	Structural (Major*)	Thoracolumbar / Lumbar (TL/L)
6	Non-Structural	Structural	Structural (Major*)	Thoracolumbar / Lumbar - Main Thoracic (TL/L - MT)

*Major = Largest Cobb Measurement, always structural
Minor = all other curves with structural criteria applied

STRUCTURAL CRITERIA (Minor Curves)

Proximal Thoracic: - Side Bending Cobb ≥ 25° - T2 - T5 Kyphosis ≥ +20°

Main Thoracic: - Side Bending Cobb ≥ 25° - T10 - L2 Kyphosis ≥ +20°

Thoracolumbar / Lumbar: - Side Bending Cobb ≥ 25° - T10 - L2 Kyphosis ≥ +20°

LOCATION OF APEX (SRS definition)

CURVE	APEX
THORACIC	T2 - T11-12 DISC
THORACOLUMBAR	T12 - L1
LUMBAR	L1-2 DISC - L4

Modifiers

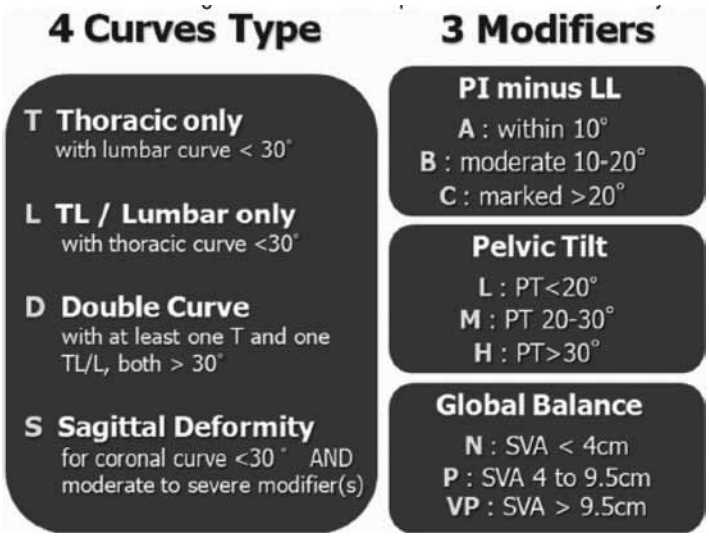
Lumbar Spine Modifier	CSVL to Lumbar Apex
A	CSVL Between Pedicles
B	CSVL Touches Apical Body(ies)
C	CSVL Completely Medial

A B C

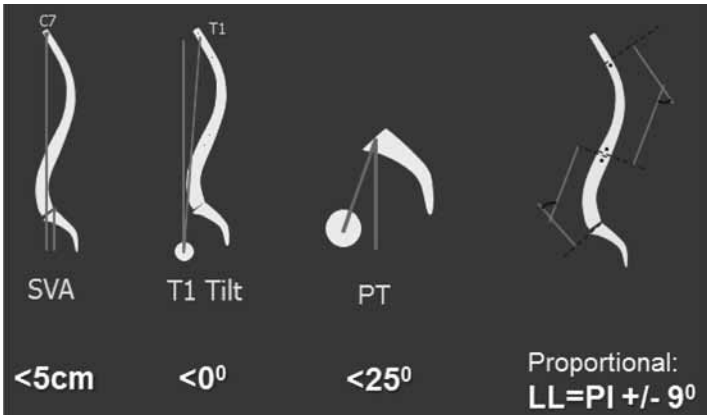
Thoracic Sagittal Profile T5 - T12	
- (Hypo)	< 10°
N (Normal)	10°- 40°
+ (Hyper)	> 40°

Curve Type (1-6) + Lumbar Spine Modifier (A, B, or C) + Thoracic Sagittal Modifier (-, N, or +)
Classification (e.g. 1B+):_____

  - b. Schwab Classification for Adult Deformity



2) Understanding Sagittal Plane



3) Measuring Outcomes of Care:
In the past decade there has been a significant change in the use of clinical outcome measures for reporting outcome of care, rather than a focus upon process variables including curve correction, fusion rates, and surgeon-based assessment of outcomes. Measuring patient-based outcomes has enabled a direct measurement of the patient's healthcare experience, and has created accountability for the most important outcome of care- the patients health-related quality of life.
   a. Health-related quality of Life
      An estimate of health status based upon patient perception and limited to consideration of domains that are impacted by physical and mental health.
   b. General Health Status
      i. SF-36
      ii. EQ5-D
   c. Disease-specific Measures
      i. SRS-22[4]

4) Surgical Techniques
   a. Three column osteotomies[5,6]
      The evolution and adoption of three column osteotomies and posterior-based techniques for deformity correction has significantly reduced the need for combined anterior and posterior approaches to deformity, and the utilization of staged surgery for spinal deformity. Improving the safety of three-column osteotomies regarding neural injury and perioperative morbidity remains an important goal for the next decade.
   b. Pedicle Screw Fixation:
      The use of pedicle screws for fixation in the thoracic and lumbar spine in deformity has increased significantly over the past decade. There is good evidence that the magnitude of curve correction and derotation of the spine is improved with the use of pedicle screws compared with hooks or wires.[7] Revision surgery rates are also lower with screws than alternative fixation.[8] However, the effects of pedicle fixation of thoracic kyphosis, adjacent segment pathology, patient safety and overall clinical outcome has not been demonstrated.
   c. Pelvic fixation
      Long fusions to the sacrum generate significant strain at the distal segment that leads to high rates of non-union, screw loosening and sacral fracture. Stable pelvic fixation has significnatly improved the reliability of sacral fixation, and improved rates of fusion. Low profile techniques including iliac screws and sacral alar iliac fixation reduce the prominence and burden of pelvic fixation.[9]

4) Limiting Complications and Patient Safety
Complications of care are intrinsic to the management of scoliosis, and indellible from the fabric of surgical care. Before the past decade, several authors recommended against surgical management of scoliosis in the adult due to unacceptable rates of complication.[10] Limiting complications is a goal of evidence-based medicine. Choice of Levels to avoid adjacent segment complications, and development of techniques for stable fixation are important areas have limited complications in the past decade.
   a. Adjacent Segment Complications
      i. Proximal Junctional Kyphosis
         PJK remains an important challenge in pediatric and adult deformity surgery. Fusion to a neutral or lordotic segment, cement augmentation, less rigid fixation, interspinous augmentation, and hybrid fixation are all techniques that may limit junctional kyphosis.[11,12]
      ii. L5 vs S1
         Long fusions from the thoracic spine to L5 have a high incidence of subsequent advanced degeneration at L5-S1 and may be unreliable.[13] Poor bone density, sagittal plane deformity and symptomatic degeneration at L5-S1 are all factors that may increase failure of long fusions to L5.[14]
   b. Neuromonitoring
      Neuromonitoring with motor-evoked potential and multiple myotomes has led to measurable improvements in the ability to detect spinal cord and peripheral nerve injury, and has contributed to the safety of spine surgery by enabling surgeons to react to changes promptly and effectively.[15]
   c. Biologics and Fusion
      Effective arthrodesis of the spine over multiple levels is challenging, especially in the adult with spinal deformity. The introduction

of bone graft extenders and substitutes in the past decade has significantly improved the effectiveness of spinal fusions in deformity surgery.[16] The cost effectiveness of bone graft substitutes in degenerative and deformity surgery remains unknown. Optimization of cost effectiveness may determine an appropriate cost point for future biologics.

G) Future Direction: The Decade to Come

1) Optimizing quality and value in spinal deformity surgery:
Quality and value of care are distinct concepts, and require different measures. Quality of care is measured as a degree of excellence, and the standards or dashboards for measuring quality may be challenging to define. Quality of care in deformity surgery may be measured by process variables that include compliance with clinical care pathways and care guidelines, complication and readmission rates, and variability in utilization rates compared with established norms. Value of care encompasses the net benefits of one care compared with an alternative, or incremental benefit, and includes consideration of the direct cost and risk of providing care. Porter and Teisberg suggest that the right goal for healthcare delivery is superior patient value.[17] Patient value is measured at the level of specific medical conditions. Measurement of outcomes of care needs to reflect the patient's long-term healthcare experience, and the impact of one intervention compared with alternatives on the patients self-assessment of health-related quality of life.

The Value Equation:

The value equation in healthcare is an analysis of the benefits of care relative to the direct cost and risk of providing the care

Value= Fxn(Benefit/Cost)

The value equation may vary depending on the perspective of the stakeholder in the healthcare economy. Hospitals and facilities providing care may measure outcome and costs by factors that affect their short-term, single admission interaction, including length of stay, implant utilization, and complications. Third party payors for healthcare may focus on a timeframe that is longer that a single admission, and may include factors in the value equation such as readmission within 90 days, or cost of outpatient care.

Patients, physicians, and society consider value over a lifetime. The cost of a single episode of care will be significantly discounted by the duration of the benefit. Patient preference for different health states over time offer the most useful measure of value of healthcare interventions.

(Endnotes)

1 Oxman AD, Sackett DL, Guyatt GH: Users' guides to the medical literature. I. How to get started. The Evidence-Based Medicine Working Group. JAMA. 1993 Nov 3;270(17):2093-5

2 Clements DH, Marks M, Newton PO, Betz RR, Lenke L, Shufflebarger H; Harms Study Group: Did the Lenke classification change scoliosis treatment? Spine (Phila Pa 1976). 2011 Jun 15;36(14):1142-5.

3 Lenke LG, Betz RR, Harms J, Bridwell KH, Clemente DH, Lowe TG, Blanke K: JBJS 2001;83A:1169-1181.

4 Asher M, Min Lai S, Burton D, Manna B: The reliability and concurrent validity of the scoliosis research society-22 patient questionnaire for idiopathic scoliosis. Spine (Phila Pa 1976). 2003 Jan 1;28(1):63-9.

5 Suk SI, Kim JH, Kim WJ, Lee SM, Chung ER, Nah KH: Posterior vertebral column resection for severe spinal deformities. Spine (Phila Pa 1976). 2002 Nov 1;27(21):2374-82.

6 Lenke LG, Sides BA, Koester LA, Hensley M, Blanke KM: Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res. 2010 Mar;468(3):687-99

7 Watanabe K, Lenke LG, Bridwell KH, Kim YJ, Watanabe K, Kim YW, Kim YB, Hensley M, Stobbs G: Comparison of radiographic outcomes for the treatment of scoliotic curves greater than 100 degrees: wires versus hooks versus screws. Spine (Phila Pa 1976). 2008 May 1;33(10):1084-92.

8 Kuklo TR, Potter BK, Lenke LG, Polly DW Jr, Sides B, Bridwell KH: Surgical revision rates of hooks versus hybrid versus screws versus combined anteroposterior spinal fusion for adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2007 Sep 15;32(20):2258-64.

9 Sponseller PD, Zimmerman RM, Ko PS, Pull Ter Gunne AF, Mohamed AS, Chang TL, Kebaish KM: Low profile pelvic fixation with the sacral alar iliac technique in the pediatric population improves results at two-year minimum follow-up. Spine (Phila Pa 1976). 2010 Sep 15;35(20):1887-92.

10 Sponseller PD, Cohen MS, Nachemson AL, Hall JE, Wohl ME: Results of surgical treatment of adults with idiopathic scoliosis. J Bone Joint Surg Am. 1987 Jun;69(5):667-75.

11 Kim YJ, Bridwell KH, Lenke LG, Glattes CR, Rhim S, Cheh G: Proximal junctional kyphosis in adult spinal deformity after segmental posterior spinal instrumentation and fusion: minimum five-year follow-up. Spine (Phila Pa 1976). 2008 Sep 15;33(20):2179-84.

12 Yagi M, King AB, Boachie-Adjei O: Incidence, Risk Factors and Natural Course of Proximal Junctional Kyphosis: Surgical Outcomes Review of Adult Idiopathic Scoliosis. Minimum 5 years Follow-Up. Spine (Phila Pa 1976). 2012 Feb 21.

13 Eck KR, Bridwell KH, Ungacta FF, Riew KD, Lapp MA, Lenke LG, Baldus C, Blanke K: Complications and results of long adult deformity fusions down to l4, l5, and the sacrum. Spine (Phila Pa 1976). 2001 May 1;26(9):E182-92.

14 Swamy G, Berven SH, Bradford DS: The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis. Neurosurg Clin N Am. 2007 Apr;18(2):281-8.

15 Lieberman JA, Lyon R, Feiner J, Hu SS, Berven SH: The efficacy of motor evoked potentials in fixed sagittal imbalance deformity correction surgery. Spine (Phila Pa 1976). 2008 Jun 1;33(13):E414-24

16 Mulconrey DS, Bridwell KH, Flynn J, Cronen GA, Rose PS: Bone morphogenetic protein (RhBMP-2) as a substitute for iliac crest bone graft in multilevel adult spinal deformity surgery: minimum two-year evaluation of fusion. Spine (Phila Pa 1976). 2008 Sep 15;33(20):2153-9.

17 Porter ME, Teisberg EO: Redefining Health Care. Creating Value-based competition on results. Harvard Business School Press, 2006.

Notes

HAS THE PROBLEM OF ADJACENT SEGMENT COMPLICATIONS ABOVE AND BELOW A FUSION FOR DEGENERATIVE DEFORMITY BEEN SOLVED OVER THE PAST DECADE?

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The demographic shift toward an older population in the United States has led to an increased prevalence of adult scoliosis, with reported rates among the elderly as high as 70%. Although surgery for symptomatic adult deformity has been shown to result in improved health related quality of life as compared to non-operative management, complications associated with complex reconstructive deformity surgery can be significant.

Adjacent segment degeneration and pseudarthrosis are among the most common long-term complications that can warrant a revision procedure. Kyphosis and other adjacent segment complications at the rostral end of instrumented fusions have been well described, but there has been substantially less has been documented about failure and degeneration at the distal end of instrumentation and fusion for adult spinal deformity. Both represent phenomenon of significant clinical importance.

A widely held belief that creation of rigid segments in the spine can lead to increased stress on and premature degeneration of the motion segments adjacent to an arthrodesis which can manifest as proximal or distal junctional pathology. In vitro evidence of increased stress and intradiscal pressure at segments adjacent to a lumbar spinal fusion was been shown in numerous publications.

Proximal adjacent segment pathology

Proximal adjacent segment pathology (ASP) can manifest itself in many different ways both clinically and radiographically. Proximal Junctional Kyphosis (PJK) is one specific form of radiographic ASP (RASP), which is a known complication that can occur after reconstructive spine surgery for kyphosis and scoliosis. Originally described radiographically as kyphosis greater than 10° between the upper instrumented vertebra (UIV) and the vertebral body two levels above, PJK in severe cases can lead to compromised outcomes and the need for revision surgery. Although the majority of PJK cases do not necessitate revision surgery, those cases that are severe and progressive can lead to a devastating neurologic compromise, so close monitoring of patients at high risk is warranted.

Since it was first described, multiple studies have attempted to elucidate the risk factors associated with its development; however, no study has been able to definitively identify a single variable associated with the development of PJK, thus its etiology is likely multifactorial. Identified risk factors include combined anteroposterior surgical approach, type of instrumentation, magnitude of correction and sagittal imbalance correction, inclusion of pelvic fixation, osteoporosis and integrity of the posterior ligamentous complex as well as the proximally instrumented vertebral level. Other factors likely to be associated with ASP include older age, fusions to the sacrum, combined anteroposterior surgery, thoracoplasty, UIV at T1-T3 and those without anatomical restoration of thoracic kyphosis postoperatively demonstrated a higher risk for the development of PJK.

There are other risk factors that are well-accepted by the spinal reconstructive surgical community that are not necessarily quantified in the literature, either because these factors are difficult to quantify or so complex that research to evaluate their effect is challenging. Disruption of muscular/ligamentous/bony tissue at or cephalad to the upper instrumented/fused level during spinal reconstructive surgeries is a widely accepted but unproven risk factor. Although all surgeons would agree that minor degrees of this occur in nearly every standard surgery performed, quantification of this disruption is difficult, making a scientific basis for our theory on this difficult to formulate. In addition, the type and degree of corrective forces utilized during actual rod placement that are a part of spinal deformity corrective surgery probably play an important role as well but are impossible to quantify currently accurately. The loads applied to the proximal portion of the implants and adjacent tissues are experiencing following a deformity correction can become non-physiologic and may play a role in the alterations between a rigid/instrumented proximal region of the spine and the abrupt transition to the mobile/un-instrumented and fused immediate cephalad to these segments.

All spinal reconstructive surgeons have experienced patients undergoing a major sagittal realignment procedure in the lumbar spine, such as a pedicle subtraction osteotomy, in order to increase lumbar lordosis and optimize global sagittal balance, where the patient developed PJK cephalad to the construct postoperatively. This can be seen very early postoperatively in those patients where the degree of lordosis produced was somewhat excessive for what the patient's regional and global balance required and is reflected by a reciprocal PJK above the instrumented segments.

Prevention principally involves reducing recognized risk factors. Osteoporosis should be aggressively treated when possible. Obtaining good sagittal alignment likely reduces stress on proximal segments but over correction of lumbar lordosis has been shown to be an independent factor associated with proximal failure. Appropriate contouring of rods is needed to assure a smooth transition with less stress on proximal segments.

Studies of surgical techniques including prophylactic vertebroplasty of the upper instrumented vertebra (UIV) or UIV+1 are ongoing. Minimally invasive techniques that reduce proximal muscle dissection are being attempted. The use of either up-going pedicle hooks or down-going transverse process hooks have been attempted as a method of reducing disruption of the promixal segments. The results of the use of hooks have not been reported in adult patients.

PJK remains a significant clinical conundrum with numerous device companies looking at new implant designs to reduce this problem. Currently there is no definitive solution, only strategies to reduce the incidence.

Distal adjacent segment pathology

Distal adjacent segment degeneration, implant failure and pseudarthrosis can be a source of pain, sagittal malalignment, and poor cosmesis, and may create increased mechanical stress on adjacent segments, eventually resulting in adjacent segment pathology. Adult spinal deformity often involves the lumbar spine and involves fusion extending down into the lower lumbar (L4 or L5) or sacral spine. There are chances of adjacent segment pathology following fusion to L4/5, with failure of long adult fusions to L5 to maintain sagittal balance subsequent at least in part due propensity of L5–S1 disc to undergo degeneration and lose lordosis during the postoperative period. Various studies that recommend routinely fusing to the sacrum and/or pelvic instead of stopping at L4 or L5 but this remains one of the most controversial aspects of the management of adult degenerative scoliosis (ADS).

Several studies have demonstrated an increased risk of distal ASP following long T-L fusion procedures. Distal Clinical Adjacent Segment Pathology (CASP) developed

in 17.7% of patients after a 2-6 year mean follow-up and 19.8% of patients after a 9-year mean follow-up, while re-operation due to CASP was reported in 15.6% of patients after 2-6 years and 14.4% of patients after 9-years. Distal Radiological Adjacent Segment Pathology (RASP) was more frequent: 44.7% to 65.5% depending on length of follow-up. Patients with preoperative sagittal imbalance were more likely to develop distal ASP.

Several studies have identified that preoperative sagittal imbalance as a risk factor for developing moderate to advanced RASP after long T-L fusions. Preoperative disc degeneration has been consistently associated with higher chances of development of RASP. Other factors reported include higher postoperative fractional curve and the use of a circumferential approach.

Elimination of distal CASP is likely not possible following long TL fusion procedures. Obtaining excellent sagittal balance is likely a key factor in slowing degeneration.

References:

1. Kim YJ, Bridwell KH, Lenke LG, Glattes CR, Rhim S, Cheh G. Proximal Junctional Kyphosis in Adult Spinal Deformity After Segmental Posterior Spinal Instrumentation and Fusion: Minimum Five-Year Follow-up. Spine. 2008;33:2179-2184 10.1097/BRS.0b013e31817c0428.
2. Denis F, Sun EC, Winter RB. Incidence and Risk Factors for Proximal and Distal Junctional Kyphosis Following Surgical Treatment for Scheuermann Kyphosis: Minimum Five-Year Follow-up. Spine. 2009;34:E729-E734 10.1097/BRS.0b013e3181ae2ab2.
3. Glattes RC, Bridwell KH, Lenke LG, Kim YJ, Rinella A, Edwards C, 2nd. Proximal junctional kyphosis in adult spinal deformity following long instrumented posterior spinal fusion: incidence, outcomes, and risk factor analysis. Spine (Phila Pa 1976). 2005;30:1643-9.
4. Yagi M, Akilah KB, Boachie-Adjei O. Incidence, risk factors and classification of proximal junctional kyphosis: surgical outcomes review of adult idiopathic scoliosis. Spine (Phila Pa 1976). 2011;36:E60-8.
5. Yagi M, King AB, Boachie-Adjei O. Incidence, Risk Factors and Natural Course of Proximal Junctional Kyphosis: Surgical Outcomes Review of Adult Idiopathic Scoliosis: Minimum 5 years Follow-Up. Spine (Phila Pa 1976). 2012;
6. Hassanzadeh H, Gupta S, Jain A, El Dafrawy M, Skolasky R, Kebaish K. The Anchor Type at the Proximal Fusion Level has Significant Effect on the Incidence of Proximal Junctional Kyphosis (PJK) and Outcome in Adults Following Long Posterior Spinal Fusion. SRS Annual Meeting. 2011;Paper #24.
7. Asghar J, Samdani AF, Newton PO, Cahill PJ, Morales DC, Shufflebarger HL. Proximal Junctional Kyphosis at Five Years After Fusion for AIS: Does it Matter? SRS Annual Meeting. 2011;Paper #13
8. Pahys JM, Samdani AF, Betz RR, Trobisch PD, Garg H, Newton PO, Marks MC, Bastrom T, Group. HS, Cahill PJ. Assessment of Proximal Junctional Kyphosis and Shoulder Balance with Proximal Screws vs. Hooks in Poster Spinal Fusion for Adolescent Idiopathic Scoliosis. SRS Annual Meeting. 2011;Paper #7.
9. Cheh G, Bridwell KH, Lenke LG, et al. Adjacent segment disease followinglumbar/thoracolumbar fusion with pedicle screw instrumentation: a minimum 5-year follow-up. Spine 2007;32:2253-7.
10. Park P, Garton HJ, Gala VC, et al. Adjacent segment disease after lumbar or lumbosacral fusion: review of the literature. Spine 2004;29:1938-44.
11. Sears WR, Sergides IG, Kazemi N, et al. Incidence and prevalence of surgery at segments adjacent to a previous posterior lumbar arthrodesis. The spine journal 2011;11:11-20.
12. Durrani A, Jain V, Desai R, et al. Could junctional problems at the end of a long construct be addressed by providing a graduated reduction in stiffness? A biomechanical investigation. Spine 2012;37:E16-22.
13. Kim YJ, Bridwell KH, Lenke LG, et al. Pseudarthrosis in long adult spinal deformity instrumentation and fusion to the sacrum: prevalence and risk factor analysis of 144 cases. Spine 2006;31:2329-36.
14. Kwon BK, Elgafy H, Keynan O, et al. Progressive junctional kyphosis at the caudal end of lumbar instrumented fusion: etiology, predictors, and treatment. Spine 2006;31:1943-51.
15. Lowe T, Berven SH, Schwab FJ, et al. The SRS classification for adult spinal deformity: building on the King/Moe and Lenke classification systems. Spine 2006;31:S119-25.

Notes

AFTER A DECADE OF USE, WHICH OF THE POSTERIOR OSTEOTOMY TECHNIQUES HAS PROVEN EFFECTIVE IN RESTORING SAGITTAL BALANCE AT AN ACCEPTABLE COMPLICATION RATE?

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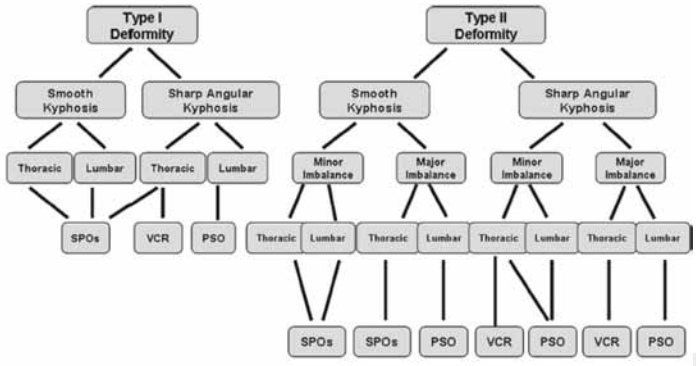
I. Introduction:
   - A. Many variations on osteotomies have been described.
   - B. 3 main categories to be covered in this lecture
     1. Posterior column osteotomies
        - a. Smith-Petersen Osteotomy (SPO)
        - b. Ponte Osteotomy
     2. Pedicle Subtraction Osteotomies
     3. Vertebral Column Resection

II. Indications:
   - A. Spinal malalignment
     1. Non-fixed deformity
        - a. In a flexible deformity choosing an osteotomy is based on how much correction and where the correction is needed. Simple posterior column osteotomies have proven effective and have decades of use behind them. The use of 3 column osteotomies is often unnecessary in these situations. Special circumstances of focal malalignment or severe imbalance may necessitate the use of a 3-column osteotomy. Literature on 3-column osteotomies generally includes cases primarily of fixed deformity.
     2. Fixed deformity
        - a. In fixed deformities 3 column osteotomies are often now the treatment of choice. Significant history and literature exists

regarding the use of true Smith-Petersen osteotomies with anterior osteoclasis in patients with Ankylosing Spondylitis, but, in general, the preference today is for a more controlled focal correction with a 3-column osteotomy. The literature supports a 3-column osteotomy to achieve a high success rate in correction of deformity and in overall HRQOL improvement, but also shows a significant complication rate that must be factored in.

i. Reported complications consistently include both early and late complications
   A. Early complications:
      1. Nerve root injury or new neurologic deficit
      2. Significant blood loss
      3. Medical complications
   B. Late complications
      1. Pseudoarthrosis
      2. Instrumentation failure

III. Choosing the right osteotomy
   A. In 2006 Keith Bridwell outlined an algorithm for surgical planning in regards to osteotomies. The algorithm still works quite well and is a useful reference. It is reproduced below[14]. It should be noted that VCRs are only recommended in the thoracic spine. A VCR in the lumbar spine can be used it is only in rare cases. The inability to sacrifice a lumbar root is one reason to avoid a VCR. Another important point is to recognize that a VCR does not have an anatomic pivot point and instead relies on a anterior cage or strut graft placed as a pivot. If a spine is being corrected into lordosis, as in the lumbar spine, a cage will become loose as the anterior gap widens with closure. VCR works well in the thoracic spine where the spine is corrected from a state of hyperkyphosis to a less kyphotic or at most neutral alignment.



PSO = pedicle subtraction osteotomy; SPO = Smith-Petersen osteotomy; VCR=vertebral column resection

Figure 10. Algorithm for osteotomy type based on the character of the sagittal deformity.

IV. Conclusion:
   A. Osteotomy techniques have been refined over decades of use
   B. 3-column osteotomies have gained popularity as all posterior corrections have in many cases replaced traditional Anterior-Posterior corrections
      1. Complications are associated with 3 column osteotomy techniques and are particularly well documented in Lumbar PSO.
      2. Despite complications posterior osteotomies have proven effective in improving spinal malalignment with significant positive impacts on HRQOL measures.
   C. Choosing the right osteotomy depends on:
      1. Spinal flexibility
      2. The amount of correction needed
      3. The anatomic location in which the correction is desired.

References:

1. Smith-Petersen MN, Larson CB, Aufranc OE. Osteotomy of the spine for correction of flexion deformity in rheumatoid arthritis. J Bone Joint Surg Am. 1945:27:1-11
2. McMaster MJ. A technique for lumbar spinal osteotomy in ankylosing spondylitis. J Bone Joint Surg Br. 1985;67:204-10
3. Lagrone MO, Bradford DS, Moe JH, et al. Treatment of symptomatic flat back after spinal fusion. J Bone Joint Surg Am. 1988;70:569-80.
4. Bradford DS: Vertebral column resection. Orthop Trans 1987; 11: 502.
5. Bradford DS, Tribus CB: Vertebral column resection for the treatment of rigid coronal decompensation. Spine (Phila Pa 1976) 1997; 22: 1590-1599.
6. Berven SH, Deviren V, Smith JA, et al: Management of Fixed sagittal plane deformity: results of the transpedicular Wedge resection osteotomy. Spine (Phila Pa 1976) 2001; 26: 2036-2043
7. Kim KT, Suk KS, Cho YJ, Hong GP, Park BJ: Clinical outcome results of pedicle subtraction osteotomy in ankylosing spondylitis with kyphotic deformity. Spine (Phila Pa 1976) 2002; 27: 612-618
8. Bridwell KH, Lewis SJ, Lenke LG, Baldus C, Blanke K: Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. J Bone Joint Surg Am 2003; 85: 454463.
9. Suk SI, Chung ER, Kim JH, et al: Posterior vertebral column resection for severe rigid scoliosis. Spine (Phila Pa 1976) 2005; 30: 1682-1687.
10. Suk SI, Chung ER, Lee SM, et al: Posterior vertebral column resection in fixed lumbosacral deformity. Spine (Phila Pa 1976) 2005; 30: E703- E710.
11. Cho KJ, Bridwell KH, Lenke LG, Berra A, Baldus C: Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. Spine (Phila Pa 1976) 2005; 30: 2030-2037.
12. Boachie-Adjei O, Ferguson JA, Pigeon RG, Peskin MR: Transpedicular lumbar wedge resection osteotomy for fixed sagittal imbalance: surgical technique and early results. Spine (Phila Pa 1976) 2006; 31: 485-492.
13. Yang BP, Ondra SL, Chen LA, et al: Clinical and radiographic outcomes of thoracic and lumbar pedicle subtraction osteotomy for fixed sagittal imbalance. J Neurosurg Spine 2006; 5: 9-17.
14 Bridwell KH: Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. Spine (Phila Pa 1976) 2006; 31: S171- S178.
15. Buchowski JM, Bridwell KH, Lenke LG, et al: Neurologic complications of lumbar pedicle subtraction osteotomy: a 10-year assessment. Spine (Phila Pa 1976) 2007; 32: 2245-2252.
16. Kim YJ, Bridwell KH, Lenke LG, Cheh G, Baldus C: Results of lumbar pedicle subtraction osteotomies for fixed sagittal imbalance: a minimum 5-year follow-up study. Spine (Phila Pa 1976) 2007; 32: 2189-2197.
17. Mummaneni PV, Dhall SS, Ondra SL, Mummaneni VP, Berven S: Pedicle subtraction osteotomy. Neurosurgery 2008; 63: 171-176.
18. Lenke LG, O'Leary PT, Bridwell KH, et al: Posterior vertebral column resection for severe pediatric deformity: minimum two-year follow-up of thirty-five consecutive patients. Spine (Phila Pa 1976) 2009; 34: 2213-2221.
19. Tack KP, Park KJ, Lee JH, Osteotomy of the spine to correct deformity. Asian Spine J. 2009;3(2):113-123
20. Schwab FJ, Patel A, Shaffrey CI, Smith JS, Farcy JP, Boachie-Adjei O, Hostin RA, Hart RA, Akbarnia BA, Burton DC, Bess S, Lafage V. Sagittal realignment failures following pedicle subtraction osteotomy surgery: are we doing enough? J Neurosurg Spine. 2012 Jun;16(6):539-46. Epub 2012 Mar 30.

21. Kim KT, Lee SH, Suk KS, Lee JH, Jeong BO. Outcome of Pedicle Subtraction Osteotomies for Fixed Sagittal Imbalance of Multiple Etiologies: A Retrospective Review of 140 patients. Spine (Phila Pa 1976). 2012 Mar 16. [Epub ahead of print]

22. Auerbach JD, Lenke LG, Bridwell KH, Sehn JK, Milby AH, Bumpass D, Crawford CH 3rd, O'shaughnessy BA, Buchowski JM, Chang MS, Zebala LP, Sides BA. Major complications and comparison between 3-column osteotomy techniques in 105 consecutive spinal deformity procedures. Spine (Phila Pa 1976). 2012 Jun15;37(14):1198-210.

Notes

WHAT IS THE LIKELY OUTCOME OF A LONG FUSION TO THE SACRUM NOW AND ARE THE CURRENT TECHNIQUES MORE EFFECTIVE THAN 10 YEARS AGO?

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Background:

Ten years ago the standard for a long fusion to the sacrum was anterior and posterior surgery. The anterior was largely done with a thoracoabdominal-type approach. Sacropelvic fixation was gathering some enthusiasm and support, but not universally. The standard for bone grafting was the iliac crest. The standard for fixation points was pedicle screws in the lower lumbar spine and largely hooks in the thoracic spine with some utilization of sublaminar wires.

Presently, it is more common to utilize pedicle screws throughout the thoracic and lumbar spine. There are differing views on the best way to fix the sacrum/pelvis. I believe the most common technique is a combination of S1 and iliac screws. However, some favor S2 alar screws and some favor the S2 iliac technique. Most surgeons try to limit the amount of anterior surgery performed. Thoracoabdominal approaches are not performed as frequently. More commonly anterior surgery is either limited to the lower lumbar spine through a paramedian-type approach or transforaminal lumbar interbody fusion (TLIF) approach or potentially no interbody support. Iliac crest is not currently harvested as often as 10 years ago. This has been limited in part to save the ilium for fixation and in part to reduce morbidity with the surgery. Biologics have been utilized, although the extent in terms of volume and quantity of biologics is quite variable from center to center.

Limitations of past techniques:

There are few studies that have attempted to assess problems and nonunion rates 10 years ago. On balance, those studies suggested the nonunion rate was between 25 and 30%. It is clear that if the implants fail and a nonunion presents, the majority of these patients become symptomatic and, if medically able, should have revision surgery.

Although it has not been widely published in peer-reviewed journals, there is common knowledge and one excellent podium presentation several years ago that brought forth the morbidity associated with thoracoabdominal approaches. Many of the younger and physically fit patients tolerate this approach without any problems, but many middle age and older patients develop an abdominal chest bulge, which is often misinterpreted as a hernia. It is not a hernia per se, it is a pseudohernia related to the muscle not healing very well and potentially a component of denervation. Therein, surgeons do not currently perform thoracoabdominal approaches as often. DLIF and XLIF type approaches have been considered.

Limitations and benefits of current techniques:

Today most surgeons use a higher implant density, meaning the number of fixation points per level. Screws can accomplish this more readily than hooks. Therein, the current standard is to have an implant density of 1.8 to 2 fixation points per segment. Pedicle screws take up less of the surface area than hooks and this seems to improve nonunion rates.

The utilization of biologics has also improved the nonunion rate. A few comparative studies have suggested the nonunion rate 10 years ago was 30% and is currently 5%. This may be somewhat related to the use of biologics. If the biologics utilized is <5mg/level, the nonunion rate is still substantial, but if >5mg/level is utilized, it seems to be substantially reduced. There are many factors playing into why the nonunion rate is lower now. Not just the implant density, but the fact that pedicle screws do not cover the facet joints allows for a better decortication and placement of bone graft products. We still really have no idea if freeze dried or fresh frozen allograft works, helps or benefits at all to achieve a solid fusion. Allograft bone may represent a reasonable bulking agent, but perhaps not. See thse tables comparing outcomes now vs. 10 years ago:

Comparison of Preop to Postop SRS and ODI Scores And Changes in The Two Groups

	Preoperative			Final[3]		
SRS Domain	Circa 2012[1]	Circa 2002[2]	P-value*	Circa 2012[1]	Circa 2002[2]	P-value*
No.	19	13		19	13	
Function	3.1 ± 0.9	3.6 ± 0.8	0.1	3.6 ± 0.6	3.9 ± 0.4	0.27
Appearance	2.6 ± 0.8	2.9 ± 0.8	0.29	4.4 ± 0.5	3.6 ± 0.7	0.001
Mental Health	3.8 ± 0.9	N/A	N/A	4.4 ± 0.5	3.9 ± 0.7	0.03
Pain	2.7 ± 0.8	3.2 ± 1.0	0.18	3.7 ± 0.9	4.0 ± 1.1	0.17
Satisfaction	2.7 ± 1.3	N/A	N/A	4.6 ± 0.6	4.6 ± 0.4	0.49
ODI						
No.	19	12		19	12	
	37.7 ± 18.9	29.7 ± 13.8	0.46	20.4 ± 13.5	12.8 ± 9.9	0.1

1-SRS-30 outcome scores
2-SRS-24 preoperative and SRS-30 for postoperative outcome scores
3-SRS and ODI scores were at final follow-up in all patients, and after pseudarthrosis repairs in the 6 pseudarthrosis patients.
*Independent Samples Mann-Whitney U-test

Zebala LP et al. rhBMP-2 and modern surgical techniques significantly reduce the pseudarthrosis rate in long fusions to the sacrum for complex adult spinal deformity. Presented at IMAST 2011, Copenhagen, Denmark.

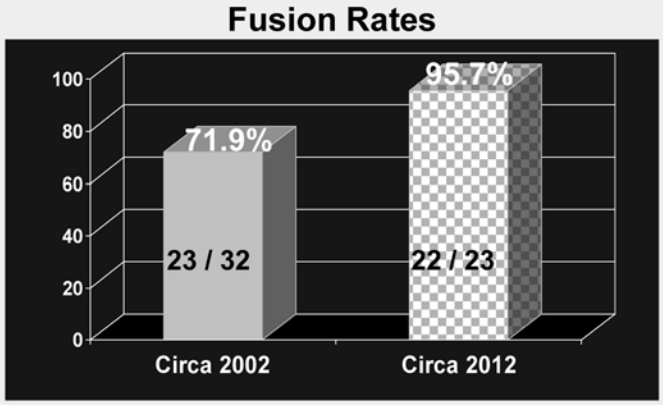
Change in SRS and ODI Scores in The Two Groups

	Change		
SRS Domain	Cica 2012[1]	Circa 2002[2]	P-value*
No.	19	13	
Function	0.56 ± 0.73	0.3 ± 0.72	0.47
Appearance	1.8 ± 0.77	0.72 ± 0.84	0.002
Mental Health	0.51 ± 0.76	N/A	N/A
Pain	0.71 ± 1.25	0.83 ± 1.4	0.79
Satisfaction	1.9 ± 1.49	N/A	N/A
ODI			
No.	19	12	
	-15.3 ± 16.5	-16.9 ± 15.7	0.89

1-SRS-30 outcome scores
2-SRS-24 preoperative and SRS-30 for postoperative outcome scores
3-SRS and ODI scores were at final follow-up in all patients, and after pseudarthrosis repairs in the 6 pseudarthrosis patients.
*Independent Samples Mann-Whitney U-test

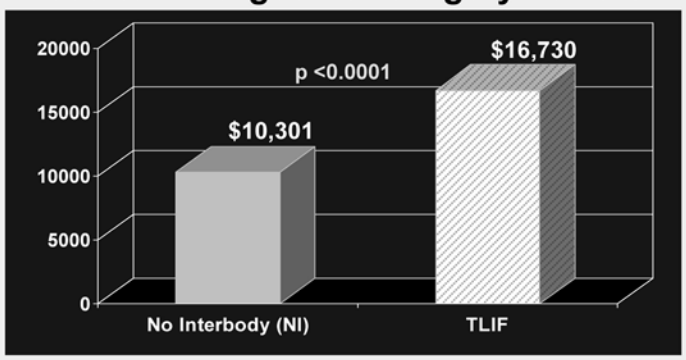
Zebala LP et al. rhBMP-2 and modern surgical techniques significantly reduce the pseudarthrosis rate in long fusions to the sacrum for complex adult spinal deformity. Presented at IMAST 2011, Copenhagen, Denmark.

Maeda T, Buchowski JM, Kim YJ, Mishiro T, Bridwell KH. Long adult spinal deformity fusion to the sacrum using rhBMP-2 *versus* autogenous iliac crest bone graft. Spine 2009;34(20):2205-2212



p = 0.057 (by chi-square test with Yates compensation)

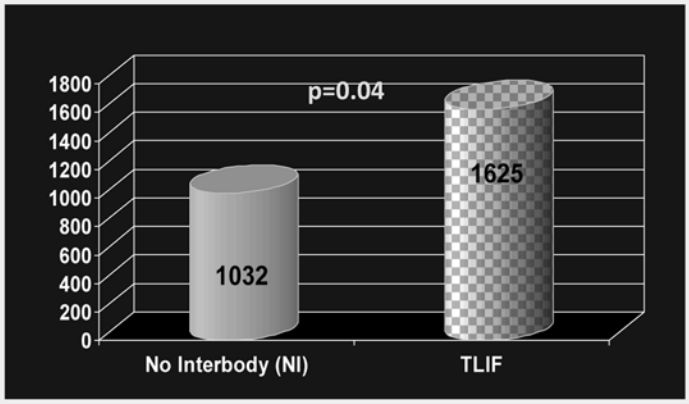
Results: Charges For Surgery At L5-S1



NI = $10,301 (20mg BMP: Large + Medium Kit)
TLIF = $16,730 (Cage, Large BMP, Surgeon Fee, OR)

Rahman RK, Bridwell KH, et al. Are TLIFs necessary for L5-S1 arthrodesis in long constructs to the sacrum/pelvis in primary adult deformity patients? Paper #26 presented at the SRS46th annual meeting, Louisville, KY, September 14-17, 2011

EBL: Excluding Pontes



Rahman RK, Bridwell KH, et al. Are TLIFs necessary for L5-S1 arthrodesis in long constructs to the sacrum/pelvis in primary adult deformity patients? Paper #26 presented at the SRS46th annual meeting, Louisville, KY, September 14-17, 2011

Many past studies have suggested the two regions of the spine most amenable to failure and nonunion are the thoracolumbar junction and L5-S1. Therein, many surgeons prefer interbody and circumferential fusion at L4-L5 and L5-S1. This may take some of the stress off the sacral screws, but it's clear that iliac fixation protects the sacral screws more than interbody fusion and interbody fusion per se does not protect the sacral screws adequately. Whether there is really a difference between an ALIF vs. a TLIF approach at L4-L5 and L5-S1 is not clear. There is some early suggestion that concentrating the bone graft products at L4-L5 and L5-S1 may obviate the need for interbody fixation and fusion. See data:

Other considerations and options:

The other movement that has gained steam lately is that of minimally invasive fixation, in which the fusion in the lumbar spine is accomplished through a combination of XLIF/DLIF down to L4 and an AxiLIF at either L4-L5 and L5-S1 or L5-S1. There is some suggestion that the AxiLIF may be stable enough biomechanically that it is as good as iliac screws, but this is not widely accepted. There are risks associated with those approaches. We know an XLIF/DLIF approach to L3-L4 and L4-L5 runs the risk of injuring the vena cava and L4 nerve root. We know an AxiLIF approach at L5-S1 runs the risk of injuring the peritoneal contents. It appears the XLIF/DLIF approach provides good anterior fusion when utilized with biologics, based on CT scan studies, but it is not really known if facet fusions done posteriorly through a minimally invasive approach provide a fusion or not.

Outcomes:

It is very hard to compare patient-reported QOLs today vs. 10 years ago. The most sensitive instrument is clearly the SRS-22/29/30 and not the Oswestry. This instrument was not universally applied to patients 10 years ago as it is now. It is very hard to tell if changes/improvement in responses to these standardized validated outcomes instruments are better now. There is a general belief that the complications associated with long fusion to the sacrum and pelvis are substantially less now than 10 years ago, but this has been very hard to qualify and quantitate.

References

1. Bradford DS, Tay BK-B, Hu SS. Adult scoliosis: surgical indications, operative management, complications and outcomes. Spine 1999;24:2617-2629.
2. Charosky S, Guigui P, Blamoutier A, Roussouly P, Chopin D, Suidy Group on Scoliosis. Complications and risk factors of primary adult scoliosis surgery: a multicenter study of 306 patients. Spine Deformity 2012;37(8):793-700.
3. Cunningham BW, Lewis SJ, Long J, Dmitriev AE, Linville DA, Bridwell KH. Biomechanical evaluation of lumbosacral reconstruction techniques for spondylo-listhesis: An in vitro porcine model. Spine 2002;27(21):2321-2327
4. Dekutoski MB, Cohen M, Schendel MJ, Transfeldt EE, Wood KB, Ogilvie JW: Fusion to the sacrum in adult idiopathic scoliosis: The role of sagittal balance. Orthop Trans 1993/1994;17(1):125
5. Edwards C, Bridwell K, Patel A, Rinella A, Della Rocca G, Berra A, Lenke L: Thoracolumbar deformity arthrodesis to L5 in adults: The fate of the L5-S1 disc. Spine 2003;28(18):2122-2131
6. Enami A, Deviren V, Berven S, Smith JA, Hu SS, Bradford DS. Outcome and complications of long fusions to the sacrum in adult spinal deformity. Spine 2002;27:776-686.
7. Horton WC, Bridwell KH, Glassman SD, Hu SS, Berven SH, Schwab FJ, Kostuik JP, Neuwirth MG. The morbidity of anterior exposure for spinal deformity in adults: an analysis of patient-based outcomes and complications in 112 consecutive cases. Paper #32 presented at the Scoliosis Research Society 40th Annual meeting, Miami, FL, October 27-30, 2005.
8. Kim HJ, Buchowski JM, Zebala LP, Dickson DD, Koester L, Bridwell KH. RhBMP-2 is superior to iliac crest bone graft for long construct sacropelvic fusions in adult spinal deformity: 4-14 year follow-up. Paper #48 presented at the 18th International Meeting on Advanced Spine Techniques (IMAST), Copenhagen, Denmark, July 13-16, 2011
9. Kim YJ, Bridwell KH, Lenke LG, Cho K, Edwards II C, Rinella AS: Pseudarthrosis in adult spinal deformity following multisegmental instrumentation and arthrodesis. J Bone Joint Surg 2006;88(4):721-728
10. Kuhns CA, Bridwell KH, Lenke LG, Amor CJ, Lehman Jr RA, Buchowski JM, Edwards CC: Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc with a minimum 5-year follow-up. Spine 2007;32 (24):2771-2776
11. McCord DH, Cunningham BW, Shono Y, Myers JJ, McAfee PC. Biomechanical analysis of lumbosacral fixation. Spine 1992;17(8S):S235-243
12. O'Shaughnessy BA, Bridwell KH, Cho W, Baldus C, Chang MS, Auerbach JD, Crawford CH. Does a long fusion "T3-sacrum" portend a worse outcome than a short fusion "T10-sacrum" in primary adult scoliosis surgery? Spine 2012;37(10):884-890
13. O'Shaughnessy BA, Lenke LG, Bridwell KH, Cho W, Zebala LP, Chang MS, Auerbach JD, Crawford CH, Koester LA. Should symptomatic iliac screws be electively removed in adult spinal deformity patients fused to the sacrum? Spine 2012;37(13):1-7
14. Rahman RK, Bridwell KH, Lenke LG, Stephens B, Dorward IG, Koester L. Are TLIFs necessary for L5-S1 arthrodesis in long constructs to the sacrum/pelvis in primary adult deformity patients? Paper #26 presented at the Scoliosis Research Society 46th annual meeting, Louisville, KY, September 14-17, 2011
15. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C. Minimum 5-year analysis of L5-S1 fusion using sacropelvic fixation (bilateral S1 and iliac screws) for spinal deformity. Spine 2006;31(3):303-308
16. Zebala LP, Buchowski JM, Bridwell KH, Cho SK, Payhs JM, Kang MM, Cho W. rhBMP-2 and modern surgical techniques significantly reduce the pseudarthrosis rate in long fusions to the sacrum for complex adult spinal deformity. Paper #47 presented at the 18th International Meeting on Advanced Spine Techniques (IMAST), Copenhagen, Denmark, July 13-16, 2011
17. Zimmerman RM, Mohamed AS, Skolasky RL, Robinson MD, Kebaish KM. Functional outcomes and complications after primary spinal surgery for scoliosis in adults aged forty years or older. Spine 2010;35(20):1861-1866

Notes

BONE GRAFT SUBSTITUTES
BMP – OFF LABEL USE INTERBODY DOSE EFFECTIVENESS, COMPLICATIONS UPDATE 2012

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Purpose:

- To define the ADVERSE EVENTS associated w BMP
- What are the Types of AE's?
- What is the Incidence of AE's?
- Is there a definable dose-response relationship?

1) WHY: Iliac Crest Donor Site Morbidity
   - Level I -Dimar JBJS 2009 PRCT
     - Post Lumbar- 461 Pts
     - 24mon FU - 60% Donor Site Pain
   - Level I – Burkus JBJS 2005 PRCT
     - ALIF 131 Pts
     - 24M -47% Donor Site Pain
   - Level II Sasso JSD 2005 PRCT ALIF
     - 24 M FU 31% Donor Site Pain

   Why Use BMP: Fusion Rate
   - Level I – Burkus JBJS 2005 PRCT
     - ALIF 131 Pts
     - 24 Mon. Fusion 99% BMP v 76%
   - Level I -Dimar JBJS 2009 PRCT
     - InSitu Post Lumbar- 461 Pts 24 Mon.
     - Fusion Rate 96% BMP2 v 89% (p=0.14)
   - Level II - Dawson JBJS 2009 PRCT
     - Inst.Post Lumbar – 40 Pts – 24 Mon.
     - Fusion 95% BMP vs 70% ICBG

- Level II Singh JSD 2006
  - InSitu Post Lumbar 70 Pts
  - Fusion 97% BMP v 77% ICBG

Why Use BMP:

Clinical Outcome Back Pain

- Level I – Burkus JBJS 2005 PRCT
  - ALIF 131 Pts
  - 24 Mon. Back, Leg Scores SF-36 p= 0.015
- Level I -Dimar JBJS 2009 PRCT
  - InSitu Post Lumbar- 461 Pts 24 Mon.

BMP vs Autograft: PosteroLateral Fusion Operative Time, Blood Loss, Hospital Time

ODI Posterolateral Arthrodesis: BMP2 vs Autograft

Meta Analysis PLat Fusion ICBG vs BMP 2 & 7

- 7 RCT, I PC- 383 Pts
- BMP-2 Efficacious Fusion
  - RR=0.42 95%CI p=0.00001
- BMP7 Equivalent to ICBG
- Hosp Stay Shorter BMP by 1.03days
  - 95%CI 0.61-1.45
- Operative Time BMP Shorter p=0.00001

2) Complications of Osteobiologics

Osteolysis – Lumbar Spine

The most common complication

- 7 Studies

Reported rates <u>vary widely</u>, 0-100%

- No Standard for Diagnosis
- Studies lack uniformity
  - Various types of procedures
  - Various doses
  - Various types of cages
  - Inconsistent reporting of results

Subsidence and Graft Migration with BMP

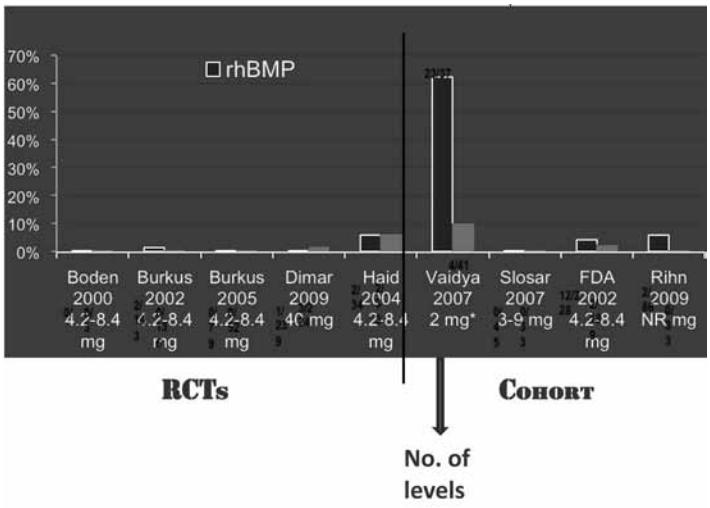
- 5 Studies -

The 2nd Most Common Complications

Reported Osteolysis by BMP Dose for RCTS and Cohort Studies

Osteolysis, Subsidence, Migration

- All exist to varying degrees
- Literature is inconclusive:
  - Study heterogeneity
  - Relationship to dose and regional placement of BMP?
  - Clinical management?
  - Radiographic outcome?
  - Clinical outcome?



Ectopic Bone Formation with BMP

- 13 Studies –

The 3rd Most Common Complication

- Haid 2004 PLIF 4-8 mg BMP-2 / level
  - 75%, if within 2mm from canal (P<0.0001)
  - No clinical effect
  - Joseph 2007 PLIF / TLIF 4.2 mg BMP-2 / level
  - 21%
  - No clinical effect
  - Miesel 2008 PLIF 12 mg BMP-2 / level
  - 6%
  - No clinical effect

3) Cancer Risk???

Two year incidence of cancer following lumbar fusion using a higher and a lower dose of rhBMP-2 in two randomized controlled trials – NSD 8 v 2

- Patient Safety

Bibliography

Hsu, W.K., Wang, J.C.: The use of bone morphogenetic protein in spine fusion. Spine J, 8: 419, 2008

Boden, S.D., Zdeblick, T.A., Sandhu, H.S. et al.: The use of rhBMP-2 in interbody fusion cages. Definitive evidence of osteoinduction in humans: a preliminary report. Spine, 25: 376, 2000

Burkus, J.K., Gornet, M.F., Dickman, C.A. et al.: Anterior lumbar interbody fusion using rhBMP-2 with tapered interbody cages. J Spinal Disord Tech, 15: 337, 2002

U.S. Food and Drug Administration: InFUSE Bone Graft/LT-CAGE Lumbar Tapered Fusion Devices: Approval Letter, vol. 2009, 2002

Ebara, S., Nakayama, K.: Mechanism for the action of bone morphogenetic proteins and regulation of their activity. Spine, 27: S10, 2002

U.S. Food and Drug Administration: InFUSE Bone Graft/LT-CAGE Lumbar Tapered Fusion Devices: Summary of Safety and Effectiveness, vol. 2009, 2002

Papakostidis, C., Kontakis, G., Bhandari, M. et al.: Efficacy of autologous iliac crest bone graft and bone morphogenetic proteins for posterolateral fusion of lumbar spine: a meta-analysis of the results. Spine, 33: E680, 2008

Wright, J.G., Swiontkowski, M.F., Heckman, J.D.: Introducing levels of evidence to the journal. J Bone Joint Surg Am, 85-A: 1, 2003

van Tulder, M., Furlan, A., Bombardier, C. et al.: Updated method guidelines for systematic reviews in the cochrane collaboration back review group. Spine, 28: 1290, 2003

West, S., King V, Carey TS, et.al.: Systems to Rate the Strength of Scientific Evidence. Evidence Report/Technology Assessment No. 47 (Prepared by the Research Triangle Institute-University of North Carolina Evidence-based Practice Center, Contract No. 290-97-0011): Agency for Healthcare Research and Quality, Rockville, MD, 2002

Benglis, D., Wang, M.Y., Levi, A.D.: A comprehensive review of the safety profile of bone morphogenetic protein in spine surgery. Neurosurgery, 62: ONS423, 2008

Haid, R.W., Jr., Branch, C.L., Jr., Alexander, J.T. et al.: Posterior lumbar interbody fusion using recombinant human bone morphogenetic protein type 2 with cylindrical interbody cages. Spine J, 4: 527, 2004

Joseph, V., Rampersaud, Y.R.: Heterotopic bone formation with the use of rhBMP2 in posterior minimal access interbody fusion: a CT analysis. Spine, 32: 2885, 2007

Meisel, H. J., Schnoring, M., Hohaus, C. et al.: Posterior lumbar interbody fusion using rhBMP-2. Eur Spine J, 17: 1735, 2008

Kanayama, M., Hashimoto, T., Shigenobu, K. et al.: A prospective randomized study of posterolateral lumbar fusion using osteogenic protein-1 (OP-1) versus local autograft with ceramic bone substitute: emphasis of surgical exploration and histologic assessment. Spine, 31: 1067, 2006

Burkus, J.K., Sandhu, H.S., Gornet, M.F.: Influence of rhBMP-2 on the healing patterns associated with allograft interbody constructs in comparison with autograft. Spine, 31: 775, 2006

Burkus, J.K., Dorchak, J.D., Sanders, D.L.: Radiographic assessment of interbody fusion using recombinant human bone morphogenetic protein type 2. Spine, 28: 372, 2003

Mummaneni, P.V., Pan, J., Haid, R.W. et al.: Contribution of recombinant human bone morphogenetic protein-2 to the rapid creation of interbody fusion when used in transforaminal lumbar interbody fusion: a preliminary report. Invited submission from the Joint Section Meeting on Disorders of the Spine and Peripheral Nerves, March 2004. J Neurosurg Spine, 1: 19, 2004

Singh, K., Smucker, J.D., Gill, S. et al.: Use of recombinant human bone morphogenetic protein-2 as an adjunct in posterolateral lumbar spine fusion: a prospective CT-scan analysis at one and two years. J Spinal Disord Tech, 19: 416, 2006

Slosar, P.J., Josey, R., Reynolds, J.: Accelerating lumbar fusions by combining rhBMP-2 with allograft bone: a prospective analysis of interbody fusion rates and clinical outcomes. Spine J, 7: 301, 2007

Villavicencio, A.T., Burneikiene, S., Nelson, E.L. et al.: Safety of transforaminal lumbar interbody fusion and intervertebral recombinant human bone morphogenetic protein-2. J Neurosurg Spine, 3: 436, 2005

Furlan, J.C., Perrin, R.G., Govender, P.V. et al.: Use of osteogenic protein-1 in patients at high risk for spinal pseudarthrosis: a prospective cohort study assessing safety, health-related quality of life, and radiographic fusion. Invited submission from the Joint Section on Disorders of the Spine and Peripheral Nerves, March 2007. J Neurosurg Spine, 7: 486, 2007

Vaccaro, A.R., Whang, P.G., Patel, T. et al.: The safety and efficacy of OP-1 (rhBMP-7) as a replacement for iliac crest autograft for posterolateral lumbar arthrodesis: minimum 4-year follow-up of a pilot study. Spine J, 8: 457, 2008

Vaccaro, A.R., Patel, T., Fischgrund, J. et al.: A pilot safety and efficacy study of OP-1 putty (rhBMP-7) as an adjunct to iliac crest autograft in posterolateral lumbar fusions. Eur Spine J, 12: 495, 2003

McKay, B., Sandhu, H.S.: Use of recombinant human bone morphogenetic protein-2 in spinal fusion applications. Spine, 27: S66, 2002

McClellan, J.W., Mulconrey, D.S., Forbes, R.J. et al.: Vertebral bone resorption after transforaminal lumbar interbody fusion with bone morphogenetic protein (rhBMP-2). J Spinal Disord Tech, 19: 483, 2006

Pradhan, B.B., Bae, H.W., Dawson, E.G. et al.: Graft resorption with the use of bone morphogenetic protein: lessons from anterior lumbar interbody fusion using femoral ring allografts and recombinant human bone morphogenetic protein-2. Spine, 31: E277, 2006

Vaidya, R., Sethi, A., Bartol, S. et al.: Complications in the use of rhBMP-2 in PEEK cages for interbody spinal fusions. J Spinal Disord Tech, 21: 557, 2008

Vaidya, R., Weir, R., Sethi, A. et al.: Interbody fusion with allograft and rhBMP-2 leads to consistent fusion but early subsidence. J Bone Joint Surg Br, 89: 342, 2007

Boden, S.D., Kang, J., Sandhu, H. et al.: Use of recombinant human bone morphogenetic protein-2 to achieve posterolateral lumbar spine fusion in humans: a prospective, randomized clinical pilot trial: 2002 Volvo Award in clinical studies. Spine, 27: 2662, 2002

Luhmann, S.J., Bridwell, K.H., Cheng, I. et al.: Use of bone morphogenetic protein-2 for adult spinal deformity. Spine, 30: S110, 2005

Vaccaro, A.R., Lawrence, J.P., Patel, T. et al.: The safety and efficacy of OP-1 (rhBMP-7) as a replacement for iliac crest autograft in posterolateral lumbar arthrodesis: a long-term (>4 years) pivotal study. Spine, 33: 2850, 2008

Buttermann, G.R.: Prospective nonrandomized comparison of an allograft with bone morphogenic protein versus an iliac-crest autograft in anterior cervical discectomy and fusion. Spine J, 8: 426, 2008

Shields, L.B., Raque, G.H., Glassman, S.D. et al.: Adverse effects associated with high-dose recombinant human bone morphogenetic protein-2 use in anterior cervical spine fusion. Spine, 31: 542, 2006

Smucker, J.D., Rhee, J.M., Singh, K. et al.: Increased swelling complications associated with off-label usage of rhBMP-2 in the anterior cervical spine. Spine, 31: 2813, 2006

Tumialan, L.M., Pan, J., Rodts, G.E. et al.: The safety and efficacy of anterior cervical discectomy and fusion with polyetheretherketone spacer and recombinant human bone morphogenetic protein-2: a review of 200 patients. J Neurosurg Spine, 8: 529, 2008

Vaidya, R., Carp, J., Sethi, A. et al.: Complications of anterior cervical discectomy and fusion using recombinant human bone morphogenetic protein-2. Eur Spine J, 16: 1257, 2007

Baskin, D.S., Ryan, P., Sonntag, V. et al.: A prospective, randomized, controlled cervical fusion study using recombinant human bone morphogenetic protein-2 with the CORNERSTONE-SR allograft ring and the ATLANTIS anterior cervical plate. Spine, 28: 1219, 2003

Boakye, M., Mummaneni, P.V., Garrett, M. et al.: Anterior cervical discectomy and fusion involving a polyetheretherketone spacer and bone morphogenetic protein. J Neurosurg Spine, 2: 521, 2005

Rasmussen, P.A., Trost, G.R., Tribus, C.: Use of bone as an interbody fusion device. Techniques in Neurosurgery, 7: 110, 2001

U.S. Food and Drug Administration: FDA Public Health Notification: Life-threatening complications associated with recombinant human bone morphogenetic protein in cervical spine fusion, vol. 2009, 2008

Lewandrowski, K.U., Nanson, C., Calderon, R.: Vertebral osteolysis after posterior interbody lumbar fusion with recombinant human bone morphogenetic protein 2: a report of five cases. Spine J, 7: 609, 2007

Laursen, M., Hoy, K., Hansen, E.S. et al.: Recombinant bone morphogenetic protein-7 as an intracorporal bone growth stimulator in unstable thoracolumbar burst fractures in humans: preliminary results. Eur Spine J, 8: 485, 1999

Wong, D.A., Kumar, A., Jatana, S. et al.: Neurologic impairment from ectopic bone in the lumbar canal: a potential complication of off-label PLIF/TLIF use of bone morphogenetic protein-2 (BMP-2). Spine J, 8: 1011, 2008

Brower, R.S., Vickroy, N.M.: A case of psoas ossification from the use of BMP-2 for posterolateral fusion at L4-L5. Spine, 33: E653, 2008

Perri, B., Cooper, M., Lauryssen, C. et al.: Adverse swelling associated with use of rh-BMP-2 in anterior cervical discectomy and fusion: a case study. Spine J, 7: 235, 2007

Notes

WHAT ARE THE CURRENT BLOOD REPLACEMENT STRATEGIES IN 2012: WHAT IS THE ROLE OF BLOOD AUTO-DONATION, CELL SAVER AND PHARMACOLOGICAL BLOOD LOSS TECHNIQUES?

Charles H. Crawford, MD
Norton Leatherman Spine Center
Louisville, Kentucky, USA

I. General Concepts
   a. Anticipating Blood Loss (surgeon/institution variability)
      1. Adolescent Idiopathic Scoliosis
      2. Neuromuscular Scoliosis
      3. Pediatric Vertebral Column Resection
      4. Adult Deformity PSF/PSSI T10-Pelvis
      5. Adult Deformity PSF/PSSI T3-Pelvis
      6. Adult Pedicle Subtraction Osteotomy
   b. Pediatric versus Adult
      1. Percent Blood Volume
         a) Total Blood Volume in Adults (70-90mL/kg) (e.g. 5000mL)
         b) Total Blood Volume in Pediatrics (80-90mL/kg) (e.g. 2500mL)
      2. Risks of Acute Blood Loss Anemia (cardiovascular disease)
      3. Transfusion Recommendations (Hgb <7)
      4. Risks of thrombosis or embolism with anti-fibrinolytics
   c. Pre-operative Optimization
      1. Evaluate and Treat Anemia
         a) Iron Deficiency, etc…
         b) Erythropoetin (consider if pre-op donation)
            (1) Adverse events reported in cancer patients
      2. Evaluate and Treat Coagulopathy
         a) History of bleeding disorder
         Stop aspirin, NSAIDs, Anti-platelets, Coumadin, etc…

II. Pre-Operative Auto-Donation
   a. Benefits/Efficacy
      1. Avoid transfusion risks
   b. Risks/Adverse Events
      2. Start with lower Hgb?
   c. Cost
      3. Includes time and inconvenience

III. Cell Saver
   a. Benefits/Efficacy
      1. Must have enough blood loss to "spin" and return to patient (500cc?)
      2. Risks/Adverse Events
      3. Potential for coagulopathy, etc… but few adverse events reported
   b. Cost
      1. Institutional variability, more if spun for transfusion

IV. Pharmacological Options
   (Aprotinin, Tranexamic Acid, Aminocaproic Acid)
   a. Benefits/Efficacy
      1. Inhibit plasmin-mediated fibrinolysis (anti-fibrinolytics)
      2. Decreases surgical blood loss and transfusion
   b. Risks/Adverse Events
      1. Aprotinin recalled - renal failure, MI, stroke, mortality
      2. Others seem to have better safety record, but not yet proven
   c. Cost

References

1. Sherman CH, MacIvor DC. Blood utilization: fostering an effective transfusion culture. J Clin Anesthesia 2012:24(2).
2. Johnson RG, Murphy M, Miller M. Fusions and tranfusions: An analysis of blood loss and autologous replacement during lumbar fusions. Spine 1989;14:358-362.
3. Sharma S, Sharma P, Tyler LN. Transfusion of blood and blood products: indications and complications. Am Fam Physician. 2011 Mar 15;83(6):719-24.
4. Moran MM, Kroon D, Tredwell SJ et al. The role of autologous blood transfusion in adolescents undergoing spinal surgery. Spine 1995;20:532-536.
5. Murray DJ, Forbes RB, Titone MB, et al. Transfusion management in pediatric and adolescent scoliosis surgery. Spine 1997;22:2735-2740.
6. Bailey TE, Mahoney OM. The use of banked autologous blood in patients undergoing surgery for spinal deformity. J Bone Joint Surg Am 1987;69:329-332.
7. Goodnough LT, Marcus RE. Effect of autologous blood donation in patients undergoing elective spine surgery. Spine 1992;17:172-175.
8. Cha CW, Deible C, Muzzonigro T, et al. Allogeneic transfusion requirements after autologous donations in posterior lumbar surgeries. Spine 2002;27: 99-104.
9. Gause PR, Siska PA, Westrick ER, et al. Efficacy of intraoperative cell saver in decreasing postoperative blood transfusions in instrumented posterior lumbar fusion patients. Spine 2008;33: 571-575.
10. Siller TA, Dickson JH, Erwin WD. Efficacy and cost considerations in intraoperative autologous transfusion in spinal fusion for idiopathic scoliosis with predeposited blood. Spine 1996;21:848-852.
11. Bowen RE, Gardner S, Scaduto AA, et al. Efficacy of intraoperative cell salvage systems in pediatric idiopathic scoliosis patients undergoing posterior spinal fusion with segmental spinal instrumentation. Spine 2010;35:246-251.
12. Behrman MJ and Keim HA. Perioperative red blood cell salvage in spine surgery: A prospective analysis. ClinOrthopRelat Res 1992;278:51-57.
13. Reitman CA, Watters WC, and Sassard WR. The cell saver in adult lumbar fusion surgery: A cost-benefit outcomes study. Spine 2004;29:1580-1584.
14. Keverline JP and Sanders JO. Hematuria associated with low-volume cell saver in pediatric orthopaedics. J PediatrOrthop 1998;18:594-597.

15. Halpern NA, Alicea M, Seabrook B, et al. Cell saver autologous transfusion: Metabolic consequences of washing blood with normal saline. J Trauma 1996;41:407-415.
16. Long TR, Stans AA, Shaughnessy WJ, Joyner MJ, Schroeder DR, Wass CT. Changes in red blood cell transfusion practice during the past quarter century: a retrospective analysis of pediatric patients undergoing elective scoliosis surgery using the Mayo database. Spine J 2012 May 5 [Epub]
17. Levy JH. Pharmacologic methods to reduce perioperative bleeding. Transfusion 2008 Mar;48(1 Suppl):31S-38S.
18. Elgafy H, Brandsford RJ, McGuire RA, Dettori JR, Fischer D. Blood loss in major spine surgery: are there effective measures to decrease massive hemorrhage in major spine fusion surgery? Spine (Phila Pa 1976) 2010 Apr 20;35(9 Suppl):S47-56.
19. Savvidou C, Chatziioannou SN, Pilichou A, Pneumaticos SG. Efficacy and cost-effectiveness of cell saving blood autotransfusion in adult lumbar fusion. Transfus Med 2009 Aug;19(4):202-6.
20. Chanda A, Smith DR, Nanda A. Autotransfusion by cell saver technique in surgery of lumbar and thoracic spinal fusion with instrumentation. J Neurosurg 2002 Apr;96(3 Suppl):298-303.
21. Thompson GH, Florentino-Pineda I, Poe-Kochert C, Armstrong DG, Son-Hing JP. The role of Amicar in same-day anterior and posterior spinal fusion for idiopathic scoliosis. Spine (Phila Pa 1976) 2008 Sep 15;33(20):2237-42.
22. Thompson GH, Florentino-Pineda I, Poe-Kochert C. The role of amicar in decreasing perioperative blood loss in idiopathic scoliosis. Spine (Phila Pa 1976) 2005 Spe 1;30(17 Suppl):S94-9.
23. Florentino-Pineda I, Thompson GH, Poe-Kochert C, Huang RP, Haber LL, Blakemore LC. The effect of amicar on perioperative blood loss in idiopathic scoliosis: the results of a prospective, randomized double-blind study. Spine (Phila Pa 1976) 2004 Feb 1;29(3):233-8.
24. Verma K, Errico TJ, Vaz KM, Lonner BS. A prospective, randomized, double-blind single-site control study comparing blood loss prevention of tranexamic acid (TXA) to epsilon aminocaproic acid (EACA) for corrective spinal surgery. BMC Surg 2010 Apr 6;10:13.
25. Weiss JM, Skaggs D, Tanner J, Tolo V. Cell Saver: is it beneficial in scoliosis surgery? J Child Orthop 2007 Oct;1(4):221-7.
26. Baldus CR, Bridwell KH, Lenke LG, Okubadejo GO. Can we safely reduce blood loss during pedicle subtraction osteotomy procedures using tranexamic acid or aprotinin? A comparative study with controls. Spine (Phila Pa 1976) 2010 Jan 15;35(2):235-9.
27. Ker K, Edwards P, Perel P, Shakur H, Roberts I. Effect of tranexamic acid on surgical bleeding: systematic review and cumulative meta-analysis. BMJ 2012 May 17;344:e3054.
28. Eubanks JD. Antifibrinolytics in major orthopaedic surgery. J Am Acad Orthop Surg 2010 Mar;18(3):132-8.
29. Gill JB, Chin Y, Levin A, Feng D. The use of antifibrinolytic agents in spine surgery. A meta-anaylsis. J Bone Joint Surg Am 2008 nov;90(11):2399-407.
30. Tzortzopoulou A, Cepeda MS, Schumann R, Carr DB. Antifibrinolytic agents for reducing blood loss in scoliosis surgery in children. Cochrane Database Syst Rev 2008 Jul 16;(3):CD006883.

Notes

ABOUT SRS

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 35 orthopaedic surgeons to an international organization of more than 1,000 health care professionals.

Mission Statement

The purpose of Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

Membership

SRS is open to orthopaedic surgeons, neurosurgeons, researchers and allied health professionals who have a practice that focuses on spinal deformity.

Active Fellowship (membership) requires the applicant to have fulfilled a five-year Candidate Fellowship and have a practice that is 20% or more in spinal deformity. Only Active Fellows may vote and hold elected offices within the Society.

Candidate Fellowship (membership) is open to all orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice which includes at least 20% spinal deformity. Candidate Fellows stay in that category for five years, during which time they must demonstrate their interest in spinal deformity and in the goals of the Scoliosis Research Society. Candidate Fellows may serve on SRS committees. After five years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Candidate Fellowship does not include the right to vote or hold office.

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.

Programs and Activities of the SRS are focused primarily on education and research and include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Regional Conferences, a Global Outreach Program, a Research Endowment 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 Web site Committee works to ensure that the Web site 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 and printable membership applications, please visit the SRS website www.srs.org.

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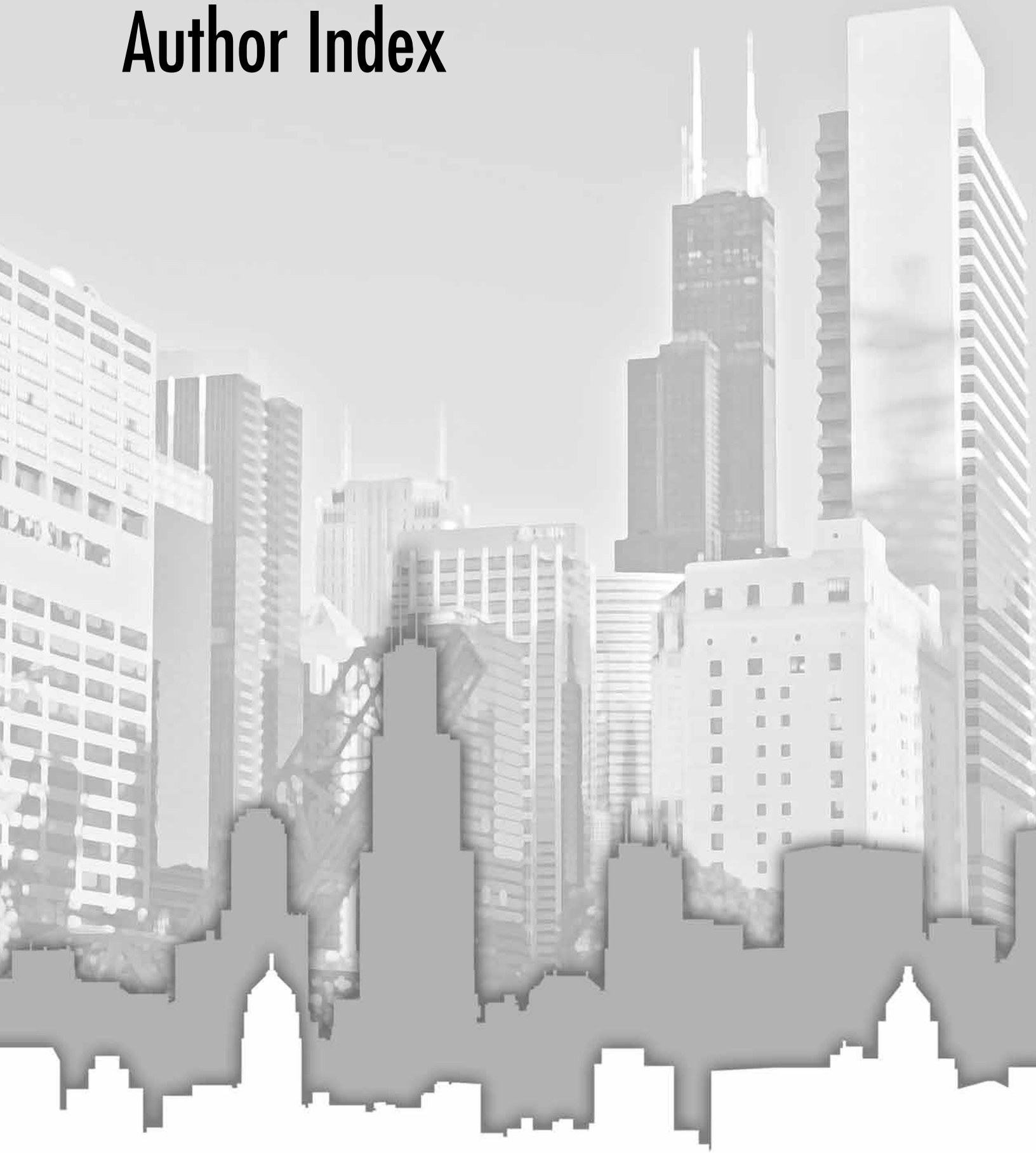

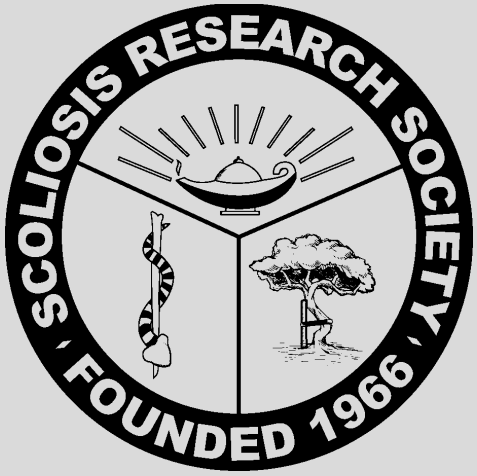
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SAVE THE DATES

Abstract Submission Open
November 1, 2012

Abstract Deadline
February 1, 2013

Registration Open
January 2013

July 10-13, 2013
Vancouver, British Columbia
Canada

IMAST

20th International Meeting on
Advanced Spine Techniques

WWW.SRS.ORG

48th Annual Meeting & Course

Scoliosis Research Society

SEPTEMBER 18–21, 2013

Lyon, France

Abstract Submission Open - November 1, 2012
Abstract Deadline - February 1, 2013
Registration Open - May 2013

47TH ANNUAL MEETING & COURSE

MEETING OUTLINE

Monday, September 3, 2012

7:00am – 5:00pm	Board of Directors Meeting	Columbus Room, Lobby Level

Tuesday, September 4, 2012

7:00am – 5:00pm	SRS Committee Meetings	Ohio, Mississippi, Arkansas, Colorado & Missouri Rooms, Level 2
1:00 – 5:00pm	Hibbs Society Meeting	Michigan Room, Level 2
2:00 – 6:00pm	Poster Set-Up	Sheraton 1-3, Level 4
2:00 – 6:00pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
7:00 – 10:00pm	SRS Leadership Dinner (by invitation only)	University Club of Chicago

Wednesday, September 5, 2012

6:30am – 6:00pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 6:00pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
8:00am – 11:30am	Pre-Meeting Course – Morning Session	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
11:45am – 12:45pm	Lunchtime Symposia:	
	Research Outcomes	Michigan Room, Level 2
	Global Outreach	Chicago 8-10, Level 4
1:00 – 4:10pm	Pre-Meeting Course – Afternoon Session	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
4:30 – 5:45pm	Case Discussions	Ohio, Mississippi, Arkansas, Colorado & Missouri Rooms, Level 2
6:00 – 7:30pm	Opening Ceremonies	Sheraton/Chicago Ballroom, Level 4
7:30 – 9:00pm	Welcome Reception	Sheraton/Chicago Ballroom Promenade, Level 4

Thursday, September 6, 2012

6:30am – 4:30pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 4:30pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast	Sheraton/Chicago Ballroom Promenade, Level 4
7:30 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 12:15pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
12:15 – 1:30pm	Lunch & Networking for Half-Day Course Participants (ticket required for lunch)	Sheraton 1-3, Level 4
1:30 – 4:30pm	Half-Day Courses:	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4;
	Minimally Invasive Surgery	Michigan Room, Level 2
	Infection	
	Sagittal Balance	

Friday, September 7, 2012

6:30am – 5:30pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 5:30pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast	Sheraton/Chicago Ballroom Promenade, Level 4
7:30 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 11:50am	Scientific Program	Sheraton/Chicago Ballroom & Chicago 8-10, Level 4
12:00 – 1:00pm	Lunchtime Symposia:	
	Coding	Chicago 8-10, Level 4
	Non-Operative Management	Michigan Room, Level 2
1:15 – 5:23pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
7:00 – 10:00pm	Farewell Reception	Art Institute of Chicago

Saturday, September 8, 2012

6:30am – 12:45pm	Registration Open	Sheraton/Chicago Ballroom Promenade, Level 4
6:30am – 12:45pm	Internet Kiosks, E-Posters Open	Sheraton 1-3, Level 4
6:30 – 7:45am	Members Business Meeting	Chicago 8-10, Level 4
6:30 – 7:45am	Non-Members Continental Breakfast	Sheraton/Chicago Ballroom Promenade, Level 4
7:00 – 10:00am	Guest Hospitality Suite	Columbus Room, Lobby Level
8:00am – 12:39pm	Scientific Program	Sheraton/Chicago Ballroom, Level 4
12:39pm	Meeting Adjourns	
1:00 – 3:30pm	Board of Directors Meeting	Columbus Room, Lobby Level