50th ANNUAL MEETING & COURSE

September 30–October 3, 2015
MINNEAPOLIS, MINNESOTA, USA

SCOLIOSIS RESEARCH SOCIETY 50th ANNIVERSARY 2015

SCOLIOSIS RESEARCH SOCIETY FOUNDED 1966

Final Program

www.srs.org

Sponsored by the Scoliosis Research Society

Corporate Support

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2014-2015.

Support levels are based on total contributions throughout the year and include the Annual Meeting, IMAST, Courses, Scholarships, and Fellowships and the Research Education Outreach (REO) Fund.

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50th ANNUAL MEETING & COURSE

General Meeting Information

SCOLIOSIS RESEARCH SOCIETY 50th ANNIVERSARY 2015

The Scoliosis Research Society gratefully acknowledges DePuy Synthes for their support of the Pre-Meeting Course, Half-Day Courses, Webcast, Video Archives and overall support of the 50th Annual Meeting & Course.

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Scoliosis Research Society
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meetings@srs.org
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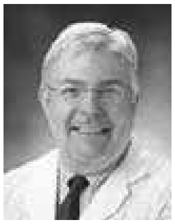
President's Message



Friends & Colleagues:

In 1966 we began this remarkable journey with 37 members, one annual meeting and no non-North American members. Today we have more than 1,250 members, 33 percent from outside of the U.S., representing 54 countries; two large international meetings, the SRS Annual Meeting and IMAST; seven worldwide courses; travelling fellowships; over 60 spine deformity neurosurgeon members and numerous other providers; and hundreds of initiatives spanning education, research and advocacy. This historic 50th anniversary is a reminder of what the SRS has contributed in the past five decades and our ability to impact the future of spinal deformity education, research and treatment.

We are thrilled to have such a large number of attendees join us at this landmark anniversary meeting. In addition to the exceptional educational and scientific programs, we have also planned several special features to highlight this momentous occasion, including the 50th Anniversary Museum, which offers an exploration of the history of SRS and spinal deformity; presentations from SRS living legends, the Society's founders and leaders; and programming throughout the meeting focusing on the history, future and evolution of spinal deformity.

I would also like to express my thanks to our local hosts Joseph H. Perra, MD and Sherry Perra and the other SRS members of the state of Minnesota for welcoming us back to Minneapolis, the host city for both the 1st and 25th Annual Meetings, and showing us how the city has grown and changed through the years.

Once again, the Program and Education Committees have worked hard to present an exceptional program for this milestone meeting. The Pre-Meeting Course day, organized by Education Committee Chair Sigurd H. Berven, MD will examine the past, present, and future of spine deformity in the course *Where Have We Been, Where Are We Now, and What is the Future?* An outstanding group of faculty will examine present day approaches with a look back at the historical basis for this current knowledge.

On Wednesday, September 30 at 4:45pm, following the Pre-Meeting Course, we will once again begin the Annual Meeting with a series of case discussion sessions. This year, there will be a different approach to the standard case discussion session. Each case will pair thought leaders, including father-son and mentor-mentee pairings, to discuss specific cases focusing on the evolution of treatment and understanding of spinal deformity over the years.

Following the case discussions, we invite you to join us for the Opening Ceremonies which will be highlighted by the Howard Steel Lecture. This year the lecture will be devoted to the history and future of SRS, presented by founding members and past presidents David B. Levine, MD; Ronald L. DeWald, MD and past president Vernon T. Tolo, MD. SRS Historian and Past President Behrooz A. Akbarina, MD will moderate what promises to be a memorable highlight of the meeting.

On Thursday we begin the three-day scientific program. Thanks to a tremendous effort by the Program Committee and Program Chair, Ronald A. Lehman, MD, we have an absolutely outstanding program this year. The committee reviewed over 1400 abstracts and the 131 papers selected for this year's meeting represent the cream of the crop. Other highlights of the meeting will include the Harrington Lecture by Dennis R. Wenger, MD and Presentation of Lifetime Achievement Awards to Behrooz A. Akbarnia, MD and Randal R. Betz, MD.

Additional elements of the Educational Program include the Lunchtime Symposia on Wednesday and Friday and three outstanding Half-Day Courses offered on Thursday afternoon. These options include *Making Spinal Deformity Surgery Sustainable*; *Sagittal Alignment- Evaluation and Applications* and *Spondy Smackdown! Head-to-Head Match-Ups on the Controversies in Pediatric Spondylolisthesis*. The *Sagittal Alignment- Evaluation and Applications* afternoon course, chaired by Munish C. Gupta, MD; S. Rajasekaran, MD, FRCS, MCh, PhD and Christopher I. Shaffrey, MD will be broadcasted live over the internet to those who could not join us in Minneapolis.

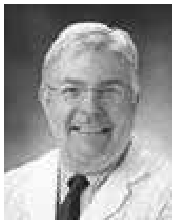
On Friday night, the 50th Annual Meeting & Course will culminate with the Farewell Banquet; a formal plated dinner and a silent and live auction at the former Old Milwaukee Road Railway Depot. The Depot, a Renaissance Revival Style building listed on the National Register of Historic Places will serve as the perfect backdrop for this historic celebration. As a reminder, tickets must be purchased in advance; a limited number of tickets may be available for purchase at the registration counter.

Finally, I would like to thank Tressa Goulding and the SRS staff, a group that has worked tirelessly to make the Society a success this year. I would like to especially thank the members of the Presidential Line, Kenneth M.C. Cheung, MD and Steve D. Glassman, MD for their time and commitment each week to help me achieve my goals as president this year. And particularly, I would like to recognize and congratulate David W. Polly, Jr., MD into whose capable hands I am extremely proud to pass the SRS Presidency.

Thank you for the honor of allowing me to serve as President of the SRS this year.

Sincerely,
John Dormans, MD
Scoliosis Research Society President 2014-2015

Board of Directors - 2014-2015



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Kenneth MC Cheung, MD
Vice President

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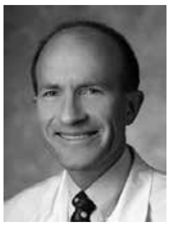

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Annual Meeting Committees

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Fernando Techy, MD
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William Warner, MD
Mark Weidenbaum, MD
Robert Widmann, MD

General Meeting Information

Venue Information

Hilton Minneapolis
1001 Marquette Avenue South
Minneapolis, MN 55403

Abstract Volume

All abstracts accepted for presentation at the 50th Annual Meeting have been published in the Final Program (pages 179-332). 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/meetings/am15/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 time inside the Hilton Minneapolis, 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, October 1 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 Banquet. The Farewell Banquet will take place at The Depot, at an additional $50 fee per ticket for registered delegates and registered guests. If you pre-registered, tickets may be found in your registration packets.

Attire

Business or Business casual (polo or dress shirts, sports coats) is appropriate for meeting sessions and for all Annual Meeting & Course sessions. The Farewell Banquet is black tie optional.

Cell Phone Protocol

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

Emergency & First Aid

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

E-Posters

There are 95 E-Posters available for your review on the E-Poster kiosks in the Rochester Room on Level 3. The E-Posters are also available on the CD-ROM included with your registration materials.

E-Poster CD-ROMs are supported, in part, by a grant from K2M.

Evaluations

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

Guest Hospitality Program

Registered guests of Annual Meeting & Course are welcome to attend the Welcome Reception for the base registration fee on Wednesday, September 30 and the Farewell Banquet on Friday, October 2 for the additional cost of $50.

Registered guests of Annual Meeting & Course are welcome to meet and plan their days over a continental breakfast, courtesy of SRS. The Guest Hospitality Suite is open Thursday, October 1 through Saturday, October 3 from 7:30 – 10:00am in the Gallery Room on the ground level of the Hilton Minneapolis, the headquarter hotels of the Annual Meeting & Course.

Internet Kiosks

Location: Rochester Room, Level 3
Attendees can search the Internet and check email at the Internet kiosks, supported, in part, by a grant from Orthofix and Zimmer Biomet.

Wednesday, September 30	6:30am – 6:00pm
Thursday, October 1	6:30am – 4:30pm
Friday, October 2	6:30am – 5:30pm
Saturday, October 3	6:30am – 12:45pm

Wireless Internet access is available throughout the Hilton Minneapolis, to log on select the Spine2015 network, and enter the password AM15.

Wireless internet is supported, in part, by a grant from Globus Medical.

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: Marquette Ballroom, Level 2

All SRS members are encouraged to attend the Members Business Meetings, held Thursday, October 1 through Saturday, October 3 from 6:30 – 7:45am in the Marquette Ballroom on Level 2 of the Hilton Minneapolis. Agendas will include reports from the various SRS committees, presentations by the 2015 Traveling Fellows recipients, and updates on SRS activities and programs. Breakfast will be served.

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 NuVasive.

General Meeting Information

Non-Members Continental Breakfast

Location: Level 3 Foyer

All non-member delegates to the SRS Annual Meeting are invited to meet with their colleagues and network over coffee and a continental breakfast served Thursday, October 1 through Saturday, October 3 from 6:30 – 7:45am in the Level 3 Foyer at the Hilton Minneapolis.

Photography Policy

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

Registration Desk

Location: Level 3 Foyer

Tuesday, September 29	2:00 – 6:00pm
Wednesday, September 30	6:30am – 6:00pm
Thursday, October 1	6:30am – 4:30pm
Friday, October 2	6:30am – 5:30pm
Saturday, October 3	6:30am – 12:00pm

Smoking Policy

Smoking is not permitted during any meeting activity or event.

Speaker Upload Area

Location: Minneapolis Ballroom, Level 3

Presenters may upload their PowerPoint presentations in the Presentation Upload Area, located at the back of the general session room, Minneapolis Ballroom, Level 3. **Presentations may not be uploaded in individual rooms but must be uploaded in the Presentation Upload Area.**

Wednesday, September 30	6:30am – 6:00pm
Thursday, October 1	6:30am – 4:30pm
Friday, October 2	6:30am – 5:30pm
Saturday, October 3	6:30am – 12:00pm

Special Needs

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

Video Recording Prohibited

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

SRS Annual Meeting & Course Mobile App

A mobile and online app will be available to all delegates during the 50th Annual Meeting & Course. The app is designed to provide all the information about the Annual Meeting & Course and Minneapolis 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/srsam15 or scan the QR code below with your smart phone.

- Download all the abstracts and final program right from the app!
- An offline mode will allow delegates to access all static content, including the agenda, speaker listing and info booth, on the app without an internet connection.
- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule.
- An information booth featuring everything you need to know about the Annual Meeting & Course, and its host city of Minneapolis, including scientific and social program details, information on the Hilton Minneapolis, as well as downtown Minneapolis dining and attractions.
- Live audience polls during the Half-Day Course and a Hibbs Award voting poll on Friday, October 2.
- Maps of the Hilton Minneapolis 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/meetings/am15.

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

http://eventmobi.com/srsam15

CME Information

Meeting Description

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

Learning Objectives

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

- Detect factors which 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.
- Describe new techniques for the treatment of patients with spinal deformity.
- Indentify the short and long-term effect of fusion for patients with spinal deformity using a variety of correction strategies and implants.

Target Audience

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

Accreditation Statement

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

VIDEO ARCHIVES

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

Credit Designation

SRS designates this live activity for a maximum of 27.5 (7.75 for Pre-Meeting Course, 19.75 for Annual Meeting) *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Disclosure of Conflict of Interest

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

FDA Statement (United States)

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

Insurance/Liabilities and Disclaimer

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

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

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

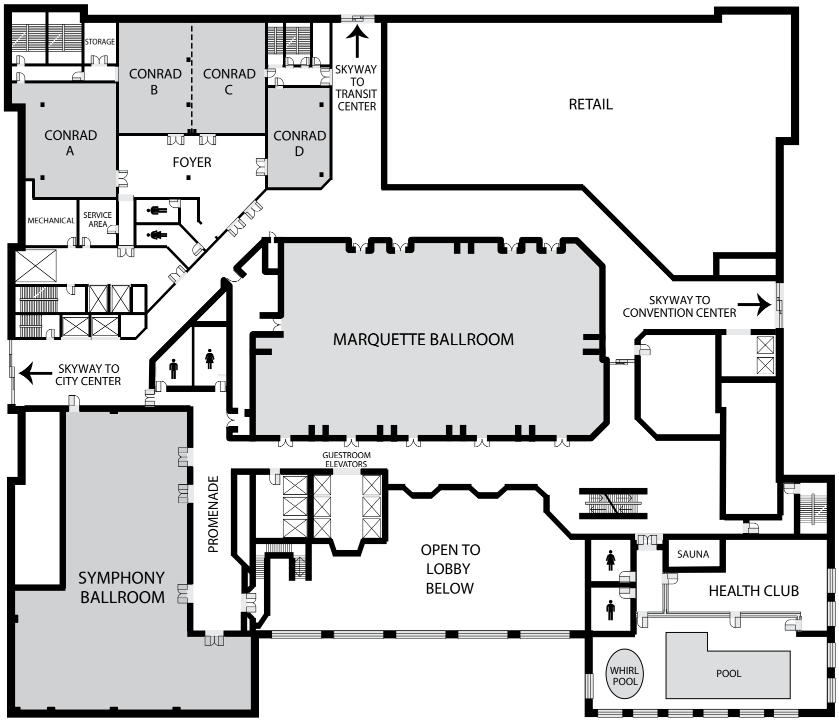
SRS disclaims any and all liability for injury or other damages resulting to any individual attending a scientific meeting and for all claims that may arise out of the use of techniques demonstrated therein by such individuals, whether these claims shall be asserted by a physician or any other person.

Hilton Minneapolis Floorplan

Level 2

Marquette Ballroom
Concurrent Sessions
Case Discussions
Member's Breakfast Meetings

Symphony Ballroom
Concurrent Sessions
Case Discussions
Membership Info Session/New Member Lunch



Level 3

Minneapolis Ballroom
General Session
Pre-Meeting Course
Case Discussions

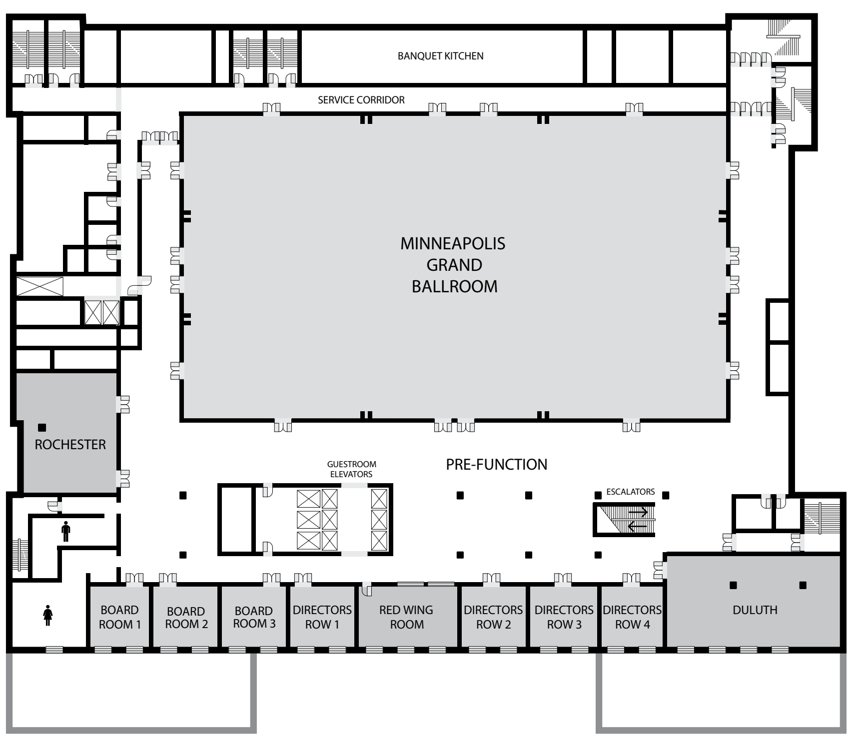
Level 3 Foyer
Registration
SRS Membership Table
Non-Member Breakfast, Breaks, Lunch

Directors Row 1-4
Corporate Supporter Rooms
Committee Meeting Rooms

Board Room 1-3
Corporate Supporter Rooms
Committee Meeting Rooms

Rochester Room
E-Posters, Internet Kiosks
Head Shot Photographer

Duluth Room
50th Anniversary SRS Museum



Meeting Outline

(subject to change)

Monday, September 28, 2015	
12:00-6:00pm	Board of Directors Meeting
Tuesday, September 29, 2015	
7:00am-5:00pm	SRS Committee Meetings
2:00-6:00pm	Registration Open
7:00-10:00pm	SRS Leadership Dinner (by invitation only)
Wednesday, September 30, 2015	
6:30am-6:00pm	Registration Open/ Internet Kiosks, E-Posters Open
8:00am-12:30pm	Pre-Meeting Course – Morning Sessions
12:30-1:45pm	Lunchtime Symposia Living Legends Presentation in the 50th Anniversary Museum
1:45-4:30pm	Pre-Meeting Course – Afternoon Sessions
4:45-5:45pm	Case Discussions
6:00-7:15pm	Opening Ceremonies
7:15-9:00pm	Welcome Reception
Thursday, October 1, 2015	
6:30am-4:30pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:30-10:00am	Spouse Hospitality Suite
7:55am-12:30pm	Scientific Program
12:30-1:30pm	Lunch & Networking for Half-Day Course Participants Member Information Session Living Legends Presentation in the 50th Anniversary Museum
1:30-4:30pm	Half-Day Courses
Friday, October 2, 2015	
6:30am-5:30pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:30-10:00am	Spouse Hospitality Suite
7:55-11:50am	Scientific Program
12:00-1:00pm	Lunchtime Symposia Living Legends Presentation in the 50th Anniversary Museum
1:15-5:03pm	Scientific Program
7:00-11:00pm	Farewell Banquet
Saturday, October 3, 2015	
6:30am-12:00pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:55am-12:45pm	Scientific Program
1:00-3:30pm	Board of Directors Meeting

Wednesday, September 30, 2015

Howard Steel Lecture

SRS: The Past 50 Years
Moderator: Behrooz A. Akbarnia, MD
SRS Historian and Past President

1966 to 1979 - David B. Levine, MD
SRS Past President

Emeritus Clinical Professor
Orthopaedic Surgery
Weill Cornell Medical College

Director
Hospital for Special Surgery (HSS)
Alumni Association & Archives
New York

During Dr. John Moe's first workshop on scoliosis, at the University of Minnesota Medical Center in 1964, Dr. David B. Levine, then a senior orthopaedic resident, proposed organizing a national scoliosis association. Dr. Moe asked Dr. Levine to draft the first bylaws. Dr. Paul Harrington pledged $1,000 as seed money, and the first meeting of the new organization was held June 10-11, 1966.

David B. Levine, MD, born in Binghamton, NY, attended Dartmouth College, was awarded his medical degree from the State University of New York Medical College, Syracuse (1957), completed his orthopaedic residency at Hospital for Special Surgery (1964) and a scoliosis fellowship with Dr. Jacqueline Perry at Rancho Los Amigos Hospital (1965). Returning to HSS, he was appointed Chief of Scoliosis (1968), a position he held for 27 Years when he retired from patient care.

Recipient of several Awards, Dr. Levine received the coveted Class of 1954 Award from Dartmouth College (1990), the SRS Lifetime Achievement Award (2009) and the establishment at HSS of the *David B. Levine, MD Chair in Scoliosis* (2006). In 2013 he published THE ANATOMY OF A HOSPITAL, a 500-page definitive history of HSS, the oldest orthopaedic hospital in America. He served as SRS Secretary-Treasurer 1970-1974. SRS President 1979 and on the Executive Committee for eleven years.

Currently, Levine resides in New York City with his wife, Janet and writes medical history, lecturing around the world.

1980 to 1995 - Ronald L. DeWald, MD
SRS Past President and Founding Fellow

Ronald L. DeWald, MD knew from an early age that his calling was in medicine. After successfully completing his undergraduate degree at the University of Illinois Champaign-Urbana in 1955, he went on to complete his Medical Degree at University of Illinois College of Medicine, Chicago in 1959. While in medical school he married Mary Lee Johnstone and soon thereafter began their family. Together they have four children, Ann, Lee, Christopher and Ronald.

While completing his orthopedic residency at the University of Illinois Research and Education Hospital in Chicago, he also served as a Captain in the US Army Orthopedic Service. Since completing his residency, Dr. DeWald has served in several clinical and academic positions throughout Illinois, most recently as Emeritus Professor – Orthopedic Surgery at Rush University in Chicago from 2005-present.

Throughout his career, Dr. DeWald has been published several times in reputable medical journals and texts. Notably, in March of 1970 his article titled, *"Skeletal traction for the treatment of severe scoliosis. The University of Illinois Halo-Hoop Apparatus,"* was published in JBJS and again in 1981, JBJS published Dr. DeWald's *"Severe lumbosacral spondylolisthesis in adolescents and children."* Both of these publications were the first of their kind. Not only has he published these notable papers and several other, but he also serves as the Co-Editor-in-Chief of "The Textbook of Spine Surgery" now in its third edition and Editor-in-Chief of "Spinal Deformities, the Comprehensive Text."

During the early years of his career, Dr. DeWald helped found the Scoliosis Research Society (SRS) in 1966. He has been dedicated to the society since its inception. In 1989, he served as president of the SRS. Since his presidency, he has been the Senior Traveling Fellow (1993), given the Harrington Lecture twice (1999 and 2003) and been awarded the Lifetime Achievement Award (2011). He continues to serve the Society as an active participant of the 50th Anniversary Task Force and one of this year's Steel Lecturers.

1996 to 2015 - Vernon T. Tolo, MD
SRS Past President

Vernon T. Tolo, MD is Chief Emeritus of the Children's Orthopaedic Center, Children's Hospital Los Angeles (CHLA). He served as chief of Orthopaedics at CHLA from 1987 to 2009. He is the John C. Wilson, Jr., Professor of Orthopaedics at the Keck School of Medicine at USC.

Dr. Tolo received his MD 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 10 years before going to CHLA. In 2001, he was inducted into the Johns Hopkins Society of Scholars.

He has been president of the Pediatric Orthopaedic Society of North America (POSNA), the Scoliosis Research Society (SRS), and of the American Academy of Orthopaedic Surgeons (AAOS). He has received the Distinguished Achievement Award from the POSNA, the Lifetime Achievement Award from the SRS, and the Tipton Leadership Award from the AAOS. He was Editor-in-Chief of The Journal of Bone and Joint Surgery from 2010 to 2014.

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

Walter P. Blount Humanitarian Award Recipient

S. Rajasekaran, MD, FRCS, MCh, PhD

Professor S. Rajasekaran is the Chairman of the Department of Orthopaedics & Spine Surgery, Ganga Hospital, Coimbatore. He has held the distinguished posts of the President of the Indian Orthopaedic Association (2012), President of the Association of Spine Surgeons of India (2008 – 2012) and Chief National Delegate of Asia Pacific Orthopaedic Association (since 2006). He was the President of International Society for the Study of Lumbar Spine, Canada (2012); President of the World Orthopaedic Concern, UK (2005-2007); and the Hunterian Professor of the Royal College of Surgeons (2012.) He is the current Chair of the International Research Commission of AOSpine and the President-Elect of SICOT.

Professor Rajasekaran started the spine unit of Ganga Hospital in Coimbatore, India in 1991, where he introduced complex spine surgery and deformity correction surgeries in that part of the country. It quickly became obvious that realities and challenges were very different from the West. Most patients came at the late stage of the disease due to lack of awareness, lack of centres and personnel who could treat deformities, a morbid fear of spine surgery and lack of funds. The challenge was due more to major social economic problems than performing complex spine surgery. Patients had to be literally 'adopted' as they were from far and wide, of different cultures, spoke different languages and poor economic support.

The experience of two big institutions in South India – the Arvind Eye Hospital and the Narayana Hrudalaya Heart Centre – made it possible to perform surgeries at an astonishingly low cost and yet often with better success rates than many western centres gave us strength to innovate a model where complex spine surgeries could be performed for less than $1500 USD.

A "low cost-high quality" model was created where:

1. Charity service was introduced into everyday work and not sporadically or seasonally.
2. Charity at our own place of work helped to harness our maximum energy, saved time and effort and was highly cost effective.
3 We realised the power of 'numbers' whenever a critical mass of surgical load was achieved. It was then possible to provide advanced facilities like Navigation, cord monitoring and cell savers with no difference in quality of treatment to even the poorest patient by integrating them into a large patient pool without extra cost.
4. By igniting a sense of social commitment to the whole team, service providers were multiplied rather than doing solo service or as a small group from time to time.
5. Wealthy patients and service organisations were increasingly happy to donate when they could be connected to individual patients who required surgery.

Project Helpline (Help for the Helpless) was created in 1997, allows any child with any deformity of any etiology of the lower socio-economic strata to be operated on entirely free of charge. Project SWASAM (meaning "new breath of life") made available 10 free beds for charity work, which improved the potential for free surgeries tremendously. In a unit which had 510 beds, we found to our delight that 10 free beds did not cause any dent in the economics of the unit. A nation-wide project, *'Let's Pledge to Give,* charged every orthopaedic and spine surgeon in the country to perform at least one surgery free of charge every year. The project caught on like fire in the country and in 2012, 6452 free surgeries were performed, of which 563 were spine surgeries to the value of nearly 3.4 million USD.

Realizing that the capability of a single unit was no match to the actual need in the country, we set upon ourselves to train as many surgeons as possible in the field of spine surgery and spine deformity correction. Nine *Live Operative Courses* benefiting a total of 2,900 delegates from 18 different countries and faculty from around the world have been conducted. Through long and short term fellowships under the aegis of World Orthopaedic Concern, Association of Spine Surgeons of India, Indian Orthopaedic Association and recently AOSpine we have trained more than 165 surgeons from 18 countries; a majority of them from the Indian sub-continent and Africa. The expertise of the unit has benefitted patients far and wide.

Recently, to overcome the lack of dedicated rehabilitation centres for spinal cord injuries, the Ganga Spine Injury and Rehabilitation Centre, with 33 beds, was created by a large personal donation of Prof. Rajasekaran. The entire rehabilitation process for each patient, including the orthosis and wheel chair cost, is subsidized to 60,000 Rupees (approximately $1000 USD). As a result of the many enthusiastic supports, most of the patients are treated entirely free of charge.

Based on the quote of the Father of India, Mahatma Gandhi, "You find yourself only when you lose yourself in the service of others" – our unit's mission statement was created - "To provide quality treatment at affordable cost so that the expertise of the unit will be available to every citizen of our country." True to this statement we are proud that more than 6000 poor spine patients and 1500 spine deformity patients have been served with no differentiation of quality or service from the rich of the country.

Guest Lectures

Thursday, October 1, 2015

Harrington Lecture

Correcting Scoliosis: The Genealogy of Ideas and Their Surgical Application

Dennis R. Wenger, MD

Doctor Dennis Wenger is a children's orthopedic and scoliosis surgeon whose career spans the incredible advances that have occurred in the scoliosis world over the last three decades.

A native of Ohio, he attended medical school at the University of Cincinnati and followed by orthopedic residency at the University of Iowa training program where he was influenced by Dr. Ignacio Ponseti, one of the world renown children's orthopedic surgeons, scoliosis researchers, and experts in spinal growth.

He then went to the Hospital for Sick Children of the University of Toronto for his fellowship in scoliosis and children's orthopedics where he came under the influence of the "John Hall System" which had been continued by other surgical luminaries. Rapid, efficient and effective scoliosis surgery was the standard with new, experimental methods being developed and studied.

He then joined the staff at the Texas Scottish Rite Hospital in Dallas where he worked for seven years with Dr. Tony Herring and others to expand both scoliosis clinical care as well developing an active research program that included a biomechanics research laboratory. During this period, he and Dr. Tony Herring founded the fellowship program in scoliosis and children's orthopedics at the Texas Scottish Rite Hospital.

In 1984, he assumed a faculty position at Children's Hospital San Diego and the University of California San Diego and shortly thereafter was named Director of the Children's Orthopedic Training Program. He, along with David Sutherland and Scott Mubarak, founded a fellowship program which has become a recognized center for education and research in both scoliosis and children's orthopedics. Dr. Wenger served as a mentor to Dr. Peter Newton who now directs the widely recognized scoliosis service and spine research program at Rady Children's Hospital San Diego.

Dr. Wenger's research interests have ranged broadly with his scoliosis research focusing on fixation methods, histologic studies of muscle in scoliosis patients, electrical stimulation of scoliosis, and imaging methods for evaluation of scoliosis.

As a result of his work he has received multiple teaching and research awards including the Walter P. Blount Award from POSNA as well as the Hibbs Society award from the SRS.

His educational efforts include authorship of more than 150 peer reviewed publications, authoring multiple textbooks related to children's orthopedics, and lecturing on scoliosis and other childhood orthopedic conditions throughout the world.

Lifetime Achievement Award Recipients

Behrooz A. Akbarnia, MD

Behrooz Akbarnia was born in Tehran, Iran, where he graduated from Tehran University Medical School in 1966. In 1968, he moved to the United States to continue his training in Orthopaedic Surgery. Following his residency at the Albany Medical Center in New York, he completed a Scoliosis and Spine Fellowship under the legendary Dr. John Moe and his colleagues at the University of Minnesota and Twin Cities Scoliosis Center. Dr. Akbarnia subsequently became Professor and Vice Chairman in the Department of Orthopedic Surgery at St. Louis University. In 1990, he relocated to San Diego, California, where he established his academic practice at the San Diego Center for Spinal Disorders, created the San Diego Spine Fellowship Program and founded both the San Diego Spine Foundation and the Growing Spine Foundation to support academic activities. He is also one of the founders of the International Spine Study Group (ISSG).

Dr. Akbarnia is a member of numerous organizations and has served as president in several of these, including SRS president in 2006. His SRS-related activities include a perfect attendance for 40 years, chairing 10 of 14 committees he served. He has also served on the Board of Directors for 13 years as Member, Treasurer, and Presidential Line (PL). He is the recipient of the SRS Walter P. Blount Humanitarian Award and of Lifetime Service Awards from the American Academy of Pediatrics and the Western Orthopaedic Association. He has also contributed to SRS at the OREF Shands Platinum level member.

His most recent work has focused on Early Onset Scoliosis and Growing Spine activities through GSSG and on establishing the ICEOS annual meeting, now in its 9th year. Dr. Akbarnia is also the lead editor of the Growing Spine textbook, now in its second edition. These efforts have culminated in the improvement of the lives of patients with EOS. His research comprises over 200 papers in peer-reviewed journals, many book chapters, and presentations and travel around the world. His greatest satisfaction has come from his mentorship to countless fellows and visitors in the spine deformity world.

Dr. Akbarnia now serves as Clinical Professor in the Department of Orthopaedic Surgery at the University of California, San Diego and Medical Director Emeritus of San Diego Center for Spinal Disorders. He has been married to his wife, Nasrin, for 48 wonderful years. They have three children, Halleh, Ladan, and Ramin, and are proud grandparents to Simia, Kian, Leila, and Luca.

Guest Lectures

Randal R. Betz, MD

Randal R. Betz, MD is currently a pediatric spine surgeon with the Institute for Spine & Scoliosis in Princeton, NJ, and New York, NY. Previously, he was on staff at Shriners Hospitals for Children—Philadelphia since 1983 and served as the Chief of Staff from 2000-2012 and the Medical Director of the Spinal Cord Injury program from 1983 to 2014. He is board-certified in both orthopaedic surgery and spinal cord injury medicine.

Dr. Betz became a member of the Scoliosis Research Society in 1986, served as Education Committee chair in 1988, started IMAST in 1994, and served as SRS President in 2005, during which he survived the hurricane meeting in Miami that year. He proposed the initiation of the SRS Traveling Fellowship in 1990 and served as senior mentor for the traveling fellows in 2013.

He received the Lifetime Achievement Award from the American Spinal Injury Association in 2009 and the A. Estin Comarr Memorial Award for Clinical Service from the American Paraplegia Society in 2003.

He cofounded three study groups: the Harms Study Group in 1995, the Spine Deformity Study Group in 2002, and the Children's Spine Study Group (formally the Chest Wall and Spine Deformity Study Group), also in 2002.

He has coedited 6 textbooks on pediatric spinal cord injury and pediatric spine deformity. He has also contributed chapters in 43 textbooks, has been the senior author or coauthor on over 300 peer-reviewed journal articles, has received over $16.5M in institutional grant monies with coinvestigators, and has been named on 12 patents in partnership with industry research.

He is married to Betsey, has four children (Chris, Randal Jr., Aimee, and Laurie), and has 13 grandchildren. He enjoys spending time with his family and sharing his passions for fishing, golf, skiing, and life in general with his many friends.

Social Events

Opening Ceremonies

Wednesday, September 30, 2015
6:00-9:00pm

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

The Annual Meeting will officially begin with the Opening Ceremonies and the Howard Steel Lecture, presented by SRS founding members and past presidents and devoted to the history and future of SRS. The evening will include an introduction of the SRS officers and honored presidents from other spine societies. All delegates and registered guests are invited and encourage to attend the Opening Ceremonies. Following the Opening Ceremonies, we will move to a hosted reception featuring heavy hors d'oeuvres, cocktails, and plenty of lively conversations and reunions with colleagues and friends.

The Welcome Reception is supported, in part, by grants from Medtronic, NuVasive and SpineCraft.

Wine & Chocolate Tasting

Thursday, October 1, 2015
4:45pm

Open to all registered delegates and registered guests. Tickets are $110 each and should be purchased in advance. A limited number of tickets may be available onsite. Name badges are required. Join us for a wine and chocolate tasting presented by The Wine Company. The tasting will feature Cabernet, Old World Syrah and New World Pinot Noir and will include a three-glass Riedel VERITAS set to take home. As an extra bit of fun and excitement the tasting will include a selection of three different chocolates which are selected to go with each wine further emphasizing the ways in which differing wines show distinctly not only in different glasses but also with an array of different food flavors. Don't miss this great opportunity for a night of great wine and fellowship.

Farewell Banquet

Friday, October 2, 2015
7:00-11:00pm

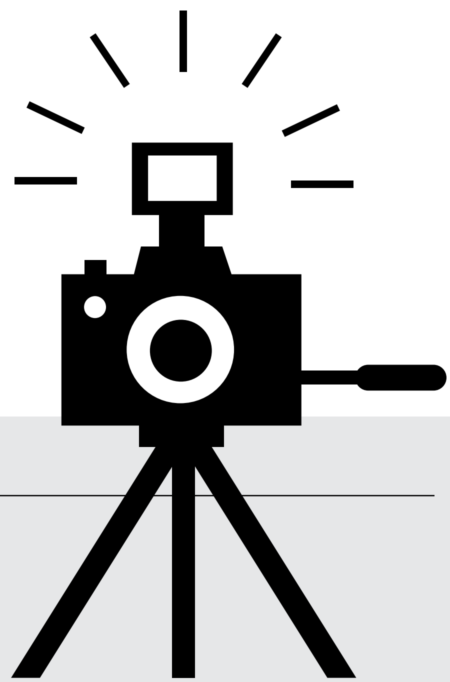
Open to all registered delegates and registered guests. Tickets are $50 each and should be purchased in advance. A limited number of tickets may be available onsite but SRS strongly urges delegates and guests to purchase tickets at the time of registration. Tickets are required.

The 50th Annual Meeting & Course will culminate with a formal plated dinner at the former Old Milwaukee Road Railway Depot. The Depot, a Renaissance Revival Style building listed on the National Register of Historic Places, will serve as the perfect backdrop for this historic celebration.

The SRS Development Committee invites you to participate in the live and silent auction during the Farewell Banquet.

All funds raised from the auction go to the Research, Education and Outreach (REO) Fund via the 50th Anniversary Campaign to honor the mission and future goals of the Society. The REO Fund supports research grants, directed research projects, scholarships, traveling fellowships and humanitarian outreach efforts that are vital in helping SRS continue its mission to foster the optimal care for all patients with spinal deformities.

Black tie optional



Is your head shot out of date?

SRS Members can take advantage of complimentary professional head shots by visiting the SRS Annual Meeting photographer in the Rochester Room on Thursday, October 1 from 10:00-11:30am and 12:45-2:00pm or Friday, October 2 from 9:00-11:00am.

Head shots are on a first-come, first-served basis.

Optional Tours

The following tours are available to registered delegates and guests through Event Lab, our partners in Minneapolis. Any questions regarding availablility, registration or tour details should be directed to Event Lab by calling +1 952-224-8558 or emailing jnoble@eventlab.net.

All tours depart and return to the Hilton Minneapolis.

Tuesday, September 29		
Minneapolis – City Tour	9:30 AM – 1:30 PM	$50.00
Abroretum Tour	11:00 AM – 3:00 PM	$50.00
Wednesday, September 30		
Saint Paul – City Tour	9:30 AM – 2:00 PM	$60.00
Minnetonka Boat Cruise	10:30 AM – 3:00 PM	$85.00
Arboretum Tour	12:30 PM – 4:30 PM	$50.00
Thursday, October 1		
Saint Paul - City Tour	12:30 PM – 5:00 PM	$60.00
Friday, October 2		
Minneapolis – City Tour	12:00 PM – 4:00 PM	$50.00
Minnetonka Boat Cruise	10:30 AM – 3:00 PM	$85.00

Minnesota Landscape Arboretum Tour

Tuesday, September 29, 2015
11:00 AM – 3:00 PM
Wednesday, September 30, 2015
12:30 – 4:30 PM
$50.00 per person

An ADVENTURE in NATURE! Experience the beauty of over 1,100 acres of magnificent gardens, stunning landscapes and natural areas including woodlands, wetlands and prairies featuring over 5,000 plant species and varieties.

A personally guided tram tour around the grounds begins your adventure. Stroll the gardens, view a hands-on demonstration, shop in the unique gift shop featuring local artists and vendors or enjoy lunch from the restaurant on the dining terrace while honeylocust trees provide shade and surrounding perennials add seasonal color. Lunch will be at your leisure. The cost of lunch is not included in the tour price.

Your senses will come alive at the breathtaking beauty of this Minnesota treasure.

Tour includes Arboretum admission, personally guided tram ride and a snack of Pearson's candy bar and bottled water.

A minimum of 20 attendees is required to operate this tour. Please see Refund Policy below for more information.

Depart and return to Hilton, Minneapolis. Motor coaches will depart from the 11th street entrance of the Hilton.

Please arrive 15 minutes prior to your scheduled tour time.

Minneapolis City Tour

Tuesday, September 29, 2015
9:30 AM – 1:30 PM
Friday, October 2, 2015
12:00 – 4:00 PM
$50.00 per person

Minneapolis—the Mill City! On this exciting and engaging tour you will experience some of the highlights including the Mississippi riverfront, iconic museums and the sights and sounds of Minnesota's largest city.

Your journey begins along the famous Minneapolis parkways, past beautiful mansions that dot city lakes. Next, a visit to the renowned Sculpture Garden to view the iconic Spoonbridge and Cherry. In addition, your guide will share stories and tales of the Mary Tyler Moore house, the world renowned Guthrie Theatre, Mill City Museum and Minnehaha Falls. This wonderful excursion culminates when you step out onto the cantilever bridge for a breathtaking view of the Mississippi River. ENJOY!

Tour includes admissions, permits, a lunch stop (individual pay) and a snack of Pearson's candy bar and bottled water.

A minimum of 30 attendees is required to operate this tour. Please see Refund Policy below for more information.

Depart and return to Hilton, Minneapolis. Motor coaches will depart from the 11th street entrance of the Hilton.

Please arrive 15 minutes prior to your scheduled tour time.

Optional Tours

St. Paul City & Gangster Tour

Wednesday, September 30, 2015
9:30 AM – 2:00 PM
Thursday, October 1, 2015
12:30 – 5:00 PM
$60.00 per person

Gangsters galore—a true tale of Saint Paul, a city for saints and sinners! The adventure begins in the historic Wabasha Caves that once housed the famous Casino Royale nightclub. Don't miss the bullet holes.

Back in the day, Saint Paul was home to gangsters and the legends tell of massacres and ghostly lore. Back on your motor coach, a lively costumed gangster guide commandeers it to explore the dark side of the city where the kidnappings and gun battles were staged with 1930's gangsters like John Dillinger, Ma Barker and Baby-face Nelson. True tales will be told of the famous bank robberies, hold-ups of mail trucks and trains and the hostages who were held for ransom. Who knew Al Capone once lived in Saint Paul! Your journey includes a trip down historic Summit Avenue—the longest avenue of Victorian homes in the country.

Tour includes admission to Wabasha Caves, Gangster Tour, buffet lunch in Wabasha Caves and a snack of Pearson's candy bar and bottled water.

A minimum of 30 attendees is required to operate this tour. Please see Refund Policy below for more information.

Depart and return to Hilton, Minneapolis. Motor coaches will depart from the 11th street entrance of the Hilton.

Please arrive 15 minutes prior to your scheduled tour time.

Lake Minnetonka Lunch Cruise

Wednesday, September 30, 2015
Friday, October 2, 2015
10:30 AM – 3:00 PM
$85.00 per person

One of the most beautiful lakes in the Metropolitan area, Lake Minnetonka has over 125 miles of shoreline dotted with magnificent homes and breathtaking scenery. You will cruise the lake in a luxury yacht and enjoy lunch on board either atop the boat or inside the cabin. A cruise on this historic Minnesota Lake is a must-do for visitors.

Tour includes private yacht cruise, lunch buffet inclusive of tax and gratuity and a snack of Pearson's candy bar and bottled water.

Weather Policy - Boats go out even in the rain because there is a large inside area and the top deck can be covered. Boats will not go out if there are weather warnings for extreme conditions such as tornado or extremely high winds. If the tour is cancelled due to weather, refunds will be issued according to the refund policy stated below.

A minimum of 35 attendees is required to operate this tour. Please see Refund Policy below for more information.

Depart and return to Hilton, Minneapolis. Motor coaches will depart from the 11th street entrance of the Hilton.

Please arrive 15 minutes prior to your scheduled tour time.

Weather Policy - This tour will operate in the rain, but will be cancelled if severe weather warnings with thunder and/or lightening occur. If the tour is cancelled due to weather, refunds will be issued according to the refund policy stated below.

A minimum of 5 attendees is required to operate this tour. Please see Refund Policy below for more information.

Depart and return to Hilton, Minneapolis. Motor coaches will depart from the 11th street entrance of the Hilton.

Please arrive 15 minutes prior to your scheduled tour time.

Refund Policy:

Refunds are available for all tours prior to tour departure date. A $5.00 per person cancellation fee will be removed from each refund amount. To cancel a tour and receive a refund, please contact Event Lab at 952-224-8558 or jnoble@eventlab.net.

A minimum number of attendees is required for each tour to operate. If your tour does not meet the minimum number of attendees, the tour will be cancelled. At that point you will be offered 3 options: 1) the opportunity to join the same tour at a different time (if available), 2) the opportunity to apply your payment to a different tour, 3) receive a full refund with no cancellation fee.

Restaurant Guide

112 EATERY – *Gourmet Comfort Food*
112 N. 3rd St., Mpls., 612-343-7696, 112eatery.com

BAR LA GRASSA – *Italian*
800 Washington Ave. N., Mpls., 612-333-3837, barlagrassa.com

MANNY'S STEAKHOUSE – *Steakhouse*
825 Marquette Ave. S., Mpls., 612-339-9900, mannyssteakhouse.com

VINCENT A RESTAURANT – *French*
1100 Nicollet Mall, Mpls., 612-630-1189, vincentarestaurant.com

RESTAURANT ALMA – *New American*
528 University Ave. SE, Mpls., 612-379-4909, restaurantalma.com

SEA CHANGE – *Seafood*
806 S. 2nd St., Mpls., MN 55415, 612-225-6499; seachangempls.com

SPOONRIVER – *American, Vegetarian/Vegan*
750 S. 2nd St., Mpls., 612-436-2236, spoonriver.com

For the complete restaurant guide, visit the "info booth" section of the mobile app or pick up a hard copy at the registration desk.

Light Rail Transit

The METRO Blue Line offers fast, quiet light-rail service to 19 stations between downtown Minneapolis and Mall of America.

The new METRO Green Line, with service to the University of Minneapolis and St. Paul, shares five downtown Minneapolis stations.

The closest METRO Line station to the Hilton Minneapolis is the Nicollet Mall Station (5th Street & Nicollet) which has access to both the Green and Blue Lines. To get to the station, pick up the "Free Bus" on 11th Street and Marquette Avenue and take it to the 5th Street Stop (5th Street & Marquette).

Fares range from $1.75 to $3.00, depending on time of day. If you're already downtown and need to hop a ride a few blocks, the fare is $.50 in the Downtown Zone. METRO Lines operate 24 hours a day, seven days a week. Trips operate every 10 minutes throughout the day, every 10-15 minutes evenings and every 30-60 minutes overnight. Visit http://www.metrotransit.org/metro-system for more information on fares, schedules and LTR maps.

Opening Ceremonies Agenda

Wednesday, September 30, 2015
Hilton Minneapolis – Minneapolis Ballroom

6:00 – 6:05 pm	**Welcome to Minneapolis** *Joseph H. Perra, MD*
6:05 – 6:10 pm	**Presidential Welcome** *John Dormans, MD, President*
6:10 – 6:20 pm	**Introduction of SRS Traveling Fellows** **Introduction of Fellowship and Award Recipients** *John Dormans, MD, President*
6:20 – 6:25 pm	**Presentation of Blount Humanitarian Award** *Introduction by John Dormans, MD, President* *Presentation by Hani H. Mhaidli, MD, PhD, Awards & Scholarships Committee Chair*
6:25 – 6:35 pm	**Acknowledgement of Corporate Supporters** *Introduction by John Dormans, MD, President* *Presentation by Steven D. Glassman, MD, Past President & Corporate Relations Committee Chair*
6:35 – 6:40 pm	**Introduction of Howard Steel Lecturer** *Behrooz A. Akbarnia, MD, SRS Historian & Past President*
6:40 – 6:45 pm	**SRS 50th Anniversary Video**
6:45 – 7:15 pm	**Howard Steel Lecture** *David B. Levine, MD, SRS Past President & Founding Fellow* *Ronald L. DeWald, MD, SRS Past President & Founding Fellow* *Vernon T. Tolo, MD, SRS Past President*
7:15 – 7:20 pm	**Closing Remarks** *John Dormans, MD, President*

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

7:20 – 9:00pm

The Welcome Reception is supported, in part, by grants from NuVasive, Medtronic and SpineCraft

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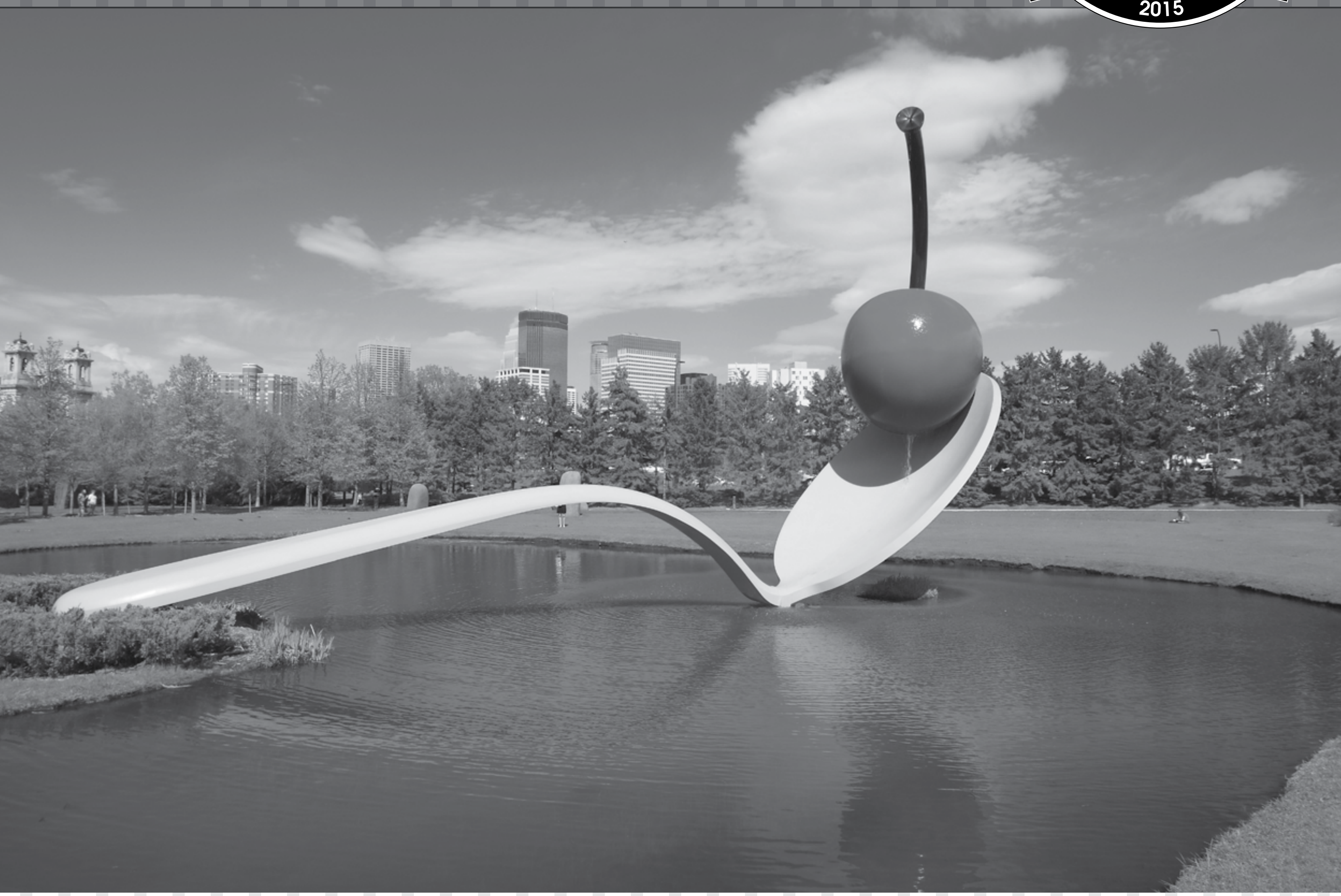
50th ANNUAL MEETING & COURSE

Conflict of Interest Disclosures

SCOLIOSIS RESEARCH SOCIETY 50th ANNIVERSARY 2015



Claes Oldenburg and Coosje van Bruggen Spoonbridge and Cherry 1985–1988 aluminum, stainless steel, paint Collection Walker Art Center Gift of Frederick R. Weisman in honor of his parents, William and Mary Weisman, 1988. Art © Claes Oldenburg and Coosje van Bruggen Photo courtesy of Meet Minneapolis.

The Scoliosis Research Society gratefully acknowledges K2M for their support of the E-Poster CD-Rom, E-Poster Kiosks, Webcast and Charging Station.

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Conflict of Interest Disclosures

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50th ANNUAL MEETING & COURSE

Pre-Meeting Course

Courtesy of Meet Minneapolis

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

Pre-Meeting Course Program

Where Have We Been, Where Are We Now, and What is the Future?

Course Chair: Sigurd H. Berven, MD

Wednesday, September 30th, 2015
8:00am - 4:30pm
Hilton Minneapolis
Minneapolis Ballroom

Sponsored by the Scoliosis Research Society

Session 1: Historical Perspectives Moderators: Sigurd H. Berven, MD & Hani H. Mhaidli, MD, PhD		
Time	Title	Speaker
8:00am	Welcome & Course Introduction	John Dormans, MD & Sigurd H. Berven, MD
8:05 – 8:13	Mission and Goals of SRS: Then and Now	John P. Kostuik, MD
8:14 – 8:22	Significant Paper: Natural History of AIS	Stuart L. Weinstein, MD
8:23 – 8:31	Significant Paper: Natural History of Spondylolisis & Spondylolisthesis	John P. Lubicky, MD
8:32 – 8:40	Significant Paper: Natural History of Congenital Scoliosis	Michael J. McMaster, MD, DSc, FRCS
8:41 – 8:53	Discussion	
8:54 – 9:02	Significant Paper: Predictors of Curve Progression in AIS	John E. Lonstein, MD
9:03 – 9:11	Significant Paper: Long-Term Follow-Up of Brace and Operative Treatment in AIS	Aina Danielsson, MD
9:12 – 9:20	Significant Paper: Neural Complications in Deformity Surgery: Detection and Avoidance	John Dormans, MD
9:21 – 9:30	Discussion	
Session 2: Surgical Approaches to Complex Deformity Moderators: Kamal N. Ibrahim, MD, FRCS(C), MA & David S. Bradford, MD		
9:31 – 9:36	Anterior Surgery: Then and Now	Henry F. H. Halm, MD
9:37 – 9:42	Posterior Based Surgery: Evolution of Fixation Strategies	Ulf R. Liljenqvist, MD
9:43 – 9:48	Posterior Osteotomies for Adolescent Deformity	Harry L. Shufflebarger, MD
9:49 – 9:54	Osteotomies for Adult Deformity	Oheneba Boachie-Adjei, MD
9:55 – 10:00	Spinal Osteotomy Strategies for Complex Spinal Deformity	Yan Wang, MD
10:01 – 10:13	Discussion	

10:14 – 10:19	Techniques for Optimal Correction of AIS	David S. Marks, FRCS (Orth)
10:20 – 10:25	Minimally Invasive Approaches to Deformity	Gregory M. Mundis, Jr., MD
10:26 – 10:31	Spondylolisthesis: When and How to Reduce	Hubert Labelle, MD
10:32 – 10:37	Evolution of Surgical Techniques: What is the Impact?	Ronald L. DeWald, MD
10:38– 10:50	Discussion	
10:50 – 11:05	BREAK	

Session 3: Early Onset Scoliosis Moderators: Richard E. McCarthy, MD & Lori A. Karol, MD		
Time	Title	Speaker
11:05 – 11:13	A Historical Perspective of the Management of Early Onset Scoliosis	Behrooz A. Akbarnia, MD
11:14 – 11:22	Classification of Early Onset Scoliosis	Michael G. Vitale, MD
11:23 – 11:31	Evidence to Support Present Surgical Approaches to Early Onset Scoliosis	Laurel C. Blakemore, MD
11:32 – 11:41	Discussion	
Session 4: Adolescent Idiopathic Scoliosis Moderators: Marinus de Kleuver, MD, PhD & James O. Sanders, MD		
11:42 – 11:50	Classification of AIS (Then, Now, Future)	Lawrence G. Lenke, MD
11:51 – 11:59	Bracing in Non-Operative Care of AIS	John B. Emans, MD
12:00 – 12:08	Evolution of Surgical Strategies for AIS	Haemish A. Crawford, FRACS
12:09 – 12:17	How Have Goals of Care in AIS Changed Over Time? – Are We Over-treating Scoliosis	B. Stephens Richards, III, MD
12:17 – 12:30	Discussion	

12:30 – 1:45	Lunchtime Symposia: 12:40 – 1:40	How to Accelerate Recovery of AIS Patients after PSF for AIS - *Marquette Ballroom* Update on Missions and Activities in Endorsed Global Outreach Sites - *Symphony Ballroom* Minimally Invasive Spinal Deformity Techniques - *Minneapolis Ballroom*

Session 5: Adult Scoliosis Moderators: Steven D. Glassman, MD & Serena S. Hu, MD		
Time	Title	Speaker
1:45 – 1:53	A Historical Perspective on the Operative Approaches to Deformity Surgery in the Adult	Keith H. Bridwell, MD
1:54 – 2:02	Classification of Adult Deformity	Frank J. Schwab, MD
2:03 – 2:11	Understanding Sagittal Balance	Pierre Roussouly, MD
2:12 – 2:21	Discussion	
2:22 – 2:30	Junctional Pathology	Robert W. Gaines, Jr., MD
2:31 – 2:39	Cervicothoracic Deformity in the Adult	Christopher P. Ames, MD
2:40 – 2:48	Cost and Value Considerations in Spinal Deformity Surgery	David W. Polly, Jr., MD
2:49 – 2:58	Discussion	
Session 6: Basic Science Moderators: Kenneth M.C. Cheung, MD & Nancy Hadley-Miller, MD		
2:59 – 3:07	Biomechanics of Spinal Deformity	Hilali H. Noordeen, FRCS
3:08 – 3:16	Etiology of AIS: Genetics	James W. Ogilvie, MD
3:17 – 3:25	Etiology of AIS: Non-Genetic Factors	Morio Matsumoto, MD
3:26 – 3:35	Discussion	
3:35 – 3:50	BREAK	
3:50 – 3:58	Future in Patient-Specific Planning for Deformity	Virginie Lafage, PhD
3:59 – 4:07	Basic Science Priorities for the Next Decade and Beyond	Kenneth M.C. Cheung, MD
4:08– 4:14	Discussion	

Session 7: The Future Moderator: Lawrence G. Lenke, MD		
Time	Title	Speaker
4:15– 4:30	Panel Discussion: Future Directions for the Spinal Deformity Specialty	John Dormans, MD; Steven D. Glassman, MD; Randal R. Betz, MD; Alvin H. Crawford, MD; Kamal N. Ibrahim, MD, FRCS(C), MA; Courtney W. Brown, MD

Case Presentation Sessions Begin at 4:45

Pre-Meeting Course Program

2014-2015 Education Committee

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Kit M. Song, MD, MHA
Fernando Techy, MD
Yan Wang, MD
Mark Weidenbaum, MD

Course Objectives and Outcomes

As a result of participating in this activity, participants should be able to:

- Perform evidence-based pre-operative planning.
- Evaluate patients with spinal deformity, including early onset, adolescent, and adult and recommend appropriate treatment.
- Perform surgical techniques with knowledge of indications and complications.
- Minimize complications and optimize patient safety.
- Understand the evolution of evidence-based care over time

Target Audience

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

Continuing Medical Education (CME) Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the sponsorship of the Scoliosis Research Society (SRS). SRS is accredited by the ACCME to provide continuing medical education for physicians. SRS designates this live activity for a maximum of *7.75 AMA PRA category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Disclosure of Conflict of Interest

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

CME Certificates and Certificates of Attendance

CME Certificates will be available to pre-registered delegates immediately upon the close of the meeting at www.srs.org/professionals/meetings/am15.

Delegates should log onto the website listed above and enter their last name and the ID# list on your Annual Meeting badge. The system will then ask delegates to indicate which sessions they attended, and then will generate a PDF certificate which may be printed or saved. Session attendance information is saved in the database, and certificates may be assessed again, in the event the certificate is lost or another copy is required.

Certificates of Attendance will be emailed to all attendees upon checking in at the registration desk. Please note that only Certificates of Attendance will be emailed from the meeting; not CME certificates. The online certificate program is the only source for this documentation. If you have any questions, please visit the registration desk, or email the SRS office at cme@srs.org.

Pre-Meeting Course Program

FDA Statement

All drugs and medical devices used in the United States are administered in accordance with Food and Drug Administration (FDA) regulations. These regulations vary depending on the risks associated with the drug or medical device, the similarity of the drug or medical device to products already on the market, and the quality and scope of clinical data available. Some drugs and medical devices demonstrated in Scoliosis Research Society meetings or described in Scoliosis Research Society print publications have FDA clearance for use for specific purposes or for use only in restricted research settings. The FDA has stated that it is the responsibility of the physician to determine the FDA status of each drug or device he or she wishes to use in clinical practice, and to use the products with appropriate patient consent and in compliance with applicable law.

Disclaimer

The material presented at the SRS Annual Meeting & Course has been made available by the Scoliosis Research Society for educational purposes only. This material is not intended to represent the only, nor necessarily best, method or procedure appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement or opinion of the presenter which may be helpful to others who face similar situations.

SRS disclaims any and all liability for injury or other damages resulting to any individuals attending a session for all claims which may arise out of the use of the techniques demonstrated there in by such individuals, whether these claims shall be asserted by a physician or other party

The 2015 Pre-Meeting Course is supported by grants from DePuy Synthes, Medtronic, and NuVasive

Lunchtime Sessions

The following symposia will take place during the lunch hour:

How to Accelerate Recovery of AIS Patients after PSF for AIS

Location: Marquette Ballroom
Chair: Lawrence L. Haber, MD

Current treatment trends are significantly reducing the amount of time patients stay in the hospital after PSF for AIS. The intent of this one hour symposium is to communicate to the audience post-operative treatment care plans that will allow routine discharge of these on post-operative day 2 and 3, even when utilizing a PICU. Initially, we will present the historic obstacles to rapid discharges. We will then review and discuss the Atlanta Post-Operative Protocol, a multimodal pain regimen and address GI issues. By the end of this symposium, the audience will have a good understanding of how to accelerate recovery of AIS Patients after PSF. In our value based environment, efficiency will be a critical component in allowing us to best utilize our recourses for our patients.

Update on Missions and Activities in Endorsed Global Outreach Sites

Location: Symphony Ballroom
Chair: Anthony S. Rinella, MD

Meet the members of the SRS Global Outreach Committee and representatives from the SRS Endorsed and proposed sites at the Global Outreach Committee Lunchtime Symposium, "Update on Missions and Activities in GOP Sites" This symposium will be informative for anyone who has ever thought about volunteering skills and knowledge in another country or wants to learn about some of the current treatment of less common conditions such as Pott's disease or untreated severe scoliosis. During the symposium, representatives from the SRS Endorsed Sites will report on the last year's activities at some of the sites where they have volunteered. If you have already been involved in Global Outreach in spinal deformity care, this is an excellent opportunity to network with colleagues.

Minimally Invasive Spinal Deformity Techniques

Location: Minneapolis Ballroom
Chair: Praveen V. Mummaneni, MD

Learning Objectives:
1. To learn the biomechanics and pathophysiology of adult spinal deformity.
2. To review the history of the development of MIS spine surgery.
3. To learn the indications for open and minimally invasive treatment of adult spinal deformity utilizing an algorithmic approach.
4. To understand the advantages/disadvantages of anterior, posterior, and lateral approaches for the correction of adult spinal deformity.
5. To learn complication avoidance and management strategies for minimally invasive spinal deformity correction surgery
6. To understand the role of MIS surgery in pediatric patients.

Notes

Historical Perspectives

Moderators:

Sigurd H. Berven, MD & Hani H. Mhaidli, MD, PhD

Faculty:

John P. Kostuik, MD; Stuart L. Weinstein, MD; John P. Lubicky, MD; Michael J. McMaster, MD, DSc, FRCS; John E. Lostein, MD; Aina Danielsson, MD; John Dormans, MD

Missions and Goals of SRS: Then and Now

John P. Kostuik, MD, FRCS
Past President, SRS (1987)
Professor Emeritus, Johns Hopkins University
Past Chairman, Johns Hopkins Department of Orthopaedics
Founder, Past Chairman, Director and Chief Medical Officer, K2M, Inc.
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SRS – 50 YEARS OF GLORY [1]

ORIGIN

- The idea for the SRS was suggested by Dr. David Levine
- The formation was led by Dr. John Moe and he became the first president
- The mission of the SRS was / is optimal treatment of patients with spinal deformity
- Ideals
  Dissemination of knowledge to improve care of patients with spinal deformities
- The Organization was / is dedicated to education, research & treatment of spinal deformity
- In 1966, 37 members attended the first meeting held in Minneapolis, Minnesota
- The initial focus was the adolescent patient base
- The SRS led to the development of spine deformity societies throughout the world

JOHN MOE, MD [3-5]

Figure 1. John Moe, MD

- John Moe was the first president of the SRS, serving from 1966-1969
- He was known as 'the father of modern posterior fusion'
- Moe convinced Paul Harrington to add fusion to rod correction
- Square ended rods & square holed Harrington hooks
- Ambulatory Risser localizers after Harrington instrumentation
- Halo femoral traction
- Subcutaneous rods without fusion for malignant early onset curves

THE EARLY GIANTS

- The early members made up an impressive cast
  John Moe, MD
  John Hall, MD
  Dean McEwen, MD
  Paul Harrington, MD
  David Levine, MD
  Robert Winter, MD
  Kenton Leatherman, MD
  Louis Goldstein, MD
  William Kane, MD
- There have been 45 presidents to date
- David Polly, MD is the current president-elect and will become the 46th president

Figure 2. Attendees of the First SRS Meeting [1]

LEADERSHIP, EDUCATION, RESEARCH & DEVELOPMENT

- The presidential line
- Committees
- Courses
- Meetings
- Research: start up grants
- Morbidity & mortality reports
- Publications
  The following are the first publications of adult deformity
  Nilsonne (Sweden 1970)
  Kostuik, JBJS (Canada, 1973)
  Ponder, Dickson, et al (USA, 1974)
- The SRS was the first of many spine associations
  Offshoot associations include ISSG, Harms Study Group, Growing Spine, etc.
  Subsequent associations include NASS, CSRS, ISSLS, POSNA, etc.

Figure 4. Past Presidents of the SRS [7]

Figure 3. Past Presidents of the SRS [6]

EVOLUTION OF SRS MEMBERSHIP [7]

- In 1966, the 37 members were originally from either the US or Canada
- There was a smattering of non-North American corresponding fellows (non-voting)
- All presidents of known international spine societies were invited to the 1987 annual meeting held in Vancouver, Canada
- Traveling fellowships were instituted in the late 1980s and alternate between North America, Europe & Asia
- By 2015, there are > 1200 members representing 49 countries
- In 2016, Professor Kenneth Cheung of Hong Kong becomes the first non-North American president to be elected, thus in line to become the 47th president.

EVOLUTION OF SRS ANNUAL MEETINGS

- Originally the meetings were 3 days, including a ½ day golf tournament
- Future meetings involved a swim meet, organized by Les Nash Teams were The Idiopathics, The Congenitals and The Paralytics (neuromuscular)
- Half-day courses were added in the 1970s
- The 1974 Meeting was the first to be held outside North America
  The pre-course was held in Lyon, France
    Notable French surgeons were in attendance (e.g., Stagnara, Cotrel, Salannova, Michel, Dubousset & Picault)

  The meeting itself was held in Göteborg, Sweden and hosted by Alf Nachemson
- SRS celebrates its 50th anniversary at the 2015 meeting

SUBSEQUENT DEVELOPMENTS

- A greatly enhanced committee structure
  Committees now include: advocacy & public policy, historical, awards & scholarships, education, global outreach, membership, SRS outcomes, Hibbs Society, non-operative management, etc.
- 2015 saw IMAST's 22nd meeting
- Global courses include Turkey, China, Egypt, Korea, Russia, etc.

MAJOR INNOVATIONS BY SRS MEMBERS

- Harrington rods & hooks (1958)
- Halo (Nickel & Perry)
- Luque sublaminar wires (1970s)
- Harri-Luque
- Wisconsin buttons, Drummond wires
- Dwyer anterior cables (1970s)
- Halo pelvic (DeWald)
- Zielke instrumentation (early 1970s)
- Cotrel-Dubousset instrumentation (1983)
- Pedicle screws in the 1960s (Boucher, Roy-Camille, Steffee, etc.)
- Growing rod systems
- Continued development by SRS members paves the pathway to modern era instrumentation & solutions

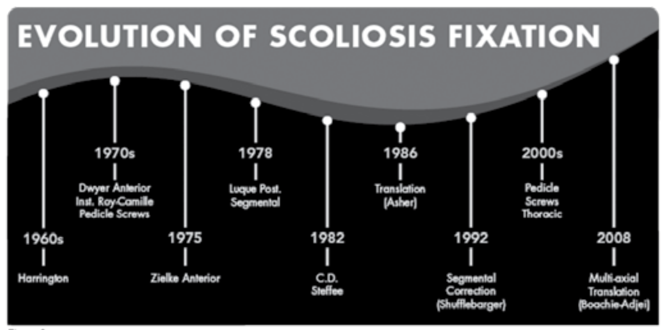

Figure 6.

Figure 4

PAUL HARRINGTON, MD

THE HARRINGTON SYSTEM [8]

- Comprised of hooks and rods
- Provided distraction and compression
- The distraction system had hooks only at each end
- Corrected only mobile ends of the curve and flattened lumbar lordosis
- The greatest stimulus to the development of spinal surgery was Paul Harrington's rods. This led directly to the formation of the Scoliosis Research Society.

PIERRE STAGNARA, MD [9, 10]

Stagnara developed the first approach to manage scoliosis with braces & casts

LYON BRACING MANAGEMENT FOR SCOLIOSIS

- Use of plaster casts
- Use of the Lyon brace
  An adjustable and rigid brace with no collar
  The brace was originally made of leather and steel
  t gradually evolved to use aluminum bars & polyethylene plexidur
  There are a handful of variations on the Lyon classical thoracic or Double Major Brace.
- He was one of the first to surgically treat complex adult deformities
- In 1973, Stagnara developed the 'wake up test' which is still used today

ALAN DWYER, MD

DWYER TITANIUM CABLE SYSTEM [11]

- A titanium cable is stretched from vertebra to vertebra by a special clamp
- Then secured to each vertebra with screws and clips

RAYMOND ROY-CAMILLE, MD [12]

- In 1963, Camille developed the concept of placing a screw in the pedicle
- He was the first to use hooks and screws, then connecting them with rods or plates
- In the later 1960s, he popularized the technique in Europe
- The technology and technique was later introduced in the United States in 1979
- Camille's spinal plating system has been referred to as "the predecessor of most modern pedicular screw-plate fixations."

KLAUS ZIELKE, MD

ZIELKE ANTERIOR DEROTATION DEVICE

The device provides curve correction for scoliosis

EDUARDO LUQUE, MD [13]

LUQUE SYSTEM FOR POSTERIOR SEGMENTAL FIXATION

The system provides posterior segmental fixation with sublaminar wires which greatly increased stability

YVES COTREL, MD & JEAN DUBOUSSET, MD

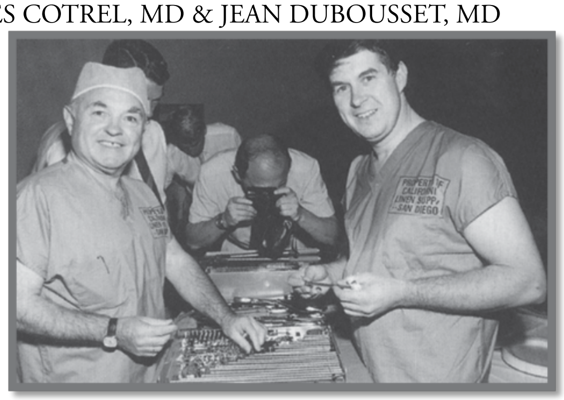

Figure 5. Yves Cotrel & Jean Dubousset ~1986 [14]

CD SYSTEM [15]

- The system was developed in France in the early 1980s
- The CD system is a double rod system made of steel that allows for segmental fixation through lamina hooks and/or conical pedicle screws.

21st CENTURY ADVANCEMENTS FOR THE TREAMENT OF A MYRIAD OF SPINAL PATHOLOGIES

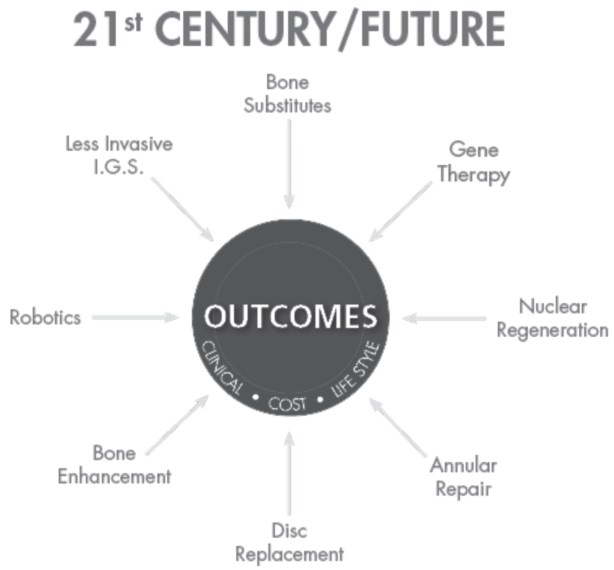

Figure 6

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Notes:

Natural History of AIS

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Ignacio V. Ponseti Chair and Professor of Orthopaedic Surgery
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Iowa City, Iowa, USA

Most important part of any discussion with patient and family

- What are we trying to prevent when we treat a patient with AIS?
- Who needs treatment?
- Who needs surgery?
- Why do we operate?

First Step in evidence based practice

- Understand the natural history of a condition
- Learn adult consequences

All AIS patients are individuals

- Discussion today relates to "Generalities" about all AIS patients

Natural History 1960's to 1980's Grim Prognosis

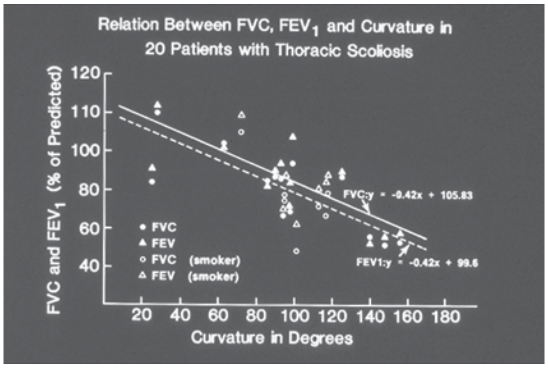
- Nilsonne and Lundgren 1968
- Nachemson 1968
  - All studies suffer from faults of retrospective reviews most importantly mixed etiology
  - Misconceptions that all types of idiopathic scoliosis inevitably lead to disability from back pain and cardiopulmonary compromise

Iowa Natural history follow- ups.
(patients seen initially 1932-1948

- Ponseti and Friedman 1948 average 2 year retrospective follow up
  - Identified 4 curve patterns in AIS
- Collis and Ponseti 1969 Retrospective follow up of this cohort
- Weinstein et al. 1976 began prospective evaluations of cohort
  - Weinstein, Zavalla and Ponseti 1981 average 40 year follow up
  - Weinstein and Ponseti, 1983 Publication of Curve Progression Data
  - Weinstein, Dolan, Spratt et al 2003: 51 year average follow up with Lifetime natural history of untreated AIS
    - 223 patients with new information at ave f/u 51 years, ave age at follow up 66 years
    - Serial measurements at all follow ups
      - Back Pain
      - Pulmonary Symptoms
      - General Function
      - Depression
      - Body Image
    - Patients personally examined by SLW at 40 and 51 year followups
    - Age and sex matched controls at each follow up screened to insure no scoliosis.
    - Cobb Angles (mean) at final follow up (worst case scenario)
      - Thoracic 85 degrees (23-156)
      - Thoracolumbar 90 degrees (50-155)
      - Lumbar 49 degrees (15-90)
      - Double Major
        - Thoracic 79 degrees (30-104)
        - Lumbar 76 degrees (32-110)

Natural History

- Pulmonary Symptoms
  - Having a Cobb angle of greater than 50 degrees at skeletal maturity is a significant predictor of decreased pulmonary function



From Weinstein, Zavala and Ponseti JBJS 1981

Mortality:
- No evidence to link untreated AIS with increased rates of mortality in general, or from cardiac or pulmonary conditions potentially related to the curvature.
- The estimated probability of survival was 0.55 (95 percent CI, 0.47 – 0.63) compared to 0.57 expected for the general population of people born in the same time frame

Curve Progression
- 68% of curves progress after maturity
    - Curves less than 30 degrees at skeletal maturity tended not to progress, regardless of the curve pattern.
    - Curves measuring between 50 and 75 degrees at maturity, particularly thoracic curves, progressed the most.

Back Pain (at fifty one year follow up)
- More chronic back pain
- More acute pain of greater intensity and duration
- Ability to work and do ADL similar to controls
- Despite back pain this group of untreated patients continues to function at a high level indicating that the natural history of AIS does not necessarily include functional disability

Marriage Rates:
- Same as rates for population born in same years as cohort
- Same as controls

Psychosocial Indices (Depression Index)
- Scoliosis patients 47.53 (9.74)[24.21-69]
- Control patients 48.17 (10.02)[29.63-66]

Body Satisfaction
- On all scales patients were slightly dissatisfied to slightly satisfied

<u>**Summary**</u>

AIS is a unique entity whose natural history is very different than that of early onset scoliosis or scoliosis caused by other etiologies.

Untreated AIS does not lead to early disability or death or the inability to have a normal life.

Untreated scoliosis may lead to increased back pain, cosmetic concerns and in large thoracic curves pulmonary symptoms

Curves over 50 degrees at skeletal maturity have a tendency to progress throughout life

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Notes:

Spondylolisthesis and Spondylolysis –The History of Their Discovery and the Natural History of Their Behavior

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Spondylolisthesis is a generic term for a condition in which one vertebra slips on another. The most common level for this to occur is at the lumbosacral junction. Like a number of other musculoskeletal conditions now typically diagnosed by imaging studies such as Klippel-Feil syndrome, spondylolisthesis was discovered and described before radiography was available. Spondylolisthesis was initially recognized by the obstetrician Kelian in 1854. Further anatomic details were provided by Neugebauer in the 1800s as well. It was felt to be problematic for obstetricians because in its severe form it could block passage of the fetus during delivery through the pelvis. Its role in causing back pain and neurologic issues became more well-known after imaging techniques were discovered. The ability to visualize the deformity on radiographs allowed researchers to characterize different types of spondylolisthesis (as well as spondylolysis) and correlate the findings with symptoms and signs.

As mentioned previously, the early description of spondylolisthesis was actually by obstetricians and a number of them contributed to knowledge about this entity. In addition to Kelian's cases reported in 1854, also in the 1850s Breslau examined pathologic specimens in the Pathologic Museum of Munich. Another researcher, Rokatansky, characterized the deformity as well. Neugebauer, mentioned previously, though an obstetrician, spent most of his later career studying this deformity. Robert did cadaveric experiments to produce the spondylolisthesis and showed that as long as the articular processes were in place, slipping could not occur even with sectioning of the ligaments of the spine as long as there was no defect in the pars or pedicles. A concept known as hydrorrhachis was offered as a cause of slippage with elongated pars and an enlargement of the spinal canal and this may have been a description of a truly dysplastic type of spondylolisthesis. A number of other investigators in the late 1800s offered both corroborative as well as alternative theories of the etiology of the deformity. But overall these researchers fairly accurately described the abnormality and how the deformity develops and is not contrary to what is known about it today.

Spondylolisthesis and spondylolysis are relatively common spinal conditions and are on somewhat of a spectrum of abnormality and can arise from different causes and can have variable natural histories. While spondylolysis and spondylolisthesis may exist concomitantly, frequently spondylolysis remains just a pars defect that does not eventually result in a slip. Conversely, slippage can occur with intact although elongated pars, that is, without the spondylolytic defect. It seems only natural then that some sort a classification system would be developed to separate the different types and thus help to predict their natural courses. The Newman Wiltse classification is the most well-known and separates the types based on the anatomic abnormality and/or etiology. However the isthmic type that is described there is often confused with the dysplastic type in discussions about spondylolisthesis. In the Wiltse classification the pars defect was emphasized to be an essential component and perhaps did not emphasize enough the fact that the pars defect may occur later in the evolution of the slip or may not occur at all even in the presence of a large degree of slippage. Marchetti and Bartolozzi recognized this dilemma and described a more precise differentiation between the developmental and acquired types of spondylolisthesis/spondylolysis. For the dysplastic type they emphasized the dysplastic nature of the posterior elements (the hook and clasp concept) as well as the disk bond in providing stability to the motion segment. This also helped separate the more serious natural history of the dysplastic types compared to the acquired lytic types. In recent years the disk bond has been further studied and severe developmental slips in young patients have been -shown to be analogous to physeal separations of the intervening disks. Unfortunately confusing these categories of spondylolisthesis in discussions of spondylolisthesis in textbooks and published papers still exists. This may lead to a misunderstanding of the natural history as well as the presentation of these two different forms of spondylolisthesis.

Over the years the different prognoses between a developmental versus a lytic type a spondylolisthesis has been described. A number of studies have shown that the lytic type will unlikely progress to a severe deformity and generally the maximum amount of slip will have been attained by age eight and not increase further after that. On the other hand various radiographic parameters have been identified in the dysplastic type that portend to a poor prognosis such as a high slip angle, a high vertebral index, and rounding of the dome of the sacrum. Additionally hypoplasia of the L5-S1 facet joints, spina bifida occulta, and an insecure disk bond can contribute to progressive deformity. Physical findings reflect this abnormal anatomic relationship with a high-grade dysplastic slip producing the classic lumbosacral step-off, the jump position on standing, the backward rotation of the pelvis, an abnormal gait and tight hamstrings - findings rarely seen with the truly acquired lytic type. The dysplastic type frequently familial as well.

These factors are important when counseling patients as those with the acquired type may develop low-back pain but rarely neurologic deficits or severe deformity. Patients, especially children and adolescents who present with an already advanced dysplastic slip, may expect a greater likelihood of further progression with growth and concomitant symptoms and signs as noted previously. Interestingly and ironically many patients remain asymptomatic except for the deformity despite the presence of severe slips and whose deformities are discovered serendipitously because of imaging studies done for another reason. Thiscreates a treatment conundrum and also speaks to the idea that the mere presence of severe deformity does not always cause trouble nor does it constitute an indication for invasive and potentially dangerous surgery.

A short discussion about spondylolysis seems necessary for completion. Spondylolysis alone without a slip or with a minor one may exist on a spectrum of severity that may be associated with an asymptomatic course or be a cause of sudden acute back pain and hamstring spasm. Acute spondylolysis (a pars stress fracture) is an example of the latter. The fractures may heal with simple immobilization if detected early while the automatic healing process is still active as demonstrated on a technetium bone scan. However, immobilization in the face of either a positive or negative bone scan may result in relief of symptoms even without healing of the pars defect. Immobilization has some chance of aiding the healing of recent pars fractures if the increased metabolic activity at the fracture is still active. Surgical repairs of persistently symptomatic pars defects especially proximal of L5 can be successful in relieving chronic pain without sacrificing a motion segment. An L5-S1 fusion for L5 spondylolysis sacrifices one. So the natural history of spondylolysis is variable. It could be associated with slippage. It may remain asymptomatic or may be the cause of acute or chronic back pain that requires treatment.

In spondylolisthesis at L5-S1 conceptually the entire spine along with L5 is translated anteriorly and in high-grade dysplastic types it is also translated caudally in front of the sacrum due to the kyphotic relationship of L5 to S1. This describes an unstable and unnatural position of the spine and this instability intuitively could be expected to cause symptoms especially pain. The outward physical manifestation of this translation depends on each individual's specific spinopelvic relationship that involves the pelvic incidence and the ability of the spine to lordose enough to compensate. Those with high pelvic incidence often cannot and have significant sagittal plane malalignment. These factors are important in choosing the type of surgical procedure, if indicated, as they may dictate the need for realignment versus in situ stabilization to relieve symptoms and improve spinal balance. Advancements in imaging and quantifying anatomic relationships enable better evaluation of a patient's deformity including the contents of the spinal canal. This discussion illustrates anatomic factors that could understandably result in various symptoms especially pain.

Given the theory that some degree of spinopelvic instability could cause symptoms, relief of those symptoms would naturally lead to the idea that stabilizing the deformity and this has been the mainstay of treatment for spondylolisthesis. This could be accomplished simply by temporary or chronic external immobilization with casts or braces supplemented with physical therapy to strengthen back and abdominal muscles so as to provide some dynamic support for the spine to surgical fusion of the displaced segment. For those patients with the deformity but who are asymptomatic from the start or those who benefited from the simple measure of external immobilization and physical therapy, that may be all that is ever needed though repeated courses of treatment might be indicated as time goes on.

For those who do not respond, more aggressive treatments have been developed and the methods used have ranged from in situ fusions without instrumentation, various reduction maneuvers of the slip as well as spondylectomy. Good results (for the relief of pain and other symptoms) have been reported over the years from simple fusion in situ which remains the gold standard for treatment. It is safe and effective for most patients. Pseudo-arthrosis has been recognized as a frequent problem but ironically symptoms are often relieved nonetheless. (This also remains an enigma even today in patients who have instrumented fusions though in general, instrumentation lowers the pseudarthrosis rate & patients with solid fusions have better outcomes than those who do not). Fusion in situ is associated with generally a low risk of complications but cauda equine syndrome has been reported after that procedure. Various kinds of closed reduction techniques have been used such as traction, reduction using a Risser frame followed by cast immobilization along with an in situ fusion as well as some rather novel methods such as slow reduction with a windlass device connected percutaneously to the posterior vertebral elements and attached to a cast to slowly reduce the slip followed by fusion. These techniques were hard on the patients and the results were often disappointing.

Although various instrumentation constructs have been used for this deformity over the years, the introduction of pedicle screws has revolutionized the treatment of spondylolisthesis for in situ fusions as well as more complicated treatment paradigms such as reductions. Pedicle screw instrumentation offers strong fixation and allows for powerful maneuvers to realign the spine and thereafter providing stable preservation of the correction. Various specific fusion techniques besides posterolateral bone grafting include using structural bone grafts that cross the lumbosacral junction. For those patients with spondyloloptosis, the most severe form of spondylolisthesis, L5 vertebrectomy has been described by a number of authors in which case the entire L5 vertebra is removed and the reduction of L4 into the sacrum is performed. While this procedure offers tremendous correction and realigns the spine over the pelvis it has been associated with a high degree of neurologic deficit although it may be temporary.

Currently, it is not clear that reduction of spondylolisthesis is clearly better than a fusion in situ based on a number of patient reported outcomes instruments that reflect quality of life, function or patient satisfaction, although conceptually it would seem better to normalize spinal alignment and thereby provide better anatomic stability as well as aligning bone graft and the fusion mass in a more favorable orientation for healing and support. It would also improve cosmesis which has been found to be important in self-image after surgery. Reduction might be necessary in those who cannot compensate for their spinopelvic abnormality in order to improve the sagittal alignment. Others who have a relatively high degree of slip but who have favorable spinopelvic relationships and whose physical appearance is not very abnormal, can be well-served by a simpler and safer instrumented fusion in situ.

Spondylolisthesis remains a somewhat controversial topic as far as treatment and natural history is concerned. It certainly is interesting that some patients that have a high degree slip are asymptomatic and function normally while others with relatively mild deformity suffer from chronic back pain, gait abnormalities and neurologic deficit. A thorough evaluation of the type of spondylolisthesis that the patient has and examination of their spinopelvic parameters will aid in appropriate treatment courses for these patients. Those that are asymptomatic but have large slips probably should be left alone and surgeons should not be tempted to offer procedures, just because of the presence of the deformity, that may be risky and will not improve their function or quality of life. It cannot be emphasized enough that the natural history of a spondylolisthesis differs from individual to individual.

Notes:

NATURAL HISTORY OF CONGENITAL SCOLIOSIS

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Congenital scoliosis is a lateral curvature of the spine due to the presence of developmental vertebral anomalies which produce a localized imbalance in the lateral longitudinal growth of the spine.These vertebral anomalies are present at birth, but the scoliosis may not become obvious until later childhood when the diagnosis is made radiographically. Some patients present with small curves which do not progress whereas others progress rapidly to become a severe deformity at an early age and can impair lung growth and development.

In order to formulate a course of management it is necessary to have a thorough knowledge of the natural history of all types of congenital scoliosis.

CLASSIFICATION of congenital scoliosis is based on

- The embryological maldevelopment of the spine and the type of vertebral anomaly causing the scoliosis.
- Site at which the anomaly occurs.

The objective of classification is to identify those types of curves with a bad prognosis which require early prophylactic treatment

There are 3 groups of vertebral anomalies which can produce a scoliosis

- First, those due to a unilateral defect of vertebral formation – the most common of which is a hemivertebra.
- Secondly, those due to a unilateral defect of vertebral segmentation of two or more vertebrae
- Finally, a third group which cannot be classified because they have a complex mixture of anomalies.
- A wedged vertebra and a block vertebra do not by themselves cause a clinically significant scoliosis.

A **HEMIVERTEBRA** is the most common cause of a congenital scoliosis but the severity of the deformity varies greatly, and there is debate as to the necessity and timing of treatment.

The potential for a hemivertebra to cause a significant scoliosis depends on 3 factors.

1. Most importantly, the pathological anatomy and relationship of the hemivertebra to the adjacent vertebrae in the spine. The hemivertebra may be fully segmented, which is most common, semisegmented or incarcerated which is least common.
2. The site of the hemivertebra is important, especially those occurring at the cervico-thoracic and lumbosacral junctions.
3. The number of hemivertebrae and their relationship to each other in the spine - one or two hemivertebrae and are they on the same side or are they opposing.

A *fully segmented hemivertebra* is separate from the adjacent normal vertebrae and can occur anywhere in the spine. The prognosis for a *single fully segmented hemivertebra* can be difficult to predict and requires careful monitoring. The majority of curves usually progress relatively slowly at one or two degrees per year. A *lumbosacral hemivertebra* is the most pernicious and deforming type of hemivertebra. Here it causes an oblique take-off of the lumbar spine from the sacrum and the patient lists to one side. This requires early surgical treatment.

Two unilateral hemivertebrae are less common but have a much worse prognosis. These curves usually progress at 3 to 4 degrees per year and the majority will exceed 50 degrees by the age of 10 years and requires early prophylactic surgical treatment. By skeletal maturity, the majority will exceed 70 degrees.

Two opposing hemivertebrae have a more variable prognosis depending on the site and types of hemivertebrae. If the hemivertebrae are close together in the same region, the spine remains balanced and there is only a minimal cosmetic deformity. If, however, the hemivertebrae are widely separated in different regions, the spine is often unbalanced which is much more deforming and may require surgical treatment.

A semi-segmented hemivertebra is synostosed to the neighbouring vertebra and usually occurs in the lumbar region. The scoliosis progresses very slowly resulting in a mild deformity which may not require treatment.

An *incarcerated hemivertebra* is a small ovoid piece of bone, with poor growth potential, lying in a niche in the spine which remains straight. No treatment is required.

A UNILATERAL UNSEGMENTED BAR is due to a unilateral failure of segmentation of two or more vertebrae. This may occur anywhere in the spine, affecting a mean 3 vertebrae, and no one region is more commonly affected than the other.

Without treatment the majority of patients have a bad prognosis. Mean rate of curve progression 5° per year with the scoliosis exceeding 50° by the age of 10 years and 70°at skeletal maturity. This requires early prophylactic surgical treatment.

There is also a smaller less well recognised group of patients who have an even worse prognosis. These patients have not only a **UNILATERAL UNSEGMENTED BAR, BUT ALSO ONE OR MORE HEMIVERTEBRAE ON THE CONTRALATERAL SIDE OF TH SPINE AT THE SAME LEVEL.**

These anomalies occur in all regions of the spine and result in the most severe and rapidly progressive of all types of congenital scoliosis. Mean rate of curve progression 6-7° per year before 10 years. Majority will exceed 50° by age 2 years.

There is also severe vertebral rotation with constriction of the rib cage associated with congenital rib fusions (22%) which can impair lung growth and development leading to a thoracic insufficiency syndrome. Requires early prophylactic surgical treatment.

A *secondary structural scoliosis* can occur in association with a unilateral unsegmented bar with or without hemivertebrae whose apex is at T4, 5, 6 or 7. This produces a rotational torque which is transmitted further down the spine resulting in a severe thoracolumbar scoliosis on the opposite side. This becomes fixed and severely rotated producing the major deformity.

A scoliosis caused by a jumble of **UNCLASSIFIABLE VERTEBRAL ANOMALIES** can be difficult to predict and requires careful monitoring.

<u>KEY TO SUCCESSFUL TREATMENT</u>

- Early diagnosis
- The ability to anticipate what is likely to happen based on the type and site of the vertebral anomaly and spinal growth remaining.
- The application of prophylactic surgical treatment to prevent severe deformity and possible respiratory complications.

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Notes:

Historical Perspectives: Prediction of Curve Progression in Idiopathic Scoliosis

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The Prediction of Curve Progression in Untreated Idiopathic Scoliosis during Growth*†

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J Bone Joint Surg 66A; 1061, 1984.

Progression in Adolescence in the literature at the time of the study

	# Pts.	Progression	Curve
Brooks	134	5.2%	
Rogala	603	6.8%	
Clarisse	110	35%	10-29°
Fustier	70	56%	<30°
Bunnell	326	20%	<30°
		40%	>30°

Factors from the literature stated as important for curve progression are: 1. curve pattern, 2. age, 3. maturity, 4. Risser and 5. menarche

It is beneficial to be able predict which curves will progress as a knowledge of natural history essential for decision making

Aims of the study were to investigate factors related to curve progression, and to predict the prognosis in a specific patient

1. **Series inclusion criteria** were 1. AIS / JIS, 2. first seen between 1970 and 1979, 3. initial curve of 29° or less and 4. followed to maturity or progression.

   A clinical definition of progression was used
   a. For curves under 19° there had to be a 10° change,
   b. For curves between 20° and 29° a 5° change.

The series consisted of: 727 patients of whom 79% were female with an age range from 10 to 15 years (77% aged 10 to 14 years). The curve magnitude on presentation ranged from 10° to 29°, with 39% being 20° to 29°, and the Risser grade was 0 or 1 in 62% of cases

Results

1. A total of 169 cases progressed (23%)
2. 78 improved 5° or more (11%),
   a. these being less mature
   b. with a larger percentage of curves under than 15°.
3. 131 of the 169 cases that progressed needed treatment (78%), giving 18% of the cohort needing treatment.
   a. 85 with the Milwaukee brace,
   b. 35 with a TLSO,
   c. 10 with ESO and

d. 1 with surgery.

Thirty-eight patients were not actively treated, and just observed, progressing at a slow rate, and at maturity having a curve under 40°. These patients in addition were more mature and had smaller initial curves.

Prognostic factors

The prognostic factors that were related to curve progression were:

1. Curve pattern. All the curve patterns had a 25 to 30% progression rate except for single lumbar or thoracolumbar curves which had a 10 to 15% progression rate.
2. Curve magnitude. The larger the curve, the greater the incidence of progression.
3. Age. The older the patent the lower the incidence of progression.
4. Risser sign. The higher the Risser sign, the lower the incidence of progression.
5. Menarche. 68% of the non-progressive cases were post-menarchal, while 32% of the progressive curves were post-menarchal.

Thus the greater the growth potential - with a younger age, lower Risser sign and pre-menarchal status, - the greater the incidence of progression

The factors that were found to be not related to the incidence of curve progression were family history, sagittal contour, rotational prominence, decompensation, lumbosacral abnormalities and numerous radiographic measurements.

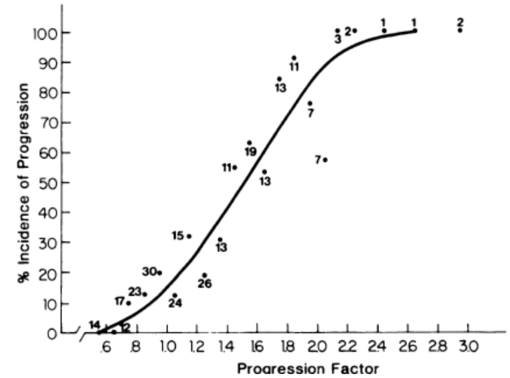
Multivariate analysis showed that the factors most strongly related to the incidence of curve progression were Risser sign and curve magnitude, and on this basis the following table was developed.

Curve magnitude

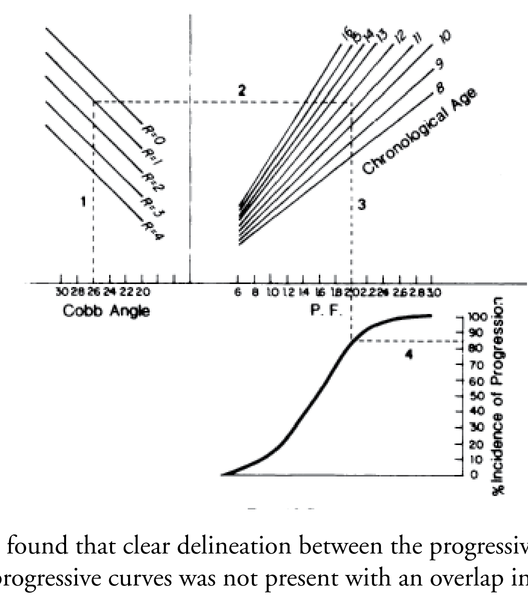
		5-19°	20-29°
	0-1	22%	68%
Risser	2-4	1.6%	23%

A **prognostic factor** was developed using the most prognostic factors – curve magnitude, chronological age and Risser sign.

PF= Cobb Angle –3x Risser Sign
Chronological Age



A **nomogram** was developed using the formula to determine the Prognostic factor using the Cobb angle, Risser sign and chronological age.



It was found that clear delineation between the progressive and non-progressive curves was not present with an overlap in the prognostication, so the prognostic factor was less useful, and the table above was more useful in guiding care and counseling to patients and parents.

In retrospect what could I have done to improve the study?

1. Include curves 20° to 30° - But we did not follow these curves, they were treated without observation.
2. Correlate curve progression with bone age as well as chronological age. The only assessment at that time was the Greulich and Pyle atlas.
3. Started a prospective study with sequential bone ages
4. Only 78% 0f the progressive cases required treatment. In the treated cases what was the result?
   a. Was bracing successful?
   b. Was fusion necessary?
   c. What was the final curve magnitude?
   d. Were there any factors that correlated with bracing success?
   e.

1. It must be remembered that natural history studies are the average of the population studied, and each patient has His/her own natural history. Thus it is necessary to follow / monitor each patient to learn their individual natural history, and we can predict likelihood of progression in general, but not precisely for an individual patient.

Future research.

Future research in this field should be to evaluate all factors in patients with progression including the factors above and more accurate bone ages using Tanner/Whitehouse and Saunders data as well as genetic factors. This should be in a consecutive retrospective population evaluating progression as well as treatment outcome. The roadblock in such a study is having all the data necessary on all the patients. A prospective study is a solution but this had logistic Obstacles, and will take 8-10 years.

Notes:

Long-Term Follow-Up of Brace and Operative Treatment in AIS

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Introduction

- Aim: To give a summary of our own and other long term studies of outcome after treatment of AIS in the light of the BrAIST study. [1]
- Presentation of comparisons between patients with AIS braced or operated before maturity.
- This historical perspective and the long term studies of IS that we have performed were possible by use of the Gothenburg Scoliosis Data Base, founded by Prof. Alf Nachemson in 1968.
- Many other studies in terms of long term outcome after treatment have been published, not all can be cited during this 8-minute presentation.

Is bracing effective and do curve sizes increase after maturity?

- The BrAIST study [1] in 2013 showed that:
  - "treatment success in 72% compared to 48% after observation and
  - bracing significantly decreased progression of high-risk curves to the threshold of surgery in patients with AIS. The benefit increased with longer hours of brace wear."
- The Swedish patients of the 1995 SRS brace study [2] were re-evaluated mean 16 y after maturity [3]. Two groups, one braced, n=41 and one observed, n=65, were followed.
  - During adolescence: within the group that was brace treated immediately no one progressed until surgery, while in the observed group, 20 percent went on to bracing and another 10 % were operated before maturity.
  - Long term outcome: no braced patients had undergone surgery after maturity during the follow-up period. Curve increase was mean 5.7° during the mean 16 Y FU, 45% increased 6° or more but only 1 patient had a curve size above 45°.
- Other studies show similar results, some curve increase but few surgeries:
  - Danielsson (Boston), 2001, n=109, age 41 y: curve increase mean 8°/22 y, 4% increased >10°. 1 (1%) pat op due to curve progression. [4]
  - Gabos 2004 (Wilmington, n=51, 15 Y FU after maturity) 7 pts (13%) increased >or=5 degrees of progression of the curve (maximum 17°) compared with start of treatment. No patients had been operated upon. [5]
  - Lange 2009: (Boston, n=109, m 19 Y FU, age mean 35 y) Curve size at start 33°, at weaning 28° and at FU 34°. 13% had curve size >45° at FU. No surgeries reported. [6]

Radiographic outcome after surgery and reoperations

- Various degree of complications and reoperations, this seem to have some effect on curve size at FU
- Published studies – results:
  - Danielsson (Harrington), 2001, n=139: curve increase 4°/23 y, complication rate 5%, reop. rate 5% [4].
  - Padua (Harrington), 2001 n=70: curve increase 20°/24

y, rod removal in 68% (complications) [7].

- Helenius (Harrington), 2003 n=78: curve increase 7°/21 y, complic. 12%, rod removal in 64% (routine) [8].
- Helenius (CD), 2003 n=57: curve increase 7°/13 y, complic. 26% [8].
- Benli (TSRH) 2007 n=109: curve increase 8°/ 11 y, complic. Rate 20%, reoperation rate 9%. Abnormal balance: preop 80%, postop 5%, FU 9% [9].
- Larson (TSRH/CD, thoracic only) 2013 n=19: curve increase 9°/20y [10].
- Sudo (anterior instrumentation, thoracic curves) 2013 n=25: curve increase 9°/ 15y [11].
- Min (pedicle screws) 2013, n=48: curve increase 5°/10y. 6/48 pat rod removal due to low grade infection, lost correction from initial 70% to 42% [12].

Mobility and muscle strength

- Danielsson et al 2006, n=135, 23 Y FU [13]
  - Range of motion of the lumbar spine was significantly decreased in both braced and operated patients (decreased by 37 and 61% respectively).
  - Operated patients also had a reduction of thoracic and cervical motion, with a significantly reduced finger-floor distance (12 vs. 4 cm in braced pts, p<0.0001).
  - The length of fusion into the lumbar spine correlated inversely with lumbar range of motion.
  - Muscle endurance for both lumbar flexor and extensor muscles was significantly decreased compared to controls, for ST with 31 and 41% and fot BT with 30 and 29 % respectively.
  - The stronger and the more mobile the spine was in the operated patients, the better the physical function (SF-36). Braced patients with reduced lumbar spine motion had higher pain intensity and larger extension of pain area.

Degenerative Changes

- Concerns about discs below the fusion
- Published studies – results:
  - Radiography:
    - Danielsson 2001 showed >25 % disc height reduction of the lumbar spine in 16% of braced and in 25% of operated patients, compared to 0% in matched controls. [4]
  - MRI:
    - Danielsson (Harrington), 2001, 25 Y FU, n=32: If fused to L4 or L5: 75% had severe degenerative changes on unfused discs on MRI. Correlated to lumbar pain and decreased lordosis [14].
    - Green 2011, 12 Y FU, posterior fusion LIV T12-L3: new disc pathology in 85% of pts, mostly L5-S1 disc [15].

Back Pain and Function

- Back pain occurs. Most studies show: light pain, few patients with severe pain. Do not seem to correlate to curve size.
- Braced patients:

Study	Back pain n(%)	ODI (0-100)	VAS (0-10)	General
UNTREATED pts				
Weinstein et al 2003 51y, [16]	*61*	-	-	*Normal ADL and no great impact on work*
BRACE TREATED PATIENTS				
Danielsson et al 2003 20-28y [17]	67	7.7	2.7	Slightly reduced physical function, normal ADL
Gabos et al, 2004 10-19y [5]	31	-	-	Normal ADL and functional activities
Haefeli et al, 2006 10-60y [18]	-	12.8	2.8	Generally do well, if >45° slightly reduced physical function
Andersen et al 2006 10-14y [19]	-	-	1.6	Normal ADL
Lange et al 2011 16-32y [20]	-	9.3	-	Results satisfacory, late juvenile IS=AIS
OPERATED PATIENTS				
Danielsson et al 2003, FU 20-28y (Harr.) [21]	65	8.3	2.4	Slightly reduced physical function, normal ADL
Helenius 2003, FU 21y (Harr.) [8]	13	-	-	Normal ADL and functional activities
Helenius 2003, FU 13y (CD) [8]	11	-	-	Generally do well, if >45° slightly reduced physical function
Niemeyer 2005 , FU 11-30y (Harr.) [22]	-	6.0	0.5	Normal ADL
Bjerkreim 2007, FU >10y (CD) [23]	45	6.9	-	Back function good/excellent/fair in 97%, seldom analgesics
Bartie 2009, FU 19 y (Harr.) [24]	75	-	-	Fused down to L4: pain more frequent
Kelly 2010, FU 17 y (anterior surgery) [25]	-	8.1	-	
Larson 2013, FU 20y (TSRH/CD) [10]	-	4.3	2.5	
Akazawa 2013, FU 31 y (mixed ant./post.) [26]	68	-	-	No difference in terms of Roland-Morris Disability Score towards control group

ODI = Oswestry Disability Index, VAS= Visual Analogue Scale for pain, Harr.= Harrington instrumentation
ADL = Activities for Daily Living

Mental well-being

- Bracing period
  - might be a burden during treatment period
    - reduced QoL (Climent, Freidel 2002) [27,28]
    - no change of QoL (Ugwonali 2004) [29]
  - No negative long term effects (Danielsson et al, 2000, 2012) [30,31]
    - Mental subscales of SF-36 (10-20 y FU)
    - Patient General Well-Being Index
    - SRS-22 (16 y FU)
    - But braced patients seem to get more focused on their appearance and change their body image after treatment
- Surgery
  - does not seem to cause these concerns
  - Curve correction correlated to satisfaction [32] (Note: braced patients do not receive any correction!), but others have found the opposite [33,34]

Quality of Life (QoL)

- General Health Related Quality of Life – SF-36:
  - SF-36 - comparable to general populations as most countries have national norm values
    - Danielsson 2000 (brace + op): somewhat reduced Physical function, otherwise at normal levels [30]
    - Padua 2001 (op) [7] and Andersen 2006 (brace + op) [19] – similar results
    - Götze 2003 (op) [35] summary scores only, the

physical score same as age norms but mental subscore lower than age-related.
- Bartie 2009 (op): minimal reduction [24]
- Simony 2015 (brace + op): PCS and MCS at normal levels [36]

- Scoliosis specific quality of life: Scoliosis Research Society Questionnaire
  - SRS-22, most studies show results at similar levels
    - Benli 2007 (TSRH) [9]
    - Akazawa 2012 (op): lower results than the control group [26]
    - Lange 2009 (brace) [6]
    - Simony 2015 (brace + op): braced and operated at normal levels [36]

Pulmonary function (PF)

- Pehrsson 2001 (operated w. Harrington n=139, and braced, n=110) 25 Y FU [37]
  - On a group level, operated patients had lower PF than braced patients, before treatment and at the long term FU. Both groups had improved values at FU compared to the pre-treatment values.
  - Both groups had improved values at FU compared to the pre-treatment values. Patients of both groups with moderate curve sizes before treatment had low PF values before treatment.
  - Braced patients were close to normal at the 25 Y FU after start of treatment, FVC was mean 89 % of pred. values, but with large variations (56-127 %). 21% had FVC <80% at FU (i.e. subnormal levels)
  - Operated pats had FVC of mean 84 % of predicted at the FU, also with large variations (47-123). 42% had FVC <80% at FU.
  - For operated patients, the pulmonary function (FVC % of predicted) before surgery was correlated to the pre treatment curve size (r= -0.31, p<0.001)
  - The surgery itself improved the PF with only mean 6% of predicted FVC (range -28 to + 34%)
  - There was a gradual improvement after surgery of mean 11% (range -26 to + 31)

  - Conclusions: Despite improvement of mean values of both groups, a number of patients reduce their PF over time.
  - In which patients and why??
  - Therefore save the PF as much as possible and do not let it reduce before treatment, as this might violate the future PF.
  - A spirometry might be used as a guide for decision on when to initiate treatment
- Gitelman 2011 (Operated patients n=49, mean age around 25 y) FU 10 Y postop. [38]
  - Importance of surgical approach in the long term was presented, Intraoperative chest wall violation at surgery (ant. surgery or posterior with thoracoplasty) had reduced their FVC by mean 6.5 % of predicted at the 10 Y FU, while patients with posterior surgery were unchanged. Mean values for FVC was 79 and 85% respectively at FU.
- Sudo 2013 (Operated patients n=25, all anterior surgery, mean age around 32 y) FU 15 Y postop. [11]
  - FVC was 81 % of predicted preoperatively and 73 % at FU. No patients had complaints related to PF.

CONCLUSIONS

- Long term studies show that braced patients in comparison with operated patients treated for AIS have
  - back pain
    - located more in the thoracic region compared to operated patients who have more lumbar pain
    - but pain level and back function are equal between groups
  - better spine mobility and less degenerative changes.
    - Shorter fusions does not seem to save totally for degenerative changes below the fusion
  - Equal function and general quality of life. Most patients are at normal levels
  - Pulmonary function that is better than PF in operated patients on a group level
    - Both groups include patients with reduced pulmonary function and which deteriorate over time
    - Fewer braced than operated patients have a reduced PF
- But:
  - Operated patients more satisfied than braced (Satisfaction domain/SRS-22, Simony 2015 [36])
    - Achieve a curve correction which Is not the case for braced patients
    - Braced patients seem to be more concerned about or change their body image after treatment
- ….. and
  - when informing the patient, this knowledge must be presented to the individual patient in order to help and guide in case there is a choice between brace or surgery.

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Notes:

Neural Complications in Deformity Surgery: Detection and Avoidance

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1) Background [1]

a) Spinal Deformity Surgery
- More powerful ways to correct deformity
- More aggressive surgical techniques
- Risk vs. benefits
- Goals of Intraoperative Neurophysiological Monitoring (IONM)

b) Study background
- Bridwell, et al Spine 2000 Greatest concern in parents and patients: neurologic injury
- SRS 2004 report: Neurologic deficit for idiopathic scoliosis: 1.0%
- Increased risk (0.72% MacEwen 1975)
- Hypothesis: Increasing further with powerful pedicle screw corrections?
- What is the SOC Spinal Cord Monitoring Philadelphia?
- How does one best try to answer this question?

2) Neurological monitoring evolution

a) Wake-up test → somatosensory evoked potentials → multimodal monitoring → multimodal monitoring with tcMEPs and H reflex

b) Why conduct the Wake-up test?
- Too little test of gross function
- Too late, delay after surgical maneuver

c) 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

3) Phase 1

- 3 active Pediatric Deformity Centers:
- Children's Hospital of Philadelphia
- St. Christopher's Hospital, Philadelphia
- Robert Wood Johnson, New Brunswick, NJ

a) Methods (Philly regional Scoliosis Neuromonitoring Study)
- AIS only
- 3 participating institutions, 2000-2004
- Standardized protocol
  (1) TIVA, no hypotension
  (2) Multimodal NM

- 488 consecutive patients
  - (1) 387 girls, 13.7 yrs.
  - (2) 101 boys, 15.5 yrs.
- Transcranial Electric Motor Evoked Potentials (tcMEP) Facts
- Site of mediation
  - (1) Corticospinal tract (CST)
  - (2) Spinal interneurons
  - (3) Anterior horn cells
  - (4) Alpha moto-neurons
- Technically more challenging than SSEPs TIVA
- Identifies inadequate spinal cord perfusion pressure

b) Results
- No complications of monitoring
- No scalp burns
- No seizures
- No tongue-bite injuries

c) Conclusions
- Multimodal NM is a safe & effective method
- No tongue-bite injuries
- No monitoring complication in 488 cases
- No false –
- False positives?
- Wake-up test may not be required on a routine basis (AAOS 207)

4) Phase 2
- Added 4th institution and longer collection period >1000 cases
- Compare the efficacy of tcMEP vs. SSEP
  - (1) Sensitivity/Specificity
  - (2) Temporal response
  - (3) Hypotheses: SSEP alone may initially miss up to 20% of alerts detected early with tcMEPs (delays or misses)
- SRS Hibbs Award Winning Paper 2007

a) Study Hypotheses
- tcMEPs monitoring is more sensitive in detecting impending neurologic deficit vs SSEPs
- Change in SSEPs lag behind those of tcMEPs in the presence of emerging event

b) Materials & Methods
- Retrospective data analysis from 4 institutions (2000-2004), 1121 consecutive AIS-only patients
- Single neuromonitoring group (SMA) and standardized multi-modality neuromonitoring protocol
- Standardized anesthetic protocol
- Operational Definitions
  - (1) Alert, significant tcMEPs and/or SSEP amplitude change prompting surgical or anesthetic intervention
- True/false negatives
- True/false positive

c) Results
- No results 96.6% (n=1083)
- Resolved alerts 2.6% (n=29)
- Unresolved alerts 0.8% (9)

Testing operating characteristics for tcMEP detection of neural events:

tceMEP	Post-op Deficit	No Deficit
+	9 TP	0 FP
-	0 FN	1112 TN

SSEP	Post-op Deficit	No Deficit
+	5 TP	0 FP
-	4 FN	1112 TN

d) Conclusions [2]
- 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

5) Phase 3

a) Protocols, advocacy, organization

6) Personal Experience

a) Intra-op decrease or temporary loss of TcMEPs
- Many (Not false positive) Raise BP, PRBCc, "back off" correcting forces

b) Intra-op complete loss of TcMEPs: 3 cases in 18 yrs. (50/50 spine/tumor)

c) None with permanent deficit

7) Summary

a) Factors affecting Neurological Outcome Following Spine Surgery
- Spine surgeon must understand anesthesia and monitoring

8) Moving Forward [3]

a) The signals just changed? Utilize protocol based approach

b) Loss of Intraoperative Neurophysiological Monitoring
- (1) Review checklist for the Response to IONM Changes in Patients with a Stable Spine

c) Discussion
- What is the "standard of care" in your community?

d) SRS Statement
- *Position Statement on Somatosensory Evoked Potential Monitoring of Neurological Spinal Cord Function*, September 1992
- *Neuromonitoring Information Statement*, January 2009

9) Establishing a standard of care (SOC) for neuromonitoring [4]

a) What should "SOC" be?

b) Evolving technologies can affect definitions of SOC

c) Factors leading to difficulty in establishing a SOC in neuromonitoring during spine surgery

d) Other factors affecting establishment of preferred practice patterns

e) Conclusion – SOC IONM

- Need for unified, unbiased group of surgeons, physicians and experienced professional neurophysiologists (Ph.D., Au.D, DC) to define standards
- Rapidly evolving
- Surgeons should adopt high standards
- SOC should be data-driven, EBM-based, and at minimum, based on selection of the most sensitive/specific and cost effective monitoring modalities available (SRS 2009)

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Notes:

Surgical Approaches to Complex Deformity

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Indications for Anterior Based Surgery Techniques for Spinal Deformity

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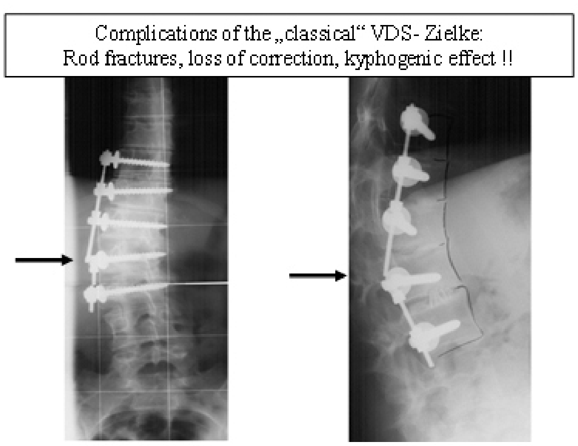
Introduction

First published in 1969, the Dwyer-Instrumentation by Alan Dwyer from Australia was the first anterior system for correction of scoliotic deformities of the spine. Major disadvantages of this system were a marked kyphogenic effect, ineffectiveness of derotation, frequent cable fractures with pseudarthrosis and screw pullouts. The Ventral Derotation Spondylodesis (VDS), also known as Zielke Instrumentation by Klaus Zielke from Germany, was developed to preserve the advantages and to eliminate the disadvantages of Dwyer´s technique. Zielke- VDS, first published in 1975 was the golden standard of scoliosis surgery from the anterior approach two to three decades ago. Whereas frontal plane correction and derotation have been reported to be superior to posterior instrumentation techniques, the influence of VDS on the sagittal plane has been discussed differently during the last two decades. A few authors pointed out, that the sagittal plane can be positively influenced with VDS, because in the more severe curves derotations moves the vertebral bodies back anterior and thus can decrease kyphosis, especially if the intervertebral spaces are filled up with load carrying bone grafts. However, most authors have reported a kyphogenic effect. Another major disadvantage of VDS is lack of stability, which makes long term brace or even cast treatment necessary. Screw pullouts, especially at the most superiorly instrumented level and fractures of the weak threaded rod were reported by several authors. This was associated with painful pseudarthrosis and loss of correction in quite a number of patients. Newer modern anterior systems are either solid single or dual screw rod systems, with which true threedimensional correction and primary stability can be achieved.



disadvantage of single screw rod system with a weak 4mm threaded rod: kyphogenic effect; frequent rod fractures with loss of correction due to pseudarthrosis

Part 2
Biomechanical considerations

Single screw to rod systems with and without cages

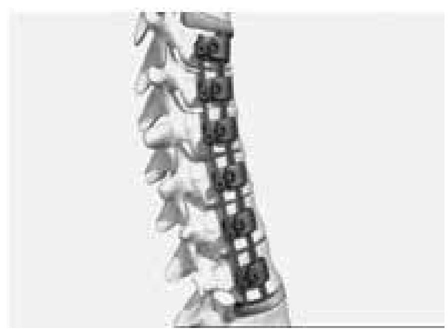
Anterior single rod systems with a solid 5mm, 5,5 mm or even 6 mm rod are significantly stronger in terms of stability (load displacement curves) and fatigue behavior compared to the older single rod systems with a weak threaded rod (VDS- Zielke). However without intervertebral stablization using cages even those systems can not restore the spine to the level of the intact spine.

Single screw- rod systems with a solid rod and in combination with cage are capable to restore the stability of the spine to the level of the intact spine, however except for torsional stiffness.

Another weakness of single screw rod systems is the fact that the vertebral body only has one fixation point by one screw. That means that the complications of screw loosening and screw pullout compared to Zielke-VDS are not reduced, which means that with single screw rod systems the bone metal interface remains weak.

Dual rod systems

Solid dual rod systems are the only systems capable to restore the stability of the spine to the level of the intact spine in **all** planes. This means that the biomechanical complication rates related to either the bone metal intervace (screw pullout) or metal metal interface (fatigue failure) should be the lowest in solid dual rod systems and are therefore recommended.



Solid dual rod systems are the most stable construct in terms of bone metal as well as metal metal interface stability. In order to obtain the best possible bone metal interface, bicortical screw fixation is recommended as seen in the picture on the right.

Contralateral cortex penetration should be limited to one thread to avoid damage to vascular or visceral structures.

Indications for idiopathic adolescent scoliosis

Classical indications for idiopathic scoliosis surgery from the anterior approach are single thoracic (Lenke 1) and single thoracolumbar or lumbar curves (Lenke 5).

In selective cases also Lenke 2, Lenke 3 and Lenke 5 curves can be approached from anterior, when the minor curves are partially flexible and correct to an acceptable degree with a compensated spine and level or almost level shoulders postoperatively. Examples will be demonstrated.

Since the majority of thoracic curve are hypokyphotic, convex compression during correction will increase kyphosis to normal values in the majority of cases.

If possible open anterior surgery in older adult patients should be avoided due to significantly higher approach related complications

Fusion levels

The fusion levels in anterior scoliosis surgery typically reach from end to end vertebral of the major curve to be instrumented. Depending on the bending films and the flexibility of the major curve as well as the minor and compensatory curve the fusion area may be chosen one level longer or shorter.

Surgical technique

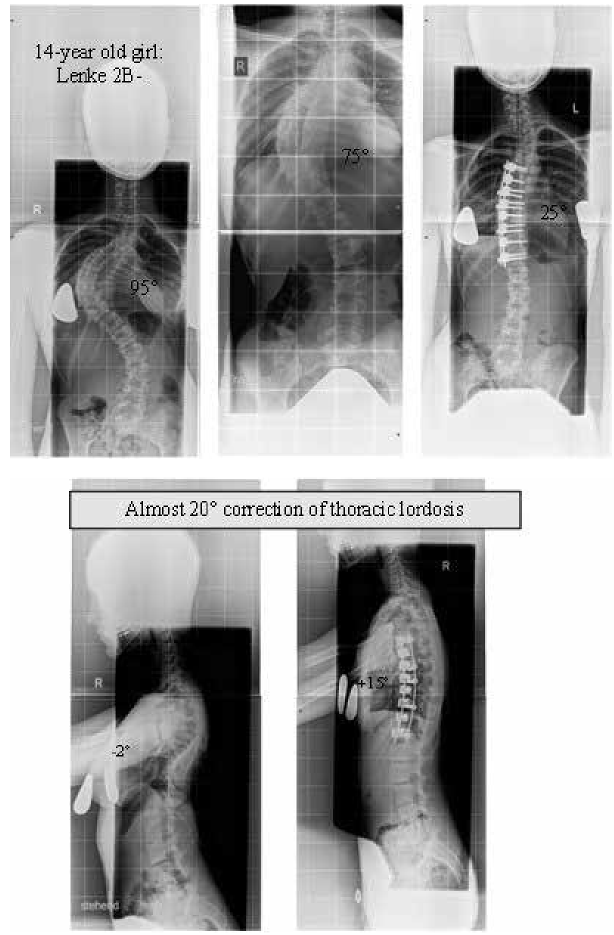
The patient is positioned on the lateral side and on the concavity of the major curve to be instrumented. That means that the spine is typically approached from the convexity.

For thoracic curves a classical open thoracotomy, typically an internal double thoracotomy is performed to reach the most cranial and most caudal vertebral body to be instrumented.

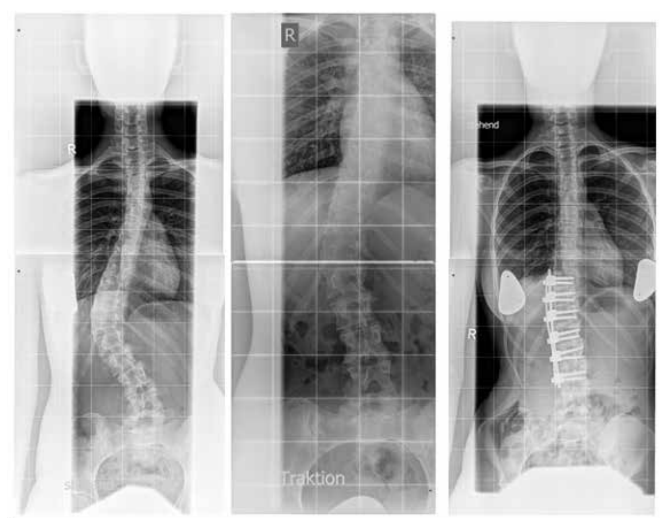
For thoracolumbar and lumbar single curves a classical thoracolumbophrenotomy is performed. For both approaches a rib may be resected during the approach, that is morselized and can be used for intervertebral fusion purposes.

In the thoracic spine the parietal pleural above the lateral aspect of the vertebral bodies is split, in the lumbar spine the iliopsoas muscle with the sympathetic chain is reflected posteriorly. Then the segmental vessels are ligated or coagulated and then separated. This is followed by disc resection and endplate curettage in order to obtain an optimal situation for bony fusion.

This is followed by instrumentation and instrumented correction and fusion from the convex side, which will be demonstrated with a short video animation.



Severe Lenke 2B- curve with good correction of the frontal plane and thoracic lordosis fully corrected to physiological thoracic kyphosis. Slight low right shoulder on the right postoperatively.



Lenke 5CN curve of 60 degree Cobb angle with anterior instrumented correction and fusion, fused to the lower end vertebra and one level short of the upper end vertebra.
Almost full 3D correction with short fusion levels.

Comparison of anterior and posterior instrumented correction and fusion in single idiopathic adolescent curves does not show significant differences concerning the amount of correction in the frontal plane and complication rates in the majority of studies. Some publications are in favor of posterior instrumentation, some of anterior instrumentation. Derotation and rekyphosing the thoracic hypokyphotic or lordotic sagittal plane is better with anterior instrumentation. Lung function at one year follow up seems to be slightly better with posterior instrumentation, however there is no evidence of clinical relevance.

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Notes:

Posterior Based Surgery: Evolution of Fixation Strategies

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More than 50 years ago, spine surgery was revolutionized by the introduction of the **Harrington instrumentation** (Harrington, 1962). Until then, deformity correction was carried out by casting and in-situ fusion techniques with only limited correction abilities. The Harrington instrumentation was a pure distraction device: a rod was placed on the concavity of the scoliotic curve and fixed with an upward directed infralaminar hook at the top and a downward directed supralaminar hook at the distal end of the construct to the spine. Satisfactory correction in the frontal plane was achieved by distraction at the concavity of the curve but the rotational deformity remained unaddressed. Due to the distractionforces and the straight, non-bended rod both thoracic kyphosis and lumbar lordosis were reduced resulting in a so-called flat back. Furthermore, the patients needed to were a cast postoperatively for many months until bony fusion with still a significant pseudarthrosis rate.

Eduardo Luque was the first to introduce a multisegmental spinal system with an increased stability (Luque, 1982). Multiple sublaminar wires were placed along the curve and the spine was approximated to the rod. Although the stability and the correction potential were superior to the Harrington system, the neurological risks of multisegmental wiring were too high to allow a wide acception of this technique in the treatment of idiopathic curves. The main indication remained neuromuscular scoliosis. However, the principle of placing multiple anchors and approximating the spine to a (prebent) rod has basically remained unchanged over the last 30 years.

In the 80`s the french spine surgeons **Yves Cotrel** and **Jean Dubousset** developed a revolutionary universal spinal system, the **Cotrel-Dubousset Instrumentation** (Cotrel et Dubousset, 1988). Multiple hooks (supra- und infralaminar, transverse and pedicle hooks) were placed at strategic points along the curve and a prebent rod was inserted and rotated by 90°, resulting in a correction of both the frontal and the sagittal plane deformity. Despite conflicting statements in the literature, a true segmental derotation was not achieved. **The fusion length remained mainly unchanged compared to the Harrington Instrumentation**. Due to the multiple spinal anchors and the placement of two strong rods the primary stability was high. Patients could be mobilized without any external support and the pseudarthrosis rate decreased dramatically.

Parallel to the evolution of corrective hook based instrumentation systems for spinal deformities, **pedicle screws** had been developed to stabilize the lumbosacral spine or reduce spondylolisthesis. ***Boucher*** was one of the first authors publishing the technique of pedicle screw instrumentation in 1959. It were mainly the authors **Roy Camille 1970, Schöllner 1975** and **Steffee 1986** who refined and standardized the technique of pedicle screw instrumentation. Numerous studies could demonstrate the superior results using pedicle screws in the surgical treatment of fractures, degenerative instabilities and spondylolisthesis with superior reduction and fusion rates and a shorter fusion length.

Due to the superior biomechanical properties of lumbar pedicle screws compared to hooks (Zindrick et al. 1986) their application was extended to scoliosis surgery. In the 90`s first reports on pedicle screws in lumbar scoliosis surgery were published (Suk et al. 1994, Halm et al. 1995, Hamill et al. 1996). The authors reported a superior amount of correction and for the first time a reduction of the fusion length compared to hook based systems saving vital lumbar motion segments. Later studies could also demonstrate the superior fixation strength of pedicle screws compared to hooks in the thoracic spine (Liljenqvist et al. 2002). The application of the pedicle screw technique was extended to thoracic curves and **Suk** and **Liljenqvist** were the first authors to report on encouraging results of pedicle screws in the treatment of thoracic scoliosis (Suk et al. 1995, Liljenqvist et al. 1997). Beside excellent frontal and sagittal plane correction, Suk et al. found an apical vertebral derotation of 59%.

Studies with extensive analysis of lumbar and thoracic pedicles in both straight (Ebraheim et al. 1997, Zindrick et al. 1987, Vaccaro et al. 1995) and scoliotic spines (Liljenqvist et al. 2000, 2002) were published. Furthermore, the technique of pedicle screw insertion in scoliotic vertebrae was refined and measures to increase safety established (Kim et al. 2004, Lonner et al. 2009). **Thus, hooks were replaced by pedicle screws and segmental pedicle screw instrumentation with a high implant density became the standard procedure in the surgical management of idiopathic scoliosis.** New screw designs i.e. reduction or favored angle screws and instruments emerged and the technique of direct vertebral derotation to increase correction of the rotational deformity was established (Lee et al. 2004). While strong emphasis on frontal and transverse plane correction was laid, the sagittal plane was somewhat neglected and reports on increased numbers of postoperative thoracic hypokyphosis became more frequent. Refinement of the correction techniques and especially, new rod materials like cobalt chrome rods, however, seem to have eliminated this problem (Lamerain et al. 2014).

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Notes:

Posterior Osteotomies for Adolescent Deformity

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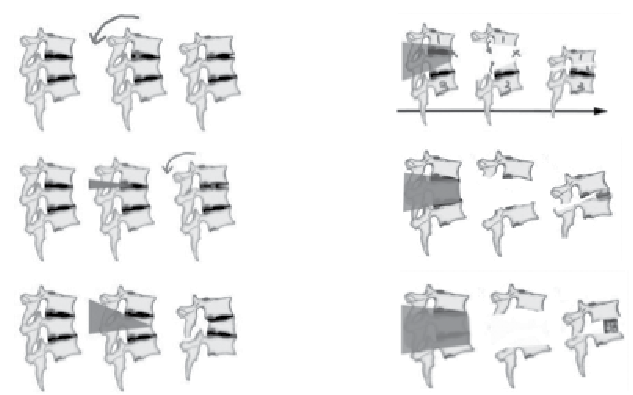
<u>**General requirements**</u>

Ability for SSEP & TcMEP or ability to do wake-up test or both
Ability to use pedicle screw system
Surgical team
Total intravenous anesthesia

Osteotomies are progressive destabilization procedures to obtain mobility to correct

Six grades of mobilization or progressive destabilization. Courtesy Frank Schwab



Six grades of destabilization are depicted, 1-3 on left and 4-6 on right. (Courtesy Frank Schwab MD.) #2 is Ponte, 3 & 4 PSO, and 5 & 6 are VCR.

Plan surgery and amount of destabilization estimated to be required. Begin with Grade 1 at every level. Progress to grade 2 at the peri-apical areas.

Grade 2 of destabilization, or the Ponte osteotomy, is the favored osteotomy for virtually all adolescent deformities. The Ponte osteotomy is easily accomplished and increases the mobility of the deformity. The author routinely employs the Ponte osteotomy.

Grades 3 and 4 of destabilization are necessary for larger deformities, particular in the sagittal plane. Grades 5 and 6, VCR, may be required in deformities in excess of 1000, with <25% bend correction. Temporary rods are mandatory in Grades 5 & 6, and may be useful in 3 & 4, particularly in the thoracic spine.

Fox retrospective study of pediatric VCR had 4 presentations at 2010 SRS.

- 147pediatric patients, 89 scoliosis
- 33 blood loss > 1 blood volume. Antifibrinolytics very valuable.
- 36% complication rate
- generally good results
- 27% intra-operative neurological event.

VCR can be extremely useful and effective procedure, but, with a significant degree of risk.

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Notes:

Osteotomies for Adult Deformity

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1. Introduction

a. Spinal osteotomy involves removal of a section of the posterior spinal articulation in an un-fused or fused vertebral column

b. It may also include removal of the middle and anterior column.

c. Posterior arch only resections as commonly referred to as Smith Peterson or Ponte Osteotomy involves removal of an entire facet and segment of the laminar.

d. Three column Osteotomies include resection of the posterior elements, the pedicle and a portion of the vertebral body (Pedicle subtraction Osteotomy-PSO) or resection of the entire posterior element and one or more vertebral bodies (Vertebral column resection-VCR)

e. Spinal osteotomy can be undertaken adult patients who present with deformity in one or more planes and requires release/destabilizing operations (osteotomies/resection) to achieve the desired correction.

2. Indications

a. Untreated rigid severe scoliosis, or postoperative coronal malalignment with or with adjacent segment degeneration.

b. In the sagittal plane Shueremann's kyphosis, Ankylosing spondylitis, and proximal junctional kyphosis in a previously fused spine

c. Multi-planar deformities from either complex kyphoscoliosis or previously fused spine with progressive deformity as a result of pseudarthrosis the adjacent segment degeneration.

3. Posterior Osteotomy

a. Advantages

  i. Single Stage and can obviate need for anterior approach

  ii. Increased safety with shortening techniques

  iii. Avoid Thoracotomy complications

  iv. Best for Pulmonary Compromised patient

4. Surgical Techniques

a. Smith-Petersen Osteotomies

  i. Originally described in 1945 for the treatment of Ankylosing spondylitis and is most commonly performed in the lumbar spine

ii. Produces correction in the sagittal plane of about 10 to 15 degrees per level with approximately 1-degree correction per 1mm bone resected.

iii. Can also be applied in coronal plane deformities as in severe scoliosis with primary ankylosis of the motion segments or in a previously fused spine in the thoracic or lumbar spine.

iv. Performing multiple Smith Petersen Osteotomies to achieve the desired correction requires a mobile anterior column.

v. In a purely sagittal plane deformity with anterior ankylosis as in Ankylosing spondylitis an extension of the anterior column with bony osteoclasis results.

b. Alberto Ponte Osteotomy

i. Similar to Smith-Petersen osteotomy to correct coronal/sagittal deformities by removal of the entire facet and closure of same in unfused spine such as in Scheauremann kyphosis or in a kyphoscoliosis patients.

c. Results and Complications of Smith-Petersen/Ponte Osteotomy

i. Dural tear, cauda equina compression, post operative Ileus, pseudarthrosis and inadequate correction.

ii. Such lengthening of the anterior column may also lead to vascular injuries

iii. The void created by the extension of the anterior column may require a supplemental anterior augmentation with structural bone or metal cages and grafts.

iv. Importance of undercutting the Osteotomies to avoid encroachment on neural structures closure of the osteotomy site.

v. Simmons reported on the Smith Petersen osteotomy for Ankylosing spondylitis and reported a mortality of 8-10% and neurological deficit including paralysis of 30%.

vi. We reported a series of 27 adults who underwent either multiple anterior discectomies or anterior osteotomies combined with Smith Petersen Osteotomy and achieved a postoperative sagittal balance of approximately 6.5cm.

d. Pedicle Subtraction Osteotomy (PSO)

i. In 1985 Thomasen first described the three column posterior osteotomy for patients with fixed sagittal plane deformities

ii. PSO is a posterior based three column osteotomy performed for a fixed sagittal or coronal plane deformity and is a posterior shortening operation

iii. Deemed to be safer than the anterior column lengthening procedure in Smith-Petersen Osteotomy.

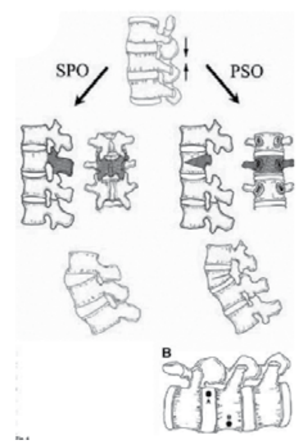
iv. Main Indications for PSO include

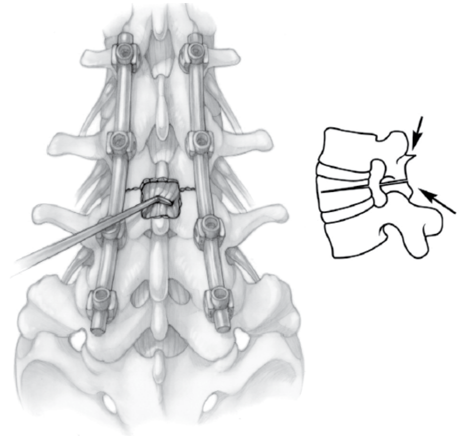
1. Patients for whom posterior osteotomies alone (i.e. Smith-Petersen osteotomies) are likely to provide inadequate correction.
2. Cases where at least 30 degree of corrective lordosis is required.
3. Although the osteotomy may be performed in the thoracic spine, most often it is performed in the lumbar spine typically at the L2 or L3 level, the normal apex of Lumbar Lordosis and also distal to the conus.
4. The size of the osteotomy is based on preoperative standing radiograph measurements. The goal of surgery is restoration of normal sagittal balance with the C7 plumb line falling at or within 4 cm of the posterior-superior corner of S1.

v. In patients with biplane deformity a unilateral or biplane PSO can be performed with asymmetric removal of the.

vi. Surgical Technique of PSO

1. Typically at least six fixation points (preferably pedicle screws) should be used both proximal and distal to the level of the osteotomy.
2. Removal of Vertebral bodies through the pedicle
3. Circumferential osteotomy through lateral walls of the vertebral body without violating anterior aspect, which acts as a hinge.
4. Osteotomy site can be closed with temporary rods or hyperextension of chest and legs of the operating table.
5. Bridwell suggests creating a central space at the osteotomy site to allow inspection of the dura.
6. An extended PSO as per Schwab type 4 will include removal of the proximal disc to allow more correction and also enhance bony healing anteriorly.
7. A PLIF or TLIF can also be done at the adjacent segments to achieve improved healing circumferentially





e. Vertebral Column Resection (VCR)

Fig 1: Technique of SPO, PSO and central enlargement after corrective osteotomy

i. Resection of one or more vertebral segments, including the posterior elements, Pedicles, Vertebral Body, and discs.

ii. Indicated when the deformity is not amenable to other osteotomies such as SPO, PSO

iii. Can be performed via a combined anterior /posterior approach or posterior only

iv. Vertebral column resection is the most complicated of the three column osteotomies that carries a substantial neurologic risk to the patients.

v. Indicated for sharp angular thoracic and thoracolumbar kyphosis,.

vi. A VCR is particularly useful when the kyphosis is associated with significant coronal deformity

vii. VCR also a good option for hemivertebra or when the anterior column has to be reconstructed in the setting of tumor, infection, and trauma.

viii. Instances where the posterior vertebral column resection is the only viable indication is the hyperkyphosis deformity in an adult patient with congenital, post traumatic or post infectious kyphosis exceeding 100 degrees.

ix. Surgical Technique

1. Posterior circumspinal resection, posterior shortening and anterior column lengthening. The spine is completely destabilized after the resection and require and anterior column support with a cage or strut graft is provided
2. Posterior elements are removed and wide lateral dissection to the Transverse processes performed.
3. In the Thoracic spine costo-tranversectomies are performed to facilitate removal of vertebral body(ies)
4. Temporary rods are essential to maintain spinal stability during the resection.
5. Reconstruction of the anterior column is achieved with a metal cage, autograft or allograft.

i. Results and Complications of PSO and VCR

6. Continuous monitoring by somatosensory-evoked potentials (SSEPs) and neurogenic motor-evoked potentials (NMEPs) or transcranial motor evoked potentials (tcMEP) is critical to avoid a neurologic sequela.
7. The Scoliosis Research Society morbidity and mortality database found that patients who had 3 column Osteotomies had a higher rates of complications when compared with other surgical procedures.
8. The complication rate associated with these complex Osteotomies is reported to be as high as 59%.
9. Associated risk factors include advanced age, sagittal deformity, kyphosis, long fusions and revision surgery.

f. Conclusions

i. Spinal Osteotomy especially Pedicle subtraction osteotomy and vertebral column resection are effective methods for correcting adult sagittal, coronal and multi-planar deformities while providing biomechanical stability.

ii. Despite these advantages, the procedures are technically demanding and are associated with considerable intra- and post-operative complications.

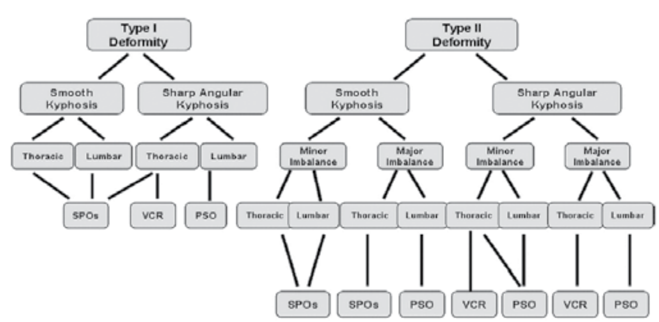
iii. Careful assessment of the potential risks and benefits are essential before undertaking a major reconstructive procedure utilizing these procedures.

iv. Older ASD patients with a lumbar single-level, large resection angle 3CO and short fusion more likely to develop PJK.

v. Longer fusion and iliac fixation are critical in minimizing PJK rates, and improved global alignment

vi. Ames and others have demonstrated that 2 surgeons operating decreases the OR time, EBL, post op complication and premature case termination.

vii. Fig 2. Below: Algorithm for choosing osteotomy type



PSO = pedicle subtraction osteotomy; SPO = Smith-Petersen osteotomy;
VCR=vertebral column resection

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Notes:

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Spinal Osteotomy Strategies for Complex Spinal Deformity

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Background

Spinal deformity may arise from many pathological circumstances, including congenital, inflammatory, posttraumatic, idiopathic, and so on. The main surgical strategies are neurological decompression, deformity correction, and fusion.

However, spinal osteotomy should be undertaken in pediatric and adult patients who present with some severe spinal deformity in one or more planes and require release operations to achieve the desired correction. (Ankylosing spondylitis, Pott's deformity and adult degenerative scoliosis). Up to now, there are four major osteotomy techniques: SPO, VCR, PSO, VCD and so on.

History of Spine Osteotomy

1. SPO

   SPOs involves resection of posterior elements including the bilateral facet joints, part of the lamina and the posterior ligaments at the osteotomy level. In the correction of mechanism, SPO is opening wedge osteotomy, which is with the hinge at the posterior aspect of the disc space by manual extension. But it is not present with the rigid sharp angular spinal deformity. The excessive shortening of the area may result in buckling of dura and spinal cord, which is very dangerous.

2. PSO

   Pedicle subtraction osteotomy (PSO) includes the resection of posterior column and transpedicles wedge osteotomy, which is characterized with the hinge located at anterior column of vertebral body. Compared with the SPO method, the PSO technique is described as shortened posterior and middle column without lengthening of the anterior column, thus drastically shortening the spinal canal.

3. VCR

   Vertebral column resection was a vertebrectomy from posterior only approach for treatment of severe scoliosis. As the most powerful tool for correction of spinal deformity, VCR is generally reserved for sever fixed sagittal and coronal imbalance. Despite the power of correction of VCR, However, limitations of the VCR are evident and include spinal column instability, greater blood loss, extensive manipulation performed in spinal cord territory, and greater risk of neurologic deficits. (Figure.1)

4. VCD

   Vertebral column decancellation (VCD) technique, a new spinal osteotomy, is firstly introduced in series studies for 13 adult patients with severe rigid congenital kyphoscoliosis and 9 patients with severe Pott's kyohosis. The technique is a combination of eggshell technique, SPO and PSO methods.

Figure.1

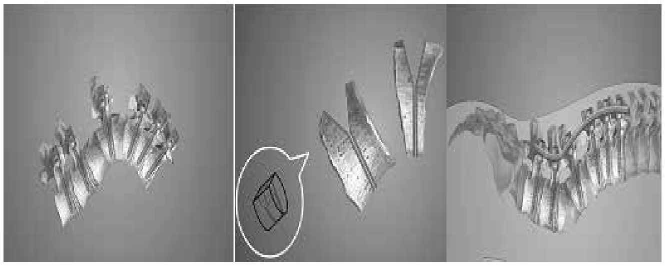
Osteotomy strategies for complex deformity

There are three main curve types in angular spinal deformities: round angular, sharp angular deformity and kyphoscoliosis.

For round angular deformity

Several spinal osteotomy techniques are available for treating round angular deformities, including SPO, PSO, VCR, VCD and so on.

The VCD technique is a combination of eggshell technique, SPO and PSO methods, which preserved the middle of the vertebral column. VCD is a "Y" shape osteotomy rather than "V" shape. If the correction is not enough when the middle column gap was closed, open the anterior column with the assistant of operation table or spinal rod until the correction is fitted to the preoperative design. The "Y" type osteotomy properly makes the proper shortage of posterior column and opening of anterior column realized in the meantime, which decrease the rate of complications which frequently happened in SPO and PSO. (Figure.2)



VCD for round angular deformity (Figure.2)

In the sagittal CT scan of entire spine postoperative immediately, we can clearly observed the elongation of the anterior column and the proper shortage of the posterior column. (Figure.3)

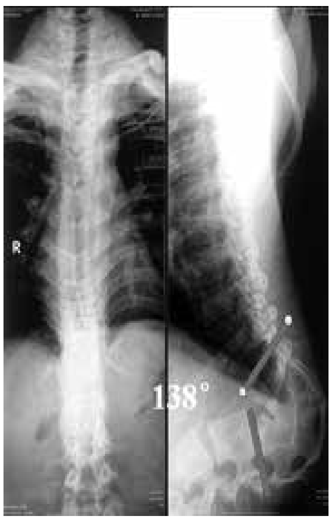
For sharp angular deformity

The sharp angular deformity in Pott's deformity patients can be corrected by the PSO, VCR. We can also use VCD technique to correct the sharp angular deformity.

The sharp angular deformity in Pott's patients can be corrected by the VCD technique, which includes proper elongation and regional opening of the anterior column without dangerous spinal extension and ventral vessel complications ; Reasonable shortage of the posterior elements without an aggressive posterior spinal cord and dura buckling after correction.

All in all, the core of VCD technique is preserving more the middle of the column as hinge point, which serves as "bony cage" to take the place of metal mesh described in VCR techniques. (Figure.4)

VCD for sharp angular deformity (Figure.4)



(Figure.5)

Notes:

Techniques for Optimal Correction of AIS

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Introduction: This presentation will focus on current pre and intra-operative correction techniques available to surgeons to optimize spine and chest wall deformity correction in Adolescent Idiopathic Scoliosis.

It is intended that following this review, the reader will have a comprehensive assessment of the recommended options to facilitate the best outcome for the surgical treatment of their patients.

The presentation will draw on literature published or presented in the last decade which it is believed, will give the audience the most up to date information and allow comparatives to be drawn with more traditional surgical techniques.

Method: Review of the available literature dealing with pre and inter-operative surgical techniques employed in AIS correction. Illustrated with salient case examples.

Techniques reviewed:

1) Traction – pre and peri-operatively
2) Spinal releases – anterior / posterior / combined
3) Spinal Osteotomy options
4) Construct patterns and implant density – anteriorly and posteriorly
5) Vertebral rotation (and its effect on chest wall deformity)
6) Adjuvant chest wall surgery
7) 'Progressive' correction devices and 'temporary' constructs

Specific benefits and any controversies will be highlighted.

Conclusions: An analysis of each of the techniques listed above, supported by review of the salient literature justifying their inclusion, will allow the surgeon formulate an 'a la carte' surgical menu for optimal care of for each individual patient.

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Three-staged correction of severe rigid idiopathic scoliosis using limited halo-gravity traction

Koptan W et al Eur Spine J 2012; 21: 1091-98

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Helenius I J Child Orthop 2013 Feb; 7(1): 63-68

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Low density versus high density thoracic pedicle screw constructs in AIS: do more screws lead to a better outcome?

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Implant distribution in surgically instrumented Lenke 1 AIS: does it affect curve correction?

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Do multilevel Ponte osteotomies in thoracic idiopathic scoliosis surgery improve curve correction and restore thoracic kyphosis?

Halanski et al J Spinal Disord Tech 2013 Jul; 26(5): 252-5

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Posterior Vertebral Column Resection for Severe Paediatric Deformity

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Direct vertebral body derotation, thoracoplasty, or both: which is better with respect to inclinometer and SRS-22 scores?

Samdani AF et al Spine 2012 Jun 15; 37(14): E849-53

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Martino J et al Spine 2013 Jan 15; 38(2): E73-83

Management of severe and rigid idiopathic scoliosis

Teixeria da Silva L E C et al Eur J Orthop Surg Traumatol 2015; 25(1) 7-12

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De Kleuver M er al Eur Spine J 2014;12(12): 2603-18

Notes:

Minimally Invasive Approaches to Deformity

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1. Background
   a. Significance of finding alternate means to treating adult spinal deformity
   b. Unacceptably high complication rate with ASD surgery
   c. High reoperation rate
   d. PJK
2. Approaches as a solution to decreasing morbidity
   a. LLIF: Lateral lumbar interbody fusion
   b. MIS TLIF: Minimally invasive transforaminal interbody fusion
   c. Percutaneous pedicle Screws
3. LLIF
   a. Growing number of data suggesting that LLIF is a safe means to correcting coronal plane deformity
   b. Not all coronal deformity is equal
      i. Idiopathic scoliosis is an abnormality of development
         1. Does not derotate indirectly
      ii. De Novo scoliosis is an abnormality of degeneration
         1. Derotates indirectly
   c. The sagittal plane remains a concern
      i. There is a ceiling effect to what can be accomplished based on historic data

ii. Flawed in that it does not reflect current practices

d. ACR as a means of correcting larger sagittal plane deformities

i. If correction needs to be achieved similar to 3CO then ACR is a viable MIS alternative

ii. Usually requires posterior release

iii. Can be accomplished posteriorly MIS but becomes technically more demanding

4. MIS TLIF

a. Benefits:

i. Allows for single approach surgery from S1 and superior to upper lumbar spine

ii. Can release bilateral facets for near full posterior release (Schwab type 1 osteotomy)

iii. Can release the concavity directly

iv. Can directly decompress the nerve roots and central canal

v. Get interbody +/- posterolateral fusion

b. Downsides:

i. Interbody device contains little room for the biologic material

ii. Removal of an entire facet on one side, leaves the area vulnerable for pseudoarthrosis

iii. More difficult to get height restoration

iv. Direct exposure of nerve roots and dura put them at increased risk of injury (durotomy, post operative dysesthesia)

v. Requires bilateral approach…if you are a single surgeon then doing 2 exposures can be painful

vi. Multilevel surgery

5. Percutaneous pedicle screws

a. Benefits:

i. Significantly reduces the morbidity of the posterior approach

ii. Can be performed through stab incisions when stability is desired

iii. Wiltse approach for facet fusions and Schwab type 1 osteotomies

iv. Midline incision with lateral paraspinal stabs when midline release is needed (type 2 osteotomies)

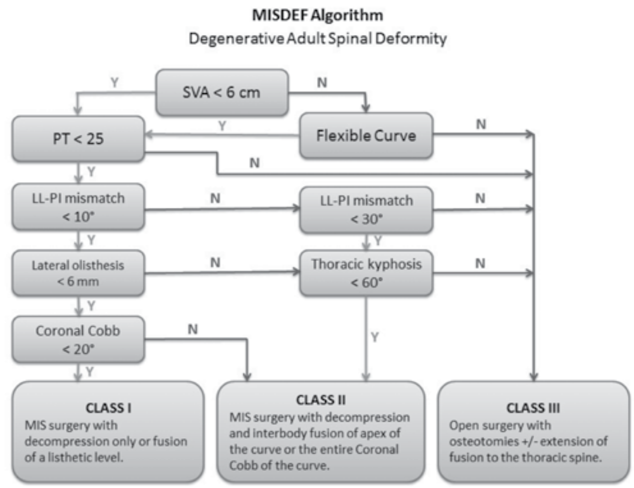
b. Downsides:

i. Not getting a good soft tissue release

ii. Questionable fusion (role of bone morphogenetic protein-2)

iii. Learning curve is significant

6. How do I know if my patient is a candidate? The MISDEF algorithm



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Notes:

Spondylolisthesis: When and How to Reduce

Hubert Labelle, MD
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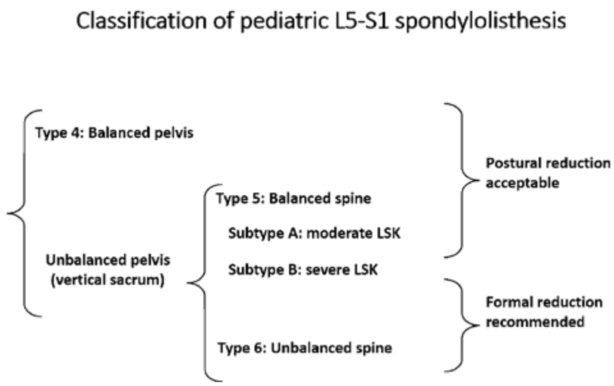
1- When to reduce? When sagittal balance is abnormal in high grade spondylolisthesis



2- How to reduce? Posterior approach preferred, reduction of lumbo-sacral kyphosis is the key, while only partial grade reduction is necessary. Circumferential fusion is mandatory.

Formal reduction and fusion

- Patient positioning (care to pad ASIS adequately)
- Ensure good visualization of the levels to be included in the fusion
- Subperiosteal exposure of affected level
- Gill removal of L5
- Facetectomy of any remaining structures
- Screw placement (may need fluoroscopy-assisted placement)
- Formal decompression of the foramen (usually performed on the most affected side
- Disk preparation through lateral approach (between PLIF and TLIF approach)
- Formal reduction of spodylolisthesis either with the use of reduction screws or external apparatus attached to pedicle screws.
- Reduction can be facilitated by using a disk dilator to correct the lumbo-sacral kyphosis locally
- Interbody cage placement through PLIF
- Rod attachment
- Compression to further increase local lordosis
- Postero-lateral decortication and bone graft bed preparation.
- When formal reduction is not warranted, the fusion will usually be extended to L4 as the pedicles of L5 are not readily accessible.
- The fusion is also usually protected with iliac screws.

- For spodyloptosis, S1 pedicular screws can be positioned to extend to the vertebral body of L5 (modified Bohlman procedure). Alternatively, a bone dowel can be inserted from S1 to L5 to support structurally the fusion.

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Notes:

Evolution of Surgical Techniques: What is the Impact?

Ronald L. De Wald
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Rush University
Chicago, Illinois, USA

Technology impacts all aspects of a spine surgeon world

THE PATIENT: faster, safer, better results

THE SURGEON: Who is qualified to use new instruments or perform new procedures? Is there a probationary period? Who will supervise?

THE HOSPITAL: Who decides which new technology is to be used? What are the guidelines for sales representatives in the operating room?

THE ACCREDITING AND CERTIFYING BODIES: If new technology is not taught or not being used should the program be accredited? Should the surgeon be certified or recertified?

Notes:

Early Onset Scoliosis

Moderators:

Richard E. McCarthy, MD & Lori A. Karol, MD

Faculty:

Behrooz A. Akbarnia, MD; Michael G. Vitale, MD; Laurel C. Blakemore, MD

A Historical Perspective of the Management of Early Onset Scoliosis

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Early years: Casting and bracing were the only options

Ponseti and Friedman (1950): Differentiated Early Onset Scoliosis (EOS) from late onset.

Harrington (1962): Progressive scoliosis in a child less than ten years old can be managed with the apparatus alone without fusion, whereas in a child more that ten years old, fusion should be done at the time of initial correction."

Mehta (1979): Non operative treatment with casting was introduced

Moe (1984): Instrumentation without fusion with subcutaneous rods

Dubousset, Herring and Shufflebarger (1989) Crankshaft phenomenon

Dimeglio (1990): Spine growth patterns

Campbell and Smith (1991): Rib based distraction (VEPTR)

Dickson (1994) the term EOS was reemphasized for children 5 years and younger. New terminology

San Diego SRS/ POSNA Growing Rod Tutorials (2000)

Study Groups (GSSG &CSSG) SRS Growing Spine Committee

Akbarnia et al (2005): Dual growing rod report

ICEOS (first in 2007) Presentations and Publications

Growth Guidance System (Shilla) (2010)

MCGR (MAGEC) First case internationally in 2009 and FDA clearance 2014

Future Growth study, prospective studies and more evidence based?

Multicenter and long-term follow-ups

Notes:

C-EOS: Classification for Early-Onset Scoliosis

Michael G. Vitale, MD, MPH
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New York, New York, USA

<u>Purpose of the Classification for EOS (C-EOS)</u>

- Predict the disease course of individual patients
- Prognosticate and determine beneficiaries of differing treatment modalities
- Improve communication among EOS providers and facilitate research

<u>Any classification should be:</u>

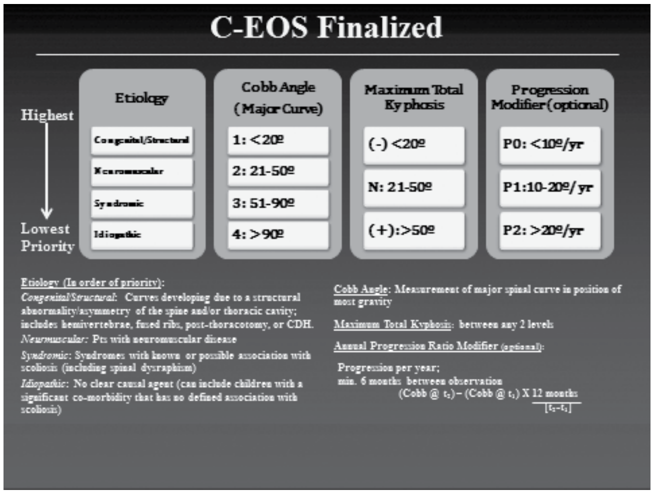
- Comprehensive Applicable to all EOS pts
- Practical Utilized in daily practice
- Prognostic Predictive of course
  Guide Informs treatment decisions
  Methods: Iterative Survey & Group Discussion
- Group Discussion/Proposing Variables (July 2011)/ Iterative Survey (July 2011) Finalizing Variables (Nov 2011)

<u>Identification of Variables for Inclusion:</u>

Results of Variable Identification Survey

	Not Useful	Useful	Essential	CVR	Sum of Ranks
COBB	0	1	14	0.87	29
ETIOLOGY	0	3	12	0.60	27
KYPHOSIS	0	4	11	0.47	26
AGE	5	0	10	0.33	20
PROGRESSION	3	5	7	-0.07	19
CHEST WALL ABNORMALITIES	2	9	4	-0.47	17
FLEXIBILITY	4	6	5	-0.33	16
OTHER CO-MORBIDITIES	3	8	4	-0.47	16
PULMONARY FUNCTION	3	9	3	-0.60	15
AMBULATORY ABILITY	2	12	1	-0.87	14
NUTRITIONAL STATUS	5	8	2	-0.73	12
MENTAL FUNCTION	10	5	0	-1.00	5
BONE QUALITY	11	4	0	-1.00	4

<u>Final CEOS:</u>



<u>**Early Validation:**</u>
To assess C-EOS' ability to prognosticate outcomes in a clinical setting

- CEOS has excellent intra and interobserver reliability
- CEOS predicts risk of anchor failure and other complications in children with EOS

Notes:

Evidence to Support Present Surgical Approaches in Early Onset Scoliosis

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Thoracic Insufficiency Syndrome
Campbell
TIS: inability of thorax to support normal respiration or lung growth
No cardioresp. failure when vital capacity >40% predicted

This concept changed thinking

How much spinal growth is needed to allow normal thoracic and lung growth?

Alveolar growth:
max # by age 8

Rib growth:
30% by age 10

Thoracic Volume:
30% adult by 5 yrs
50% by 10 yrs
100% by 15 yrs

Effect of fusion on spine growth

Dimeglio
data on avg thoracic height from birth- maturity (11 cm-26-28 cm)

Emans et al *Spine 2005*
Pelvic width as predictor of chest size

Effect of fusion on lung growth

Goldberg: early fusion for IIS (<10 y.o.)
averaged FVC 41% vs 68% in those fused at > 10 y.o.

Vitale: fusions for cong scoliosis avg 4 yo
thoracic curves had longer fusions, higher Cobb angle, lower pulm function and lower QOL scores

Karol *JBJS 2008*
early fusion for mixed diagnosis
avg FVC 58%, correlated to % T-spine fused
threshold thoracic spine height of 18 cm correlated to absence of restrictive lung disease

Revision rates high(even after A/P)
37% (Goldberg et al)
39% (Karol et al)

So early fusion does not reliably arrest progression of deformity

really not a good option until close to PHV

JPO 2012

The Ideal Instrument Would:
control alignment of progressive curves
decrease curve over time (when growth potential exists)
allow most normal growth of spine and thorax
not require repeated surgery
leave spine flexible

<u>**EVIDENCE ON GROWTH MODULATION VERTEBRAL BODY TETHERING/STAPLING**</u>
Vertebral Body Stapling (VBS)

Spine 2003
10 patients with curves < 50°
60% remained stable, 40% progressed

Spine 2010
curve stabilization in 87% all lumbar curves
and 79% of thoracic curves that were 35° or less.

Tethers: Animal Research Braun 2006, others ongoing

Mechanical creation of scoliosis in immature goats using tethers

Theoretical advantages of fusionless correction: preservation of growth, motion, and function of spine
currently ongoing research in several centers for variety of anchor types

VBT early clinical data

Pahys, Samdani et al paper 202 IMAST 2015
100 cases, no major complications
avg 49% Cobb angle correction

Samdani Spine J 2014
2 yr f/u 11 pts
4420 ・ 13 deg at 2 yr f/u
2 pts returned for loosening to prevent overcorrection

“EVIDENCE GUIDING GUIDED GROWTH”

SUBMUSCULAR RODS

Submuscular Rod Indications

Progressive early onset scoliosis of any etiology

Still no consensus on:
- Ideal age
- Threshold Cobb angle
- Lengthening interval

Submuscular rod indications

Size of Curve70 deg or bigger
Age à pref. over 4 but not past 9-10 y.o.
E.g., POSNA survey 2010 (Fletcher JPO 2011) most respondents would treat a progressive 70 deg idiopathic curve with growing rods
“Buy time” when possible to delay start
Akbarnia et al 2008
13 pts dual growing rods
Cobb angle 81º-27º
46% complications- implant, infection
Growth 1.8 cm/yr (slightly higher than expected normal)

Law of Diminishing Returns
38 pts 5 centers GSSG

Bess et al JBJS 2010
140 pts mean 5 yr f/u GSSG
Overall comp rate 58%
Complication risk increased by 24% for each additional surgical procedure

MAGNETIC CONTROLLED GROWING RODS

Hickey Eur J Sp 2014, LaRosa JPO 2015
- Sinilar rates anchor failure, loss of distraction, rod breakage, PJK (Cheung AM 2014 EP)

Cheung SRS AM 2014- longer follow-up
- 10/23 (43%) required re-op at avg 17 mo postop

Cost analysis
- Jenks Appl Health Econ Health Policy 2014
- Rolton Eur J Spine 2015
- Cost-benefit break point vs. conventional rods

14 pts, mean f/u 10 mo, 68 distractions
DR better than SR
Complications included superficial infection in 1 SR, prominent implant in 1 DR
some distraction loss 14/68 distractions

APICAL FUSION WITH SLIDING END ANCHORS

McCarthy
Apical fusion, percutaneous instrumentation, non-locked screws at ends
Implants move along rods without need for repeat surgery
Concerns:
- fusion of significant portions despite percutaneous placement
- metallosis
- failure of implants to self-lengthen

McCarthy JPO 2014
10 pts 2 yr f/u
3 revisions, 2 infections
Avg. correction 70-27 deg maintained
Andras podium paper 33 IMAST 2015
- law of diminishing returns doesn’t seem to apply

“RIB BASED” DISTRACTION

Potential Advantages?
ElHawary JPO 2015
- 35 pts 5 yr f/u mixed etiology
- increase in total spine height 20 -28 cm by the 15th lengthening.
- maintained >75% of expected age-matched spine growth until age 10 years
- lengthening procedures did not appear to follow a law of diminishing returns.

Looked at complication rates for spine-spine GR, rib-spine GR and “rib based” distraction”
Overall 73% complication rate (2.3 per S-S, .86 per R-S GR pt)
One neurologic deficit (“rib based” distraction)

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Notes:

Notes

Adolescent Idiopathic Scoliosis

Moderators:

Marinus De Kleuver, MD, PhD & James O. Sanders, MD

Faculty:

Lawrence G. Lenke, MD; John B. Emans, MD; Haemish A. Crawford, FRACS; B. Stephens Richards, III, MD

Classification of AIS: Then, Now and Future

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Surgeon-in-Chief, The Spine Hospital at New York-Presbyterian/Allen
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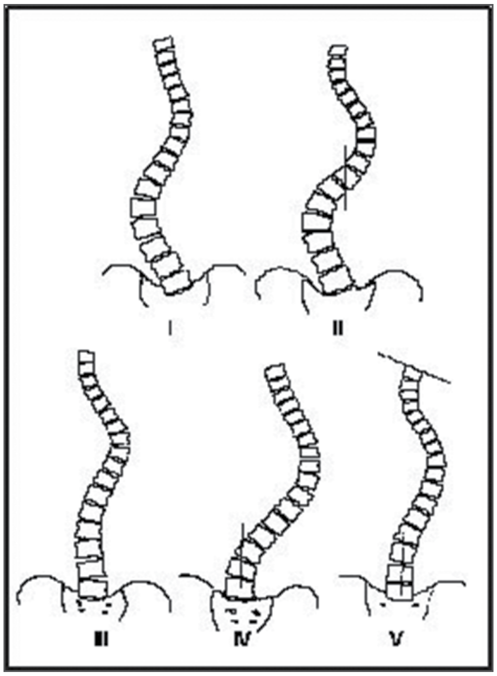


Why Classify AIS?
- Communication
- Understanding
- Education
- Research
- Treatment Recommendations

King, Moe et al. (JBJS 1983) – 5 TYPES "1D Classification":

I. L>T (both cross midline)

II. T>L (both cross midline)

III. Thoracic only

IV. Thoracic only (L4 tilted into curve)

V. Double Thoracic (+ T1 tilt)

Benefits
- First treatment-based classification
  - Based on extensive Harrington instrumentation experience
  - Promoted "Selective Fusions" of Type II curves when appropriate
  - Recognized Double Thoracic curve pattern when appropriate (V)
  - Gold standard for 20 years!

Problems
- Fair to poor inter & intraobserver reliability by 2 separate studies (Lenke et al. & Cummings et al. JBJS 1998)
- Uniplanar – coronal plane only assessment ("1D")
- Often tough distinction between Type II & III curves (does the lumbar curve cross the midline?)
- Double & Triple Major curves and isolated thoracolumbar/lumbar curves excluded
- Based on Harrington instrumentation principles
- Outdated in era of segmental spinal instrumentation?

New Classification to Guide Extent of Spinal Arthrodesis Lenke, Betz Et Al. (JBJS 2001;83(8):1169-81) – Six Goals

1)

2) Comprehensive – all curve types

3) 2-Dimensional – increased emphasis on sagittal plane

4) Treatment-based

5) Reliable – inter & intraobserver

6) Specific objective criteria to separate curve types

7) Practical and easily understood/usable to scoliosis surgeons

Spinal Column Regions – 2D
- PT – Proximal Thoracic
- MT – Main Thoracic
- TL/L – Thoracolumbar/Lumbar

Definitions (SRS)
- Major Curve = Largest Cobb
  - Always Included in Fusion
- Minor Curve = All Others
  - ??? Included in Fusion

Minor Curve Structural Criteria
- Coronal S.B.
  - PT ≥25°
  - MT ≥25°
  - TL/L ≥25°
- Sagittal
  - PT: T2-T5 ≥+20°
  - MT: T10-L2 ≥+20°
  - TL/L: T10-L2 ≥+20°

Curve types (1-6)

CURVE TYPE	PT	MT	TL/L	DESCRIPTION
1	NS	S*	NS	Main Thoracic (MT)
2	S	S*	NS	Double Thoracic (DT)
3	NS	S*	S	Double Major (DM)
4	S	S*	S*	Triple Major (TM)
5	NS	NS	S*	Thoracolumbar/Lumbar (TL/L)
6	NS	S	S*	Thoracolumbar/Lumbar-Main Thoracic (TL/L-MT)
S = Structural, NS = Non-Structral, * indicates Major (Largest Curve)				

Coronal Lumbar Modifier

- A – CSVL falls between Apical Pedicles
- B – CSVL touches Apical Pedicles/Lateral Body
- C – CSVL falls Lateral to Apical Pedicles/Body

Sagittal Thoracic Modifier (-, N, or +)

T5-T12 SAGITTAL	
COBB ANGLE	MODIFIER
<+10°	-
+10 - +40°	N
>+40°	+

Lenke Classification System of AIS – 3 Components

- Curve Type (1-6) + Lumbar Spine Modifier (A, B, or C) + Sagittal Thoracic Modifier (-, N, or +)

  = Curve Classification (eg. 1B+)

Rx Direction

CURVE TYPE	REGIONS FUSED	APPROACH
1 (MT)	MT	ASF or PSF
2 (DT)	PT & MT	PSF
3 (DM)	MT & TL/L	PSF
4 (TM)	PT, MT & TL/L	PSF
5 (TL/L)	TL/L	ASF or PSF
6 (TL/L-MT)	MT & TL/L	PSF

3rd Modifier: Touched Vertebra (TV)

- The TV is the most cephalad TL/L vertebra touched by the CSVL.
- "A" – Between the pedicles
- "B" – Touches any part of the pedicle
- "B-" – Touches corner of vertebra but not pedicle
- "C" – Does not touch vertebra (postop assessment only)

- Easy to remember as same principle as the lumbar modifier
- Preop – only A, B, or B-
- Postop – A, B, or C in relation to actual LIV

Most Common Classifications

TYPE	ABBREVIATIONS	% CASES
1AN	MT	19%
1BN	MT	11%
2AN	DT	10%
5CN	TL/L	10%
1CN	MT	8%
		Total: 58%

Why Aren't Rules Followed?

- Side Bending Radiographs
  - Subjective
  - Non-uniform from center to center
  - 25° rule (24° vs. 26°)
- Clinical Exam – may overrule x-rays
- Skeletal Immaturity
- Desire to perform Selective Fusion

Selective Thoracic Fusions – When can the Lumbar Curve Remain Unfused?

- 1C (Main Thoracic)
- 2C (Double Thoracic)
- 3C (Double Major)
- 4C (Triple Major)

Where do I Start and Stop the Instrumentation/Fusion?

- Most common question I am asked by scoliosis surgeons around the world!
- First step is classification and determination of region(s) to be fused
- Next step is to determine UIV & LIV
  - For ASF – UEV & LEV
  - For PSF – very controversial/idiosyncratic

UIV Selection

- Clinical/Radiographic Shoulder Height
  - Left High/Balanced/Right High
- Size & Stiffness of PT Curve
  - Structural S.B. ≥ 25°
- Hyperkyphosis of PT Region

- ≥ +20° kyphosis
- Amount of MT Correction Planned
  - Dynamic Criteria

LIV Selection

- Extremely Idiosyncratic
- Lenke Rules
  - Combination of Touched Vertebra (TV)
  - Lumbar Modifier
  - Rotation
  - Skeletal Maturity
- Suk Rules
  - End/Neutral/Stable
- Cotrel-Dubosset: Disc Reversal on Side Bending

Results of Fusing to the TV in 1AN AIS Curves: Minimum 5 year Follow-Up

68 Cases 1AN at 5 year follow-up

- Preop TV: 52 (76%)
  - Postop LIV: "A" - 40 (77%), "B" - 12 (23%), "C" - 0
- Preop TV-1 (Short): 11 (16%)
- Postop LIV: "A" - 6 (55%), "B" - 3 (28%), "C" - 2 (18%)
- Preop TV+1 (Long): 5 (7%)
  - Postop LIV: "A" – 5 (100%)

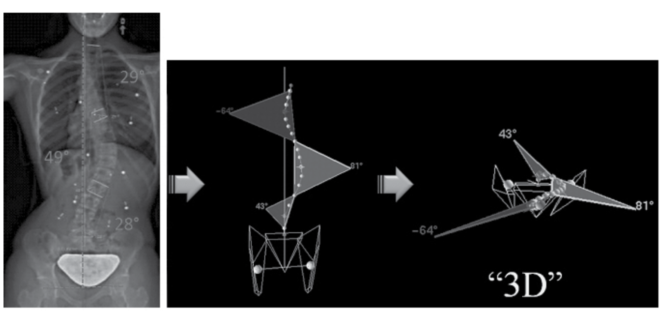
SRS Lunchtime Symposium: 3D Analysis of Scoliosis

Towards a 3D Classification of AIS: SRS 3D Terminology Committee

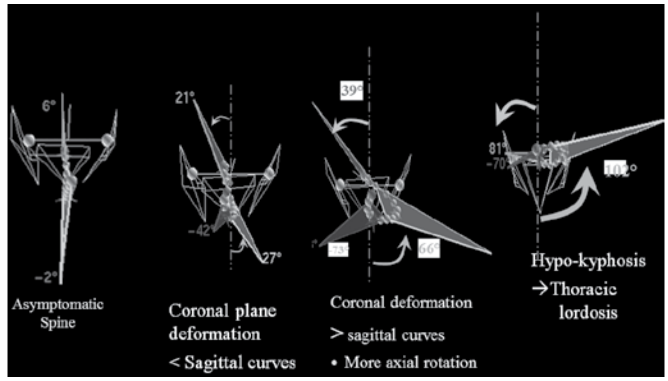
Members: CE Aubin, H Labelle, L Lenke, R Jackson, P Newton, IAF Stokes

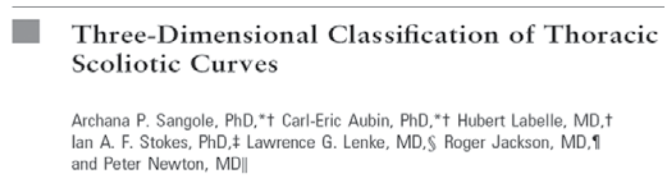
Ad hoc members: M Abel, K Cheung, R McCall, M Mendelow

Mandate (2006): To develop a clinically useful 3D classification of AIS (of any age or magnitude) and to validate this classification



Interpretation of the Planes of Maximum Curvature





Three-Dimensional Classification of Thoracic Scoliotic Curves

Archana P. Sangole, PhD,*† Carl-Eric Aubin, PhD,*† Hubert Labelle, MD,† Ian A. F. Stokes, PhD,‡ Lawrence G. Lenke, MD,§ Roger Jackson, MD,¶ and Peter Newton, MD||

3D Analysis & Classification

- Will it change our operative approaches?
- Will it lead to superior radiographic & clinical outcomes?
- Will optimal 3D alignment of the spine lead to a more satisfied patient? Better pulmonary function?
- Will it lead to less revision surgery early and late? (↓ junctional issues?)

Conclusions

- X-Rays -> Classification (2D – 3D) -> Treatment -> Outcome -> Optimal Treatment

Notes:

Bracing in AIS After 50 Years of SRS Leadership

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Bracing after 50 years of SRS leadership

Bracing can work, but where are we now?

And where are we headed?

SRS founding goals included:

- *Early detection and non-surgical treatment (bracing) of AIS*
- *A noble goal but:*
  - Screening for AIS proved imperfect
  - Natural history of mild AIS proved to be quite variable
  - Bracing effectiveness hard to quantify

At SRS inception, bracing (Milwaukee brace) was felt to be effective. Is bracing (still) effective for AIS?

- *Bracing* can *be effective*
  - But not always!
  - Considerable evidence that bracing can work provided by SRS members over decades
    - Early Retrospective studies of bracing in AIS – about 2/3 curves controlled:
      - Winter, Lonstein, Bowen, Katz, Emans, Richards, etc.
    - Negative reviews of scoliosis bracing during 90's-
      - Goldberg 1993, Dickson 1999, Weinstein, Noonan 1996, USPHS task force on screening 1996, 2004
    - Prospective studies – about 2/3 curves controlled:
      - SRS prospective study – Nachemson 1995
      - BRAIST NIH-sponsored prospective study 2013 – Weinstein, Dolan and many sites
      - Rigorous reviewers outside of orthopedics however dispute that we have proven the case!
- *How can we make bracing effective more often?*
  - Bracing wear compliance is critical, one thing we can affect
    - TSRH study Karol et al – 14.3 hrs/day avoids progression, 13.1 hrs/day avoids surgery
    - BRAIST - 12.9 hrs linked with success in 90% of pts
    - Karol – compliance counseling useful in increasing compliance
    - Support from team, family, peers helpful
    - Compliance monitor available, provides objectivity, feedback
  - Better, more corrective braces:
    - What type is best? Quality of brace more important than type.
      - Exportable system, computer-aided designs may help
    - Orthotist's skill, experience, education important
    - Physician evaluation of brace, assessment, feedback to orthotist improves results.

Education about bracing has changed significantly since SRS inception

- *Orthotists –*
  - 1970 - Scoliosis bracing was not included in formal training
  - Contemporary training includes an excellent formal curriculum on bracing
- *Physical Therapists –*
  - 1970 - PT programs included significant training about spine deformity and posture – a carryover from poliomyelitis.
  - Contemporary PT programs touch briefly on deformity.
- *Surgeons –*
  - 1970 - Residency programs included a section on prosthetics and orthotics, some deformity bracing. Fellowships addressing scoliosis included extensive exposure to bracing.
  - Contemporary residency programs include indications for bracing as a competency, but not brace evaluation or management. Fellowships are variable. Some pediatric ortho fellowships (Boston, TSRH and others) learn fundamentals of bracing, most do not. Spine fellowships rarely provide exposure or formal training in bracing.
- *1980's and 90's 'Brace Courses' tried to fill the education gaps.*
  - 'Boston Brace' Courses led by Hall, Watts, Emans, Hresko
    - Team concept promoted, entire team had to attend course.
    - Week long training for orthotists including brace manufacture for real scoliosis patients
    - Surgeons , PT's and Nurses had shorter course but also made braces
    - All team members knew brace manufacture, evaluation, exercises.
  - Similar efforts for Wilmington, Charleston, Providence and SpineCor
- *1998 – SRS Meeting in NYC – instructional course in scoliosis bracing*
- *1997 – Brace manuals online at SRS web site*
- *2013 – SRS meeting in Lyon – half day course on non-operative treatment for scoliosis*

Who does scoliosis bracing now?

- *'Team' bracing (orthotist, physician, nurse, PT under same roof) less common*
  - Mainly at pediatric teaching institutions
- *'Distributed' bracing more common:*
  - Orthotist, PT (if used), physician (=/- nurse coordinator) not physically located together.
  - Physician to orthotist feedback uncommon or at a distance
- *Non-surgeons, non-teams responsible for more bracing:*
  - PA's or nurses
  - Physiatrists
  - PT's
  - Chiropractors
  - Free-standing scoliosis treatment centers
  - No hospital or MD affiliation

How is brace technology changing?

- Goal – a better tolerated, more corrective brace for all, less dependent upon individual orthotist skill.
  - Creating a uniformly better, more exportable brace drove development of 'systems' like Boston, Wilmington, etc.
- *Source of brace mold has evolved (and gone back!):*
  - 1965 - Casting with poured positive modified for creation of final mold
  - 1975 - Measurement –based system to choose from prefabricated symmetric modules
  - 1985 - Laser scan creation of positives then modified according to individual brace design
  - 2005 - Individual cast, extensive modification and addition to positive – Rigo Cheneau
- *Brace design has changed:*
  - 1965 – MD writes prescription ('right thoracic left lumbar curve'), Orthotist does not see xray.
  - 1980's – Brace design principles codified for several brace types. Orthotist gets to see xray!
  - 2008 – Engineer gets 3-D data on body surface shape, digitized 3-D xray data. Computer helps design mechanically most effective brace (Aubin et al)
- *Brace compliance monitors*
  - Available
  - Evolved into simpler, smaller versions, better software
  - Don't necessarily improve compliance, but removes the 'he said – she said' and focuses the conversation on possible improvements to compliance..

Are there alternatives to bracing?

- *Schroth exercise-based treatment*
  - Schroth dogma includes bracing for moderate curves!
- *Tethering?*
  - Will tethering replace/supplant bracing for larger thoracic curves not responding to bracing?

Looking forward – what can we do to provide the best non-operative care for AIS

- *At the national, societal level:*
  - SRS and POSNA continue with committee-based non-operative efforts.
  - SOSORT increasingly draws members from the surgeon community
- *At the fellowship/training level:*
  - *Incorporate exposure to bracing and brace evaluation in your fellowship.*
- *At the individual practitioner level:*
  - Remain educated about contemporary brace types
  - Know what's out there on the internet – your patients will quickly know all the internet offerings – your credibility as an 'expert' includes awareness of what's offered
  - Strengthen or establish a relationship with your orthotist. The orthotist and your patients will profit.
  - Identify and reach out to the Schroth practitioners in your area or institution. Schroth has tremendous appeal to the sophisticated family and they will find it early in their internet search. Working with, rather than against Schroth practitioners is better for patients.
  - Remain involved in bracing.
    - As a surgeon you are the best informed to judge progress/failure and weigh the advantages/disadvantages of bracing vs. surgery. Your suggestions command respect.
  - Convey realistic enthusiasm about bracing to patients and staff. If you don't believe bracing can work, all those around you will pick up on the negative attitude.

My concerns:

- *Surgeons are less involved with non-operative care.* We are abdicating brace treatment to others with less knowledge of natural history, pathoanatomy and treatment alternatives.
- *Our successors are not being trained or exposed to bracing,* making it difficult for them to oversee bracing. They will have trouble 'believing' that bracing can work if they have never seen it work.

Notes:

Evolution of Surgical Techniques for AIS.

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The surgical goals in scoliosis surgery have never really changed: Straighten the spine as much as possible and achieve a solid fusion to maintain the correction.

The way we achieve that goal has changed over the last 50 years with our surgical techniques. A more sophisticated definition of our goals in 2015 might be: to achieve a 3-dimensional correction of the scoliosis deformity with a solid fusion over as small a number of vertebrae as possible to maintain the correction.

That is not to say our forbearers didn't have the same "modern " goal in mind. In fact they thought of most of the principles well before we did. The difference is we have had the ability to retrospectively look at long-term outcomes of their surgery to refine our surgical planning and techniques. We also have had the advantage of revolutionary implant technology that has allowed us to manipulate individual motion segments to try and achieve our goal.

It is scary to think what those great pioneers of scoliosis surgery could do today if they had the technology we often just take for granted!

Not only have there been changes in surgical strategies but also great advances in the whole perioperative care of the AIS patient. Anaesthesiology has improved, minimising the use of blood products, regulation of blood pressure, regional blocks, tranexamic acid etc. Spinal cord monitoring advances has allowed more accurate intraoperative assessment of spinal cord function. This has led to the surgeon feeling more comfortable performing aggressive resections and corrections to achieve a balanced spine. The consensus agreements of safety in the operating room and reducing infection put forward by Dr Michael Vitale and his groups have highlighted the importance of so many "non surgical " factors that help us achieve our surgical goals. (1)

This talk will concentrate on the surgical strategies that have evolved over the last 50 years and the following speaker Dr Stephan Richards will talk on whether these changes in techniques have led to a change in outcomes.

Russell Hibbs was the first surgeon to perform a "fusion operation" for scoliosis and this was in a tuberculosis spinal deformity back in 1911. Within a few years he was using this technique in a number of different cases with varying etiologies.

This initial surgery for scoliosis was either a posterior release or excision of the intervertebral discs and application of a cast (personal communication Dr I Ponseti). Unfortunately this often led to pseudarthrosis and decompensation of the temporary correction. The introduction of bone grafting from the iliac crest improved fusion rates however excision of the facet joints allowed both a better correction of the scoliosis and a higher fusion rate.

Cotrel and others then utilised structural grafts (often tibial shaft) to maintain and achieve a solid correction.

The Harrington rod was introduced in 1960. This revolutionised scoliosis surgery worldwide. Initially developed for the treatment of the collapsing polio spine it was widely adapted to all etiologies of scoliosis including AIS. Finally surgeons were able to release the spine, hold the corrected position with an implant and the patient did not require long periods of immobilisation in a cast. Long-term problems with the Harrington rod patients were the poor sagittal balance and development of the "flat back syndrome". Despite this many patients had very satisfactory outcomes. (2) The Harrington rods were initially inserted without performing a formal fusion. John Moe helped improve the outcomes with the Harrington rod by convincing surgeons to perform a concurrent fusion.

At a similar time Eduardo Luque had developed a system of two L rods with multilevel sub laminar wires for the correction of scoliosis. This had proven an effective treatment option and some surgeons were using the stainless steel wires and the Harrington rod as a "Harri-Luque" construct. (3)

Yves Cotrel attended a workshop with Eduardo Luque in Little Rock, Arkansas in 1982. After returning home with some of Luque's instrumentation that had been given to him he decided that combining the Harrington distraction and Luque segmental translation and rotation technique an effective implant could be made. He took the idea to Paris and met with Jean Dubousset. The Paris unit had studied the scoliotic spine extensively and published on how the rotation of the segments was the primary pathology. (4) The result of these 2 great minds was the development of the Cotrel-Dubousset system where 2 rods, a series of closed and open hooks and 2 crosslinks are used to derotate, translate and lengthen the spinal column. The first case was performed at the Hospital Saint-Vincent-de-Paul on January 21, 1983. 25 cases using CD instrumentation were performed that year in their hospital, 7 for adolescent idiopathic scoliosis. The first operation in the USA using CD instrumentation was at Kosair Hospital, Louisville September 17,1984.

The instrumentation would only be released to a surgeon if they "could provide written proof that they had participated in at least four operations conducted in the presence of a qualified "instructor"". (3) If this teaching strategy had been adhered too with the introduction of all new spinal technology, outcomes may well have been improved over the years.

Since the introduction of the CD instrumentation new surgical strategies have largely built upon and modified the basic principles that Cotrel and Dubousset had described. The hook system was refined, pedicle screws were used, more extensive releases performed, stiffer rods, and more complex derotation manoeuvres developed.

Roy Camille introduced the pedicle screw to Cotrel in 1985 as a way of getting better fixation to the vertebrae. Some surgeons used pedicle screws distally however Suk and Lenke really popularised the use of multiple pedicle screws to get rigid fixation and the ability to really manipulate the spine. (5,6,7) This rigid fixation has allowed the development of aggressive osteotomies of the whole spinal column (PSO, VCR) that were not possible or as safe with lesser instrumentation. The need for thoracoplasty has also decreased as the rib prominence has decreased with greater derotation of the apical vertebrae. This has also resulted in improved anterior rib cage symmetry.

These more effective surgical techniques have led too less anterior surgery for AIS correction. Curves that were previously corrected with anterior release and /or instrumentation can often now treated safely with posterior only surgery. Multiple ponte osteotomies, rib resections, pedicle subtraction osteotomies (PSO) or vertebral column resections (VCR) can all be used with multiple level pedicle screw fixation and stiff rods to achieve adequate correction of the spinal deformity. If the correction is not achievable as planned a temporary rod can be inserted and staged surgery carried out a week latter. (8)

Anterior spinal surgery has decreased in popularity as a surgical technique as these posterior techniques continue to be refined. An anterior release remains an important procedure in the large (>90 degree) stiff (<50% correction on traction or side bending) scoliosis. This release can be performed through a thoracotomy or by video assisted thorascopic surgery (VATS). (9) Either way, releasing the anterior longitudinal ligament and performing multiple discectomies helps achieve the desired correction with the posterior instrumentation. Anterior instrumented scoliosis surgery in the lumbar spine and thoracolumbar junction would often "save a level" when compared with posterior only surgery. This may still remain true in the occasional case however with posterior only surgery and rigid fixation with distal pedicle screws similar levels can be fused with anterior and posterior approaches.

The Lenke classification has greatly helped the surgeon plan their strategy for correction. One of the goals of surgery is to maintain as many motion segments as possible especially distally. This classification helps the surgeon decide levels preoperatively and avoid decompensation of unfused vertebrae. (10)

In summary, surgical strategies have been evolving over the 50 years however they are largely based on the teachings of the pioneers. There has no doubt been an explosion in the technological aspects of implants and instrumentation however the basic premise of derotating the spine to achieve a 3-dimensional correction remains. The ability to do this without additional anterior surgery, fusing fewer levels, and improving sagittal balance have been important steps forward in treating AIS.

I shudder to think what ingenious thoughts those pioneer surgeons would have had if they could have had all the amazing technology we all have at our finger tips available to them!

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3. *In The Sands of Berck by* Yves P.Cotrel. Institut de France Foundation Yves Cotrel

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Notes:

Intraoperative Neuromonitoring and transexamic acid (TXA) utilized to enhance safety

Process measures (Cobb angle measurements, Fusion levels saved, etc) objectively document the increased spinal deformity correction. However, these improvements seen on process measures frequently have not equated with significant improvement in patient-reported quality of life measures *-Mulpuri et al, Spine 2007*

2) Patient-related outcomes – How do they contribute to our surgical treatment goals?
   a. Patient reported outcomes of treatment are considered crucial in advancing treatment and improvement in the ability to assess subjective outcomes is essential."

   Bastrom et al, Spine 2015

   b. There is a need to determine whether the SRS-22 HRQOL tool, or other tools, can demonstrate clinically relevant changes following surgical correction in AIS
      i. *Bastrom et al, Spine 2015*
      ii. *Shinji et al, Spine 2009*
      iii. *Carreon et al, Spine 2011*
      iv. *Sharma et al, Eur Spine J 2015*
      v. *Larson et al, Spine 2014*
3) Limit the length of spinal fusions
4) Reduce repeat surgery for AIS
   a. From pseudarthrosis, implant prominence, and late infection….to reoperations for malpositioned implants and infections.
      - *Mignemi et al, SRS annual meeting 2015*
5) Prevention of respiratory morbidity
   a. Gain a better understanding of pulmonary function limitations in AIS
      i. *Johnston et al, Spine 2011*

Are we over-treating Scoliosis?

Nonoperative

Objective compliance meters demonstrate bracing effectiveness

USPSTF

Operative

Smaller curves 40°-50°

-Ward et al, POSNA annual meeting 2015

Patient-reported outcomes
Efforts to determine clinically relevant changes following surgery with extensive implants must be continued.

MIMO study

Refined operative treatment

How Have the Goals of Care in AIS Changed Over Time? Are We Over-Treating Scoliosis?

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Surgical Goals circa 2000:

Partial Correction

Stabilization

Reduction of clinical deformity

Restoration or maintenance of well-balanced spine

Newer emphasis on sagittal plane deformity

Obtain fusion to prevent future curve progression

Do all of this safely.

-Bridwell's Textbook of Spinal Surgery 1997

-TSRH's Tachdjian Pediatric Orthopaedics 2002

Today's Goals:

1) Most of the goals remain similar BUT, because of the evolution of surgical instrumentation/constructs and the increased familiarity with complex osteotomies, *the goal of "partial correction" of the idiopathic spinal deformity has transformed to a significant degree into one of maximum correction of the clinical/radiographic deformity.*

   High-density pedicle screw constructs

   - More powerful direct vertebral derotation instruments/techniques
     - Suk et al, Eur Spine J 2012

   Increased use of Ponte osteotomies/Smith Peterson osteotomies

   Decreasing utilization of anterior releases

   VCRs for the extremely severe neglected AIS

Have nearly eliminated use of thoracoplasty

Have nearly eliminated autogenous crest graft

TL curves: currently favored approach is all posterior, without anterior surgery

-risk losing experience with anterior approaches

Notes:

Adult Scoliosis

Moderators:

Steven D. Glassman, MD & Serena S. Hu, MD

Faculty:

Keith H. Bridwell, MD; Frank J. Schwab, MD; Pierre Roussouly, MD; Robert W. Gaines, Jr. MD; Christopher P. Ames, MD; David W. Polly, Jr. MD

A Historical Perspective on the Operative Approaches to Deformity Surgery in the Adult

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Minimum Requirements for Getting a Long Fusion to the Sacrum Solid. Circa 2002

- Segmental fixation without jumps to gaps from the middle lumbar spine to the sacrum.
- 4-point fixation of the sacrum / pelvis to protect the S1 screws.
- Bicortical S1 screws.
- Load sharing with anterior column support / anterior fusion in the distal lumbar spine, if not the entire lumbar spine. This may be changing somewhat.
- Neutral or negative sagittal balance.

Problems With This Method (Iliac Bone Graft, Anterior T11-Sacrum, Hooks in Thoracic Spine, No Biologics)

- 25-30% nonunion rate.
- Chronic chest and abdominal soreness in patients >55 years old.
- Two surgeries (anterior and posterior) rather than just one.
- Options of staging them or doing one very long surgery.Can We Reduce Pseudo Rate, The Need for Anterior Surgery and Iliac Harvesting With Long Fusions To The Sacrum If We Utilize:
- More fixation points / pedicle screws.
- More extensive decortication and generation of local bone graft.
- Use of biologics proteins / fresh frozen morselized allograft.

Why Is The Nonunion Rate Better Now Than 10 Years Ago?

- Is it BMP?
- Is it related to the positive aspects of not doing iliac harvest?
- Is it due to the positive aspects of not performing a major thoracoabdominal approach?
- Is it due to the increased implant density/fixation points per level? 1.2 vs. 1.9.
- Is it due to more extensive harvesting of local bone?
- Is it just due to increased surgeon experience?

Correctives / Instrumented Fusion Techniques

- How necessary to have a TLIF or ALIF at L5-S1?
- How necessary to protect S1 screws with either iliac or sacro-iliac screws?
- How "evil" are iliac screws?

Summary / Conclusion:
What's Different Now Than 10 Years Ago?

- Less anterior surgery now.
- Higher fixation density now.
- Variety of options for sacropelvic fixation now.
- Wide variety of utilization of biologics now.
- Some suggestion, though not totally hard facts, that patient-reported outcomes are better now.
- Still fairly high complication rate, even with primary long fusion to sacrum/pelvis. Unclear if better or worse than 10 years ago. Will total complications at 5-year postop be less with MIS?
- Clearly, nonunion rate lower now with higher fixation density and less anterior surgery and more "experience" by operating surgeons.

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- *54 patients treated by standardized single stage anterior opening wedge and posterior closing extension wedge osteotomy for back pain associated with postop loss of lumbar lordosis (iatrogenic flat back syndrome).*
- *Average pre-osteotomy lordosis L1-S1 was 21.5° and was restored to 49° (equal to lordosis before initial surgery) for an average correction of 29° (range 24 to 63°).*
- *Prevention of this complication can be accomplished by maintaining normal lordosis at the time of initial surgery.*

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Best results achieved in patients with Galveston fixation and anterior fusion of all lumbar segments, as well as segmental fixation.

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- *54 consecutive patients who underwent elective combined anterior and posterior surgical reconstruction for acute spine deformity were studied.*
- *Attention to sagittal balance is critical.*
- *Luque-Galveston fixation technique has an unacceptably high rate of pseudarthrosis. Currently, the authors are using bicortical and triangulated sacral screws with anterior interbody support.*
- *They recommend using iliac fixation, although there is a higher rate of painful implants, requiring removal.*

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- *11 patients with ankylosing spondylitis and fixed kyphosis.*
- *First published full length peer-reviewed article about PSO.*

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- *27 consecutive patients between 1995-1999.*
- *Range of follow-up was 2-5 years.*
- *Most patients experienced dramatic improvements in PROs, but very high complication rate.*

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- *110 consecutive patients treated with a PSO at one institution were analyzed.*
- *Neurologic deficits occurred in 12 patients (10.9%) and were permanent in three (2.7%).*
- *Deficits, which were not detected with neuromonitoring, were thought to be due to a combination of subluxation, residual dorsal impingement, and dural buckling.*

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- *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.*

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- *Overall prevalence of pseudarthrosis following long adult spinal deformity instrumentation and fusion to S1 was 24%.*
- *Consecutive surgeries at single institution between 1985 and 2002.*
- *Average age 52 years; range 21.1 to 77.6 years of age.*
- *Patients with pseudarthrosis had significantly lower SRS outcome scores (p<0.0001).*

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- *Review of 752 patients with adult spinal deformity enrolled in a multicenter prospective database in 2002 and 2003.*
- *Positive sagittal balance was identified in 352 patients.*
- *This study shows that although even mildly positive sagittal balance is somewhat detrimental, severity of symptoms increases in a linear fashion with progressive sagittal imbalance.*
- *Kyphosis is more favorable in the upper thoracic region, but very poorly tolerated in the lumbar spine.*

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- *No complications from rhBMP.*
- *31 vs. 32 patients; 6.4% (n=2) vs. 28.1% (n=8).*
- *Both nonunion patients in the BMP group had <5mg/level.*

14. Rahman RK, Buchowski JM, Stephens B, Dorward IG, Koester LA, Bridwell KH. Comparison of TLIF with rhBMP-2 versus no TLIF and higher posterolateral rhBMP-2 dose at L5-S1 for long fusions to the sacrum with

sacropelvic fixation in primary adult deformity patients. Spine 2013;38(26):2264-2271.

- *Nonunion rates for TLIF vs. BMP group at L5-S1 identical. 31 NI vs. 26 TLIF patients.*
- *TLIF group was more expensive and had more nonunions in the midlumbar spine.*

15. 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.

- *In the adult spinal deformity population, the prevalence of elective IS removal was 6.1% at an average of 2.6±1.3 years postop.*
- *IS removal was associated with a low rate of complications, a high rate of hip/buttock pain relief (86.0% of patients were improved), and 91.7% overall satisfaction in well selected adult spinal deformity patients.*
- *Other surgeons at other institutions have reported much higher rate of problems with iliac screws down the road.*

16. 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.

- *Fusion rate at L5-S1?*
- *Late degeneration of the SI joints? NO.*
- *"Changes" in the iliac screws. Most asymptomatic.*
- *Other surgeons at other institutions have reported more problems with iliac screws.*

17. Kebaish KM. Sacropelvic fixation: techniques and complications. Spine 2010;35(25): 2245-2251.

- *Highlights advantages of S2 alar iliac fixation.*
- *Potentially lower profile, no connector, bigger and longer screw.*
- *Does traverse the SI joint and its cartilage.*
- *Particularly helpful if ilium has been substantially harvested before.*

Notes:

Classification of Adult Deformity

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Introduction

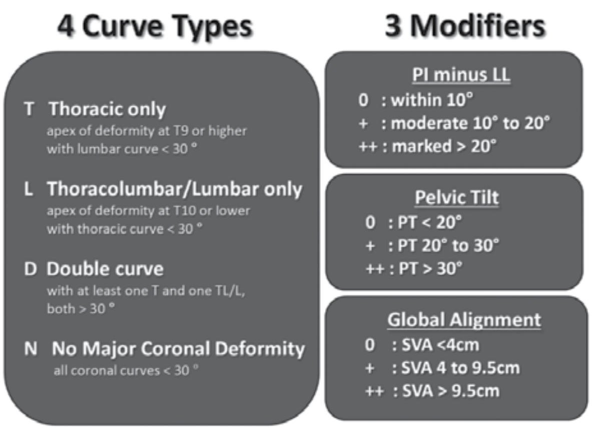
30 years ago, the most common topic in the most influential spine textbooks on spinal deformity focused on pediatric and adolescent deformity. With the inevitable aging of the population and the advances in surgical technique, knowledge of evaluation and treatment of adult spinal deformity (ASD) has gained popularity. While primary deformities are common, some of the most challenging patients present with one or several previous surgeries and spinal malalignment. Several studies have demonstrated that adult deformity is not only associated with pain and disability but is also quite prevalent with an incidence of 60% in the older population (ie >60 years of age).[1] Despite the substantial number of patients meeting criteria for adult spinal deformity, this complex pathology remains somewhat poorly understood. One limitation relates to the diversity of pathologies associated with spinal deformity in the adult, lack of a coherent system for categorizing patients, and until recently, poor understanding of correlations between deformity parameters and patient reported disability.

Classification systems are created to provide organization to pathologic conditions and guide treatment options for disease states that share a common theme. A classification ideally provides a cohesive approach to a disease state that (1) identifies different severities of the disease state (often in a hierarchical manner), (2) facilitates communication between health care providers and researchers to assure accuracy and reproducibility in describing the disease state, (3) allows for comparison of different treatment methods and, as a consequence, (4) allows for creation of accurate treatment recommendation guidelines.

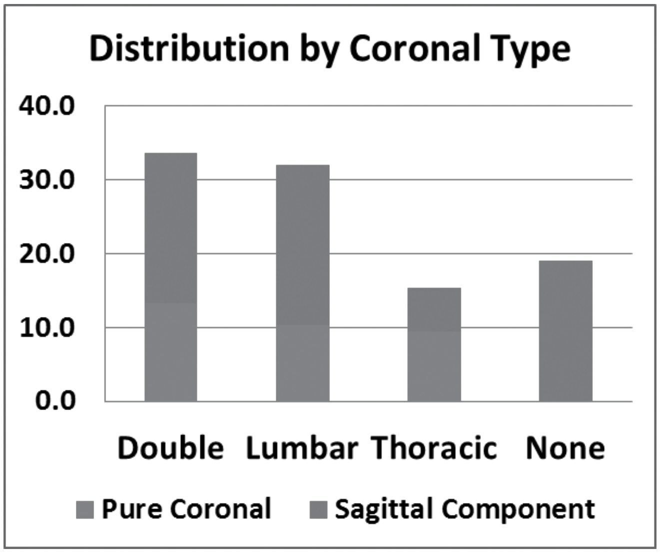
Previous classifications for ASD have been proposed in several versions. However, unlike adolescent idiopathic scoliosis, of which the coronal deformity is paramount, it has been repeatedly shown that sagittal malalignment is a fundamental component of ASD, and that sagittal malalignment is a primary determinant of pain and disability in the ASD population. Based on these concepts, initial work by Schwab and colleagues established a foundation for a clinical impact classification for ASD that integrated radiographic parameters correlating with poor health-related quality of life (HRQOL) parameters.[2]

Understanding adult spinal deformity through classification

- This hybrid Scoliosis Research Society (SRS)-Schwab classification uses frontal and sagittal full-length x-rays in order to provide a full picture of the spino-pelvic complex.
  - o The curve type of the classification aims to describe the relevant coronal aspects of the deformity (double curves, thoracic, lumbar, or no curve)
  - o The sagittal modifiers of the classification are defined based upon their correlation with patient reported outcomes.



- Three sagittal modifiers were included based on work by Lafage and colleagues with the discovery of spinopelvic parameter thresholds associated with pain and severe disability.
  - o SVA, PT, and PI–LL were the 3 parameters with the highest correlation to HQROL scores.
  - o Regression analysis has also shown that ODI could be calculated and predicted using each of the three modifiers.
  - o Furthermore, values including PT greater than 22°, PI-LL greater than 11°, and SVA greater than 46 mm have been shown to correlate with Oswestry Disability Index (ODI) scores greater than 40 (severe disability) in a prospective cohort of patients with ASD.
- Despite the diversity of ASD patients, SRS-Schwab classification did represent most of the patients.
  - o In a set of 600 ASD patients, about 1/3 were classified into T or N Type, 1/3 into D Type and 1/3 into L Type in terms of curve type.
  - o In regard of sagittal modifier distribution, approximately 50% patients were regarded as Grade 0, while Grade + and Grade ++ constituted the rest 50% with 25% each. When combined, it was shown that most of the patients with a lumbar curve component had at least one sagittal modifier grade of + or ++.
- To summarize, the SRS-Schwab classification represents the "average" patient without floor/ceiling effect.



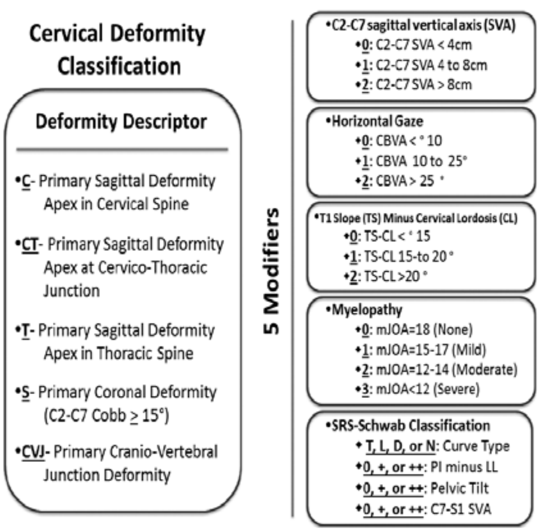
Validation and reliability

- From a statistical standpoint, a classification system should have high construct validity (the extent to which classification accurately measures the disease state) and high reliability as shown by high intra-rater reliability (consistent grading by 1 rater at different time points) and inter-rater reliability (consistent grading by different raters). The classification should also have high reproducibility (the degree of agreement between measurements on replicate specimens in different locations by different observers).
- For SRS-Schwab classification for adult spinal deformity, the criteria were generated from a multicenter database with a US population. As a testament to the classification system's validity, reliability and reproducibility, several studies have validated SRS-Schwab classification in the Asian and European populations from both a radiographic aspect and a quality of life aspect.
  - o With non-premarked radiographs, Liu et al. reported excellent intra- and inter-reliability of SRS-Schwab classification in the Chinese population. The main disagreement centered on the differentiation of type T from L and determining PI-LL.
  - o The same research group further validated the excellent reliability of SRS-Schwab classification in adult idiopathic scoliosis and de novo scoliosis.
  - o Regarding to the HRQOL in European population, strong correlations were observed between HRQOL measure-

ments and sagittal modifiers, demonstrating the validity in a non-US population in terms of HRQOL.

From back to neck, what could be learned from classification?

- Changes in reciprocal regional spinal alignment have been reported after correction of thoracolumbar deformity, e.g. the reciprocal increase in thoracic kyphosis after lumbar pedicle subtraction osteotomy and the reciprocal decrease in lumbar lordosis after correction of thoracic hyperkyphosis. [3] However, the evaluation of cervical spine in ASD patients still requires investigation.
  - o From a thoracolumbar point of view, severe sagittal modifiers in ASD patients have been associated with a higher prevalence of cervical positive sagittal malalignment. Therefore evaluation of thoracolumbar deformity should include assessment for concomitant cervical deformity.[4]
  - o From a cervical point of view, it had been demonstrated that patients with large cervical lordosis were associated with sagittal modifiers + and ++, implying that patients with hyperlordosis should be assessed for thoracic kyphosis malalignment.[5]
- Similar to the correlation between thoracolumbar deformity and HRQOL, the correlations between cervical sagittal parameters have also been recently investigated.
  - o Tang et al. defined a 4cm threshold for C2-C7 SVA, which was correlated with disability in patients following posterior cervical fusion.
  - o C2-C7 lordosis and C2-C7 SVA were also correlated with HRQOL measurements in both non-operative and operative groups, as reported by Protopsaltis et al.[6]
- In line with the SRS-Schwab classification, a novel classification system for cervical deformity patients was proposed, in which the SRS-Schwab classification serves as one of the modifiers. The intra- and inter-observer reliability of this cervical deformity classification has also been validated in a small sample size, reporting as in moderate agreement.



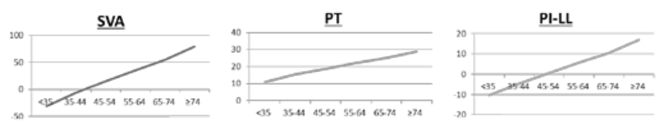
From classification to clinical practice

- The classification offers a consistent method of analysis for all patients, instills a discipline to see all patients in regards to deformity disability drivers, and serves a foundation to developing treatment plans and goals.
- ASD patients tend to undergo either non-operative or operative treatment.
  - o Differences have been reported in terms of clinical outcomes between patients with different curve types, indicating that patients with L or TL curve types were less likely to improve with non-operative treatment, specifically in terms of reaching minimal clinically important difference (MCID).[7]
  - o In a retrospective radiographic study, Terran et al.[8]correlation with treatment has not been assessed. OBJECTIVE: To assess the clinical relevance of the SRS-Schwab classification based on correlations with health-related quality of life (HRQOL demonstrated that patients with primary sagittal deformity (N Type) were significantly more likely to present with history of spinal surgery compared to patients with coronal deformity.
  - o Regarding to surgical strategy, N Type patients were more likely to undergo osteotomy while D or L Type patients had the tendency for circumferential procedures.
- More importantly, sagittal modifiers play an important role in predicting both post-operative radiographic and clinical outcomes.
  - o In terms of sagittal modifiers, patients who underwent surgical correction had worse sagittal modifiers (PI-LL, SVA, and PT). As a consequence, the surgical correction of the three sagittal parameters showed a significant influence on the likelihood of reaching MCID for HRQOL measurements.[8]correlation with treatment has not been assessed. OBJECTIVE: To assess the clinical relevance of the SRS-Schwab classification based on correlations with health-related quality of life (HRQOL
  - o The baseline sagittal modifiers could be used to predict best or worst clinical outcomes for ASD patients, reported by Smith et al., who demonstrated that greater baseline sagittal deformity predicted worse clinical outcomes evaluated by SRS-22 and ODI scores.[9] In a smaller set of ASD patients with PI-LL mismatch but normal SVA, the surgical correction has also been reported to be as satisfactory as those with decompensated SVA, implying that PI-LL mismatch could be regarded as a potential indication for surgery and that evaluation of sagittal malalignment should go beyond measuring SVA alone.[10]
  - o A similar conclusion was drawn in a study focusing on the conversion from non-operative to operative treatment. For the 42 patients who converted from non-operative treatment to operative treatment, a significantly larger PT, SVA, and PI-LL mismatch were observed.

- In minimally invasive surgery, similarly, the SRS-Schwab classification has been reported to predict clinical outcome.
  - o Mundis et al. stressed that minimally invasive techniques could successfully treat patients with Grade 0 and Grade + deformity with improved HRQOL and that patients with Grade ++ deformity showed less improvement clinically, implying the necessity of a standard open surgery.[11]coronal cobb = 20\u00b0, SVA > 5 cm, or PT > 25\u00b0. Patients were stratified by SRS-Schwab global alignment modifier (GAM

A look to a potential evolution of the classification
The most obvious area for improvement in regard to alignment objectives relates to the necessity to take patient age into account.

- o In 2010, Mendoza-Lattes et al. confirmed the gradual increase in SVA in both asymptomatic and symptomatic adults with linear regression models.[12]and 2 positional parameters, the pelvic tilt, and sacral slope (SS
- o Hence, age-specific alignment thresholds are needed to better determine the goal of surgical correction of ASD patients.
- o Schwab et al.[13] have performed a study to determine the validity of alignment objectives according to age, based a multicenter ASD database. The preliminary results revealed an increase in all the sagittal modifiers with age. The authors concluded that younger patients require a more "rigorous" alignment to meet age-specific ODI/PCS while the alignment objective for older patients should be less aggressive.



Conclusions
The treatment of ASD remains challenging and complex. Collective efforts over the past decades have established drivers of disability based on radiographic analysis combined with clinical outcomes. The establishment of a classification system and treatment goals in the setting of deformity have brought standardized and reproducible approaches to the treatment of ASD in clinical practice. In addition to clinical evaluation, the radiographic analysis should rely on high quality, full length, standing x-rays for all spine patients. Routine use of key radiographic measures should be extended to all patients and not be restricted to those with complex deformities.

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Notes:

Understanding Sagittal Balance

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Balance definition:

A balanced status is a physical situation where the different acting forces are neutralized. As the human body is not a rigid structure, maintaining the standing position requires muscles action to keep the body center of mass over the feet area. In balanced situation, the vertical alignment of the spine and pelvis remains in a small area in order to minimized the need of muscles and by the way decrease the stress on the bony-joints structures.

Three anatomical landmarks are well recognized to characterize the spino-pelvic balance: C7 plumb-line (C7PL), Sacral Plateau (SP), Femoral Heads (FH). The balance alignment combines the FH-SP relation (depending on the pelvic shape), and the spinal shape (a combination of spinal curvatures, Lumbar Lordosis and Thoracic Kyphosis). The link between these structures is the sacral plateau whose orientation, Sacral Slope (SS), indicates both SP and LL orientation. In a normal situation the only rigid structure is the pelvis, determined by the well known angle: Pelvic Incidence (PI). The ability of pelvic rotation around the femoral heads permits an adaptation of SS by pelvic retro or anteversion. Given the geometrical relation PI=PT+SS, and the large natural range of PI, the positional pelvis ability is directly linked to the pelvic shape(PI).

Spinal curves. Shape and distribution.

The anatomical segmentation between Thoracic Kyphosis (T1-T12) and Lumbar Lordosis (L1-S1) is still used in many recent studies. Berthonnaud gave a functional definition, considering Lordosis as the area where the vertebrae are in extension and Kyphosis where vertebrae are in flexion. TK and LL were bounded by the Inflexion Point were LL transitions in TK. Each curve is segmented in two arcs of circle, tangent on the apex. The Lower arc of LL is equal to SS. The upper arc of LL is equal to the lower arc of TK. There is a double reciprocal relation between LL and TK in length and angle (Fig. 1):

- When LL is short (proximal positioning of IP), TK is long (Thoraco-lumbar kyphosis) and vice versa.
- the upper arc angle of LL and lower TK arc are changing the same way.

The other geometrical constraint is SS. As the LL lower arc is equal to SS, there is a direct relation between LL and SS.

- When SS decreases, the lower arc angle decreases the same way.
  - o The lower arc tends to disappear, leaving the upper arc as the only expression of LL. LL is short (IP on L3), and TK extends in thoraco-lumbar area
  - o The lower arc is poorly curved with a global flat back
- When SS increases, lower arc angle and length increase

Due to the relation PI=PT+SS, there is a direct effect of PI on SS (confirmed by the strong correlation between PI and SS). When PI is low, generally SS is low. But in some cases an anteverted pelvis (small PT) may induce a higher value of SS than expected. When PI is high, in normal situation, SS is always high. A reduction of SS by pelvic retroversion (increasing PT) is always a pathological compensation.

We describe five types of normal spino-pelvic organization depending on SS and PI (Fig. 2).

Pathological compensations:

In pathology, a very classical situation is *the anterior unbalance*. It is generally due to an increasing TK or a decreasing LL, and sometime both. There are two levels of compensation:

- Hyperextension of the adjacent levels of the pathological kyphotic area. It could be an increasing LL below an increasing TK, or a decreasing TK above a decreasing LL. It may arise on one or several segments.
- When this mechanism is unsufficient to restore the balance (C7PL behind FH), the second mechanism is the pelvis retroversion (increasing PT), decreasing SS in the same time. This mechanism has two limits:
  - o The ability of Pelvis retroversion is linked to PI value. Due to PI=PT+SS, the maximum value of PT depends on PI, with a bigger possibility of PT with bigger PI. A high PT is always linked to a high PI.
  - o But Pelvis retroversion is depending on Hips extension and

cannot be sustained a long time and mainly when walking. When Hips extension is overpassed the knees have to flex to reach extreme values of PT.

Schwab, Lafage have given limits to assess the balance in Adult Scoliosis: PT>20° and SVA>5cm. We prefer the FH as forward C7PL limit of anterior unbalance rather than SVA distance.

Another rare pathological situation is due to *Lumbar hyperlordosis*. We have seen that in a normal population, we found patients with anteverted pelvis and hyperlordosis (anteverted Type 3). This Pelvis anteversion (PT<5°) when extreme, could be a cause of anterior unbalance. We will see that this situation is coming frequently by hyper reduction of LL after surgical correction.

Surgical treatment and reverse compensation

Glassman demonstrated a good correlation between good clinical result and restoration of a good balance. By the way this restoration is the main objective of surgical treatment of AS. Matching LL with PI was the main challenge proposed by Schwab. The big amount of PJK occurring in the last series analyzing balance after surgery demands further mechanical exploration to explain this phenomenon. TK post-op evolution was probably under estimated.

As we saw previously, balance is an economic situation with a minimal muscular action to maintain C7PL behind FH, and have 5°<PT<20°. But these balance criterions seems insufficient and PJK may occur even if balance parameters were correct. As PJK are always occurring in TK area, the role of curvatures (TK-LL) seems crucial.

We know that according to PI, there is a geometrical determination of spinal curvatures. PI is stable along the life and may be a signature of the initial patient shape before degenerative changes occur. Our proposal is to restore a Type 1 or 2 when PI is low (<50°) and a Type 3 or 4 when PI is high (>50°).

What are the optimal solution and the main mistakes?

Whatever the LL pathological shape there are two main situations for TK: flat or curved (hypo or hyper kyphosis).

- Hypo kyphosis
  - o Structural Flat TK (Type 2 flat back); it has to be respected and maintained as it.
  - o Hypo kyphosis may be an active compensation: local hyper extension to compensate a loss of lordosis below.
- Hyper Kyphosis
  - o Structura,l due to previous pathologies: degenerative, Sheuerman, fracture. It may be short (only thoracic) or long (predominant in TKL area). It's always inducing hyper lordosis compensation.
  - o Reverse compensation: PJK

Let us analyze the different scenarios according to PI signature.

- PI is low <50°; two options: Type 1 or 2
  - o Type 1: the less frequent shape in normal population is becoming very frequent in AS (45%), mainly in Thoraco lumbar and lumbar scoliosis. Our proposal: maintain Type 1 shape. Main error would be to flatten the kyphosis (equivalent to restore a Type2). The second mistake (sometime associated) is to increase the length of LL, inducing an anteverted pelvis. In both cases the risk of proximal PJK is major. The system is too much tilted posteriorly and the only place for kyphosis expression is in the cervico-thoracic area.
  - o Type 2: frequent in pure degenerative lumbar scoliosis. Our proposal: maintain the flat back. Sometime a slight PSO may be necessary to restore a Type 2 lordosis. Difficult to treat when associated to a proximal thoracic hyper kyphosis. Main mistake: to increase too much the angle of LL inducing an anteverted pelvis with anteverted Type 3 and risk of thoracic kiphotic compensation. Some treatment options like distal disc atrhroplasties have turn a Type 2 in Type 1 with TL PJK.
- PI is high >50°: Type 3 or 4. The most classical unbalanced situation; retroverted pelvis (PT>20°) and forward displacement of C7PL (Increasing SVA,or C7PL forward FH)
  - o Balanced system: slight loss of LL, and same amount of Kyphosis. Treatment option: maintain the curves harmony, regarding the scoliosis level an average fusion (T10-S1) may be acceptable
  - o Hypo lordosis with hyper TK: global kyphosis. Option treatment: long fusion LL has to be positioned in adequation between PI and TK. TK has to be respected. Main mistake: extend LL too proximal and reduce TK too much: risk of proximal PJK
  - o Hypo lordosis and compensative hypo TK (global flat back with retroverted pelvis). This is the most difficult challenge because of the uncertain TK shape evolution. With an average fusion (T10-S1) addressing only the lumbar and thoraco-lumbar area, the restoration of LL will induce a release of thoracic compensation, turning back to kyphosis. The upper limit of instrumentation may be stressed in flexion inducing a PJK. The other optional treatment may be an extension of the instrumentation to the proximal thoracic vertebrae (T3-S1). If the rods are not bent enough, and TK too much reduced, the necessary compensative upper thoracic flexion occurs with a proximal PJK. The proximal vertebrae escape forward from the rods.

Conclusion:

Analyzing Sagittal Balance in Adult Deformities is not only restoring a vertical alignment of the spine and pelvis, it is also taking in account the curves harmony and reciprocity imposed by the pelvic shape and its parameter the Pelvic Incidence. The recent occurrence of PJK, is a proof of the necessity of o good treatment strategy.

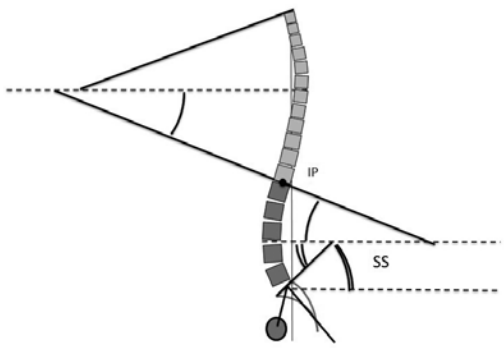

Figure 1

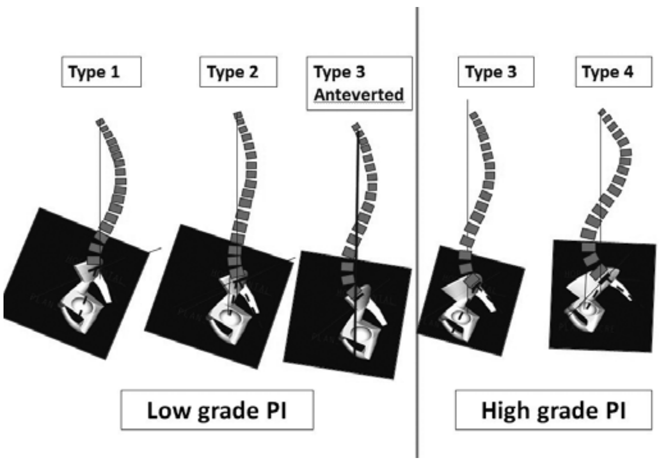

Figure 2

Notes:

Junctional Pathology

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The most common serious complication of surgical management of adult deformity.

Junctional problems are iatrogenic, they are common, they are serious and they are preventable.

"Junctional problems" were rare before pedicle screw instrumentation, since internal fixation techniques were so ineffective. Reports following dramatic corrections of scheurmann's kyphosis were the only reported cases. Rarely, spinal cord injury did occur, in these rare cases.

Early/previous literature citations using pedicle screws did mention junctional problems, but did not identify the potential clinical seriousness of PJK/PJF—and certainly not spinal cord injury.

Recently, a classification of PJK and PJF was published by Yagi, et. Al., characterization and surgical outcomes of proximal junctional failure in surgically treated patients with adult spinal deformity, spine, volume 39 , number 10 , pp e607 - e614 ©2014, lippincott williams & wilkins.

Cases of spinal cord injury in association with cases of PJK/PJF were also well-identified and characterized (Yagi, et. Al. SPINE, see reference above).

Three previous Hibbs Society meetings entirely focused on identification, classification and prevention of PJK/PJF. The programs from these meetings are attached so committed surgeons/presenters/authors are easily identified--- for interested members.

Sethi, r., et. Al. Presented---for the first time---a way to reduce their 40% incidence of "junctional pathology" (either PJK or PJF) last year in anchorage.

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

Rajiv K. Sethi, MD, Ryan P. Pong, MD, Jean-Christophe Leveque, MD, Thomas C. Dean, MD, Stephen J. Olivar, MD, Stephen M. Rupp, MD,   Spine Deformity 2 (2014) 95e103

A "combined pre-operative conference"---including internists, anesthesiologists, nurses behavioral health, and neuro and orthopaedic surgeons--- produced a clearly and statistically significant reduction in their rate of PJK and PJF in their patients—from 40% to 8% at 3 yrs post-op.

A subsequent manuscript on the same topic is being prepared for submission to JBJS.

"Reduction in surgical complications with system improvements for adult scoliosis patients undergoing complex spinal surgery": Karen J. Wernli PhD,[1,2] Melissa L. Anderson MS,[1] Eric A.

Baldwin,[1] Mary Shea [1] Lisa Ross MPH, [1] Rajiv Sethi MD[1,2] , IN PREPARATION FOR JBJS, 2015.

Correspondence to: Karen J. Wernli, Group Health Research Institute, 1730 Minor Ave, Suite 1600, Seattle, WA 98101; email: wernli.k@ghc.org; telephone: 206.287.2934; fax: 206.287.2871

At last year's Hibbs Society Meeting, this approach was recommended for more widespread use.

In addition, preliminary efforts were made to create a basic science study-- including radiologists, biomechanical engineers, and orthopaedic spinal surgeons---under the granting supervision of the SRS---to thoroughly investigate and eradicate---this scourge which has afflicted so many of our patients.

Our society is ideally suited to facilitate, fund and supervise research on this extraordinarily important topic to our members----and our patients.

So far, this grant has not been identified or funded.

I encourage our vigorous, research-minded members to create and apply for this grant. The results of the work will directly and immediately create improvements in patient-care.

The problem continues to be unsolved and needs prevention---not more treatment.

2012 Hibbs Society Program--- ---PJK----CHICAGO
Introduction---

HJ Kim/Bridwell---SRS scores of 364 consecutive adult pts. w 40% post-op PJK and 3.5 yr mean FU—

Yagi/Boachie---PJK at HSS

Bess-ISSG experience w PJK (1)

Hart---ISSG experience w PJK (2)

Rahm—PJK w severe neural deficit/cord injury

Charosky---PJK in France---sagittal plane

Kebaish---Prevention of PJK in adults

Jwalant Mehta---British PJK in adolescents

Mezentzev---PJK in EOS in Ukraine

Kebaish---Prevention of PJK in adults

Gross—multi-rib-hook technique for proximal fixation---a new suggested option

Akbarnia---minimally invasive Rx of PJK

Dr. Keyi Yu—PJK/F from PUMC, Beijing, China

ROUNDTABLE---Lenke, Noordeen, Kostuik, audience---"How I avoid PJK in my practice at this time"

14th Hibbs Society Program

Lyon, France 9/17/13—1-5pm

Experimental Studies

1) Bylski-Austrow (Cincinnati)---Tps Hooks Vs. Screws at The Top of Long Constructs In Pigs

2) Dekleuver (The Netherlands)---Screw Misplacement In Patients—Clinical Study

3) Gross (Charleston)---Hook Fixation on The Ribs In Pediatric Patients---Biomech Study

Case Reports

4) Gehrchen (Copenhagen)---Two Cases of PJK

5) Benny Dahl (Denmark) ---One Case of PJK

6) Crawford (Louisville)---Two Cases of PJK/PJF

7) Mehdian (Nottingham)---Osteoporosis and PJK/PJF

8) Kebaish (Baltimore)---Update on PJK/PJK Prevention

Invited Speakers/Experts

9) "Current Concepts of PJK/PJF"---Special Invited Expert—Dr Mitsuru Yagi---Tokyo, Japan

10)"Prevention Paradigm For PJK/PJF—2013"---SRS President, Dr Steven Glassman---Louisville, Ky.

15TH HIBBS SOCIETY PROGRAM (3RD YR. FOCUSSED ON PJK/PJF) 9/7/14---ANCHORAGE, ALASKA

Indian approach to avoiding PJK/PJF---Dr. Arvind Jayaswal---Director Spine Deformity Program---All-India Institute for Medical Sciences---New Delhi, India---"Special Invited Expert"---2014

PJK/F IN EOS

El-Hawary/chest wall/spine study group---27% PJK/PJF in 40 patient/3 yr EOS series--= incidence w spine/rib instrumentation

PJK/F IN SCHEURMANN'S KYPHOSIS

DeKleuver/The Netherlands---long-term Follow-up with posterior correction and PJK

Mehdian/Nottingham---long-term Follow-up with PJK and rib-hook re-operation

Gaines/Missouri---long-term follow-up of 8 cases with anterior-only "bone-on-cage" w NO PJK/PJF

PJK/F P CORRECTION OF ANKYLOSING SPONDYLITIS ---Qian/Qiu—Nanjing, China

PJK/F IN ADULT DEGEN

President Glassman ---"Alignment is not balance"

Yagi/Japan---Classification of PJK/PJF from series of 1668 Adult Spine Deformity series ---1.4% PJF/22%

PJK incidence; 11 cases w SCI from PJF---and 50% new PJF p re-operation for first PJF

Ames/SRS adult committee---crying need for Classification/SRS membership survey---

Hart/Ames/ISSG---evaluation of Classification criteria in predicting new PJK/PJF

Sethi, et.al./Seattle---Conference-based approach to reducing PJK/PJF/complications in ASD series

Dewald/Chicago---SS implants have reduced incidence of PJK/PJF vs. Ti and CoCr in ASD

Yagi/Japan---Teriparatide pre-op reduces PJK/PJF in ASD when used pre-operatively

Obrien/Washington, DC---Intra-op vertebroplasty of UIV isn't "uniform" in preventing PJK/PJF

SPIN0-PELVIC PARAMETERS AND MATHEMATICAL MODELS MAY APPLY TO JUNCTIONAL PROBLEMS

Deinlein/Hedlund---how to apply "spine equation" to ? avoid PJK/PJF ???

NEW IDEAS TO PREVENT JUNCTIONAL PROBLEMS

Bylski-Austrow/Cincinnati---flexible rods for correction of EOS—exptl. study

Albert/Dayton---SSI w polyester bands totally avoid PJK/PJF in neuromuscular series of 29 children

Notes:

Advanced Cervical Thoracic Deformity Assessment and Treatment Techniques

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<u>Radiographic Assessment in Cervical Deformity</u>

I. Radiographic Assessment of Cervical Alignment

a. What is normal alignment of the cervical spine?

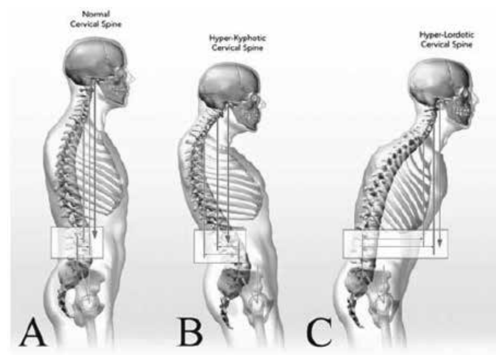
b. Cervical alignment in the setting of subjacent spinal pelvic alignment

c. Importance of assessing cervical alignment on standing 3 foot scoliosis films

i. AP and lateral

ii. UT scoliosis

iii. Shoulder balance for coronal deformities



II. Why does cervical sagittal mal-alignment cause pain?

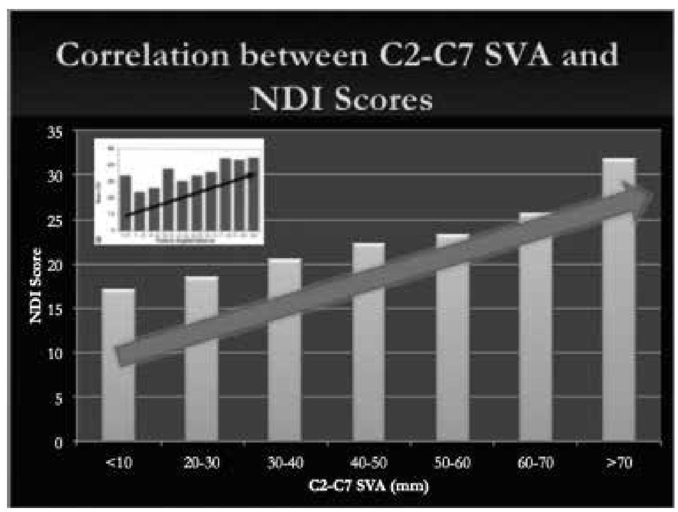
a. Cantilever forces at cervical thoracic junction

b. Why would cervical sagittal mal-alignment contribute to myelopathy

MJOA Correlations to Cervical SVA

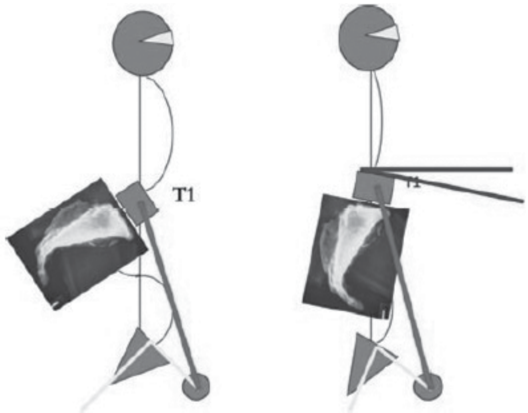
III. Plain radiographic parameters important in the assessment of cervical alignment

a. C2-C7 cSVA



b. C1-2 lordosis (PT of cervical spine)

c. T1 slope (a moving target PI for the c spine)



d. Cervical Lordosis

e. T1 slope – CL <20

f. Upper thoracic kyphosis T1-T4

g. PI-LL, SVA, PT

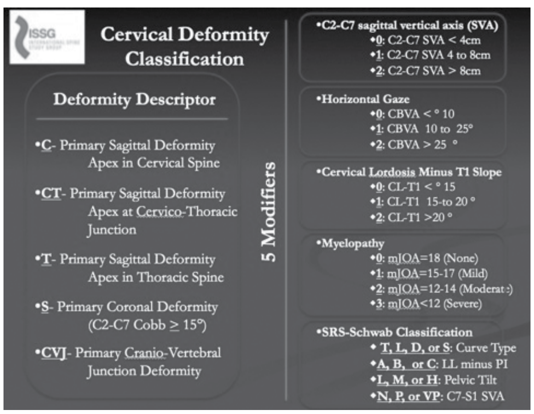
h. ROM on flexion and extension films

i. Traction Films

IV. Realignment planning

a. Towards a radiographic clinical impact classification for cervical deformity

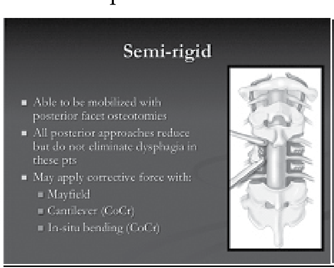
b. Realignment targets

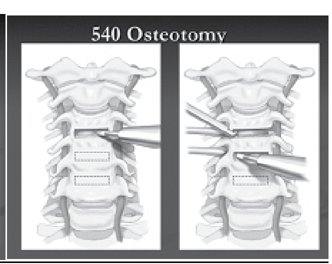


V. Metal Selection

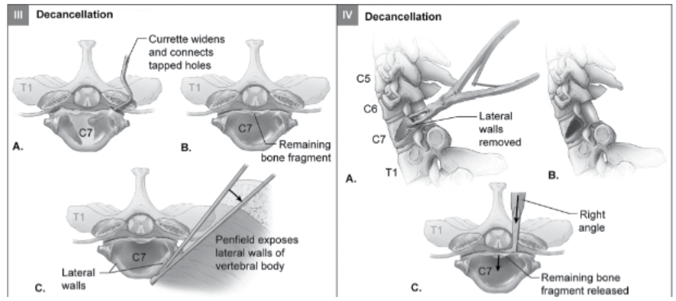
Titanium Rod Deformation

VI. Techniques





C7 PSO



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Notes:

Cost and Value Considerations in Adult Spinal Deformity Surgery

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Impetus to Determine Value

The task of defining value in health care has been steadily gaining momentum. ASD surgeries have incurred a substantial increase in both volume and expense.13

Several initiatives call for efficiency, effectiveness, and transparency in providing health care Ex. Center for Medicare and Medicaid Innovation, Bundled Payments, Accountable Care Organizations, Shared Savings Models

Appropriately addressing these requires an understanding of not only the costs and outcomes of care, but also of the trade-offs and challenges of defining value in realty.

Overview:
Defining value in Adult Spinal Deformity surgery (ASD) relies on 2 primary areas: 1) health-related quality of life (HRQoL) outcomes and 2) the costs of treatment. What can we impact?

Do we Improve Outcomes with Surgery for ASD?

Yes! HRQOL measures have become widely accepted as standardized estimates of patient health. Typically pre and post treatment scores are analyzed to determine whether health improvements are observed. A variety of survey instruments, filled out by patients and sometimes physicians, have become commonplace in the treatment of spine deformity. Numerous studies have found significant improvements in HRQoL outcomes following spinal deformity surgery, and have tied these outcomes to medical and radiographic outcomes as well.[1,3,9,10,18-20]

One difficulty in practical use of the surveys for economic research is the ability to compare survey instrument, as each tool uses a different scale (Ex. ODI ranges 0-100, SRS-22 ranges 1-5). Therefore researchers have developed scoring algorithms that collapse the raw responses into a single index score. This index score can be used along with a time component to produce quality adjusted life years

Survey instruments commonly used in Spine:

- **SRS-22/SRS-22r- Scoliosis Research Society-22**
- **ODI- Oswestry Disability Index**
- **SF-36- 36-Item Short Form Health Survey**
- **NDI- Neck Disability Index**
- **EQ-5D- EuroQol 5 Dimension**

(QALYs): A QALY is on a scale from 0-1, where 1 indicates perfect health and 0 indicates death. The EQ-5D, SF-36(SF-6D), and ODI have all have been used to estimate QALYs.[2,4]

Minimum Clinically Important Difference & Substantial Clinical Benefit (MCID/SCB): Methods to relate statistical significance to clinical relevance[5,6,12]

What is the Cost of ASD Surgery?

Due to the nature of spinal deformity surgery, i.e. the need for expensive and labor intensive resources, the costs of spine deformity surgery is a large and important piece of the value ratio. The average expense of ASD surgery has been reported to be as much as $120,394 per surgery.[14] Costly implants are necessary and account for 41% of total direct costs.[16] Many caveats and specifics to ASD surgery are important in relation to costs. Some important areas are the various surgical techniques, including staging, surgical approach, operating room time, and invasiveness of procedure.

In addition, the durability of spine surgery is especially important to account for the costs of complications and revisions that can occur over a longer time horizon. The need for subsequent spinal revisions is frequent, with an estimated revision rate ranging from 9% to 45%.[11,14,17]

Defining Costs

Hospital Costs- direct resources consumed for the intervention, Direct and Indirect Costs

Indirect Costs-Opportunity costs, time of patients and families burden by the intervention

Charges: Due to markup and contracting seldom represents true expense

Payments/Reimbursements/Allowable Rates: Public Payor data is easily accessible, but differs dramatically from Private Payor payments. Not easy to access managed care claims data.

There exists a variety of potential cost metrics depending on the analysis, the perspective considered, and simply what cost measures are available. While all measures of costs provide some useful information, they are not applicable to every population and cannot be used interchangeably. In addition to the difficulty in defining costs, statistical methodologies necessary to perform cost analyses require careful empirical considerations.

Putting it together:
How much improvement must be achieved to make surgery valuable?

Cost-Effectiveness:
Ratio of Costs to Outcomes

Incremental Cost-Effectiveness Ratio (ICER)

$$(Cost_{Surgery} - Cost_{No\ Surgery})/(Outcome_{Surgery} - Outcome_{No\ Surgery})$$

Other metrics, such as reduced length of stay, costs of specific resources, or number of pain-free days have been the outcome of interest in cost-effectiveness studies.

Incremental Cost-Effectiveness Ratios (ICERs) for ASD surgery typically exceed the commonly used thresholds. Existing literature on the cost effectives of ASD have reported cost-effectiveness ratios from $$33,018to $455,600.[7,8,15,21,22] What is the appropriate threshold? Who decides the Willingness-to-pay? From who's perspective?

Durability - Due to high costs and small changes in HRQoL improvements cost-effectiveness over a longer time horizon are more informative than shorter time horizon.

How do we increase Benefits?

Patient Selection- Evidence based risk adjusted algorithms needed to determine which patients are likely to benefit from surgery

Patient Pre-Operative protocol- Awareness of expense of non-operative treatments

Avoid complications- Implement best practices

How do we decrease Costs?

Which elements of costs do we have control over? Implants, Length of Stay, Neuromonitoring, Blood Products, Intensive Care Unit Utilization, Post-acute Care & Rehabilitation

Implant Costs

Vendor Negotiation and Contract Pricing

- Harrington rod inflation adjusted costs
- Group Purchasing Agreements
- Rebating and other Contract Structure

Optimal Use

- How many screws per level are needed?
- How many interbodies?

Trade-Offs

- Get it right the first time in order to avoid future readmissions
- Is it worth saving on supply costs if it increases Operating Room time?

Compare Improvement to What?

- Non-operative Care costs and outcomes

- Change in surgical patients HRQoL from baseline
- Crossover patients
- Population Norm Values

Selection bias into surgery

Difficult to quantify changes in HRQoL that would have occurred without surgical intervention: This relates to the argument regarding whether surgery should be pursued earlier rather than later.

Biologics in Adult Spinal Deformity

- **Prominent On and Off-label Use**
- **Most products are considered modestly processed human tissue, so not labeled for use**
- **Efficacy and dose response for spinal deformity has not been established**
- **Efficacy of Autograft has been found to be variable depending on age**

Comparisons between operative and non-operative patient populations are empirically challenging

Chronic nature of spinal deformity can cause higher baseline, patients have lived with condition for many years and adjust their expectations of well-being

What Can We Do Today?

Answer questions related to quantifying the value of spine deformity surgery, leading to the development of evidence-based treatment algorithms incorporating predictors of cost and health-related quality-of-life outcomes to improve the efficiency of spine treatment for our patients.

When to Use Cell-Saver?

- Projected return at an Expected Blood Loss (EBL) of 500 cc

When to use adjunctive coagulation strategies?

- Tranexemic acid probably any case where EBL > 500 cc
- Energy directed devices

When to utilize Neuromonitoring?

- When correcting deformity at cord level

When to utilize ICU vs intermediate care? Or Home Care vs an Acute Rehab facility?

When to consider Bracing?

What are the costs of Revisions and Complications of ASD over time?

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Notes:

Notes

Basic Science

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Biomechanics of Spinal Deformity

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Upright posture: Humans differ from quadrupeds & spine has primary / secondary curves

In Sagittal plane: Spine is 'S' shaped. Cervical lordosis develops when baby begins to sit

& lumbar lordosis when the toddler begins to stand / walk.

The center of mass lies below the vertebral column

Dominant force vector is *axial* compression: Influenced by dorsally directed *shear* forces

causes spinal deformity (facet joints – resist only *ventrally* directed shear forces)

Biomechanics of spinal deformity: The basics
My fellows ask me – I am a *surgeon* & I should know how to operate. Why study it and

how is it important to me (i.e. for surgeons)?

My answers: Scoliosis is a 3D deformity – Always has a rotational component to it

Helps in understanding the pathogenesis & principles behind corrective forces Insight into treatment: How to achieve & maintain correction

Strategies used to restore alignment & balance *safely!*

My talk today: Cover mainly AIS & briefly touch on sagittal / multi-planar deformities

Principles of *rib-cage* reconstruction for scoliosis (congenital / neuromuscular)

Biomechanics of AIS: The basics
Disproportionate growth rate of anterior & posterior elements (front vs. back asymmetry)

Vertebral bodies: Grow faster than posterior elements (tall bodies & short pedicles)

Manifests as lordoscoliosis: If severe in thoracic spine – causes major airway obstruction

Severe rib-hump: Razor back / appearance deformity (forward bending test)

Corrective forces: Axial distraction (coronal pl) vs. Translational moment (transverse pl)

Critical angle: 53^0 (distractive & translational forces are equally effective)

How AIS develops: Role of dynamic factors
Principles of Euler-Bernoulli and Timoshenko beam theories and their formulae

Front vs. back asymmetry and *not* right vs. left asymmetry as previously thought

Dynamic interplay between bony structures & anatomy vs. musculature

Role of intervertebral disc: Wedging of disc (and vertebrae)

Creep / stress relaxation: Viscoelastic materials undergo deformation following initial

loading & tend to deform permanently under prolonged *constant* loading

Function of time: Decrease in stress with time under a *constant* strain (this principle is

exploited during corrective surgery to surgeon's advantage!

AIS Classification: Biomechanics taken into consideration
Move from 2D based to 3D based systems (though largely for research purposes) Historical classifications: Friedman & Ponsetti and King & Moe

Recently: Lenke (USA) / Noordeen (UK) / Peking Univ (China)

Da Vinci representation: Labelle et al - Severity represented as vectors on line diagram

Role of Biomechanics in Treatment: I will cover these under *two* categories
I - Non-operative: Biomechanics of Milwaukee brace (MB)

II – Corrective surgery

Non-operative treatment: Biomechanics of MB
Designed by Blount & Moe in 1945

Only scoliosis brace to truly apply both axial & translational corrective forces

Translational corrective forces: Thoracic pad bending moment at the apex

Axial forces: Counter pads resist the bending moment of the apex at the two ends

Comprised of Shoulder / thoracic strap, Thoracic pad (apex) & lumbar pads

Torque: Influenced by pulling angle of shoulder / thoracic straps

Can also be used to correct Scheuermann's kyphosis

Thoracic kyphosis (TK) of $<20^0$: Small pulling angle with short outrigger

TK of $>40^0$: Long outrigger with large pulling angle to ↑ anterior forces

With breathing, the MB can produce up to:

45% ↑ in average resultant force

35% ↑ in average resultant torque

Operative treatment: The basics

Load bearing axis: Thoracic spine – Ventral aspect of vertebral bodies

Lumbar spine – Dorsal aspect of vertebral bodies

Corrective forces: Translational: push / lever towards midline

Cantilever: Engage the rod to anchor (pull / push: up / down)

Derotational: Direct vs. indirect

Exploit the viscoelastic property: Pause between distractions for *creep* relaxation

Safe application of corrective forces: How much is too much?

OK to have under correction with *intact* neurology than a straight spine with *paraplegia*

What system to use: Harrington (obsolete) vs. Luque-trolley vs. Cotrel-Dubosset vs.

Pedicle screw based contemporary systems (all screw vs. hybrid constructs)

Familiarize oneself with how instrumentation systems work biomechanically

HR & LT work on diametrically opposite biomechanical principles

Harrington rods (HR): Distraction based with end fixation (geometrically limited)

Luque-trolley (LT): Transversely applied forces with segmental fix^{n} (not geometrically limited). The moment arm of two systems is equal at 44^{0}.

CD system: Segmental fixation with derotation (indirectly by rod rotation)

Current pedicle screw-based systems: Application of all types of corrective forces

DVR (direct vertebral rotation) vs. VCA (Vertebral coplanar alignment)

Anchors: Hooks vs. Wires vs. Screws vs. Combined / hybrid

Screw: Biomechanically is a device that converts rotational force to linear motion

Monoaxial vs. polyaxial – Rotational implications on DVR

Internal diameter & pitch – Implications on pull-out strength

Unicortical vs. bicortical purchase & triangulation: ↑ pull-out strength

Hooks: Inherently less pull-out strength than a screw

Could be laminar (supra / infra) or pedicle (with / without screw augment)

Laminar hook: Compromise of spinal canal dimension (*steel stenosis*)

Do TP hooks prevent medial migration of proximal screw anchors?

Wires: usually passed sub-laminarly – risk of injury to thecal sac / dura

Augment pull-out strength of anchors (hooks / screws)

Rods: Titanium vs. stainless steel vs. titanium alloy vs. Co-Cr

Rod diameter: Strength (stress modulus) increases by fourth power of radius

Make use of biomechanical principles & mechanical properties to *enhance* safety

AIS correction: How do I do it? – Intraoperative neuromonitoring in all (multi-modal)

Combination of cantilever, translation & direct vertebral rotation manoeuvres (i.e. CTD)

Low implant density index (IDI) constructs: Alternating pedicle screws at convex & concave sides (one anchor per vertebra) except end vertebrae which have two

My IDI is *always ≤1.5*. Bilateral pedicle screws at all levels is *not* needed

Differential rod contouring: Concave rod to normal sagittal kyphus & convex rod is Under-contoured to facilitate application of compressive forces

First insert: Convex rod – corrects scoliosis by translation and use concave rod to restore

sagittal kyphosis

Finally correct: Axial rotation by DVR (coupled or uncoupled – depends on severity)

I prefer Co-Cr rods to maintain sagittal alignment: Less deformation than titanium

Proximal anchors: Usually screws in AIS (liberal with use of hooks) & hybrid in EOS

If convex shoulder is down: pedicle hook to distract the upper end vertebra (UEV)

If convex shoulder is up: Transverse process (TP) hook to compress the UEV

Scheuermann's kyphosis correction: How I do it? – *Four point bending force application*

Proximal anchors: Bilateral pedicle hooks (or hybrid) – at least 3 segments (6 anchors)

When hybrid: UEV pedicle hooks + other two segments – screws (2H + 4S)

Distal anchors: All screw constructs (at least 4 anchors & 6 anchors in obese)

Always include the first lordotic disc in the fusion. LEV is in sagittal stable zone

Liberal use of *Ponte* osteotomies & aggressive facet joint resections

Correction predominantly by Cantilever forces: Simultaneous approximation of both rods

Unique considerations:
Pediatric spine:

Syndromic & neuromuscular scoliosis: Know natural history / individualized Rx

Crankshaft phenomenon - Recurrence of deformity (excessive anterior growth)

Migration of screw anchors - Proximal anchors: medial displacement (cord injury)
Distal anchors: caudal displacement (root injury)

Geriatric spine: Osteoporosis

Cement augmentation of anchors: Assess risk vs. benefit ratio

Metabolic bone diseases: Osteomalacia / Vit D deficiency etc – needs medical optimiz^{n}

Revision surgeries: Osteobiologics & role of graft substitutes (inductive vs. conductive)

Rib cage reconstruction:
Costoplasty: To address rib-cage deformation of AIS – Convex rib resections vs. concave rib recessions in PSF (changes in PFT – transient)

Internal thoracoplasty: Performed in anterior releases (increasingly becoming obsolete)

Opening thoracostomy to address thoracic insufficiency syndrome (TIS)

Main-stay of treatment for TIS is VEPTR: Congenital & syndromic EOS etiologies

Tips & Tricks of the trade with *my two cents*
If correcting by selective rod rotation (SRR): Insert concave rod first

Rely on concave rod to restore sagittal kyphus: Always *over-contoured* than convex rod

Ponte osteotomies: Not routinely required for AIS correction unlike in SK correction except in severe lordoscolisois – be liberal with osteotomy facet jt resections

Congenital spinal deformities: Judicious use of corrective forces under normotension

Hypotensive anesthesia is *not good* (cord infracts / ischemic injuries with irreversible neurological deficits are higher)

In multi-planar deformities: Focus on decompressing apex of kyphosis (good pulsatile dura is mandatory) & decompression of apex of scoliosis is optional

In early-onset scoliosis (EOS): The *Taj Mahal* construct proximally (2H+4S) facilitates distribution of forces over a larger area & prevents medial screw migration

Minimize in-situ bending of rods: May cause anchor dislodgement or ↓ pull-out strength For fixation to pelvis: Aim for triangulation with bicortical S1 screw fixation

Do not stop at apex or at junction in long-segment fusions: Causes add-on deformity

For correction of translational deformity: Parallelogram reduction technique is helpful

In correction of sagittal deformities: Tighten set-screws / end caps only to *friction glide tightness* to facilitate application of compressive forces

Osteoporotic bone: Use pedicle screws with differential thread pitch (thread pitch is inversely proportional to core diameter of the screw)

Summary: To *Fellows* and *Residents*
Have I managed to convince you *why a surgeon* needs to know about biomechanics?

Knowledge of *physiological* principles built on sound biomechanical rationale will aid in improving your surgical outcomes / results.

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Adolescent Idiopathic Scoliosis - Genetics

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1. AIS has long been suspected to have a strong familial component.

- Wynne-Davies *JBJS, Br.* 1968[1]
- Cowell *JBJS, Am.* 1972[2]
- Risborough, Wynne-Davies *JBJS, Am.* 1973[3]
- Blank, Raggio, et al *Lupus* 1999[4]
- Ogilvie, Braun, Ward, et al *Spine* 2006[5]

  In multi-generational pedigrees, 97% of AIS subjects were related to other families with AIS.

  -109 Intermountain families with 145 members having AIS.

  -Multi-generational family pedigrees constructed, some dating to the 1500's

  -Genetically diverse population.

  -Parenthetically, when mapping the Human Genome Project Caucasian Haplotype, due to their genetic diversity, 51 of 60 families were from Utah. The BRCA1 and BRCA2 genes were also identified in a similar Intermountain database. There are no "Utah" genes.

2. AIS is a complex, multiple gene trait.

- Most of the family connectedness found in the pedigrees took place long before pioneers gathered in Utah in 1847.
- Data base of 34 million ancestors of original 10,000 Utah pioneers and 3 million descendants. This proprietary database contained Caucasian ancestors from Scotland, England, Wales, Scandinavia, Germany, Northern Italy and Ireland.

3. Identity by descent or "founders' effect" identified: 14 families with a common ancestor in Essex circa 1560 AD and 17 families have a common ancestor in Sussex circa 1530 AD. One Founder has ~25,000 descendants, many in the US.[7]

4. Past research has used linkage analysis and single nucleotide polymorphisms (SNPs) to find associations with AIS:

- Studies from Japan and French Canada (some unanswered questions), confirm that AIS SNPs are highly ethnicity specific.
- Copy number variants (replication of large segments of DNA). CNVs are known to be associated with some disease processes.[6] CNVs are present in AIS.[7]

5. In humans, the exome is 1.5-1.7% of the genome, but contains ~85% of disease related mutations.[8, 9]

- Whole exome sequencing (sequencing that is restricted to the protein-coding regions of the genome) may identify the actual mutations, not just genetic markers, in AIS-related genes.
- This could lead to an understanding of molecular pathogenesis that may have targeted therapeutic application as in lysosomal storage disorders, i.e. Hurler syndrome and others.

6. Possible AIS genetic research pathways.

- Identify which genes, not genetic markers, and which combination of genes are clinically relevant.
- Whole exome sequencing may identify which genes or combination of genes are most associated with AIS progression and better understand the role of ethnicity in AIS.
- Understand phenotype-genotype concordance and pathogenesis.
- Define the role of copy number variants in progressive AIS.
- Are there significant epigenetic influences?

7. AIS is predominantly autosomal and polygenetic, probably involving dozens of genes in several metabolic pathways: neurodevelopment, cartilage and bone growth, post-receptor signal transduction, etc.

- AIS may present with multiple gene combinations.
- Recessive, dominant, co-dominant and some could have X-linked patterns.
- The earlier designation of 10 years at onset for AIS may need to be altered due to females maturing at least one year earlier than 50 years ago.
- Environmental or epigenetic factors may influence AIS gene expression, but those factors have not been identified.
- Many, but not all, estrogen receptors have been tested and those tested are not related to progressive AIS in Caucasians.[6] However, metabolic pathways and molecular genetics of estrogens are complex. Female preponderance has not been explained.
- Some families may have a private mutation causing spine deformity separate from AIS.
- AIS genotypes in Caucasians are different than idiopathic early onset scoliosis.[7]

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Etiology of AIS (Non-Genetic Factors)

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Background

Although etiology of adolescent idiopathic scoliosis (AIS) has yet remained to be elucidated, genetic and non-genetic factors are considered to play a role in the onset of AIS.

5 subgroups of non-genetic factors:

1. Abnormalities in nervous system
2. Abnormal skeletal growth
3. Hormones and metabolic dysfunction
4. Biomechanical factors
5. Environmental and life style factors.

Abnormalities in nervous system

1. Anatomical abnormalities
   - Hindbrain problems with cervicothoracic syrinx
   - Low-lying cerebellar tonsils with or without abnormal cerebrospinal fluid dynamics
   - Abnormalities in mid-brain, pons and medulla and vestibular system
   - Differences in white matter in corpus callosum and internal capsule
   - Differences in vestibular system morphology
2. Neurophysiologic Dysfunction
   - Body spatial orientation disorder
   - Oculovestibular function
   - Lateral gaze palsy
   - Motor cortex asymmetric hyperexcitability
   - Dynamic balance during standing and gait
   - Sensorimotor integration disorder
3. Abnormal central control and neuro-osseous maturation timing
   - Discoordinated control of neuro-osseous timing of maturation
   - Neuromuscular condition and asymmetry of the transversospinalis muscles produced by spinal cord or central mechanisms
4. Disharmony in spine and trunk between autonomic and somatic nervous systems
   - Double neuro-osseous theory for AIS pathogenesis
     - Leptin-hypothalamic-sympathetic nervous system concept(LHS concept)
     - Escalator concept

Abnormal skeletal growth

1. Growth Velocity and Skeletal Size for Age

   Rapid skeletal enlargement producing skeletal sizes for age beyond the capacity of postural mechanisms of the somatic nervous system to control the initiating deformity.
   - AIS patients are taller than the healthy controls
   - Girls with AIS are shorter before their menarche but taller and longer in arm span during growth spurt than the control subjects
   - Higher growth velocity during puberty in girls with moderate and severe AIS.
2. Imbalance between spine and spinal cord growth
   - "Roth-Porter concept": Uncoupled spinal neuro-osseous growth for the pathogenesis of AIS
     - Roth's speculation: IS results from a disproportion of vertebro-neural growth either because of a short spinal cord or a too rapid growth spurt of the spine. Roth demonstrated his speculation with a spring model.
     - Porter demonstrated that the overall length of vertebral canal was short relative to summated vertebral bodies based on anatomic specimens. Longer vertebral bodies, shorter pedicle heights, and longer interpedicular distances in patients with AIS demonstrated using MRI.
3. RASO (relative anterior spinal overgrowth)- asynchronous spinal neuro-osseous growth
   - Growth of anterior vertebral endplate of AIS patients are more active than that in the posterior vertebral column.
   - Longer vertebral column length both in thoracic and whole spine in AIS using MRI reformatting technique.
   - The reduced ratio of cord-to-vertebral column length was negatively correlated with the increased ratio of antero-posterior/transverse diameter of the cord, and cerebellar tonsillar level in AIS.
   - Relative tethering could result in subclinical neurologic dysfunction such as abnormal somatic sensory evoked potential.
4. Disc wedging
   - Disc wedging occur during the curve acceleration phase , and progressive vertebral wedging occurring later
5. Extraspinal Skeletal Length and Bilateral Asymmetries
   - Upper arms and iliac height , asymmetries
   - Skeletal length asymmetries and proximo-distal disproportion in lower limbs are related not to spinal curve severity but to its presence.
   - Asymmetry of periapical rib length and anterior chest wall blood supply, in girls with right thoracic (RT) AIS
6. Intrinsic Vertebral Directional Rotational Asymmetry

- Intrinsic directional rotational asymmetry, in addition with dorsal shear forces in humans could predispose to the onset and progression of AIS.

Hormones and metabolic dysfunction

1. High levels of GH in AIS girls notably from 7 to 12 years of age, and in pubertal stage 2
2. High levels of IGF-I .
3. Circulating levels of estrogen are reported to be normal or lower, and testosterone raised or lower in AIS girls.
4. Melatonin
    - Lower plasma melatonin levels through 24 hours only in progressive AIS curves and concluded that melatonin disturbance has more of a role in progression than in the cause of AIS.
    - The hypothesis that circulating melatonin deficiency is a causative factor of AIS was controversial.
    - The C57/BL6J mouse: knockout major enzyme (NAT gene) involved in the melatonin synthesis developed scoliosis (100% with bipedal mice and 25% with quadrupedal mice).
    - Pinealectomized nonhuman primate failed to develop scoliosis.
5. Melatonin-signaling Pathway Dysfunction
    - In progressive AIS, impaired melatonin-signaling transduction in osteoblasts, myoblasts, and lymphocytes linked to the inactivation of Gi proteins
    - The melatonin-signaling transduction was associated with high levels of a circulating osteopontin that seems essential for the initiation and progression of AIS.
    - Abnormal effect of melatonin on the proliferation and differentiation of osteoblast and chondrocytes from AIS.
6. Calmodulin
    - Calmodulin regulates the contractile properties of muscle and platelets. Melatonin functions may include modulating calcium-activated calmodulin
    - Increased calmodulin levels in platelets in AIS
    - Asymmetric distribution of calmodulin in paraspinal muscle in AIS
7. Osteopenia and Abnormal Bone Quality
    - Low BMD was reported in patients with IS firstly by Burner
    - BMD measured by dual energy x-ray absorptiometry showed osteopenia in 33.3% of girls with AIS
    - Persistent osteopenia was found in 80% of the osteopenic AIS followed up longitudinally to skeletal maturity.
    - Osteopenia as a prognostic factor of curve progression
    - The osteopenia in girls with AIS caused by the late onset of menarche, higher bone turnover, and relative low-calcium intake
8. Leptin
    - Adipocyte-derived cytokine, leptin regulate body growth and development particularly during childhood and adolescence.
    - Leptin levels correlated significantly with body weight, body mass index, and BMD in AIS

Biomechanical factors

1. Vicious Cycle and Mechano-transduction in the Spine
    - "Hueter-Volkmann Law": Growth can be retarded by increased compression and accelerated by tension.
    - "Vicious cycle": Scoliosis deformity produces asymmetrical loading of the skeletally immature spine. This can lead to vertebral wedging and abnormal disc loading.
    - Disc wedging contributed mainly to early curve progression with vertebral wedging occurring mainly after the curve acceleration phase. Early rapid curve progression is attributed to convex-vertebral endplates under relative tension growing more rapidly than concave-vertebral endplates by which they are functionally tethered.

Environmental and life-style factors

1. Nutrition, diet, calcium, vitamin D intake, and exercise level.
2. Sport activities

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Future in Patient-Specific Planning for Deformity

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Introduction: Adult Spinal Deformity

Adult spinal deformity (ASD) in the skeletally mature patient, with an incidence up to 32% in adults and 60% in the elderly, is becoming a more commonly recognized condition among spine surgeons and general healthcare providers.[1–4] Sagittal malalignment in particular has been proven in the literature to be one of the key considerations in adults affected by spinal deformity and correlates to patient reported outcomes.[5, 6] As a disabling condition, ASD has been shown to impact the quality of life as significantly as cancer, diabetes, and heart disease.[7] Moreover, recent work by the European Spine Study Group (ESSG) emphasized the global burden of ASD on eight industrialized countries and that this chronic disease warranted more research and attention.[8]

Significant progress has been made in regards to surgical treatment and non-operative management (a prudent and necessary approach for certain patients). Thus, it is important to thoroughly assess all treatment options in a tailored fashion which fits the patient-specific deformity and clinical state.

This presentation will go over the recent concepts and methodology which empower health care providers for better planning for deformity treatment.

How to define success? Health Related Quality of Life Scores.

Radiographic parameters such as sagittal vertical axis (SVA), pelvic tilt (PT) and pelvic incidence minus lumbar lordosis (PI-LL) play a center role in treatment of spinal pathologies, mainly ASD.[9] There has been growing consensus supporting the simplicity and applicability of these modifiers as drivers for successful realignment and eventual clinical score improvement.[10] On the other hand interpretation of HRQOL is not well defined. How much disability is acceptable, what should the treatment target be and how to be more patient-specific are still questions to be answered.

The concept of a minimal clinically important difference (MCID) has been introduced in the spine literature to quantify the absolute minimum change that can be considered a success.[11–13]which is an important consideration in large procedures such as spinal fusion and instrumentation.\n\nPURPOSE: The purpose of this study was to describe a method of assessing treatment success based on prospective, patient-reported \"minimum acceptable\" outcome for which they would undergo a procedure. These goals can then be compared at follow-up to gauge how frequently patient goals are met and determine correlation with patient satisfaction.\n\nSTUDY DESIGN: This is a clinical descriptive study of the patient-reported minimum acceptable outcomes for spinal fusion surgery.\n\nOUTCOME MEASURES: Minimum acceptable outcomes were determined by patients on preoperatively administered standard questionnaires regarding ultimate pain intensity, functional outcome (Oswestry Disability Index [ODI] Using this concept, several studies have demonstrated the possibility of successful non-operative treatment for a subset of ASD patients with certain characteristics.[14, 15]

However, the MCID approach seems to favor patients with greater baseline disability or who are severely symptomatic (i.e. room for improvement). This potential bias is a call for more patient-centered HRQOL targets and more research to redefine success/failure in ASD treatment.

Surgical treatment and planning:
In spinal deformities, mapping a surgical plan for each patient is challenging. Planning in the context of realignment surgery is based upon established surgical objectives such as reducing Cobb angles[19, 20] or improving sagittal modifiers[21]pelvic tilt, and lumbar lordosis for coronal or sagittal alignment. The increased use of long-cassette standing x-rays, as well as full body images, can significantly enhance the surgical planning for spinal pathologies [22]performed without appreciation of global spinal alignment, may have negative consequences. Our objective was to assess whether the extent of recommended surgery for lumbar pathology would significantly change with the addition of long-cassette standing x-rays. Methods: This was an international on-line survey of spine surgeons. A series of 15 cases of lumbar spine pathology were presented with a brief clinical vignette and lumbar imaging (x-rays and MRI/CT. For challenging procedures such as spinal osteotomies, surgical planning with the use of trigonometric formulas and radiographic thresholds can appear burdensome.[23–25]a new theoretical planning that can be used regardless of the etiology of the deformity and the type of osteotomy is described and assessed. METHODS: The spinopelvic sagittal balance can be expressed by two parameters: pelvic tilt (PT A more methodological approach is needed for step by step guidance. The following points are important and should be respected when approaching surgical treatment for ASD:

1. Find the driver of the malalignment
2. Quantify compensation
3. Define Alignment Objective
4. Simulation
5. Identify Possible Surgical Strategy(ies)
6. Control during Surgery
7. Learn from mistakes

Find the driver of the malalignment:
Loss of lumbar lordosis (LL) is one of the common drivers for malalignment. Normal LL has been studied and exists as a seemingly broad range of normative values[26], thus, loss of LL should always be quantified by the spino-pelvic mismatch concept (PI-LL), which ties the lumbar curve to the pelvic morphology and narrows the broad range of normal LL. Restoring PI-LL to normal values (<10°) is a common method to re-establish spinal alignment.[21, 27]this study seeks to determine whether the new adult spinal deformity (ASD However, this concept was recently fine-tuned by Schwab et al [28]their applicability remains limited in the setting of abnormal thoracic kyphosis (TK to count for patients with extreme values of PI, and/or abnormal thoracic/thoracolumbar alignment.[29] Schwab proposed a simple formula to determine the ideal LL, tailored to both pelvic morphology and thoracic kyphosis: LL = ½ (PI+TK) + 10.

Quantify compensation:
Compensatory mechanisms are the patient's progressive response to their sagittal plane deterioration. Following a mild positive sagittal malalignment, the patient starts recruiting mechanisms to compensate. These mechanisms may start in the flexible parts of the spine, moving distally to the hip and lower extremities.[30] Patients use these maneuvers to counter the forward or backward translation of Center of Mass (COM) [31]. The most common mechanisms are: flattening of the thoracic spine[23], , pelvic retroversion, and flexion of the knees and ankles.[30, 32, 33]retroversion of the pelvis in addition to knee flexion and pelvic shift. However, lower limb mechanisms of compensation remain poorly described. 161 patients with sagittal spinal deformity (SSD Assessment of compensatory mechanisms is important to further characterize the patient's deformity. For example, patients who lack pelvic compensation with severe sagittal decompensation are found to be more disabled and require more extensive screening for potential neurologic or soft-tissue pathologies.[6]

Define alignment objectives:
The Scoliosis Research Society (SRS)-Schwab classification characterizes sagittal alignment in ASD with three parameters: (1) regional deformity represented by the PI-LL mismatch (2) compensatory mechanisms represented by the Pelvic Tilt (PT) and (3) global alignment measured by the sagittal vertical axis (SVA). As research in the field of spine surgery has progressed, one of the modern goals is to develop a "tailor-made" approach to fit each individual's specific needs and characteristics, such as age. Thus, Lafage R and Schwab have recently proposed age-adjusted targets to further individualize treatment. (Figure 2).[35]

Age	PT	PI-LL	SVA
<35	11.0	-10.5	-30.5
35-44	15.4	-4.6	-5.5
45-54	18.8	0.5	15.1
55-64	22.0	5.8	35.8
65-74	25.1	10.5	54.5
≥74	28.8	17.0	79.3

Figure 2: Age-adjusted alignment thresholds

Simulation and identify several strategies:
When pre-operative analysis and alignment targets of interest are decided, post-operative alignment stimulation is essential to judge the plan and adjust if necessary. Akbar et al proposed a step by step methodology for surgical planning in a recent publication.[36] One of the limitations of software simulation is the inability to count for the spine flexibility, reciprocal changes in unfused segments, and local surgical limitations such as previous fusion or pseudarthrosis. Thus, several strategies and plans should be ready before surgical intervention in order to secure reaching alignment targets.

In the OR:
A recent study by Henry et al investigated the change between pre-operative surgical planning and actual intra-operative execution of the plan for 71 ASD patients. The unpublished data showed that the plan changed in 49% of cases due to various OR causes. Moreover, Henry concluded that the pre-operative plan was the greatest determinant of postoperative alignment; when planned PI-LL overcorrected, matched, or undercorrected patients with respect to their age, the actual post-operative alignment matched the plan in 73%, 68% and 73% of cases, respectively. This data emphasizes the importance of surgical realignment planning for ASD patients.

Conclusion:
Evidence based medicine draws conclusions from studies based on cohorts; however, spinal deformity management has recently shifted toward more patient-specific treatment. This requires a systematic approach that starts from a comprehensive clinical evaluation for the best-fit treatment to balance between risk and benefits. Finally, when surgical approach is indicated, surgical planning with previously mentioned methods is crucial to achieve alignment objectives.

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Notes:

Basic Science Priorities for the Next Decade

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The University of Hong Kong
Hong Kong

1. etiology

The biggest mystery in scoliosis research

A. Genetics

- i. What is the best phenotype?
  1. *Do all patients have the same disease?*
  2. *Genes that initiate scoliosis vs genes that leads to progression*
- ii. What is the best approach to identify genes
  1. *Candidate genes*
  2. *Family studies*
  3. *Genome wide association studies*
  4. *Exome sequencing*
  5. *Whole genome sequencing*
- iii. Convergence of congenital and idiopathic scoliosis in genetic predisposition?
- iv. Interplay of genes with environmental and biomechanical factors
  1. *Success of brace treatment*
  2. *Fusion level determination*
  3. *Junctional issues*
- v. Ethnic differences
- vi. International Consortium on Scoliosis Genetics
- vii. Barriers to further study
  1. *Funding*
  2. *Importance of a multidisciplinary approach*
  3. *Critical mass*
  4. *Need to support global initiatives*

2. surgical technologies

A. Implant materials

- i. Are stiffer materials really better?
  1. *Handling issues and difficulty with minimally invasive insertion*
  2. *Need for more anchor points to avoid pull out*
  3. *Contributes to adjacent level problems*
- ii. Super-elastic materials and gradual correction?
- iii. Absorbable metallic implants?

B. Less invasive approaches and enhanced recovery

- i. Navigation
- ii. Robotics
- iii. Perioperative management and the reduction of surgical stress

C. Prevention of infection

- i. Implant materials and surface coating / treatment
- ii. Early detection of infection

D. Adjacent level problems

- i. Alignment issues?
- ii. Genetics?
- iii. Implant related?

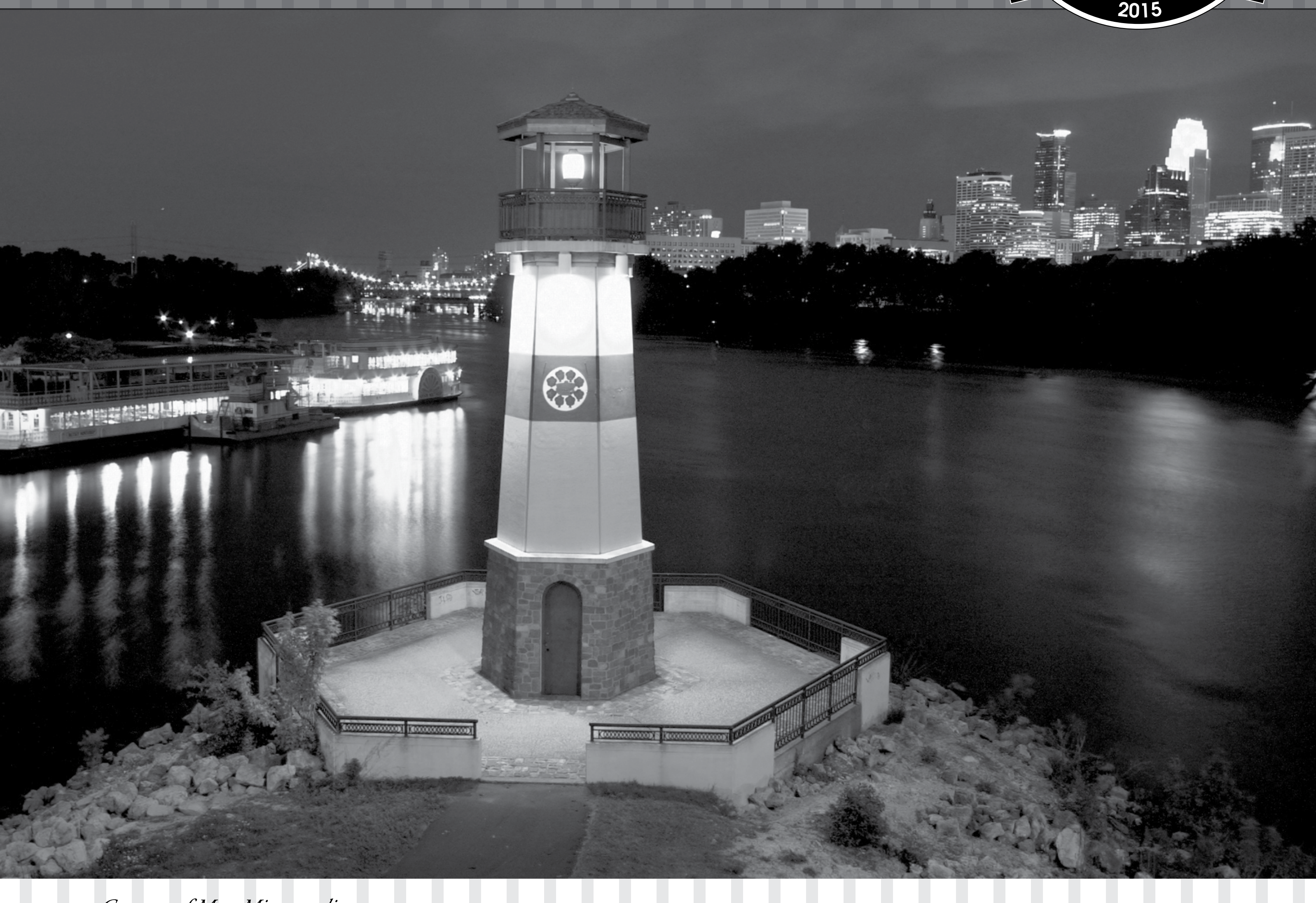
Notes:

Notes

50th ANNUAL MEETING & COURSE

Case Discussion & Educational Program

SCOLIOSIS RESEARCH SOCIETY
50th
ANNIVERSARY
2015



Courtesy of Meet Minneapolis

The Scoliosis Research Society gratefully acknowledges Medtronic for their support of the Pre-Meeting Course, Welcome Reception, Webcast, Half-Day Courses and Beverage Breaks.

Case Discussion Program

Wednesday, September 30, 2015

4:45 – 5:45 PM

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

The Case Discussion sessions allow an opportunity to present unique and challenging clinical cases to SRS with a panel of experts present to review and discuss each case and the clinical issues that are highlighted, as well as answer questions from audience participants. The panels will also prepare case studies for presentation and discussion, as time allows.

Case Discussion #1: Adolescent Idopathic Scoliosis

Room: Minneapolis Ballroom
Moderators: John Dormans, MD & David W. Polly, Jr., MD

Cases for Discussion:

1A. Lenke 1A AIS Deformity
David L. Skaggs, MD & Stuart L. Weinstein, MD

1B. Lenke 1C AIS Deformity
Michael A. Edgar, MD, FRCS & Ian J. Harding, BA, FRCS

1C. Lenke 3A AIS Deformity
Jean Dubousset, MD & Lawrence G. Lenke, MD

1D. 80 Degree AIS Deformity
Albert E. Sanders, MD & James O. Sanders, MD

Case Discussion #2: Congenital/Pediatric Kyphosis

Room: Marquette Ballroom
Moderators: Kenneth M.C. Cheung, MD & Behrooz A. Akbarnia, MD

Cases for Discussion:

2A. Congenital Scoliosis
John B. Emans, MD & Michael John McMaster, MD, DSc, FRCS

2B. Congenital Kyphosis
Richard E. McCarthy, MD & Suken A. Shah, MD

2C. VCR Case
Daniel J. Sucato, MD, MS & Se-Il Suk, MD

2D. Scheuermann's Kyphosis
Baron S. Lonner, MD & Harry L. Shufflebarger, MD

Case Discussion #3: Adult Spinal Deformity

Room: Symphony Ballroom
Moderators: Steven D. Glassman, MD & Ronald A. Lehman Jr., MD

Cases for Discussion:

3A. High Grade Spondylolisthesis
Sigurd H. Berven, MD & David S. Bradford, MD

3B. Adult Scoliosis Case
Ronald L. DeWald, MD & Christopher J. DeWald, MD

3C. Kyphotic Deformity Case
Khaled Kebaish, MD & John P. Kostuik, MD

3D. TB Case
Thanh Van Vo, MD, PhD & S. Rajasekaran, MD, FRCS, MCh, PhD

Educational Program

Pre-registration is required for all of the following sessions and space is limited. There is an additional cost of $30 for the Half-Day Courses. There may be a limited number of tickets available at the Registration Desk.

Lunchtime Symposia – Wednesday, September 30, 2015

12:40 – 1:40 PM

How to Accelerate Recovery of AIS Patients after Posterior Spinal Fusion

Room: Marquette Ballroom
Chair: Lawrence L. Haber, MD
Current treatment trends are significantly reducing the amount of time patients stay in the hospital after PSF for AIS. The intent of this one hour symposium is to communicate to the audience post-operative treatment care plans that will allow routine discharge of these on post-operative day 2 and 3, even when utilizing a PICU. Initially, we will present the historic obstacles to rapid discharges. We will then review and discuss the Atlanta Post-Operative Protocol, a multimodal pain regimen and address GI issues. By the end of this symposium, the audience will have a good understanding of how to accelerate recovery of AIS Patients after PSF. In our value based environment, efficiency will be a critical component in allowing us to best utilize our recourses for our patients.

12:40 – 12:45	**Introduction** *Lawrence L. Haber, MD*
12:45 – 1:55	**Before Y2K: What Were the Obstacles that Prevented Patients from Being Discharged in Less Time?** *George H. Thompson, MD*
12:55 – 1:05	**Options for Quicker GI Recovery After Posterior Spine Fusion** *Joseph G. Khoury, MD*
1:05 – 1:15	**Discussion**
1:15 – 1:20	**Multiple Modality Pain Protocols** *Lawrence L. Haber, MD*
1:20 – 1:25	**Discussion**
1:25 – 1:35	**An In-Depth Look at the Atlanta Postoperative Protocol** *Timothy S. Oswald, MD*
1:35 – 1:40	**Discussion**

Update on Missions and Activities in Endorsed Global Outreach Sites

Room: Symphony Ballroom
Chair: Anthony S. Rinella, MD

Meet the members of the SRS Global Outreach Committee and representatives from the SRS Endorsed and proposed sites at the Global Outreach Committee Lunchtime Symposium, "Update on Missions and Activities in GOP Sites" This symposium will be informative for anyone who has ever thought about volunteering skills and knowledge in another country or wants to learn about some of the current treatment of less common conditions such as Pott's disease or untreated severe scoliosis. During the symposium, representatives from the SRS Endorsed Sites will report on the last year's activities at some of the sites where they have volunteered. If you have already been involved in Global Outreach in spinal deformity care, this is an excellent opportunity to network with colleagues.

12:40 – 12:44	**Welcome & Introduction** *Anthony S. Rinella, MD*
12:45 – 12:52	**GOP Site: Marrakech, Morocco** *Hani H. Mhaidli, MD, PhD*
12:53 – 1:00	**GOP Site: Accra, Ghana** *Oheneba Boachie-Adjei, MD*
1:01 – 1:08	**GOP Site: Poznan, Poland** *Krzysztof B. Siemionow, MD*
1:09 – 1:16	**GOP Site: Dominican Republic** *Andrew W. Moulton, MD*
1:17 – 1:24	**GOP Site: Lima, Peru** *Alan Moskowitz, MD*
1:25 – 1:40	**Questions & Discussion** *Anthony S. Rinella, MD*

Minimally Invasive Spinal Deformity Techniques

Room: Minneapolis Ballroom
Chair: Praveen V. Mummaneni, MD

Learning Objectives:

1. To learn the biomechanics and pathophysiology of adult spinal deformity.
2. To review the history of the development of MIS spine surgery.
3. To learn the indications for open and minimally invasive treatment of adult spinal deformity utilizing an algorithmic approach.
4. To understand the advantages/disadvantages of anterior, posterior, and lateral approaches for the correction of adult spinal deformity.
5. To learn complication avoidance and management strategies for minimally invasive spinal deformity correction surgery
6. To understand the role of MIS surgery in pediatric patients.

12:40 – 12:45	**Introduction** *Praveen V. Mummaneni, MD*
12:45 – 12:55	**The Development and Evolution of MIS Surgery** *Praveen V. Mummaneni, MD*
12:55 – 1:05	**Indications and Patient Selection for Open vs. MIS Correction of Adult Spinal Deformity (Using the MISDEF Algorithm)** *Frank La Marca, MD*
1:05 – 1:15	**MIS Deformity Approach Selection: When Anterior, When Lateral, When Posterior?** *Gregory M. Mundis, Jr., MD*
1:15 – 1:25	**MIS Complication Avoidance and Management** *Juan S. Uribe, MD*
1:25 – 1:35	**MIS Approaches in the Pediatric Spine** *Daniel J. Sucato, MD*
1:35 – 1:40	**Discussion**

Lunchtime Symposia – Friday, October 2, 2015

12:00 – 1:00 PM

50-Year Evolution of the Treatment of Early Onset Scoliosis

Room: Minneapolis Ballroom

Co-Chairs: Mohammad Diab, MD; Ron El-Hawary, MD; Amer F. Samdani, MD; John T. Smith, MD

The 50-year evolution of the treatment of Early Onset Scoliosis. This symposium will provide an overview of the past, present and future techniques for the management of Early Onset Scoliosis. There will be an emphasis on outcomes of differing techniques and ask the question if growth-friendly techniques are really growth friendly.

12:00 – 12:05	**Introduction** *John T. Smith, MD*
12:05 – 12:15	**The Long Term Results of Early Fusion for Early Onset Scoliosis** *John E. Lonstein, MD*
12:15 – 12:30	**Overview of Current Growth Friendly Techniques** *John T. Smith, MD*
12:30 – 12:40	**Are Current Growth Friendly Techniques Really 'Growth Friendly'** *Ron El-Hawary, MD*
12:40 – 12:55	**New Growth Friendly Techniques - Tethering and Beyond** *Mohammad Diab, MD and Amer Samdani, MD*
12:55 – 1:00	**Conclusion** *John T. Smith, MD*

Research Grant Outcomes

Room: Symphony Ballroom

Co-Chairs: Hani H. Mhaidli, MD, PhD & Joseph H. Perra, MD

The SRS Research Grant Committee presents a Lunchtime Symposium giving recent grant recipients and opportunity to present and discuss the fruits of their labors. After presenting their final results, each project will be discussed in detail.

12:00 – 12:05	**Introduction** *Joseph H. Perra and Hani Mhaidli*
12:05 – 12:12	**Validation of a Genetic Test to Predict the Risk of Curve Progression in Adolescent Idiopathic Scoliosis** *Benjamin D. Roye, MD, MPH*
12:12 - 12:19	**Coagulation in Scoliosis Surgery** *Patrick P. Bosch, MD*
12:19 – 12:26	**Kyphosis and Implantation: Modeling a Clinical Phenomenon** *Richard H. Gross, MD*
12:26 – 12:33	**A Novel Approach to use Surface Topography Results for Assessing Scoliosis** *Eric Parent, MD*
12:33 – 12:38	**Medtronic Research Fellowship Update** *Daniel Scuibba, MD*
12:38 – 1:00	**Discussion**

3D Management of Adolescent Idiopathic Scoliosis

Room: Marquette Ballroom

Co-Chairs: Carl-Eric Aubin, PhD & Stefan Parent, MD, PhD

It is now clearly recognized that idiopathic scoliosis is not simply a lateral deviation of the spine, but rather a complex 3D ''rotatory" deformity of the spine. It is also widely acknowledged that consequently, the surgical treatment of AIS should be done in 3D and according to 3D principles of correction, explaining the extraordinary evolution of surgical instrumentations and techniques witnessed over the past 3 decades, from simple uniplanar correction using distraction with the Harrington instrumentation in the 60's, to the CD system and now to 3rd generation instrumentations and thoracic pedicle screws, allowing direct vertebral derotation or vertebral column manipulation. These technical changes have considerably increased the complexity and costs of surgery. Despite numerous claims that a more complete 3D correction can be achieved, the scientific data and supporting clinical evidence is still limited and still mostly based on 2D approaches.

Therefore, the objectives of the LS would be to present state-of-the-art 3D principles involved in the management of scoliotic deformities, including practical take home knowledge covering 3D surgical tips and ways to better assess specific curves from a three-dimensional perspective.

12:00 – 12:04	**Introduction** *Kenneth MC Cheung, MD*
12:04 -12:14	**Historical Perspective of 3D Analysis of Scoliosis** *Jean Dubousset, MD*
12:14 – 12:21	**Preliminary 3D Classification Scheme and Prediction of Scoliosis Progression** *Stefan Parent, PhD*
12:21 – 12:28	**Correction Principles and Practical Surgical Tips Based on 3D Analysis of Scoliotic Deformities** *Peter O. Newton, MD*
12:28 – 12:35	**Considerations to Optimize 3D Correction and Minimize Implant Numbers** *Carl-Eric Aubin, PhD*
12:35 – 12:55	**Case Presentation: Different Curve Types to be Treated Differently Based on 3D Anatomy and Representation** *Moderator: Stefan Parent , MD, PhD* *Panel: Hubert Labelle, MD; Peter O. Newton, MD; Lawrence G. Lenke, MD; Jean-Charles Le Huec, MD, PhD*
12:55 – 1:00	**Closing Remarks and Perspectives** *Lawrence G. Lenke, MD*

Half-Day Courses – Thursday, October 1, 2015

1:30-4:30 PM

Making Spinal Deformity Surgery Sustainable

Room: Symphony Ballroom
Co-Chairs: Rajiv K. Sethi, MD, Kit M. Song, MD, MHA & Mark Weidenbaum, MD

Section 1
Moderator: Rajiv K. Sethi, MD

1:30 – 1:32 PM	**Introduction** *Rajiv K. Sethi, MD*
1:32 – 1:42 PM	**Historical Perspective of Complications in Adult Spinal Deformity** *John P. Kostuik, MD*
1:42 – 1:52 PM	**Historical Perspective of Complications in Pediatric Spinal Deformity** *John B. Emans, MD*
1:52 – 1:59 PM	**The English Perspective on What Patients and Families Want** *David S. Marks, FRCS*
1:59 – 2:06 PM	**The Japanese Perspective on What Elderly Patients with Spinal Deformity Can Tolerate** *Morio Matsumoto, MD*
2:06 – 2:11 PM	**Discussion**
2:11 – 2:18 PM	**Sustainability of the Current Model from a QALY Perspective** *Sigurd H. Berven, MD*
2:18 – 2:30 PM	**The Payor Perspective** *Robert Mecklenburg, MD*
2:30 – 2:56 PM	**Panel Discussion** *Moderator: Rajiv K. Sethi, MD* *Panel: David S. Marks, FRCS; Morio Matsumoto, MD; Robert Mecklenburg, MD; Steven L. Ondra, MD*

Section 2
Moderator: Mark Weidenbaum, MD

2:56 – 2:59 PM	**Case #1: Severe Spinal Deformity in an Elderly Patient** *Mark Weidenbaum, MD*
2:59 – 3:05 PM	**The Seattle Spine Team Approach: When and How to Say "No"** *Rajiv K. Sethi, MD*
3:05 – 3:11 PM	**Counterpoint: Operate, There are No Other Options and This is What the Hospital Wants** *Gregory M. Mundis, Jr., MD*
3:11 – 3:40 PM	**Panel Discussion** *Moderator: Mark Weidenbaum, MD* *Panel: Sigurd H. Berven, MD; John P. Kostuik, MD; Gregory M. Mundis, Jr., MD; Rajiv K. Sethi, MD*

Section 3
Moderator: Kit M. Song, MD, MHA

3:40 – 3:43 PM	**Case #2: Pediatric Case: Congenital Upper Thoracic Kyphosis** *Kit M. Song, MD, MHA*
3:43 – 3:49 PM	**Team Approaches to Complex Pediatric Spinal Surgery** *Suken A. Shah, MD*
3:49 – 3:55 PM	**Ethical Considerations of High-Risk Spinal Deformity Surgery** *Brian G. Smith, MD*
3:55 – 4:25 PM	**Panel Discussion** *Moderator: Kit M. Song, MD, MHA* *Panel: Mark Erickson, MD; John B. Emans, MD; Suken A. Shah, MD; Brain G. Smith, MD*

Sagittal Alignment– Evaluation and Applications

Room: Minneapolis Ballroom
Co-Chairs: Munish C. Gupta, MD, S. Rajasekaran, MD, FRCS, MCh, PhD & Christopher I. Shaffrey, MD

1:30 – 1:40 PM	**The Pathology of Flat Back Syndrome** *Jean Dubousset, MD*
1:41 – 1:50 PM	**Sagittal Parameters: How Should They be Measured? What is Normal and What is Pathological?** *Virginie Lafage, PhD*
1:51 – 2:00 PM	**How to Account for Thoracic, Spinopelvic and Infrapelvic Compensation During Surgical Planning** *Themistocles Protopsaltis, MD*
2:01 – 2:10 PM	**Cervical Balance: A New Concept** *Dilip K. Sengupta, MD*
2:11 – 2:20 PM	**Surgical Evaluation and Treatment of Cervical Sagittal Plane Malalignment** *Christopher P. Ames, MD*
2:21 – 2:35 PM	**Discussion**
2:35 – 2:45 PM	**Sagittal Balance in Spondylolisthesis** *Hubert Labelle, MD*
2:46 – 2:55 PM	**Sagittal Balance, DDD and Lower Back Pain** *Jean-Charles Le Huec, MD, PhD*
2:56 – 3:05 PM	**Sagittal Balance in the Aged and Osteoporotic Spine** *Vincent Arlet, MD*
3:06 – 3:15 PM	**Sagittal Balance in Adult Scoliosis** *Munish C. Gupta, MD*
3:16 – 3:25 PM	**Understanding the Pathology of Proximal Junction Kyphosis** *Richard H. Gross, MD*
3:26 – 3:35 PM	**Prevention of PJK: Can Appropriate Surgical Planning Reduce the Risk?** *Frank J. Schwab, MD*
3:36 – 3:45 PM	**Prevention of PJK: Surgical Strategies to Reduce PJK** *Robert A. Hart, MD*
3:45 – 4:00 PM	**Discussion**
4:00 – 4:30 PM	**Panel Discussion: Clinical Dilemmas and Decision Making** *Moderator: S. Rajasekaran, MD, FRCS, MCh, PhD* *Panel: Christopher P. Ames, MD; Robert A. Hart, MD; Jean Dubousset, MD; Munish C. Gupta, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD*

Spondy Smackdown! Head-to-Head Match-Ups on the Controversies in Pediatric Spondylolisthesis

Room: Marquette Ballroom
Chair: Patrick J. Cahill, MD

1:30 – 1:35 PM	**Introduction** *Patrick J. Cahill, MD*

Match-Up 1: Old School versus New

1:35 – 1:40 PM	**Principles Established from Past Modalities/Experiences** *John E. Lonstein, MD*
1:41 – 1:45 PM	**Mistakes of Past Treatments** *Jean-Marc Mac-Thiong, MD, PhD*

Match-Up 2: Which is the Class of Classifications?

1:45 – 1:50 PM Meyerding is the Universal Language
Peter F. Sturm, MD

1:50 – 1:55 PM Marchetti and Bartolozzi or Montreal are Better
Viral V. Jain, MD

1:55 – 2:05 PM Discussion

Match-Up 3: Hit 'em from All Sides: The Role of Oblique X-Rays and Bone Scan

2:05 – 2:10 PM Oblique X-Rays and Bone Scans Are Obsolete
Jwalant S. Mehta, FRCS (Ortho)

2:10 – 2:15 PM There are Roles for Oblique X-Rays and Bone Scans
Alvin H. Crawford, MD

Match-Up 4: AO/Euro-Style versus the MIS Challenger Spondylolysis Repair Technique

2:15 – 2:20 PM Lag Screw Technique
Kim W. Hammerberg, MD

2:20 – 2:25 PM Compression Rod Technique
Joshua M. Pahys, MD

2:25 – 2:35 PM Discussion

Match-Up 5: Roundhouse versus Jab: The Role of Interbody Fusion

2:35 – 2:40 PM Interbody Fusion is Required
Jahangir K. Asghar, MD

2:40 – 2:45 PM Interbody Fusion is Not Always Necessary
James W. Ogilvie, MD

Match-Up 6: Red State versus Blue State: Asymptomatic High-Grade Spondylilisthesis: Op versus Non-Op

2:45 – 2:50 PM Non-Operative Management
Peter Pizzutillo, MD

2:50 – 2:55 PM Operative Management
William F. Lavelle, MD

2:55 – 3:05 PM Discussion

Match-Up 7: To Reduce or Not to Reduce? High-Grade Spondylolisthesis

3:05 – 3:15 PM Reduction is Not Always Indicated
Stefan Parent, MD, PhD

3:15 – 3:25 PM Reduction is Always Indicated
Harry L. Shufflebarger, MD

3:25 – 3:35 PM Reduction is Never Indicated
Dietrich K.A. Schlenzka, MD, PhD

Match-Up 8: Capital Gaines versus Strut Your Stuff: Spondyloptosis Technique

3:35 – 3:45 PM Cylindrical Strut Stabilization
David S. Bradford, MD

3:45 – 3:55 PM Gaines Procedure
Christopher J. DeWald, MD

3:55 – 4:05 PM Incremental Reduction (Edwards Technique)
Charles C. Edwards, II, MD

4:05 – 4:25 PM Discussion

4:25 – 4:30 PM Awards Presentations

50th ANNUAL MEETING & COURSE

Scientific Program

SCOLIOSIS RESEARCH SOCIETY
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Scientific Program

The Scoliosis Research Society gratefully acknowledges NuVasive for support of the Webcast, Pre-Meeting Course, and Message Board.

Scientific Program

Thursday, October 1, 2015

Session 1: Adolescent Idiopathic Scoliosis

Room: Minneapolis Ballroom
Session Time: 7:55 – 9:49 AM
Session Moderators: Lawrence G. Lenke, MD & Peter O. Newton, MD

7:55 – 8:00 AM	**Welcome & Announcements**
8:00 – 8:04 AM	**1. Intervertebral Disc Degeneration 35 Years After Surgery for Adolescent Idiopathic Scoliosis: Long-Term MRI Follow Up** *Tsutomu Akazawa; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Masaru Sonoda; Mika Fujiwara; Mitoshi Ishino; Takehide Katougi; Shohei Minami, MD, PhD*
8:04 – 8:08 AM	**2. Incidence of Cancer and Infertility in AIS Patients Treated 25 Years Prior** *Ane Simony, MD; Karl Erik Jensen, MD, DMsc; Steen Bach Christensen, MD; Leah Yacat Carreon, MD, MS; Mikkel Osterheden Andersen, MD*
8:08 – 8:12 AM	**3. Health-Related Quality of Life in Adolescent Idiopathic Scoliosis Patients 25 Years After Treatment** *Ane Simony, MD; Leah Yacat Carreon, MD, MS; Steen Bach Christensen, MD; Mikkel Osterheden Andersen, MD*
8:12 – 8:21 AM	**Discussion**
8:22 – 8:26 AM	**4. Does Symmetry Matter in Selecting Fusion Levels in Lenke 1 AIS?** *David H. Clements; Randal R. Betz, MD; Peter O. Newton, MD; Michelle Claire Marks, PT, MA; Tracey Bastrom, BS, MS; Harms Study Group*
8:26 – 8:30 AM	**5. SRS 22r Scores in Non-Operated AIS Patients with Curves less than 40 degrees** *W. Timothy Ward, MD; James W. Roach, MD; Nicole Friel, MD; Tanya S Kenkre, PhD; Maria Mori Brooks, PhD*
8:30 – 8:34 AM	**6. National Trends in Operations for Idiopathic Scoliosis: Analysis of 61,840 Children from the National Inpatient Sample Over a 13-Year Time Period** *Alexander Theologis; David C. Sing, BS; Mohammad Diab, MD*
8:34 – 8:43 AM	**Discussion**
8:44 – 8:48 AM	**7. Reduced Pulmonary Function in AIS Patients with Hypokyphosis: Mean 30-Year Follow Up** *A. Noelle Larson, MD; William J. Shaughnessy, MD; Clayton Cowl, MD; Charles Ledonio, MD; David W. Polly, Jr., MD; Michael J. Yaszemski*
8:48 – 8:52 AM	**8. Adolescent Idiopathic Scoliosis Patients Are at Increased Risk for Pulmonary Hypertension Which Reverses After Scoliosis Surgery** *Vishal Sarwahi, MD; Sarika Kalantre; Marina Moguilevitch; Rachel Claire Gecelter, BS; Dan Wang, MS; Terry D. Amaral, MD; Kathleen Maguire, MD*
8:52 – 8:56 AM	**9. A Predictive Model of Progression for Adolescent Idiopathic Scoliosis Based on 3D Spine Parameters of First and Second Visit** *Wenzhen Zuo; Marie-Lyne Nault, MD, PhD, FRCSC; Marjolaine Roy-Beaudry, MS; Jean-Marc Mac-Thiong; Jacques de Guise, PhD; Hubert Labelle, MD; Stefan Parent, MD, PhD*
8:56 – 9:05 AM	**Discussion**
9:06 – 9:10 AM	**10. Preventing DJK by Applying the Stable Sagittal Vertebra Concept to Selective Thoracic Fusion in AIS** *Alexander Broom, BA; Lindsay M. Andras, MD; Andrew G Georgiadis, MD; Kody K Barrett, BA; John M. Flynn, MD; David L. Skaggs, MD, MMM*
9:10 – 9:14 AM	**11. Curve Progression in Adolescent Idiopathic Scoliosis with a Minimum of Two-Years Follow Up After Completed Brace Weaning with Reference to the SRS Standardized Criteria** *Benglong Shi, MD; Tsz Ping Lam, MD; Jack C.Y. Cheng, MD; Saihu Mao, MD; Fiona Wai Ping Yu, MPH; Kwong Man Lee; Bobby Kinwah Ng, MD; Ze-zhang Zhu, MD; Yong Qiu, MD*
9:14 – 9:18 AM	**12. The Deformity Angular Ratio: Can It Predict High Risk Cases for Potential Spinal Cord Monitoring Alerts in Pediatric Three-Column Thoracic Spinal Deformity Corrective Surgery?** *Noah D. Lewis, BS; Sam G. Keshen, BS; Lawrence G. Lenke, MD; Michael Zywiel, MD; David L. Skaggs, MD, MMM; Taylor Elizabeth Dear, BS; Samuel Strantzas, MS, D ABNM; Stephen J. Lewis, MD, FRCSC, MS*
9:18 – 9:27 AM	**Discussion**

9:28 – 9:32 AM	**13. Relationship Between Cervical Sagittal Alignment and Health Related Quality of Life in Adolescent Idiopathic Scoliosis** *Jung Sub Lee, MD, PhD; Jong Ki Shin, MD; Tae Sik Goh, MD*
9:32 – 9:36 AM	**14. Thoracic Sagittal Plane Variations Between Patients with Moderate Thoracic Adolescent Idiopathic Scoliosis and Healthy Adolescents** *Alberto Nuñez-Medina, MD; Javier Pizones, MD, PhD; Felisa Sánchez-Mariscal, MD, PhD; Lorenzo Zuñiga Gomez, PhD; Cristina Ruiz Juretschke; Enrique Izquierdo, MD, PhD*
9:36 – 9:40 AM	**15. Preoperative MRSA Screening in Pediatric Spine Surgery: A Helpful Tool or a Waste of Time and Money?** *June C. Smith, MPH; Scott John Luhmann*
9:40– 9:49 AM	**Discussion**

Break

Room: Level 3 Foyer
9:50 – 10:05 AM
Supported, in part, by a grant from Medtronic.

Session 2: Quality, Safety and Value

Room: Minneapolis Ballroom
Sesion Times: 10:06 AM – 12:30 PM
Session Moderators: Daniel S. Brodke, MD & Henry H. Halm, MD

10:06 – 10:10 AM	**16. Different Dose Regimens of Tranexamic Acid Reduces Perioperative Blood Loss and Blood Transfusion in Adolescent Idiopathic Scoliosis Patients: A Prospective, Randomized Control Study** *Tao Li; Jingming Xie; Yingsong Wang; Ying Zhang, PhD; Ni Bi; Zhi Zhao; Zhiyue Shi*
10:10 – 10:14 AM	**17. Gelatine Matrix with Human Thrombin Decreases Blood Loss in Adolescents Undergoing Posterior Spinal Fusion for Idiopathic Scoliosis: A Randomized Clinical Trial** *Ilkka J. Helenius; Heli Keskinen, MD; Johanna Syvänen, MD; Mikko Mattila, MD; Jarmo Välipakka, MD; Olli Pajulo, MD*
10:14 – 10:18 AM	**18. Antifibrinolytic Therapy in Surgery for Adolescent Idiopathic Scoliosis: Does the Level 1 Evidence Translate to Practice?** *Baron S. Lonner; Yuan Ren, PhD; Jahangir K. Asghar, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD*
10:18 – 10:27 AM	**Discussion**
10:28 – 10:32 AM	**19. Operative Treatment of Adult Spinal Deformity (ASD) Improves Health Related Quality of Life (HRQOL) for All Deformity Types, While Patients Treated Nonoperatively Demonstrate No Change at Minimum Two Years Follow Up** *Shay Bess, MD; Breton Line, BS; Michael P. Kelly, MD, MS; Christopher P. Ames, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Richard Hostin, MD; Jeffrey L. Gum, MD; Kai-Ming Gregory Fu; Eric O. Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group*
10:32 – 10:36 AM	**20. Development of a Validated Computer Based Preoperative Predictive Model for Reaching ODI MCID for Adult Spinal Deformity (ASD) Patients** *Justin K. Scheer, BS; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Frank J. Schwab, MD; Robert A. Hart, MD; Richard Hostin, MD; Virginie Lafage, PhD; Amit Jain, MD; Douglas C. Burton, MD; Shay Bess, MD; Tamir Ailon, MD, FRCSC, MPH; Themistocles S. Protopsaltis, MD; Eric O. Klineberg, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group*
10:36 – 10:40 AM	**21. Low Fusion Grade Does Not Impact Two-Year Health-Related Quality of Life Unless Rod Fracture Occurs for Adult Spinal Deformity** *Tamir Ailon, MD, FRCSC, MPH; D.Kojo Hamilton, MD; Robert A. Hart, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Shay Bess, MD; Douglas C. Burton, MD; MunishChandra Gupta, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; International Spine Study Group*
10:40 – 10:49 AM	**Discussion**

10:50 – 10:54 AM	**22. Sagittal Spinal Alignment in 600 Healthy Volunteers: Gender Difference and Changes with Aging** *Yasutsugu Yukawa, MD; Fumihiko Kato, MD*
10:54 – 10:58 AM	**23. Proper Responding Strategies to Neuromonitoring Alerts During Correction Step in Posterior Vertebral Column Resection Patients with Severe Rigid Deformities Can Reduce Postoperative Neurologic Deficits** *Jingming Xie; Yingsong Wang; Zhiyue Shi; Tao Li; Ying Zhang, PhD; Ni Bi; Zhi Zhao*
10:58 – 11:02 AM	**24. Global Tilt: A Single Parameter Incorporating the Spinal and Pelvic Parameters Correlates with Health-Related Quality of Life Parameters** *Caglar Yilgor, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD; Ferran Pellisé, MD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R. Acaroglu, MD; Ibrahim Obeid, MD; Frank Kleinstück, MD; Ahmet Alanay, MD; European Spine Study Group*
11:02 – 11:06 AM	**25. Negative Sagittal Imbalance Following Spinal Fusion for Kyphoscoliosis** *Ian Thomas McNeill; Branko Skovrlj, MD; John M. Caridi, MD; Samuel K. Cho, MD*
11:06 – 11:17 AM	**Discussion**
11:18 – 11:22 AM	**26. Extent of Proximal Fusion Correlates with Worse Clinical Outcomes in Cervical to Pelvis Fusions** *Han Jo Kim, MD; Sravisht Iyer, MD; Alexander Theologis, MD; Todd J. Albert, MD; Lawrence G. Lenke, MD; Vedat Deviren, MD; Venu M Nemani, MD, PhD; Oheneba Boachie-Adjei, MD; Shane Burch, MD; Jun Mizutani, MD, PhD; Eric O. Klineberg, MD; Themistocles S. Protopsaltis, MD; Justin S. Smith, MD, PhD; Justin K Scheer, BS; Christopher P. Ames, MD*
11:22 – 11:26 AM	**27. Accuracy of the SRS MM Database in Adolescent Idiopathic Scoliosis: Comparison Between the SRS, NIS and KID Databases** *Javier Guzman , BS; Branko Skovrlj; Nathan J. Lee, BS; Christopher T. Martin, MD; Andrew J. Pugely, MD; Yubo Gao, PhD; John M. Caridi, MD; Sergio A. Mendoza-Lattes, MD; Samuel K. Cho, MD*
11:26 – 11:30 AM	**28. Significant Intraoperative Neuromonitoring Alerts in Patients Undergoing Fusion for AIS: What Are the Outcomes of Surgery?** *Amer F. Samdani; Robert J. Ames, MD; Jahangir K. Asghar, MD; Giuseppe Orlando, MD; Joshua M. Pahys, MD; Burt Yaszay, MD; Firoz Miyanji, MD, FRCSC; Baron S. Lonner, MD; Ronald A. Lehman, MD; Peter O. Newton, MD; Patrick J. Cahill, MD; Randal R. Betz, MD*
11:30 – 11:34 AM	**29. Two-Year Follow Up in Spine Clinical Research: An Adequate Benchmark?** *Firoz Miyanji, MD, FRCSC; Sameer Desai, BS; Amer F. Samdani, MD; Suken A. Shah, MD; Jahangir K. Asghar, MD; Burt Yaszay, MD; Harry L. Shufflebarger, MD; Randal R. Betz, MD; Peter O. Newton, MD*
11:34 – 11:44 AM	**Discussion**
11:45 – 11:50 AM	**Harrington Lecture Introduction** *John Dormans, MD*
11:50 AM – 12:10 PM	**Harrington Lecture—Correcting Scoliosis: The Genealogy of Ideas and Their Surgical Application** *Dennis R. Wenger, MD*
12:10 – 12:30 PM	**Presentation of the Lifetime Achievement Awards** *Behrooz A. Akbarnia, MD* *Randal R. Betz, MD*

Networking Lunch

Open to all Half-Day Course Participants, Tickets Required
Room: Level 3 Foyer
12:30 – 1:30 PM

New Member & Prospective Member Lunch and Information Session

Open to all Half-Day Course Participants
Room: Symphony Ballroom
12:30 – 1:30 PM

Half-Day Courses
(See pages 87-94)
1:30 – 4:30 PM

Making Spinal Deformity Surgery Sustainable
Room: Symphony Ballroom

Sagital Alignment—Evaluation and Applications
Room: Minneapolis Ballroom

Spondy Smackdown! Head-to-Head Match-Ups on the Controversies in Pediatric Spondylilisthesis
Room: Marquette Ballroom

Friday, October 2, 2015

Session 3A: Hibbs Basic Research Award Nominees
Room: Minneapolis Ballroom
Session Times: 7:55 – 8:41 AM
Session Moderators: Stefan Parent, MD, PhD & Justin S. Smith, MD, PhD

7:55 – 8:00 AM **Welcome & Announcements**

8:00 – 8:04 AM **30. Estrogen Receptor Gene Polymorphism in Patients with Degenerative Lumbar Scoliosis**
Jung Sub Lee, MD, PhD; Jong Ki Shin, MD; Tae Sik Goh, MD

8:04 – 8:08 AM **31. Three-Year Dashboard Reporting and Performance Improvement Modules (PIMs) Significantly Improved Blood Loss and Operative Time in Adolescent Idiopathic Scoliosis**
Ronald A. Lehman, MD; Harry L. Shufflebarger, MD; Michelle Claire Marks, PT, MA; John M. Flynn, MD; Lawrence G. Lenke, MD; Suken A. Shah, MD; Vidyadhar V. Upasani, MD; Peter O. Newton, MD

8:08 – 8:12 AM **32. Pedicle Screw Safety: How Much Anterior Breach Is Safe? A Cadaveric and CT-Based Study**
Vishal Sarwahi, MD; Dan Wang, MS; Terry D. Amaral, MD; Beverly Thornhill; Rachel Claire Gecelter, BS; Monica Payares, MD; Ajay Lall, MD

8:12 – 8:20 AM **Discussion**

8:21 – 8:25 AM **33. Retrieval Analysis of Traditional Distraction-Based Growing Rod Constructs for Early Onset Scoliosis**
Genevieve Hill, PhD Candidate; Srinidhi Nagaraja, PhD; Behrooz A. Akbarnia, MD; Paul D. Sponseller, MD; Peter F. Sturm, MD; John B. Emans, MD; Jeff B. Pawelek; Growing Spine Study Group ; Maureen Dreher, PhD

8:25 – 8:29 AM **34. Evaluation of Spinal Reconstruction Following Pedicle Subtraction Osteotomy: Effect of Four Rods and Interbody Support on Resulting Rod Strain**
Dennis Hallager Nielsen, MD; Martin Gehrchen, MD, PhD; Benny T. Dahl, MD, PhD; Jonathan Andrew Harris, MS; Manasa Gudipally, MS; Sean Jenkins, BS; Ai-Min Wu, MD; Brandon Bucklen, PhD

8:29 – 8:33 AM **35. Normal Human Spine Growth and Prediction of Final Spine Height Developed from a Longitudinal Cohort of Children Followed Through Their Growth Until Completion**
James O. Sanders, MD; Lauren Karbach, MD; Thomas Osinski, BS; Raymond Liu, MD; Xing Qiu, PhD; Daniel Cooperman, MD

8:33 – 8:41 AM **Discussion**

Session 3B: Hibbs Clinical Research Award Nominees
Room: Minneapolis Ballroom
Session Times: 8:42 – 9:43 AM
Session Moderators: Oheneba Boachie-Adjei, MD & Ronald A. Lehman, Jr., MD

8:42 – 8:46 AM **36. Operative Management of Adult Spinal Deformity Results in Significant Increases in QALYs Gained Compared to Nonoperative Management: Analysis of 479 Patients with Minimum Two-Year Follow Up**
Justin K. Scheer, BS; Richard Hostin, MD; Frank J. Schwab, MD; Chessie Robinson, MS; Virginie Lafage, PhD; Douglas C. Burton, MD; Robert A. Hart, MD; Michael P. Kelly, MD, MS; Malla Kate Keefe, BS; David W. Polly, Jr., MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group

8:46 – 8:50 AM **37. The Deformity Angular Ratio Describes the Severity of Spinal Deformity and Predicts the Risk of Neurologic Deficit in Posterior Vertebral Column Resection Surgery**
Xiaobin Wang, MD; Lawrence G. Lenke, MD; Earl Thuet, BS, CNIM; Kathy M. Blanke; Linda Koester; Michael Roth, BS, CNIM

8:50 – 8:54 AM **38. Cervical Spine Disease Common After Pediatric Treatment of AIS at Mean 30-Year Follow Up**
Ernest Y. Young, MD; Bradford Currier, MD; Michael J. Yaszemski; A. Noelle Larson, MD

8:54 – 9:02 AM **Discussion**

9:03 – 9:07 AM **39. Selective Thoracic Fusion for AIS: Long-Term Radiographic and Functional Outcomes**
John E. Lonstein

9:07 – 9:11 AM **40. Evolution of Adolescent Idiopathic Scoliosis: Results of a 20-Year Follow-Up Study**
Sébastien Pesenti; Benjamin Blondel, MD, PhD; Emilie Peltier, MD; Christian Morin, MD; Jérôme Sales de Gauzy, MD; Stéphane Wolff, MD; Antoine Chalopin, MD; Jean-Luc Jouve, MD

9:11 – 9:15 AM **41. Repeat Surgical Intervention Following Definitive Instrumentation and Fusion for Adolescent Idiopathic Scoliosis: A 25-Year Update**
Megan E. Mignemi, MD; Brandon A. Ramo, MD; Dong-Phuong Tran, MS; B. Stephens Richards, MD

9:15 – 9:23 AM **Discussion**

9:24 – 9:28 AM **42. Influence of Wear Time on Outcome: Results from the Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST)**
Lori Dolan, PhD; Stuart L. Weinstein, MD

9:28 – 9:32 AM **43. Long-Term Influence of Posterior Spinal Fusion on Distal Unfused Segments in Patients with Lenke Type 1 or 2 AIS**
Ayato Nohara, MD; Noriaki Kawakami, MD; Taichi Tsuji, MD; Tesuya Ohara, MD; Yoshitaka Suzuki, MD; Toshiki Saito, MD; Ryoji Tauchi, MD; Kazuki Kawakami, B.Kin.

9:32 – 9:36 AM **44. Multicenter, Randomized Placebo-Controlled Clinical Trial to Evaluate the Effect of Perioperative Use of Tranexamic Acid on Transfusion Requirements and Surgical Bleeding in Major Spine Surgery**
Maria José Colomina, PhD; Juan Bago, MD, PhD; Frederic Font, PhD; Javier Pizones, MD, PhD; Salvador Fuster, MD, PhD; Ferran Pellisé, MD

9:36 – 9:43 AM **Discussion**

Break
Room: Level 3 Foyer
9:43 – 10:03 AM
Supported, in part, by a grant from Medtronic.

Sesesion 4: Spinal Osteotomies, PJK and Complications
Room: Minneapolis Ballroom
Session Times: 10:04 – 11:45AM
Session Moderators: Benny T. Dahl, MD, PhD, DMSci & Stephen J. Lewis, MD, MSc, FRCSC

10:04 – 10:08 AM **45. Outcomes and Complications of Posterior Vertebral Column Resection for Severe Rigid Deformity Correction: Comparison of Pediatric, Adolescent and Adult Groups**
Jingming Xie; Yingsong Wang; Tao Li; Ying Zhang, PhD; Zhi Zhao; Ni Bi; Zhiyue Shi

10:08 – 10:12 AM **46. Reducing Rod Breakage and Nonunion in Pedicle Subtraction Osteotomy: The Importance of Rod Number and Configuration in 264 Patients with Two-Year Follow Up**
Munish Chandra Gupta, MD; Jensen K. Henry, BA; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Vedat Deviren, MD; Christopher I. Shaffrey, MD; Robert A. Hart, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Douglas C. Burton, MD; International Spine Study Group

10:12 – 10:16 AM **47. Clinical and Radiographic Outcomes After Posterior Vertebral Column Resection with Five-Year Follow Up**
Todd M. Chapman, MD; Lawrence G. Lenke, MD; Daniel G. Kang, MD; Jamal McClendon, MD; Lionel Nicholas Metz, MD; Brenda A. Sides; Kathy M. Blanke, RN

10:16 – 10:24 AM	**Discussion**
10:25 – 10:29 AM	**48. Comparison of Single Level versus Multi-Level Vertebral Column Resection Surgery for Pediatric Patients with Severe Spinal Deformities** *Chang Ju Hwang; Lawrence G. Lenke, MD; Brenda A. Sides; Kathy M. Blanke*
10:29 – 10:33 AM	**49. Posterior Vertebral Column Resection in Pediatric Deformity: The Advantages of Staging** *Firoz Miyanji, MD, FRCSC; Siddesh Doddabasappa, MS, MBBS; Sameer Desai, BS*
10:33 – 10:37 AM	**50. Long-Term Experience with Simultaneous Prone Video-Assisted Thoracoscopic Anterior Spinal Release (VATSR) and Posterior Spinal Fusion (PSF) in Severe Rigid Pediatric Spinal Deformities** *Chirag A Berry, MD; Viral V. Jain, MD; Alvin H Crawford, MD; Peter F. Sturm, MD*
10:37 – 10:46 AM	**Discussion**
10:47 – 10:51 AM	**51. Acute Proximal Junctional Failure: A T10 UIV May Not Be as Safe as Thought** *Nicholas Spina; Prokopis Annis, MD; Brandon Douglas Lawrence, MD; William Ryan Spiker, MD; Jonathan Belding, MD, MS; Michael D. Daubs, MD; Darrel S. Brodke, MD*
10:51 – 10:55 AM	**52. Post-Surgical Predictors of Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis** *Benjamin Todd Bjerke, MD, MS; Rehan Saiyed, BS; Zoe Beatrice Cheung, BS, MS; Grant D. Shifflett, MD; Evan David Sheha, BS, MD; Matthew E. Cunningham*
10:55 – 10:59 AM	**53. The Economic Impact of Revision Surgery for Proximal Junctional Failure After Adult Spinal Deformity Surgery: A Cost Analysis of 70 Operations in 10 Years at a Major Deformity Center** *Alexander Theologis; Matt Callahan, BS, MS; Darryl Lau, MD; Corinna Zygourakis, BS, MD; Justin K. Scheer, BS; Shane Burch, MD; Murat Pekmezci, MD; Dean Chou, MD; Bobby Tay, MD; Praveen V. Mummaneni, MD; Sigurd H. Berven, MD; Vedat Deviren, MD; Christopher P. Ames, MD*
10:59 – 11:08 AM	**Discussion**
11:09 – 11:12 AM	**2016 IMAST Preview** *Ronald A. Lehman, Jr., MD*
11:12 – 11:15 AM	**2016 Annual Meeting Preview** *Martin Repko, MD, PhD*
11:15 – 11:18 AM	**Worldwide Course Preview** *Marinus de Kleuver, MD, PhD*
11:18 – 11:25 AM	**Introduction of the President** *David W. Polly, Jr., MD* *President-Elect*
11:25 – 11:45 AM	**Presidential Address** *John Dormans, MD*

Lunch Break

Lunch Available in Level 3 Foyer and Level 2 Foyer

11:45 AM – 12:00 PM

Lunchtime Symposia

See pages 57-94

12:00 – 1:00 PM

	50-Year Evolution of the Treatment of Early Onset Scoliosis *Room: Minneapolis Ballroom*
	Research Grant Outcomes *Room: Symphony Ballroom*
	3D Management of Adolescent Idiopathic Scoliosis *Room: Marquette Ballroom*
1:00 – 1:15 PM	**Walking Break**

Session 5: Tumor, Basic Research and Miscellaneous *(Runs Concurrently with Session 6)*

Room: Minneapolis Ballrom
Session Times: 1:15 – 3:04 PM
Session Moderators: Lawrence L. Haber, MD & Hee-Kit Wong, MD

1:15 – 1:19 PM	**54. Prognostic Significance of T Gene SNP Rs2305089 in Individuals with Spinal Column Chordoma** *Peter Pal Varga, MD; Ziya L. Gokaslan, MD; Charles Fisher, BS, MD, FRCSC, MHSc; Stefano Boriani, MD; Wei-Lien Wang, MD; Aron Lazary, PhD; Niccole Germscheid, MS; Chetan Bettegowda, MD, PhD; Stephen Yip, MD, PhD; Laurence D. Rhines, MD*
1:19 – 1:23 PM	**55. Blood Loss in Spinal Tumour Surgery: Evaluation of Influencing Factors** *Naresh Kumar; Aye Sandar Zaw, MBBS, MPH*
1:23 – 1:27 PM	**56. A Modification of the Tokuhashi Revised Score Improves Prognostic Ability in Patients with Metastatic Spinal Cord Compression.** *Soren Schmidt Morgen, MD, PhD; Martin Gehrchen, MD, PhD; Sebastian Bjørck, MD; Claus Falck Larsen, MD; Benny T. Dahl, MD, PhD; Sudsel Fruergaard*
1:27 – 1:36 PM	**Discussion**
1:37 – 1:41 PM	**57. Deep Surgical Site Infection (SSI) Following Pediatric Cervical Spine Surgery** *Daniel J. Hedequist; John B. Emans, MD; Michael T. Hresko, MD; Michael P. Glotzbecker, MD*
1:41 – 1:45 PM	**58. The Local Application of Vancomycin in Spine Surgery Does Not Result in Increased Vancomycin Resistant Bacteria** *Frank Valone; Serena S. Hu, MD*
1:45 – 1:49 PM	**59. Risk Factors of Surgical Site Infection in Degenerative Lumbar Scoliosis: Detection and Management Based on Serial Proealeitonin Measurements: An Open-Label Randomised Trial** *En Xie; Dingjun Hao, MD, PhD*
1:49 – 1:58 PM	**Discussion**
1:59 – 2:03 PM	**60. The Effect of Posterior Tethers on the Biomechanics of Proximal Junctional Kyphosis: A Finite Element Analysis** *Jeffrey E. Harris; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Regis W. Haid, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Alexander William Turner, PhD*
2:03 – 2:07 PM	**61. Characterization of the Adherence Patterns and Biofilm Density of Commonly Encountered Bacterial Pathogens to Spinal Instrumentation of Differing Compositions** *Dioscaris Garcia; Alan H Daniels, MD; Alexandra M. Zega; David G. Deckey; Ayano Kondo, BS; John D. Jarrell, PhD; Craig P. Eberson, MD; Andrew Green, MD; Roman Hayda, MD; Christopher T Born, MD*
2:07 – 2:11 PM	**62. Exome Sequencing Reveals New Variants of POC5 Gene in Adolescent Idiopathic Scoliosis in French Canadian Families** *Florina Moldovan, MD, PhD; Shunmoogum Patten; Julie Couillard, PhD; Soraya Barchi, BS; Julie Joncas, BS, RN; Stefan Parent, MD, PhD*
2:11 – 2:20 PM	**Discussion**
2:21 – 2:25 PM	**63. A New Porcine Experimental Model of Severe Progressive Thoracic Scoliosis Induced by Interpedicular Bent Rigid Temporary Tethering: A Pilot Study** *Carlos Barrios; Borja Maruenda, MD; Juan Alonso, MD; Jesus Burgos Flores; Rafael Llombart, MD; Luis Gil-Santos, MD; José M Lloris, MD; Viviana Bisbal, DVM*
2:25 – 2:29 PM	**64. Hemostasis and Safety of a Novel Fibrin Dressing versus Standard Gauze in Bleeding Cancellous Bone in a Caprine Spine Surgery Model** *Charles Timothy Floyd, MD*
2:29 – 2:33 PM	**65. Investigation of a DNA-Based Prognostic Test Revealing New Predisposition Genes for Adolescent Idiopathic Scoliosis** *Lei-lei Xu, MD; Saihu Mao, MD; Jun Qiao, MD; Bangping Qian, MD; Ze-zhang ZHU, MD; Yong Qiu, MD*
2:33 – 2:42 PM	**Discussion**

2:43 – 2:47 PM	**66. Comparison of Two Segment Combined Spinal Fusion Versus Three Segment Posterior Spinal Fusion in Thoracolumbar Burst Fractures: A Randomized Clinical Trial with 10- Years Follow Up** *Cihangir Islam; Gurkan Gumussuyu, MD; Ozkan Kose; Mutlu Gungor, MD*
2:47 – 2:51 PM	**67. The Effect of Smoking Cessation on Short-Term Morbidity Risk in Lumbar Spine Surgery** *Christopher T. Martin, MD; Yubo Gao, PhD; Kyle R. Duchman, MD; Andrew J. Pugely, MD*
2:51 – 2:55 PM	**68. Atlantoaxial Rotatory Fixed Dislocation: Report on a Series of 32 Pediatric Cases** *Peter G. Passias; Shenglin Wang, MD; Nancy Worley, MS; Cyrus Jalai, BA; Chao Wang, MD*
2:55 – 3:04 PM	**Discussion**

Session 6: Early Onset, Congenital and Neuromuscular *(Runs Concurrently with Session 5)*

Room: Marquette Ballroom
Session Times: 1:15 – 3:04 PM
Session Moderators: Suken A. Shah, MD & Daniel J. Sucato, MD, MS

1:15 – 1:19 PM	**69. Utilizing the "Stable to Be Vertebra" Saves Motion Segments in Growing Rods Treatment for Early Onset Scoliosis** *Ozgur Dede; Gokhan Halil Demirkiran, MD; Senol Bekmez, MD; Peter F. Sturm, MD; Muharrem Yazici, MD*
1:19 – 1:23 PM	**70. Changing Trends in Pediatric Spine Surgery in the United States: 1997-2012** *Jeffrey R. Sawyer, MD; Lawson Copley, MD; Derek M. Kelly, MD; William C. Warner, MD*
1:23 – 1:27 PM	**71. Mortality and Causes of Death in Patients Requiring Rib-Based Distraction Surgery** *John T. Smith, MD; John A Heflin, MD; Michael G. Vitale, MD, MPH; Amer F. Samdani, MD; Jessica V Morgan, BS*
1:27 – 1:36 PM	**Discussion**
1:37 – 1:41 PM	**72. Magnetically-Controlled Growing Rod Achieves Estimated Cost Savings Compared to Traditional Growth Rods Over Five Years** *Alvin W. Su, MD, PhD; Todd Milbrandt; A. Noelle Larson*
1:41 – 1:45 PM	**73. Growth Guidance Growing Rods at Less Than Five Years: Curve and Implant Characteristics** *Richard E. McCarthy, MD; John Wilkinson, MD; Chad Songy, MD; Frances McCullough, RN*
1:45 – 1:49 PM	**74. Magnetically-Controlled Growing Rods: Does the Law of Diminishing Returns Apply?** *Jason Pui Yin Cheung, MBBS, MMedSc, FRCS; Cora Hingyee Bow; Dino Samartzis, PhD; Kenny Kwan, BM BCh; Kenneth M.C. Cheung, MD*
1:49 – 1:58 PM	**Discussion**
1:59 – 2:03 PM	**75. Middle-Aged Patients with Idiopathic Scoliosis with Onset Before Age 10 Years Who Have Reduced Pulmonary Function: Are They at Risk for Rapid Decline?** *Aina J. Danielsson, MD, PhD; Kerstin Birgitta Löfdahl Hällerman, MD, PhD*
2:03 – 2:07 PM	**76. Pulmonary Function in Children with Congenital Scoliosis and Rib Deformities: A Retrospective Study of 203 Patients** *Jun Cao, MD; Nanfang Xu, MD; David Price Roye, MD; Lin Sun, MD; Xuejun Zhang, MD*
2:07 – 2:11 PM	**77. Posterior Spinal Fusion with Ponte Osteotomies for Complex Congenital Scoliosis: A Single Institution's Experience** *Jahangir K. Asghar; Harry L. Shufflebarger, MD*
2:11 – 2:20 PM	**Discussion**
2:21 – 2:25 PM	**78. Safety and Efficacy of One-Stage Spinal Osteotomy for Severe and Rigid Congenital Scoliosis Associated with Split Spinal Cord Malformation** *Hui-Ren Tao, MD, PhD; Michael S. Chang, MD*
2:25 – 2:29 PM	**79. Local Epiphyseal Growth Modulation for the Early Treatment of Adolescent Idiopathic Scoliosis: Experimental Validation Using a Porcine Model** *Bahe Hachem, BS; Stefan Parent, MD, PhD; Carl-Eric Aubin, PhD, P.Eng.*

2:29 – 2:33 PM	**80. Factors Predicting Postoperative Complications Following Spinal Fusions in Children with Cerebral Palsy Scoliosis** *Julieanne Patricia Sees; Freeman Miller, MD; Kenneth Rogers, PhD; Kirk Dabney, MD; Tristan Nishnianidze, MD, PhD; Ilhan Bayhan, MD; Oussama Abousamra, MD*
2:33 – 2:42 PM	**Discussion**
2:43 – 2:47 PM	**81. National Trends in the Surgical Management of Duchenne Muscular Dystrophy: 2001 to 2012** *Addisu Mesfin, MD; Caroline P. Thirukumaran, MBBS, MHA; Brandon Raudenbush, DO; James O. Sanders, MD; Paul T. Rubery, MD*
2:47 – 2:51 PM	**82. Neuromotor Sub-Classification of GMFCS -5 Predicts Complications and HRQoL in Patients with Cerebral Palsy After Spine Fusion** *Amit Jain, MD; Paul D. Sponseller, MD; Patrick J. Cahill, MD; Burt Yaszay, MD; Amer F. Samdani, MD; Dolores Njoku, MD; Mark F. Abel, MD; Joshua M. Pahys, MD; Randal R. Betz, MD; Suken A. Shah, MD; Peter O. Newton, MD; Michelle Claire Marks, PT, MA*
2:51 – 2:55 PM	**83. Sacral Alar Iliac (SAI) Screws Fail 75 Percent Less Frequently Than Iliac Bolts in Neuromuscular Scoliosis** *Lior Shabtai, MD; Lindsay M. Andras, MD; Mark Portman, BS; David L. Skaggs, MD, MMM*
2:55 – 3:04 PM	**Discussion**
3:05 – 3:15 PM	**Walking Break**

Session 7: Adult Deformity

Room: Minneapolis Ballroom
Session Times: 3:15 – 5:03PM
Session Moderators: Serena S. Hu, MD & Mark Weidenbaum, MD

3:15 – 3:19 PM	**84. The Effects of Adult Spinal Deformity Surgery on Total Hip Arthroplasty Acetabular Component Position** *Altug Yucekul; Jeff Barry, MD; Alexander Theologis, MD; Gokhan Halil Demirkiran, MD; Murat Sakir Eksi, MD; Jun Mizutani, MD, PhD; Murat Pekmezci, MD; Christopher P. Ames, MD; Vedat Deviren, MD; UCSF Spine Center*
3:19 – 3:23 PM	**85. Correlation Between Lumbopelvic and Sagittal Parameters and Health-Related Quality of Life in Adults with Lumbosacral Spondylolisthesis.** *Yazeed M. Gussous, MD; Alexander Theologis, MD; Joshua Brian Demb, BS, MPH; Sigurd H. Berven, MD*
3:23 – 3:27 PM	**86. Site Variability in Surgical Technique and Outcomes in Adult Spinal Deformity** *Thomas Cheriyan, MD; Frank J. Schwab, MD; Khaled M. Kebaish, MD; Munish Chandra Gupta, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Elizabeth M. Tanzi, BS, MS; Michael P. Kelly, MD, MS; Justin S. Smith, MD, PhD; Shay Bess, MD; Robert A. Hart, MD; Richard Hostin, MD; Thomas J. Errico, MD; Virginie Lafage, PhD; International Spine Study Group*
3:27 – 3:36 PM	**Discussion**
3:37 – 3:41 PM	**87. Posterior Column Reconstruction Improves Fusion Rates at the Level of the Osteotomy in Three Column Posterior Based Osteotomies** *Stephen J. Lewis, MD, FRCSC, MS; Sofia P. Magana, BS; Chandan Mohanty, MD*
3:41 – 3:45 PM	**88. Teriparatide versus Bisphosphonates Following Surgery for Adult Spinal Deformity in Patients with Osteoporosis** *Shoji Seki, MD, PhD; Yoshiharu Kawaguchi, MD, PhD; Taketoshi Yasuda, MD, PhD; Kayo Suzuki, MD, PhD; Hiroto Makino, MD; Tomoatsu Kimura, MD, PhD*
3:45 – 3:49 PM	**89. Do All Adult Spinal Deformity Patients with Probable Pseudarthrosis at a Minimum Five-Year Follow Up Need Revision Surgery?** *Yong-Chan Kim, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Keith H. Bridwell, MD; Ki-Han You, MD; Sirichai Wilartratsami, MD; Linda Koester; Kathy M. Blanke*
3:49 – 3:58 PM	**Discussion**

3:59 – 4:03 PM	**90. Regional Thoracic and Lumbar Sagittal Cobb Angle Changes and UIV Determine Evolution of Cervical Alignment After ASD Surgery: Series of 171 Patients with Two-Year Follow Up** *Brian James Neuman, MD; Amit Jain, MD; Daniel M. Sciubba, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Lukas P. Zebala, MD; Gregory M. Mundis, MD; Virginie Lafage, PhD; Peter G. Passias, MD; Renaud Lafage, MS; Themistocles S. Protopsaltis, MD; D.Kojo Hamilton, MD; Justin K. Scheer, BS; Christopher P. Ames, MD; International Spine Study Group*
4:03 – 4:07 PM	**91. Ratio of Disability to Deformity Burden in 264 Adult Spinal Deformity Patients with Two-Year Follow-Up: Novel Insight Into Drivers of Disability** *Justin K. Scheer, BS; Jeffrey L. Gum, MD; Michael P. Kelly, MD, MS; Frank J. Schwab, MD; Richard Hostin, MD; Virginie Lafage, PhD; Shay Bess, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Munish Chandra Gupta, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group*
4:07 – 4:11 PM	**92. The Effect of Fusion Level on the Radiologic and Functional Outcomes in the Surgical Treatment of Adult Deformity in Patients Older Than 65 Years Old.** *Sinan Yilar, MD; Erden Erturer, MD; Meric Enercan, MD; Bahadir Gokcen, MD; Sinan Kahraman, MD; Mutlu Cobanoglu, MD; Amjad Alrashdan, MD; Tunay Sanli, MA; Mercan Sarier, MD; Cagatay Ozturk, MD; Azmi Hamzaoglu, MD*
4:11 – 4:20 PM	**Discussion**
4:21 – 4:25 PM	**93. Proximal Junctional Angle Predicts Need for Revision but Not Deterioration in Sagittal Radiographic Parameters after Adult Spinal Deformity Surgery** *Tamir Ailon, MD, FRCSC, MPH; Justin K. Scheer, BS; Christopher P. Ames, MD; Robert A. Hart, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Shay Bess, MD; Douglas C. Burton, MD; Munish Chandra Gupta, MD; Themistocles S. Protopsaltis, MD; Richard Hostin, MD; Frank J. Schwab, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; International Spine Study Group*
4:25 – 4:29 PM	**94. Does the Preoperative SRS Mental Health Domain Predict Clinical Outcomes in Adult Spinal Deformity Surgery?** *Xiaobin Wang, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Jacob M. Buchowski; Linda Koester; Kathy M. Blanke*
4:29 – 4:33 PM	**95. When Does Compensation for Lumbar Stenosis Become a Deformity?** *Aaron James Buckland, MBBS, FRACS; Shaleen Vira, MD; Jonathan H. Oren, MD; Renaud Lafage, MS; Bradley Yates Harris, JD; Matthew Adam Spiegel, BS; Bassel G. Diebo, MD; Barthelemy Liabaud, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Thomas J. Errico, MD; John A. Bendo, MD*
4:33 – 4:41 PM	**Discussion**
4:42 – 4:46 PM	**96. Development of New Onset Cervical Deformity in Non-Operative ASD Patients with Three-Year Follow Up** *Peter G. Passias, MD; Cyrus Jalai, BA; Nancy Worley, MS; Justin K. Scheer, BS; Alex Soroceanu, MD, MPH FRCSC; Themistocles S. Protopsaltis, MD; Eric O. Klineberg, MD; Daniel M. Sciubba, MD; Brian James Neuman, MD; Han Jo Kim, MD; D.Kojo Hamilton, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group*
4:46– 4:50 PM	**97. Cervical Kyphosis Does Not Imply Cervical Deformity: Predicting Cervical Curvature Required for Horizontal Gaze Based on Spinal Global Alignment and Thoracic Kyphosis** *Bassel G. Diebo, MD; Jonathan H. Oren, MD; Matthew Adam Spiegel, BS; Shaleen Vira, MD; Elizabeth M Tanzi, BS, MS; Barthelemy Liabaud, MD; Renaud Lafage, MS; Jensen K Henry, BA; Themistocles S. Protopsaltis, MD; Thomas J. Errico, MD; Frank J. Schwab, MD; Virginie Lafage, PhD*
4:50 – 4:54 PM	**98. Is the C7 Sagittal Vertical Axis (SVA) the Best Radiographic Measure to Predict Clinical Outcomes in Adult Spinal Deformity?** *Yong-Chan Kim, PhD; Lawrence G. Lenke, MD; Jeffrey L. Gum, MD; Ho-Guen Chang; Cheol-Jung Yang; Sirichai Wilartratsami, MD; Linda Koester; Kathy M. Blanke*
4:54 – 5:03 PM	**Discussion**

Saturday, October 3, 2015

Session 8: Bracing, Circulation and Sagittal Plane Abnormalities

Room: Minneapolis Ballroom
Session Times: 7:55 – 9:56 AM
Session Moderators: Jahangir K. Asghar, MD & Jean-Marc Mac-Thiong, MD, PhD

7:55 – 8:00 AM	**Welcome & Announcements**
8:00 – 8:04 AM	**99. The Effectiveness of the SpineCor Brace for the Conservative Treatment of AIS: Comparison with the Boston Brace** *Gabriel Gutman, MD; Mathieu Benoit; Julie Joncas, BS, RN; Marie Beauséjour, PhD; Hubert Labelle, MD; Soraya Barchi, BS; Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong*
8:04 – 8:08 AM	**100. Results of Bracing for Juvenile Idiopathic Scoliosis (JIS)** *Nanjundappa S. Harshavardhana; John E. Lonstein, MD*
8:08 – 8:12 AM	**101. Scoliosis School Screening: Analysis of the Cincinnati Metropolitan Statistical Area** *Charles T. Mehlman; Alexandria J. Greenler, BS; Kaitlyn Brennan, MPH; Progga Das, MPH*
8:12 – 8:21 AM	**Discussion**
8:22 – 8:26 AM	**102. New Imaging Protocol Allows a 50-Fold Reduction in Radiation Exposure for Scoliosis Patients** *Peter O. Newton, MD; Yash Khandwala, BS; Carrie E. Bartley, , MA; Fredrick G. Reighard, MPH; Tracey Bastrom, BS, MS; Burt Yaszay, MD*
8:26 – 8:30 AM	**103. Cardiopulmonary Exercise Testing in Scoliosis Patients** *Jianxiong Shen; Jinmei Luo; Youxi Lin; Ning Tang; Zheng Li, MD*
8:30 – 8:34 AM	**104. Anterior Vertebral Body Tethering for Immature Idiopathic Scoliosis: Results of Patients Reaching Skeletal Maturity** *Amer F. Samdani; Robert J. Ames, MD; Joshua M. Pahys, MD; Jeff S. Kimball; Harsh Grewal, MD; Glenn J. Pelletier, MD; Randal R. Betz, MD*
8:34 – 8:42 AM	**Discussion**
8:43 – 8:47 AM	**105. Prevalence and Factors Affecting Cervical Deformity in Adolescent Idiopathic Scoliosis Patients** *Xiaobang Hu; Isador H. Lieberman, MD, MBA FRCSC*
8:47 – 8:51 AM	**106. Long-Term Results of Selective Anterior Thoracolumbar/lumbar Fusion for Adolescent Idiopathic Scoliosis More Than Seven-Years Follow Up in a Single Center** *Zhang Jianguo*
8:51 – 8:55 AM	**107. Results of AIS Surgery at a Minimum of 10 Years Using Modern Implant Systems: Are Patients Troubled by Symptoms and a High Reoperation Rate?** *Daniel J. Sucato, MD, MS; Kaitlyn Elizabeth Brown, BS; Anna M. McClung, RN, BSN*
8:55 – 9:04 AM	**Discussion**
9:05 – 9:09 AM	**108. How Does Patient Radiation Exposure Compare for Low Dose CT-Guided Navigation versus Fluoroscopy for Pedicle Screw Placement in Idiopathic Scoliosis?** *Alvin W. Su, MD, PhD; Amy L. McIntosh, MD; Karl E. Rathjen, MD; Beth Schueler, PhD; Anthony A. Stans, MD; A. Noelle Larson*
9:09 – 9:13 AM	**109. Age-Related Shape Characterization of the Pediatric Thoracic Spine Using Generalized Procrustes Analysis** *James Peters, BS; Evan Bisirri; Robert M. Campbell, MD; Sriram Balasubramanian, BS, PhD, MS*
9:13 – 9:17 AM	**110. Comparison of Scheuermann's Kyphosis Correction by Combined Anterior-Posterior Fusion Versus Posterior-Only Procedure** *Mohammadreza Etemadifar, MD; Abdolali Hadi, MD*
9:17 – 9:21 AM	**111. Rib Penetration in Children with Neurofibromatosis and Scoliosis** *Scott Patrick Kaiser, MD; Sunitha Kaiser, MD; Patricia Parkin, MD, FRCSC; Reinhard D. Zeller*
9:21 – 9:30 AM	**Discussion**

9:31 – 9:35 AM **112. Prospective FDA IDE Clinical Safety Trial of a Scoliosis Growth Modulation Clip/Screw Device: Two-Year Results**
Eric J. Wall, MD; Joseph E. Reynolds, BS, MBA; Viral V. Jain, MD; Donita I. Bylski-Austrow; George H. Thompson, MD; Paul Samuels, MD; Sean Jeffrey Barnett, BS, MD, MS; Alvin H Crawford, MD

9:35 – 9:39 AM **113. Unique Device Specific Complications (DSC) of Magnet Driven Growing Rods (MdGR) Used for Early-Onset Scoliosis (EOS) and Lessons Learnt from World's First Three MdGR Graduates**
Nanjundappa S. Harshavardhana; Amr Fahmy, BS, MD, MSc; Hilali H. Noordeen

9:39 – 9:43 AM **114. Is Implant Material Related to Late Postoperative Infection in AIS?**
Scott Jacob Schoenleber, MD; Paul D. Sponseller, MD; Harry L. Shufflebarger, MD; Baron S. Lonner, MD; Geraldine Neiss, PhD; Petya Yorgova, MS; Tracey Bastrom, BS, MS; Suken A. Shah, MD

9:43 – 9:47 AM **115. A Randomized Double-Blinded Clinical Trial to Evaluate the Safety and Efficacy of Super-Elastic Memory Alloy Spinal Rod Versus a Standard Titanium Spinal Rod in Patients with Adolescent Idiopathic Scoliosis: Five-Year Follow Up**
Jason Pui Yin Cheung, MBBS, MMedSc, FRCS; Kelvin Yeung; Dino Samartzis, PhD; Michael To; Kenny Kwan, BM BCh; Keith D K Luk, MD; Kenneth M.C. Cheung, MD

9:47 – 9:59 AM **Discussion**

Transfer of Presidency

10:00 – 10:10 AM
John Dormans, MD & David W. Polly, Jr. MD

Awards Presentations

10:10 – 10:25 AM
Russell A. Hibbs Awards
Louis A. Goldstein Award
John H. Moe Award
Ronald A. Lehman, Jr., MD, Program Comittee Chair

Break

10:25 – 10:50 AM
Room: Level 3 Foyer

Session 9: Kyphosis, Sagittal Plane, Spondy and Cost

Room: Minneapolis Ballroom
Session Times: 10:50 AM – 12:45 PM
Session Moderators: John R. Dimar, II, MD & Christopher I. Shaffrey, MD

10:50 – 10:54 AM **116. Prospective Multicenter Assessment of Intraoperative and Perioperative Complication Rates Associated with Adult Spinal Deformity (ASD) Surgery in 558 Patients**
Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Christopher I. Shaffrey, MD; Shay Bess, MD; Frank J. Schwab, MD; Munish Chandra Gupta, MD; Robert A. Hart, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Douglas C. Burton, MD; Justin K. Scheer, BS; Christopher P. Ames, MD; International Spine Study Group

10:54 – 10:58 AM **117. Reciprocal Changes in Sagittal Alignment with Operative Treatment of Adolescent Scheuermann's Kyphosis: Prospective Evaluation of 96 Patients**
Baron S. Lonner; Yuan Ren, PhD; Suken A. Shah, MD; Paul D. Sponseller, MD; Burt Yaszay, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Joshua M. Pahys, MD; Stefan Parent, MD, PhD; Harry L. Shufflebarger, MD; Peter O. Newton, MD

10:58 – 11:02 AM **118. Sagittal Alignment of the Cervical Spine Following Correction of Scheuermann's Kyphosis**
Luigi Aurelio Nasto, MD; A.B. Perez Romera, MD; Saggah Tarek Shalabi, BS; Hossein Mehdian, MD

11:02 – 11:11 AM	**Discussion**
11:12 – 11:16 AM	**119. Insitu Fusion and Reduction Achieve Identical Improvement in Sagittal Parameters with L5 as the New Sacrum: A Comparative Study in 26 Cases of High-Grade Spondylolisthesis** *S. Rajasekaran, PhD, MS; Gurudip Das, MS; T. Arief Dian, MD; Ajoy Prasad Shetty, MS; Rishi Kanna, MS*
11:16 – 11:20 AM	**120. High-Grade Lumbosacral Spondylolisthesis in Children and Adolescent: Long-Term Clinical and Radiological Results of a Non-Instrumented Circumferential Fusion Technique** *Alexandra Alves; Thierry A. Odent, MD, PhD; Lotfi Miladi, MD; Christophe Glorion, MD, PhD*
11:20 – 11:24 AM	**121. Utility of Flexion-Extension Radiographs in Lumbar Spondylolisthesis: A Prospective Cohort Study with Consecutive Cases** *Kirkham B. Wood*
11:24 – 11:33 AM	**Discussion**
11:34 – 11:38 AM	**122. Development of Validated Computer Based Preoperative Predictive Model for Proximal Junction Failure (PJF) or Clinically Significant PJK with 86 Percent Accuracy Based on 510 ASD Patients with Two-Year Follow Up** *Justin K. Scheer, BS; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Virginie Lafage, PhD; Robert A. Hart, MD; Shay Bess, MD; Breton Line, BS; Bassel G. Diebo, MD; Themistocles S. Protopsaltis, MD; Amit Jain, MD; Tamir Ailon, MD, FRCSC, MPH; Douglas C. Burton, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; International Spine Study Group*
11:38 – 11:42 AM	**123. Global Sagittal Angle (GSA): A Step Toward Full Body Assessment for Spinal Deformity** *Bassel G. Diebo, MD; Jonathan H. Oren, MD; Shaleen Vira, MD; Matthew Adam Spiegel, BS; Bradley Yates Harris, JD; Renaud Lafage, MS; Barthelemy Liabaud, MD; Jensen K. Henry, BA; Themistocles S. Protopsaltis, MD; Thomas J. Errico, MD; Frank J. Schwab, MD; Virginie Lafage, PhD*
11:42 – 11:46 AM	**124. Minimum Detectable Change (MDC) for Health-Related Quality of Life (HRQL) Measures Varies According Age and Disability in Adult Spinal Deformity (ASD): Implications for Calculating Minimal Clinically Important Difference (MCID)** *Michael P. Kelly, MD, MS; Shay Bess, MD; Christopher P. Ames, MD; Douglas C. Burton, MD; Leah Yacat Carreon, MD, MS; David W. Polly, Jr., MD; Richard Hostin, MD; Amit Jain, MD; Jeffrey L. Gum, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Han Jo Kim, MD; International Spine Study Group*
11:46 – 11:55 AM	**Discussion**
11:56 AM – 12:00 PM	**125. Influence of Gender on Outcomes After Deformity Spine Surgery** *Parth A. Kothari, BS; Jeremy Steinberger, MD; John I. Shin, BS; Nathan J. Lee, BS; Javier Guzman, BS; Branko Skovrlj, MD; Dante M Leven, DO; John M. Caridi, MD; Samuel K. Cho, MD*
12:00 – 12:04 PM	**126. Impact of Cost Valuation on Cost Effectiveness in Adult Spine Deformity Surgery** *Jeffrey L. Gum, MD; Richard Hostin, MD; Chessie Robinson, MS; Michael P. Kelly, MD, MS; Leah Yacat Carreon, MD, MS; David W. Polly, Jr., MD; Shay Bess, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Steven D. Glassman, MD; International Spine Study Group*
12:04 – 12:08 PM	**127. An Analysis of the Seattle Spine Team Approach for Adult Spinal Deformity from a Health Services and Payor Perspective: Significant Reduction of Post Surgical Harms Leading to Readmission Achieved Within the First 30 Days** *Rajiv K. Sethi, MD; Jean-Christophe A. Leveque, MD; Theodore A. Wagner, MD; Karen Wernli, PhD*
12:08 – 12:17 AM	**Discussion**
12:18 – 12:22 PM	**128. Cell Saver for Adult Spinal Deformity Surgery Minimizes Cost** *Jeffrey L. Gum, MD; Leah Yacat Carreon, MD, MS; Michael P. Kelly, MD, MS; Richard Hostin, MD; Chessie Robinson, MS; Douglas C. Burton, MD; David W. Polly, Jr., MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Han Jo Kim, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group*

12:22 – 12:26 PM **129. Baseline Patient Reported Outcomes Do Not Correlate with Radiographic Parameters: A Multi-Center, Prospective NIH Adult Spinal Deformity Study of 286 Patients**
Todd M. Chapman, MD; Lukas P. Zebala, MD; Christine R. Baldus; Michael P. Kelly, MD, MS; Daniel G. Kang, MD; Jamal McClendon, MD; Lionel Nicholas Metz, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Lawrence G. Lenke, MD; Jacob M. Buchowski; Oheneba Boachie-Adjei, MD, DSc; Steven D. Glassman, MD; Keith H. Bridwell, MD

12:26 – 12:30 PM **130. What Is the Most Expensive Cause for Readmission Following Adult Spinal Deformity Surgery?**
Richard Hostin, MD; Chessie Robinson, MS; Jeffrey L. Gum, MD; Michael P. Kelly, MD, MS; David W. Polly, Jr., MD; Shay Bess, MD; Christopher P. Ames, MD; Douglas C. Burton, MD; Munish Chandra Gupta, MD; Frank J. Schwab, MD; Justin S. Smith, MD, PhD; Michael F. O'Brien, MD; International Spine Study Group

12:30 – 12:34 PM **131. Radiographic Variability Among Scheuermann's Kyphosis Patients: Appreciating the Individual Differences of the Deformity**
David B. Bumpass, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Kathy M. Blanke, RN; Randal R. Betz, MD; David H. Clements, MD; Hubert Labelle, MD; Ronald A. Lehman, MD; Baron S. Lonner, MD; Scott John Luhmann, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Stefan Parent, MD, PhD; Amer F. Samdani, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Daniel J. Sucato, MD, MS

12:34 – 12:45 PM **Discussion**

12:45 PM **Adjourn**

Notes

Notes

50th ANNUAL MEETING & COURSE

Author Index

Scoliosis Research Society 50th Anniversary 2015

The Scoliosis Research Society gratefully acknowledges Stryker for their overall support of the 50th Annual Meeting & Course.

Author Index

PRESENTATION KEY

1-132 = Paper/ Podium Presentations 200-294 = E-Posters PMC= Pre-Meeting Course CASE= Case Discussion
LTS= Lunchtime Symposium HDC= Half-Day Course

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About SRS

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 37 orthopaedic surgeons to an international organization of more than 1,200 health care professionals.

Mission Statement

The purpose of Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

Membership

SRS is open to orthopaedic surgeons, neurosurgeons, researchers and allied health professionals who have a practice that focuses on spinal deformity.

Active Fellowship (membership) requires the applicant to have fulfilled a five-year Candidate Fellowship and have a practice that is 20% or more in spinal deformity. Only Active Fellows may vote and hold elected offices within the Society.

Candidate Fellowship (membership) is open to all orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice which includes at least 20% spinal deformity. Candidate Fellows stay in that category for five years, during which time they must meet all of the requirements and demonstrate their interest in spinal deformity and in the goals of the Society. After five years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Candidate Fellowship does not include the right to vote or hold office. Candidate Fellows may serve on SRS committees.

Associate Fellowship (membership) is for distinguished members of the medical profession including nurses, physician assistants, as well as orthopaedic surgeons, neurosurgeons, scientists, engineers and specialists who have made a significant contribution to scoliosis or related spinal deformities who do not wish to assume the full responsibilities of Active Fellowship. Associate Fellows may not vote or hold office, but may serve on committees.

See webiste for membership requirement details:
www.srs.org/professional/membership

SRS Membership Information Session

Join us and learn more about the Scoliosis Research Society

Membership Info Session/New Member Lunch

Thursday, October 1, 12:30pm–1:30pm at the Symphony Ballroom

- How to Apply
- Membership Categories
- Benefits of Membership
- Leadership Opportunities
- Scholarships
- Networking
- Education

Programs and Activities

SRS is focused primarily on education and research and include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Hands-On Courses, Worldwide Conferences, a Global Outreach Program, the Research Education Outreach (REO) Fund which provides grants for spine deformity research, and development of patient education materials.

Website Information

For the latest information on SRS meetings, programs, activities and membership please visit www.srs.org. The SRS Website Committee works to ensure that the website information is accurate, accessible and tailored for target audiences. Site content is varied and frequently uses graphics to stimulate ideas and interest. Content categories include information for medical professionals, patients/public, and SRS members.

For more information and printable membership applications, please visit the SRS website at www.srs.org

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Adult Deformity – Michael D. Daubs, MD
Awards and Scholarship – Hani H. Mhaidli, MD, PhD
Bylaws and Policies – Karl E. Rathjen, MD
CME – Lawrence L. Haber, MD
Coding – Christopher J. DeWald, MD
Communications – John P. Lubicky, MD
Corporate Relations – Steven D. Glassman, MD
Directed Research TF – Steven D. Glassman, MD
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Education – Sigurd H. Berven, MD
E-Text – John C. France, MD
Ethics & Professionalism – Brian G. Smith, MD
Evidence Based Medicine TF – Douglas C. Burton, MD
Fellowship – Douglas C. Burton, MD
Fiftieth Anniversary TF – Behrooz A. Akbarnia, MD
Finance – Paul D. Sponseller, MD
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Globalization – Lawrence G. Lenke, MD
Growing Spine – John T. Smith, MD
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Historical – Behrooz A. Akbarnia, MD
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Nominating – Steven D. Glassman, MD
Non-Operative Management – Vishwas R. Talwalkar, MD
Patient Education – Craig P. Eberson, MD
Pediatric Device TF – Michael G. Vitale, MD
Performance Measures TF – Christopher J. DeWald, MD
Program – Ronald A. Lehman, Jr., MD
Research Grant – Joseph H. Perra, MD
Safety & Value – Kit M. Song, MD, MHA
3D Scoliosis TF – Carl-Éric Aubin, PhD, P.Eng
Translation – Munish C. Gupta, MD
Website – Ron El-Hawary, MD
Worldwide Conference – Marinus deKleuver, MD, PhD

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The Scoliosis Research Society gratefully acknowledges Globus Medical for their support of the Wireless Internet.

The Scoliosis Research Society gratefully acknowledges Zimmer Biomet for support of the E-Posters, Internet Kiosks, Charging Station, Pre-Meeting Course and overall support of the 50th Annual Meeting & Course.

Meeting Outline

(subject to change)

Monday, September 28, 2015	
12:00-6:00pm	Board of Directors Meeting
Tuesday, September 29, 2015	
7:00am-5:00pm	SRS Committee Meetings
2:00-6:00pm	Registration Open
7:00-10:00pm	SRS Leadership Dinner (by invitation only)
Wednesday, September 30, 2015	
6:30am-6:00pm	Registration Open/ Internet Kiosks, E-Posters Open
8:00am-12:30pm	Pre-Meeting Course – Morning Sessions
12:30-1:45pm	Lunchtime Symposia Living Legends Presentation in the 50th Anniversary Museum
1:45-4:30pm	Pre-Meeting Course – Afternoon Sessions
4:45-5:45pm	Case Discussions
6:00-7:15pm	Opening Ceremonies
7:15-9:00pm	Welcome Reception
Thursday, October 1, 2015	
6:30am-4:30pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:30-10:00am	Spouse Hospitality Suite
7:55am-12:30pm	Scientific Program
12:30-1:30pm	Lunch & Networking for Half-Day Course Participants and New Member/Prospective Member Lunch and Information Session Living Legends Presentation in the 50th Anniversary Museum
1:30-4:30pm	Half-Day Courses
Friday, October 2, 2015	
6:30am-5:30pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:30-10:00am	Spouse Hospitality Suite
7:55-11:50am	Scientific Program
12:00-1:00pm	Lunchtime Symposia Living Legends Presentation in the 50th Anniversary Museum
1:15-5:03pm	Scientific Program
7:00-11:00pm	Farewell Banquet
Saturday, October 3, 2015	
6:30am-12:00pm	Registration Open/ Internet Kiosks, E-Posters Open
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast
7:55am-12:45pm	Scientific Program
1:00-3:30pm	Board of Directors Meeting