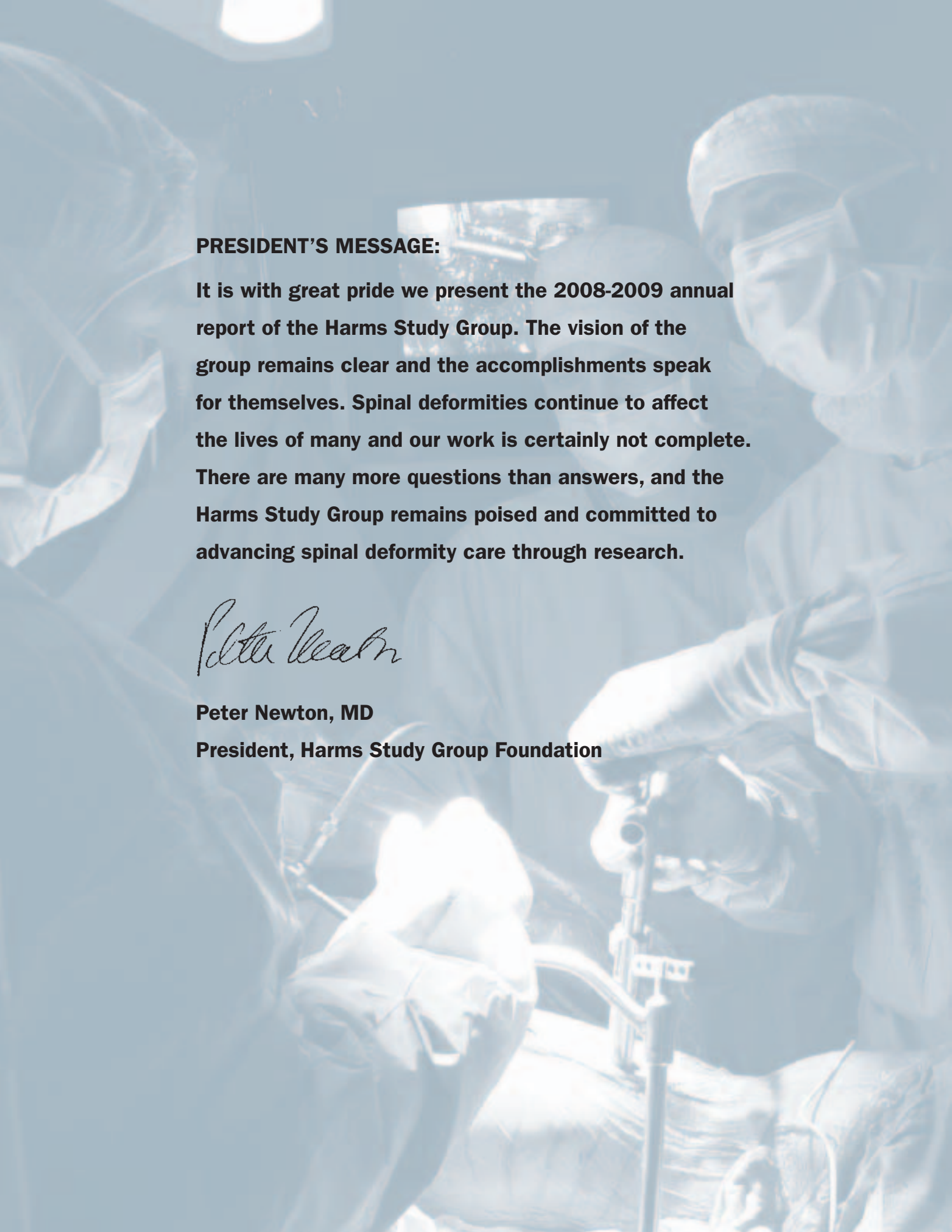
2008/2009 Annual Report

HSG

HARMS STUDY GROUP



PRESIDENT'S MESSAGE:

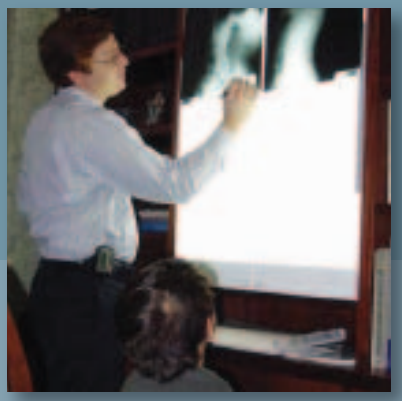
It is with great pride we present the 2008-2009 annual report of the Harms Study Group. The vision of the group remains clear and the accomplishments speak for themselves. Spinal deformities continue to affect the lives of many and our work is certainly not complete. There are many more questions than answers, and the Harms Study Group remains poised and committed to advancing spinal deformity care through research.

Peter Newton, MD
President, Harms Study Group Foundation

MISSION STATEMENT:

The Harms Study Group (HSG) is a group of surgeons dedicated to the advancement of treatment for children and adolescents with spine deformity.

Through comprehensive, multicenter prospective research studies, questions regarding treatment approach and techniques to achieve desired outcomes are studied.



Long Term Goals:

The long term goals of the study group involve maintaining a consistent level of high quality research. Important, clinical answers and treatment recommendations will be provided by the clinical questions investigated by our group's research studies.

The most recent and innovative treatment techniques and evaluative procedures will be the primary focus of our group's work. Long term follow-up data is and will continue to be the group's strength and commitment.

The Harms Study Group is sponsored in part by a research grant from DePuy Spine, Inc., a Johnson & Johnson Company.

OBJECTIVE:

To be internationally recognized for the highest quality published research on new spinal deformity surgery techniques.

The presence of this study group at national meetings and in the literature is without comparison. Through current (and past) membership, the HSG has produced hundreds of podium presentations on adolescent spinal deformity at annual meetings and peer-reviewed journal articles and book chapters. Current surgeon members of the HSG include several members of the board of directors as well as three past presidents of the Scoliosis Research Society.

The development and maintenance of a strong infrastructure and a robust database system has been the key to this group's success. This infrastructure consists of personnel with expertise in multi-center research study coordination, protocol development and implementation, database design and management (data verification and quality assurance practices), statistical analysis and interpretation as well as expertise in contracting and budget management. This infrastructure supports the group's current involvement in four prospective studies and one retrospective study:

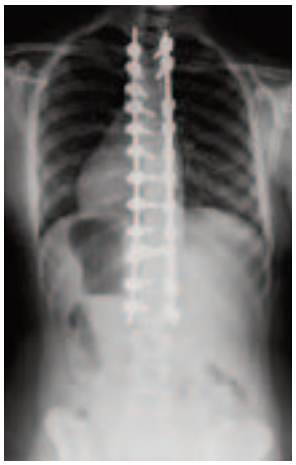
1) Prospective Adolescent Scoliosis Outcomes Database Registry

2) Prospective study of Spinal Motion Preservation Evaluation

3) Prospective study of Scheuermann's Kyphosis

4) Prospective study of Scoliosis in Children with Cerebral Palsy

5) Retrospective study of Scoliosis Correction in Marfan Syndrome Patients



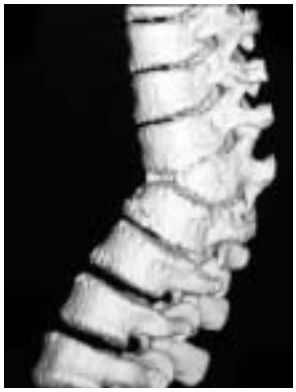
The HSG is dedicated to advancing the techniques used to analyze treatment outcomes and has implemented radiographic digital scanning procedures and digital image acquisition in all study group sites to enable central digital radiographic measuring capabilities. The group is also looking forward to utilizing three-dimensional radiographic measures in their research. Collaborations with software and hardware companies for these goals are currently underway. All data entered in the central, web-based database undergoes central data quality assurance evaluation before it is utilized in our data queries.

The goal to achieve and define the gold standard for conducting multicenter research is the group's primary focus with a "refining" of the current data in the database underway to ensure all data meets this gold standard (i.e. prospectively consented enrollment, consecutive cases, and Institutional Review Board research study approval in place).

The book project entitled "*Idiopathic Scoliosis: The Harms Study Group Guide to Evaluation and Treatment*", is a current focus of the educational goals for the HSG. This up-to-date summary of idiopathic scoliosis is planned to be completed and published in July 2010. Additional educational outreach plans for surgeons include the Peer-to-Peer meetings which are facilitated by the executive committee members of the Harms Study Group. Additional educational outreach plans for patients include launch of a HSG quarterly newsletter as well as development of website and Facebook and Twitter pages.

Plans for 2010

1) **Develop the Harms Study Group Not for Profit Foundation**
2) **Complete the Retrospective Study of Scoliosis Correction in Marfan Syndrome Patients**
3) **Develop, publish and circulate an educational handbook on scoliosis management for patients with adolescent idiopathic scoliosis**
4) **Launch HSG website, Facebook and Twitter pages to facilitate outreach for patient support**
5) **Launch HSG quarterly newsletter to maintain patient support, communication and education with our research patients**



HISTORY:

The Harms Study Group (HSG) was established in 1994 under the direction of Professor Jürgen Harms and Randal Betz.

For the past decade the group has been internationally recognized for producing the highest quality published research on new spinal deformity surgery techniques (nearly 100 peer reviewed publications). The group has achieved this standard by conducting comprehensive, multi-center prospective research studies aimed at answering important clinical questions regarding treatment approach and techniques. Currently, the executive committee consists of: Professor Jurgen Harms, Randal Betz, Peter Newton, Harry Shufflebarger, Amer Samdani, and Michelle Marks.

Funding for the group from DePuy formally began in October 2000 with a grant which consisted of an administration budget for three managing sites (Philadelphia, St. Louis and San Diego) and a data reimbursement budget for the additional study group sites. The group functioned under this yearly budget from 2000-2001 and annual spending patterns were consistent with the budgeted amounts.

In 2001, under the direction of Peter Newton and Randal Betz, the potential of the study group advanced with the development of a multi-user, web-driven, scoliosis database. All of the previous data collected by the study group was imported into this secure, multifaceted, comprehensive database. The ability to collect, manage and extract data was immediately more efficient and technologically advanced, as the new database incorporated digital images of radiographs and clinical photographs. To optimize the utility of the new database, formal prospective study protocols were updated for the two main studies of the group: The "Lenke 1 Curve Study", comparing three different surgical approaches in thoracic curves and the "Algorithm Study", comparing the approaches for all curve types in order to establish recommended treatment algorithms.

In 2002, both prospective studies were underway and the improvements and growth of the group were apparent with the implementation of standardized data collection practices and the organized dissemination of individual member database mining projects. The administration of the group was split between the Philadelphia and San Diego managing sites.

In 2003, additional formalization of the study group occurred with comprehensive data verification measures implemented and major database upgrades. In addition, the San Diego site assumed the main administrative tasks of the study group; subcontracting with each site and managing the data verification, invoicing and reimbursements. The group grew from 12 surgeon members to 16 surgeon members and the database became the largest Adolescent Idiopathic Scoliosis database in existence.

In 2004, in addition to the ongoing prospective data collection, the study group performed its first multi-center, retrospective study, evaluating the operative management of Scheuermann's Kyphosis. The data for 71 patients, including radiographic outcomes, complications, and surgical techniques was included. The productivity of the group also grew with a total of nine podium presentations presented at society annual meetings.

In 2005, the prospective study of Scheuermann's Kyphosis was launched and three multi-center retrospective studies were developed and implemented by the group:

1) Defining the Incidence of Complications and Risk Factors Associated with the Use of Single Lung Ventilation for Thoracoscopic Surgery in Pediatric Spinal Deformity
2) Retrospective Cerebral Palsy Scoliosis Study: Quantifying Outcomes and Risks
3) A Multicenter Retrospective Review of the Results of Three Classes of Surgical Treatment for Congenital Scoliosis Due to Hemivertebrae

The results of the Retrospective Multi-Center Kyphosis Study was presented as a podium presentation in addition to six other podium presentations that year.

In 2006, an additional retrospective study was implemented, Comparison of Severe Scoliosis treated with or without Halo Traction, which included the involvement of the Peer-to-Peer group of surgeons, facilitated by the HSG. This provided the opportunity for the educational outreach efforts of the HSG to unite with the HSG research endeavors. The HSG also embarked on a book project entitled, "*Idiopathic Scoliosis: The Harms Study Group Guide to Evaluation and Treatment*", to be published by Thieme Medical Publishers. This book will be an up-to-date summary of idiopathic scoliosis, focusing on new research findings in etiology, assessment, and treatment, as well as covering

the fundamentals and basic principles of spinal deformity. All members of the HSG will provide chapter contributions. In addition, a prospective study of motion preservation evaluation was launched. Productivity for the group continued to grow with 20 podium presentations at annual meetings.

In 2007, a HSG research organization infrastructure was launched to sustain the evolution of the group specifically with regards to 1) central digital x-ray measuring and storage, 2) data organization, analysis and interpretation assistance to the members of the group for their individual member projects, and 3) data quality assurance and analysis procedures for the prospective studies. The productivity of the group soared to 15 podium presentations. The mechanism for digital image transfer was developed and hardcopy films were scanned into digital images for more than half of the 1500 patients in the HSG database. The "Lenke 1 Curve Study" was completed and the "Algorithm Study" was converted into a Long-term Database Registry of AIS, in which operative and non-operative cases will be included with follow-up spanning 25 years.

In 2008, the HSG research organization infrastructure activity benefited the group's data integrity and productivity by 1) initiating the conversion of all existing manual x-ray measures to digital measures, 2) creating a new version of the multi-user web-based database, and 3) further evolution of individual member project support and assistance. The mechanisms for multi-center study participation were further strengthened by establishing data collection standardization manuals and improved, revised data collection case report forms. To ensure continual communication with all sites, a HSG web-based central folder where all of the up-to-date versions of HSG documents (protocols, CRFs, manuals) can be accessed by all participating sites was established, in addition, monthly site coordinator calls were initiated. Two new studies were launched, *"The Prospective Study of Scoliosis in Children with Cerebral Palsy"* and *"The Retrospective Study of Posterior Vertebral Column Resection in Pediatric Spinal Deformity"* which was successfully completed. The productivity of the group remained strong with 20 podium presentations and 11 published manuscripts.

In 2009, the HSG research organization focused on 1) migrating the AIS data from the original database application into the newly improved version of the multi-user web-based database, 2) continued conversion of all existing manual x-ray measures to digital measures with measurements in accuracy and reliability performed, and 3) intense data quality assurance efforts. A new multi-center retrospective study, the Retrospective Study of Scoliosis Correction in Marfan Syndrome patients was launched. Development of a potential study evaluating Minimally Invasive Surgery in Adolescent Idiopathic Scoliosis was performed and pilot data collection was being initiated. The book project was finalized with the completion of the textbook, "*Idiopathic Scoliosis: The Harms Study Group Guide to Evaluation and Treatment*", which will be published in July 2010. The group's productivity hit a new record with 26 podium presentations and 24 poster presentations at annual society meetings, and a 14 published manuscripts in one year. Despite the success in productivity, the group continued to look for areas for improvement and efforts were focused at improving the group's percentage of patient follow-up with the launch of improved HSG infrastructure support to the sites and a patient incentive program. In addition, the group launched a patient newsletter to improve outreach and education with plans to produce quarterly in future years.

The past decade has seen tremendous growth, evolution and advancement in the member participation, infrastructure and productivity of the Harms Study Group.

HSG EXECUTIVE COMMIT

Prof Dr Med Jürgen Harms

Prof Dr Med Jürgen Harms, is a founding member of the Harms Study Group and active participant since 1994 and a current member of the Executive Committee. He has been an active participant in two prospective and three retrospective studies. He completed his medical specialization in orthopaedic and Trauma Surgery in Neuburg/Donau, and Ludwigshafen and Homburg/ Saar. He has been a professor of Orthopaedic Surgery since 1977. He is currently Chief of Spine Surgery at Klinikum Karlsbad-Lagensteinbach, Germany (an institution affiliated to the University of Heldelberg Medical School) a position he has held since 1980. He also an honorary member of the Scoliosis Research Society.

Randal R. Betz, MD

Randal R. Betz, MD, is a founding member of the Harms Study Group and active participant since 1994 and a current member of the Executive Committee. He has been an active participant in four prospective and six retrospective studies. He is currently Chief of Staff and Medical Director of Spinal Cord Injury Unit at Shiners' Hospitals for Children in Philadelphia while serving as Professor of Orthopedic Surgery at Temple University School of Medicine. He completed his orthopedic training at Temple University, Philadelphia, with fellowship training at Alfred I. duPont Institute in Delaware. He was the President of the Scoliosis Research Society in 2005.

Peter O. Newton, MD

Peter O. Newton, MD, is a member of the Executive Committee of the Harms Study Group. He joined the group in 1998 and has been an active participant in four prospective and six retrospective studies. He is currently Chief of Orthopedic Research and the Scoliosis Service at Rady Children's Hospital in San Diego, while serving as Associate Clinical Professor of Orthopaedic Surgery at the University of California, San Diego. He completed his orthopedic training at the University of California, San Diego, with fellowship training at the Texas Scottish Rite Hospital for Children. He is the Research Council Chair and member of the Board of the Scoliosis Research Society and is currently the treasurer and on the Board of the Pediatric Orthopedic Society of North America.

TEE MEMBER PROFILES:

Harry Shufflebarger, MD

Harry Shufflebarger, MD, was an original member of the Harms Study Group in 1995 and reactivated his participation in 2003 and is a current member of the Executive Committee. He is an active participant in four prospective and five retrospective studies. He is currently Clinical Professor of Orthopaedics and Rehabilitation at Miami Children's Hospital while serving as Clinical Professor, Department of Orthopedics & Rehabilitation at the University of Miami. He completed his orthopedic training at Emory University, Atlanta, Georgia. He was the President of the Scoliosis Research Society in 1999 and presently serves on the IMAST program committee.

Amer Samdani, MD

Amer Samdani, MD, is a member of the Executive Committee of the Harms Study Group. He joined the group in 2006 and has been an active participant in three prospective and three retrospective studies. He is currently director of the spine service at the Shriner's Hospital for Children in Philadelphia. He completed his neurosurgery training at Johns Hopkins Medical School with a chief residency at Johns Hopkins Hospital, followed by Fellowship training at Cornell University in New York and at the Children's Hospital of Philadelphia. He is a current member of American Association of Neurological Surgeons.

Michelle Marks, PT, MA

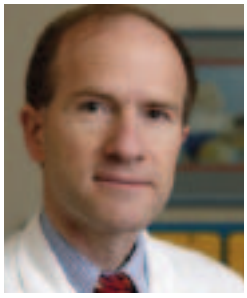
Michelle Marks, PT, MA, is a member of the Executive Committee of the Harms Study Group. Her participation in the group began in 1999 as the San Diego site coordinator for Peter Newton. She currently manages the Harms Study Group research organization and not-for-profit Foundation. She obtained her Bachelor's degree in Physical Therapy from Mount St. Mary's College in Los Angeles and her master's degree in Kinesiology and Biomechanics from San Diego State University. She is a current associate member of the Scoliosis Research Society.

HSG CORE MEMBER PR

David Clements, MD, is a founding member of the Harms Study Group and active participant since 1994. He has participated in four prospective and six retrospective studies. He is currently Director of the Spine and Scoliosis Service at Cooper Bone & Joint Institute, New Jersey, while serving as Associate Professor in the Department of Orthopaedic Surgery, Robert Wood Johnson School of Medicine and Attending Surgeon, Shriner's Hospital for Children, Philadelphia Unit. He completed an Orthopaedic Surgery Residency at Temple University Hospital in Philadelphia, PA and a Fellowship in Spine and Scoliosis at Hospital for Special Surgery/Cornell University Medical Center in New York. He is a current member of the Scoliosis Research Society as well as the Cervical Spine Research Society.

Lynn Letko, MD, is a core member of the Harms Study Group. She joined the group in 2003 and has been an active participant in two prospective and three retrospective studies. Since 2001, she has been a spinal surgeon at Klinikum Karlsbad Langensteinbach, Karlsbad Germany. She completed her orthopedic training at the Long Island Jewish Medical Center, with fellowship training at Hospital for Joint Diseases Orthopaedic Institute. She is a member of the Scoliosis Research Society.

Baron Lonner, MD, is a core member of the Harms Study Group. He joined the group in 2004 and has been an active participant in four prospective and four retrospective studies. He is currently serving as director of Scoliosis Associates and the Spinal Deformity Center at the Hospital for Joint Diseases in New York while serving as Clinical Associate Professor of Orthopaedic Surgery at New York University Medical School. He completed his orthopedic training at Albert Einstein College of Medicine, NY with fellowship training at the Hospital for Special Surgery, NY. He is the outgoing chairman of the Endowment Committee of the Scoliosis Research Society. He is the primary investigator of the Prospective Study of Scheuermann's Kyphosis, being conducted by the Harms Study Group.



Paul Sponseller, MD, is a core member of the Harms Study Group. He joined the group in 2004 and has been an active participant in four prospective and five retrospective studies. He is currently Head of the Division of Pediatric Orthopaedics at Johns Hopkins Hospital in Baltimore. He completed his orthopedic training at the University of Wisconsin, with fellowship training at Boston Children's Hospital. He is on the bracing committee of the Scoliosis Research Society and is the research committee chair and member of the Board of Directors of the Pediatric Orthopedic Society of North America. He is the primary investigator of the Prospective Study of Scoliosis in Children with Cerebral Palsy, being conducted by the Harms Study Group.

OFILES:

Suken Shah, MD, is a core member of the Harms Study Group. He joined the group in 2005 and has been an active participant in five prospective and four retrospective studies. He is currently Co-Director of the Spine and Scoliosis Service at the Alfred I. duPont Hospital for Children in Wilmington, Delaware, while serving as Assistant Professor of Orthopaedic Surgery at Thomas Jefferson University in Philadelphia, Pennsylvania. He completed his orthopedic training at the Thomas Jefferson University, with fellowship training at Alfred I. duPont Hospital for Children. He is a current member of the research committee of the Pediatric Orthopedic Society of North America as well as an active member of the Scoliosis Research Society and serves on the Bylaws and Policy Committee and Worldwide Course Committee.

Jack Flynn, MD, is a core member of the Harms Study Group. He joined the group in 2006 and has been an active participant in three prospective and two retrospective studies. He is currently Associate Chief in the Division of Orthopaedics, at the Children's Hospital of Philadelphia and Associate Professor of Orthopaedic Surgery at the University of Pennsylvania. He completed his orthopedic training at Harvard, with a Chief Residency at Boston Children's Hospital, followed by Fellowship training at Alfred I. duPont Hospital for Children. He is the current IPOS program chair for the Pediatric Orthopedic Society of North America as well the recent past chair of the Growing Spine Committee of the Scoliosis Research Society.

Firoz Miyanji, MD, is a core member of the Harms Study Group. He joined the group in 2007 and has been an active participant in 4 prospective studies and 2 retrospective studies. He is currently a spine surgeon at British Columbia Children's Hospital. He completed his orthopedic training at the University of British Columbia, Vancouver followed by Fellowship training at the Toronto Western Hospital Krembil Neurosciences Centre and subsequently at Rady Children's Hospital in San Diego, California. He is a current member of the North American Spine Society and the Pediatric Orthopaedic Society of North America, and a candidate member of the Scoliosis Research Society.

Patrick Cahill, MD, is a core member of the Harms Study Group. He joined the group in 2008 and has been an active participant in 3 prospective studies and 2 retrospective studies. He is currently a spine surgeon at Shriner's Hospital for Children in Philadelphia. He completed his orthopedic training at Loyola University in Illinois, followed by Fellowship training at Rush University in Illinois. He is a current member of the North American Spine Society and a candidate member of the Scoliosis Research Society.

Burt Yaszay, MD, is a core member of the Harms Study Group. He joined the group in 2008 and has been an active participant in 4 prospective studies and 2 retrospective studies. He is currently a spine surgeon at Rady Children's Hospital in San Diego. He completed his orthopedic training at University of Washington, followed by Fellowship training at New York University/Hospital for Joint Diseases. He is a current member of the North American Spine Society and a candidate member of the Scoliosis Research Society.

HSG ASSOCIATE MEMBE

Alvin Crawford, MD, participated in the Harms Study Group as a core member from 2001–2007. He currently participates as an associate member by contributing follow-up data on his previously enrolled patients. He currently practices in the Division of Pediatric Orthopaedic Surgery at Cincinnati Children's Hospital Medical Center.

Larry Lenke, MD, participated in the Harms Study Group as a core member from 1995–2006. He currently participates as an associate member by contributing follow-up data on his previously enrolled patients. He is the current Chief of Spinal Surgery at Shriner's Hospital for Children in St. Louis.

Daniel J. Sucato, MD, participated in the Harms Study Group as a core member from 2001–2007. He currently participates as an associate member by contributing patient data to the Prospective Study of Scoliosis in Children with Cerebral Palsy. He currently practices at the Texas Scottish Rite Hospital for Children in Dallas.

Andrew Merola, MD, participated in the Harms Study Group as a core member from 1996–2005. He currently participates as an associate member. He currently practices in New York.

Mark Abel, MD, participated as a core member of the Harms Study Group from 2006 to 2007. He currently participates as an associate member by contributing patient data to the Prospective Study of Scoliosis in Children with Cerebral Palsy. He currently practices at the University of Virginia in Charlottesville.

Christopher Reilly, MD, has participated in the Harms Study Group as an associate member since 2007, by contributing patients to three prospective studies. He is the current head of the department of pediatric orthopedics at the British Columbia Children's Hospital.

Munish Gupta, MD, has participated in the Harms Study Group as an associate member since 2008, by contributing patients to the Prospective Study of Scheuermann's Kyphosis. He currently practices at the Shriner's Hospital for Children in Sacramento.

Michael O'Brien, MD, has participated in the Harms Study Group since 2003 by contributing patients to both prospective and retrospective studies. He currently practices in Texas.

Stefan Parent, MD, has participated in the Harms Study Group as an associate member since 2009, with planned participation in the Prospective Study of Scoliosis in Children with Cerebral Palsy. He currently practices at Hôspital Ste-Justine in Montreal, Canada.

Atiq Durrani, MD, has participated in the Harms Study Group as an associate member since 2009, with planned participation of piloting the data collection for the Prospective Study of MIS in AIS. He currently practices at Center for Advanced Spine Technologies in Cincinnati.

R PROFILES:

Peter Gabos, MD, has participated in the Harms Study Group as an associate member since 2008, by contributing patients to the AIS database registry. He currently practices at Nemours Children's Clinic in Wilmington, Delaware.

Jean Ouellet, MD, participated in the Harms Study Group as an associate member since 2009, with planned participation in the Prospective Study of Scoliosis in Children with Cerebral Palsy. He currently practices at Montreal Children's Hospital in Montreal, Canada.

Stewart Tucker, MD, has participated in the Harms Study Group as an associate member since 2009, with planned participation in the Prospective Study of Scheuermann's Kyphosis & AIS database registry. He currently practices at Royal National Orthopaedic Hospital in London.

Juan Carlos Olaverri, MD, participated in the Harms Study Group as an associate member since 2009, with planned participation in the Prospective AIS database registry. He currently practices at Mamonides Hospital in New York.

Josh Auerbach, MD, participated in the Harms Study Group as an associate member since 2009, with planned participation in the Prospective Study of Scheuermann's Kyphosis & AIS database registry. He currently practices at Bronx-Lebanon Hospital in New York.

In Memory of...

Shelokov, Alexis, MD
1954-2009

The HSG would like to pay tribute to the passing of a gifted spine surgeon who practiced medicine with a patient-centered approach and generous spirit. He was a genuine friend and valued colleague. He participated as an HSG Associate member since 2007 by contributing patients to the Prospective Study of Scheuermann's Kyphosis. He practiced at the Baylor Scoliosis Center in Plano, Texas.

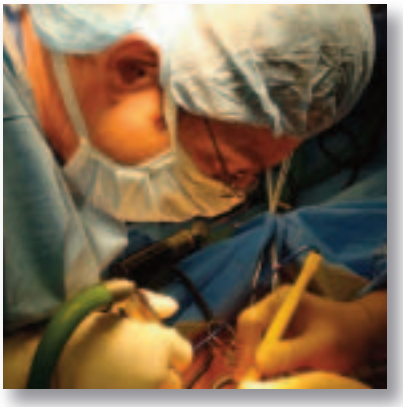
We will greatly miss him.

PRODUCTIVITY:

Harms Study Group Yearly Productivity:

YEAR	PODIUM PRESENTATIONS*	POSTER PRESENTATIONS*	MANUSCRIPTS PUBLISHED^
2000	8	10	8
2001	5	5	8
2002	6	8	6
2003	7	6	6
2004	9	3	8
2005	7	17	6
2006	5	12	2
2007	20	47	7
2008	20	31	9
2009	26	24	14

* at SRS, IMAST, NASS, POSNA, or AAOS; ^ in a peer-reviewed journal



PUBLISHED MANUSCRIPTS:

2008 Published Manuscripts

1. Patel PN, Upasani VV, Bastrom TP, Marks MC, Pawelek JB, Betz RR, Lenke LG, Newton PO. Spontaneous lumbar curve correction in selective thoracic fusions of idiopathic scoliosis: a comparison of anterior and posterior approaches. Spine 2008 May 1;33(10):1068-73. FINDINGS: Anterior and posterior instrumented fusions performed selectively on the appropriate curves result in equal SLCC when matched by LIV, flexibility of the lumbar curve and percent thoracic curve correction achieved. SLCC is independent of surgical approach.
2. Upasani VV, Caltoum C, Petcharaporn M, Bastrom T, Pawelek J, Marks M, Betz RR, Lenke LG, Newton PO. Does obesity affect surgical outcomes in adolescent idiopathic scoliosis? Spine 2008 Feb 1;33(3):295-300. FINDINGS: Overweight adolescents (BMI% >85) had a greater thoracic kyphosis before surgery compared with their healthy weight peers. Body mass, however, did not affect the ability to achieve coronal or sagittal scoliotic deformity correction, and did not increase perioperative morbidity or mortality.
3. Upasani VV, Caltoum C, Petcharaporn M, Bastrom TP, Pawelek JB, Betz RR, Clements DH, Lenke LG, Lowe TG, Newton PO. Adolescent Idiopathic Scoliosis Patients Report Increased Pain at 5 Years Compared to 2 Years after Surgical Treatment. Spine 2008 May 1;33(10):1107-12. FINDINGS: The etiology of the worsening pain could not be elucidated.
4. Ritzman TF, Upasani VV, Bastrom TP, Betz RR, Lonner BS, Newton PO. Comparison of compensatory curve sponataneous derotation after selective thoracic or lumbar fusions in adolescent idiopathic scoliosis. Spine 2008 Nov 15;33(24):2643-7. FINDINGS: Axial plane correction of the unfused minor curve in patients undergoing selective fusions does occur. Significant spontaneous correction of a thoracic rib hump after a selective lumbar fusion should not be anticipated, whereas an approximate 50% reduction in the lumbar prominence was the average after selective thoracic fusions.
5. Miyanji F, Pawelek JB, Van Valin SE, Upasani VV, Newton PO. Is the lumbar modifier useful in surgical decision making?: Defining two distinct Lenke 1A curve patterns. Spine 2008 Nov 1;33(23):2545-51. FINDINGS: Two Lenke 1A curve patterns can be described based on the direction of the L4 tilt. The tilt direction of L4 does allow subdivision of the Lenke 1A curves into 2 distinguishable patterns (1A-R and 1A-L). The 1A-L curves are similar to 1B curves and different in form and treatment from the 1A-R pattern.
6. Newton PO, Upasani VV, Lhamby J, Ugrinow VL, Pawelek JB, Bastrom TP. Surgical treatment of main thoracic scoliosis with thoracoscopic anterior intstrumentation. A five year follow-up study. J Bone Joint Surg Am. 2008 Oct;90(10):2077-89. FINDINGS: Radiographic findings, pulmonary function, and clinical measures remain stable between the 2 and 5 year follow-up timepoints. The 5 year outcomes are similar to those that have been reported for open anterior and posterior approaches.
7. Ritzman TF, Upasani VV, Pawelek JB, Betz RR, Newton PO. Return of shoulder girdle function after anterior versus posterior adolescent idiopathic scoliosis surgery. Spine. 2008 Sep 15;33(20):2228-35. FINDINGS: Approach related differences in shoulder mobility do exist: OASF imparts a significantly greater magnitude and duration of postoperative shoulder dysfunction than do the TASF or PSF approach, however these effects are transient as shoulder function normalized by the 1 yr post-op time point.
8. Yoon SH, Ugrinow VL, Upasani VV, Pawelek JB, Newotn PO. Comparison between 4.0-mm stainless steel and 4.75-mm titanium alloy single-rod spinal instrumentation for anterior thoracoscopic scoliosis surgery. Spine. 2008 Sep 15;33(20):2173-8. FINDINGS: The 4.75 Ti construct resulted in improved maintenance of deformity correction at 2-years postop and a lower incidence of instrumentation related complications. These improved outcomes may be related to mechanical properties of the implant, refined patient selection criteria, and greater experience gained with time.
9. Sponseller PD, Takenaga RK, Newton P, Boachie O, Flynn J, Letko L. Betz R, Bridwell K, Gupta M, Marks M, Bastrom T. The use of traction in the treatment of severe spinal deformity. Spine. 2008 Oct 1;33(21):2305-9. FINDINGS: Retrospective comparison of large curves with and without preoperative traction showed that curve correction, spinal length and complications were similar but vertebral column resection was more commonly employed in the absence of traction.

2009 Published Manuscripts

1. Sponseller PD, Shah SA, Abel MF, Sucato D, Newton PO, Shufflebarger H, Lenke LG, Betz RR, Marks MC, Bastrom T, The Harms Study Group: Scoliosis Surgery in Cerebral Palsy. Differences between unit rod and custom rods. Spine 34(8): 840-844, 2009. FINDINGS: Compared with custom-bent rods, unit rods provided superior correction of pelvic obliquity but were associated with higher transfusion requirements, higher infection rates, more proximal fixation problems, and longer intensive care unit and hospital stays.
2. Sponseller PD, Betz RR, Newton PO, Lenke LG, Lowe TG, Crawford A, Sucato D, Lonner B, Marks MC, Bastrom T, The Harms Study Group: Differences in Curve Behavior after fusion in AIS with Open TRC. Spine 34(8):827-831, 2009. FINDINGS: Patients with scoliosis and OTRC have a greater risk of adding-on proximally and of loss of correction with anterio-only instrumentation; they may also have less predictable lumbar correction from selective thoracic fusion. However, after combined surgery, they have results similar to those of more skeletally mature patients.
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10. Tsutsui S, Pawelek J, Bastrom T, Lenke L, Lowe T, Betz R, Clements D, Newton PO. Dissecting the effects of spinal fusion and deformity magnitude on quality of life in patients with adolescent idiopathic scoliosis. Spine. 2009 Aug 15 ;34(18):E653-8. FINDINGS: Spinal fusion has an isolated negative effect on AIS patient's quality of life (total score) due to a decrease in the activity domain. The overall positive effect of surgery depends on the negative reports and the deformity reduction.
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13. Samdani AF, Ranade A, Sciubba DM, Cahill PJ, Antonacci MD, Clements DH, Betz RR. Accuracy of free-hand placement of thoracic pedicle screws in adolescent idiopathic scoliosis: how much of a difference does surgeon experience make? Eur Spine J. 2009 Oct 29 [Epub ahead of print]. FINDINGS: Pedicle screw breach rates assessed by postoperative CT for surgeons with varying levels of experience were evaluated and found an overall breach rate of 12.5% with a trend toward fewer breaches and less medial breaches for the most experiences surgeons.
14. Lonner BS, Auerbach JD, Estreicher MB, Betz RR, D'Andrea L, Crawford AH, Lenke LG, Lowe TG, Newton PO. Pulmonary function changes following various anterior approaches in the treatment of adolescent idiopathic scoliosis. J Spinal Disord Tech. 2009 Dec;22(8):551-8. FINDINGS: Slight declines in pulmonary function at two-year follow-up were noted in both the Video-Assisted Thoracoscopic Surgery and the thoracotomy approach. No significant diminishment was noted for the thoracoabdominal group.

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2008 SRS / IMAST/NASS ABSTRACT SUBMISSIONS:

The Majority of Initial Coronal Imbalance Following Fusion Surgery for AIS Improves Within Six Months

Asghar, JahanGir; Sciubba, Daniel M.; Samdani, Amer F.; Cahill, Patrick J.; Clements, David H.; Antonacci, M. Darryl; Betz, Randal R.; Harms Study Group

SUMMARY: Review of 296 consecutive patients with AIS undergoing spinal fusion identified individuals with initial postoperative coronal imbalance. Radiographic follow up over 24 months reveals that the majority (95%) of patients will eventually obtain balance spontaneously, and the most marked improvement is noted within the first 6 months postoperatively.

INTRODUCTION: A substantial percentage of patients with AIS who undergo spinal fusion procedures will exhibit coronal imbalance (>2cm) on initial postoperative erect radiographs. Due to the flexibility of non-instrumented segments in this population, it is often assumed that initial coronal imbalance will improve over time. In this study, patients with initial coronal imbalance were followed to assess the natural history of the imbalance and to identify potential factors associated with failure to correct.

METHODS: A retrospective analysis was conducted at a single institution on patients with AIS undergoing spinal fusion from 1998-2005. Patients with radiographic coronal imbalance on initial erect radiographs were identified and serial erect radiographs at 3, 6, 12, and 24 months were evaluated. Parameters collected included: Lenke curve type, Lumbar modifier, fusion levels, stable vertebrae and length of construct, trunk shape analysis, SRS scores, self image scores, and postoperative C7 plumb line to central sacral vertical line (CSVL) distance. Correlation of persistent coronal imbalance with such factors was assessed via logistic regression analysis.

RESULTS: Of 296 patients reviewed for this cohort, 91 patients (30.7%) exhibited coronal imbalance with initial erect radiograph. At 3, 6, 12, and 24 months postoperatively, the number of patients with persistent coronal imbalance fell to 29 (9.7%), 15 (5%), 12 (4.5%), and 14 (4.7%), respectively. Logistic regression analysis revealed no factors associated with failure to return to balance.

CONCLUSION: In patients with AIS undergoing spinal fusion procedures, initial postoperative coronal imbalance (>2cm) improves dramatically, but such improvement plateaus at 6 months, with 5% still persisting.

SIGNIFICANCE: Most patients with AIS undergoing spinal fusion who show initial postoperative coronal imbalance can be expected to spontaneously obtain balance within 6 months. If patients are symptomatic from such imbalance, revision should be considered only after 6 months of observation.

Are Triggered EMG Thresholds Reliable for Assessing Thoracic Pedicle Screw Breach in the Cerebral Palsy Population?

Asghar, JahanGir; Sciubba, Daniel M.; McCarthy, James J.; Samdani, Amer F.; Cahill, Patrick J.; Clements, David H.; Antonacci, M. Darryl; Betz, Randal R.; Harms Study Group

SUMMARY: In a retrospective review of 442 thoracic pedicle screws placed in patients with cerebral palsy (CP), our rate of pedicle screw breach was 11.1%. 79% of medial thoracic pedicle screw breaches triggered at a threshold >6mA with low sensitivity and specificity. Hence, no reliable set of absolute values was identified to delineate pedicle screw placement with triggered EMG.

INTRODUCTION: Pedicle screw fixation has become increasingly common in treating all aspects of spinal deformity, including the neuromuscular spine. However, there has been relatively limited analysis of the accuracy of screw placement in neuromuscular spine deformities. Furthermore, modalities such as triggered EMG thresholds are commonly used to assess intraoperative screw placement with little or no evidence of their efficacy in this population. The purpose of our study is to evaluate the rates of CT breach and their EMG triggered thresholds in relation to postoperative CT-determined placement of pedicle screws in the neuromuscular spine.

METHODS: We reviewed 41 consecutive patients with CP with a total of 442 thoracic screws (T1-T12) placed using the "free hand" technique. All patients had postoperative CT scans. Screws placed in the thoracic spine were evaluated intraoperatively using standardized EMG measurement protocols. Threshold intensities <6mA intraoperatively were considered breached and removed or repositioned (Raynor, Lenke et al). The pedicle screw breach was determined as intraosseous or breached using post-op CT (Kim et al., 2005).

RESULTS: The incidence of thoracic pedicle screw breach on CT scan was 11.3% (50 breaches: 31 lateral and 19 medial). The mean amplitude for an intraosseous pedicle screw was 10.1 mA (range of 4-19 mA). The mean amplitude for a medially breached pedicle screw was 8.9 mA (range 4-15 mA, p=0.24). The mean for a lateral breach was 12.7 mA (range of 5-22, p=0.625). 79% of the screws with medial breaches triggered at a threshold of greater than 6 mA. Sensitivity and specificity of EMG to detect medial breach was 0.57 and 0.6, respectively. No postoperative neurologic complications were noted.

CONCLUSION: In this review, our rate of pedicle screw breach was 11.1%. 79% of medial thoracic pedicle screw breaches triggered at a threshold of > 6mA. No significant differences in triggered thresholds were noted with medial, intra-cortical or lateral breaches.

SIGNIFICANCE: The use intraoperative triggered EMG in CP is limited in its capacity to identify thoracic pedicle screw breach. Furthermore, no reliable set of absolute values exists to delineate pedicle screw placement with triggered EMG.

Surgical Trunk Rotation Correction in Patients with Moderate Thoracic AIS (< 75°): An All Pedicle Screw Construct with Derotation is Better than Thoracoplasty

Asghar, JahanGir; Samdani, Amer F.; Sciubba, Daniel M.; Clements, David H.; Cahill, Patrick J.; Antonacci, M. Darryl; Betz, Randal R.; Harms Study Group

SUMMARY: In a retrospective comparison of the residual rib prominence in patients with direct vertebral body derotation, thoracic curves less than 75° and curve flexibility greater than 50% exhibited a larger percent correction of the rib prominence at two years than a similar group with thoracoplasty.

INTRODUCTION: Thoracoplasty with spinal fusion has been used to treat thoracic rotational deformity associated with AIS. More recently, the use of pedicle screw fixation and the subsequent development of techniques for axial derotation have allowed for correction of the chest wall deformity. To date, no studies have compared the residual rib prominence and percent correction in patients with thoracoplasty (TP) versus all pedicle screw and direct vertebral body derotation (VBR).

METHODS: Our AIS database was reviewed for patients with structural thoracic curves treated with posterior spinal fusion and thoracoplasty with a hybrid hook and screw construct or direct vertebral body derotation with an all pedicle screw construct. Furthermore, for inclusion, they had to have a thoracic Cobb angle of <75° and preoperative and postoperative scoliometer readings. The postoperative scoliometer readings were done at two years. 122 patients met the criteria for the study. There were 68 patients in the VBR group and 54 in the TP group. No statistical difference was noted between the groups for pre-op thoracic curve magnitude, flexibility, or scoliometer reading.

RESULTS: The mean preoperative scoliometer reading was similar between the two groups (TP 18.8; VBR 19.1, p=0.41). The mean postoperative scoliometer reading was similar between the two groups (TP 7.25; VBR 6.15; p=0.29). However, the percent correction showed a trend toward statistical significance difference with 61.4% correction in TP group and a 67.8% in the VBR group (P=0.14). Moreover, when comparing the subgroup (VBR: n=27, TP: n=19) of patients with a curve magnitude less than 75° and thoracic curve flexibility of greater than 50%, the percent correction of the rib prominence showed a significant difference, with 67.2% correction in the TP group and 80% in the VBR group (P=0.047).

CONCLUSION: At two years, for all curves the percent corrections between the VBR and TP groups in correcting rib prominence are statistically similar. However, those whose thoracic curves had flexibility greater than 50%, the percent correction of the rib prominence was statistically greater in the vertebral body derotation group.

SIGNIFICANCE: This data suggests a thoracoplasty is rarely needed in patients with AIS with curves less than 75°.

The Interobserver and Intraobserver Reliability of Assessing Thoracic Pedicle Screw Position Based on Computed Tomography

Asghar, JahanGir; Ranade, Ashish; Cahill, Patrick J.; Samdani, Amer F.; Clements, David H.; Antonacci, M. Darryl; Betz, Randal R.

SUMMARY: In a review of 20 patients with AIS and a postoperative CT to assess pedicle screw breach, there was poor interobserver reliability with moderate intrarelater reliability of the Kim et al. definition for pedicle screw breach. This may call into question the efficacy of these criteria.

INTRODUCTION: Wide variations in the literature exist when assessing the accuracy of pedicle screw placement. Suk et al. reported an incidence as low as 0.6% and in other reports it has been reported as high as 43%. This wide variation may be due to several factors, one of which is the potential surgeon variation in assessing pedicle screw placement based on imaging modality. The purpose of our study is to evaluate the intra- and interobserver reliability of assessing pedicle screw breach based on CT, as described by Kim et al.

METHODS: The postoperative CT scans of 20 patients with AIS were independently assessed by two spine surgeons and a spine fellow using the PACS system. Each reviewer had a diagrammed copy of the Kim et al. definition of a breached and acceptable screw. Kappa statistics were used to evaluate interobserver reliability. The results of intrarater and interrater reliability were assessed by using k statistical analysis, with results classified as poor (0–.50), moderate (.51–.75), or excellent (>.75).

RESULTS: 332 pedicle screws were evaluated by the 3 reviewers, with a mean breach rate of 12.2%. Although the intraobserver reliability was moderate (kappa = 0.52), the mean kappa score (kappa = 0.38) for interobserver agreement exhibited a poor degree of agreement. When looking at thoracic (kappa=0.36) and lumbar screws (kappa=0.40), the lumbar screw had a slightly higher degree of agreement. However, overall, the intraobserver reliability was relatively poor.

CONCLUSION: The intraobserver reliability of assessing pedicle screw breach as defined by Kim et al. is relatively poor. CT scan is widely used to assess pedicle screw placement. Accurate measurement of pedicle screw breach is required to evaluate new technologies which assist in pedicle screw placement and, more importantly, determine when to remove a screw.

SIGNIFICANCE: Current methods for evaluating pedicle screw breach based on CT have poor agreement between independent observers. This may call into question the efficacy of these criteria.

Surgical Trunk Rotation Correction in Patients with Moderate Thoracic AIS (< 75°): An All Pedicle Screw Construct with Derotation is Better than Thoracoplasty

Asghar, JahanGir; Samdani, Amer F.; Sciubba, Daniel M.; Clements, David H.; Cahill, Patrick J.; Antonacci, M. Darryl; Betz, Randal R.; Harms Study Group

SUMMARY: In a retrospective comparison of the residual rib prominence in patients with direct vertebral body derotation, thoracic curves less than 75° and curve flexibility greater than 50% exhibited a larger percent correction of the rib prominence at two years than a similar group with thoracoplasty.

INTRODUCTION: Thoracoplasty with spinal fusion has been used to treat thoracic rotational deformity associated with AIS. More recently, the use of pedicle screw fixation and the subsequent development of techniques for axial derotation have allowed for correction of the chest wall deformity. To date, no studies have compared the residual rib prominence and percent correction in patients with thoracoplasty (TP) versus all pedicle screw and direct vertebral body derotation (VBR).

METHODS: Our AIS database was reviewed for patients with structural thoracic curves treated with posterior spinal fusion and thoracoplasty with a hybrid hook and screw construct or direct vertebral body derotation with an all pedicle screw construct. Furthermore, for inclusion, they had to have a thoracic Cobb angle of <75° and preoperative and postoperative scoliometer readings. The postoperative scoliometer readings were done at two years. 122 patients met the criteria for the study. There were 68 patients in the VBR group and 54 in the TP group. No statistical difference was noted between the groups for pre-op thoracic curve magnitude, flexibility, or scoliometer reading.

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CONCLUSION: At two years, for all curves the percent corrections between the VBR and TP groups in correcting rib prominence are statistically similar. However, those whose thoracic curves had flexibility greater than 50%, the percent correction of the rib prominence was statistically greater in the vertebral body derotation group.

SIGNIFICANCE: This data suggests a thoracoplasty is rarely needed in patients with AIS with curves less than 75°.

The Effect of Implant Density on the Sagittal Curve in Scoliosis Correction: Correlation with the Number and Type of Fixation Anchors

Clements, David H.; Betz, Randal R.; Newton, Peter O.; Marks, Michelle C.; Bastrom, Tracey P.; Harms Study Group

SUMMARY: An analysis of the effect of increasing implant density (number of implant sites utilized compared to the number of available implant sites)on the two year postoperative sagittal contour in AIS patients.The higher the implant density within the major thoracic coronal curve, the flatter or less kyphotic the postop sagittal contour became.

INTRODUCTION: Controversy exists regarding the number and type of spinal anchors needed to achieve optimal structural curve correction in adolescent idiopathic scoliosis (AIS). The purpose of this study was to determine how "implant density" effected the postoperative sagittal contour at 2 years in patients with AIS.

METHODS: An analysis of 360 AIS patients treated with posterior instrumentation and having greater than 2 year follow-up was performed. The sagittal curve change was measured T5-T12, T2-T12, T10-L2 and expressed as absolute change (from pre-op to 2 years post-op) and correlated with the percentage of available implant sites utilized within the measured curve (implant density, max 2 per level). The correlation of kyphosis change to the number of hooks, wires, and screws was also performed. Analysis of variance was used to evaluate change in kyphosis among all screw constructs, hybrids, and all hook constructs.

RESULTS: The higher the implant density within the curve, the greater the loss of preoperative to postoperative kyphosis. This result was significant for kyphosis measured T2-12 ($r= -0.13$, $p<0.01$), and T5-12 ($r= -0.16$, $p<0.001$). At T10-L2, increasing screw implant density correlated with decreasing kyphosis ($r= -0.40$, $p<0.001$), and increasing hook implant density correlated with increasing kyphosis ($r= 0.33$, $p<0.001$). On average, all hook constructs increased kyphosis T5-T12 by $2^\circ \pm 9^\circ$, which was significantly different than the average decrease seen in hybrids ($-4.3^\circ \pm 13^\circ$, $p=0.039$). No significant differences were observed for the screw constructs ($-3.8^\circ \pm 12^\circ$). A significant increase in kyphosis from T10-L2 was seen in hook constructs ($10^\circ \pm 15^\circ$) compared to decreases seen in hybrid ($-0.59^\circ \pm 15^\circ$, $p<0.001$) and all screw constructs ($-3^\circ \pm 11^\circ$, $p<0.001$).

CONCLUSION: The higher the implant density within the major thoracic curve, the flatter or less kyphotic the sagittal contour became at 2 years postoperatively measured from T5-12 or T2-12. At T10-L2, the sagittal contour became more kyphotic with more hooks and less kyphotic with more screws. This effect on sagittal contour should be considered in patients when surgical decisions concerning type, density of implants, and adjustments to rod contouring are made.

Use of the Double Rib Contour Sign to Determine Rib Hump Correction Following Scoliosis Surgery

Crawford, Alvin; Alfawereh, Mohammad; Lonner, Baron; Betz, Randal R.; D'Andrea, Linda P.; Guille, James T.; Samdani, Amer F.

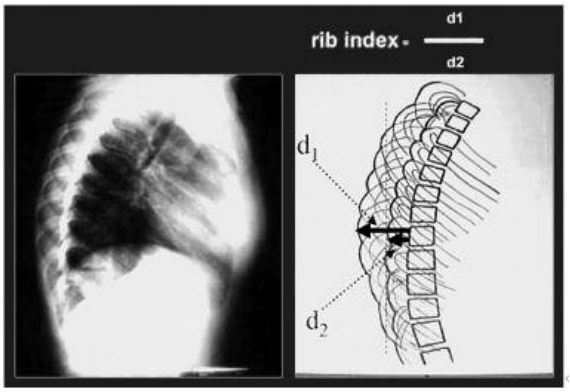
SUMMARY: The addition of costoplasty to fusion surgeries for Adolescent Idiopathic Scoliosis improves the correction of the trunk deformity (rib hump).

INTRODUCTION: Trunk deformity is comprised of vertebral rotation, posterior vertebral element and rib deformities. Surgical correction of the rotational deformity has been attempted by segmental spinal instrumentation with vertebral derotation. However, complete correction of the rib hump by derotation is controversial and rarely achieved. The purpose of this study was to determine whether costoplasty improved the correction of the rib hump .For a symmetric thorax, RI=1, with higher values indicating greater deformity.

METHODS: A multicenter registry for adolescence idiopathic scoliosis was reviewed. Inclusion criteria were AIS Lenke type I curves treated with posterior spinal fusion and instrumentation, with pedicle screws or hybrid construct, with or without costoplasty, and >2 year follow-up time. Group H+C received a hybrid construct and costoplasty; group PS-C, received pedicle screws and no costoplasty, and group PS+C received pedicle screws and costoplasty. Double rib contour sign by rib index (RI)(Fig © 2007 Grivas et al; licensee BioMed Central Ltd.) and Cobb angle were measured radiographically and both compared using ANOVA and t-test.

RESULTS: For H+C, PS-C, and PS+C, respectively mean pre-op RI (± sd) were 1.72 (±0.17), 1.61 (± 0.19), and 1.80 (± 0.30); post-op RI: 1.27(± 0.10), 1.39(± 0.13), and1.29 (±0.11). Differences in post-op, but not pre-op, RI were significant between groups ($p < 0.0001$). Further, differences between the pedicle screw constructs with or without costoplasty, were statically significant ($p< 0.0006$). There were no differences between groups in preoperative or postoperative Cobb angles.

CONCLUSION: The addition of costoplasy to the posterior spinal fusion significantly reduced trunk deformity and improved the correction of the rib hump in Adolescent Idiopathic Scoliosis.



The Role of Tranexamic Acid and Increased Bovie Setting in Blood Loss and Transfusions During Posterior Spinal Fusions for Adolescent Idiopathic Scoliosis

Crawford, Alvin; Antekeier, Shannon B.; Aronson, Lori; O'Brien, Michael; Shufflebarger, Harry L.; Shah, Suken A.

SUMMARY: TXA and an increased Bovie setting can significantly decrease intraoperative blood loss in posterior spinal fusions.

INTRODUCTION: Intraoperative blood loss in scoliosis surgery often requires transfusions. Autogenous blood decreases but does not eliminate risks typically associated with allogenic blood transfusion. Costs associated with transfusions are significant. Tranexamic acid (TXA) is a synthetic antifibrolytic agent. TXA has been shown to decrease blood loss in cardiac and total joint surgeries, but few studies have examined its use in pediatric spine surgery. Bovie use during spinal surgery has been studied and is not associated with increased infections, but its role on blood loss has not been examined. The objective of this study was to determine whether TXA and an increased Bovie setting decrease intraoperative blood loss and transfusion requirements in adolescent idiopathic scoliosis patients undergoing posterior spinal fusion.

METHODS: Three groups of 25 patients drawn from a multi-center adolescent idiopathic scoliosis database were retrospectively compared. Group A received TXA and was operated on by the senior surgeon with the Bovie set at 60. Groups B and C did not receive TXA and were matched to Group A for number of levels fused and curve type. Group B included multiple surgeons, while Group C was composed solely of patients operated on by the senior surgeon with the Bovie set at 30. Differences were determined by ANOVA ($p = 0.05$).

RESULTS: Blood loss was significantly decreased in the TXA/increased Bovie group (Group A: Mean 529 $\pm$ 318; B: 946 $\pm$ 743, C: 1263$\pm$ 876 ml; ($p=0.003$). Transfusion volumes, although decreased in the TXA/increased Bovie group, were not significantly decreased (Group A: Mean 491 $\pm$ 257; B: 530 $\pm$ 795, C: 720$\pm$ 547 ml; ($p=0.330$).

CONCLUSION: TXA and an increased Bovie setting significantly decreased intraoperative blood loss in posterior spinal fusions performed for adolescent idiopathic scoliosis. TXA and an increased Bovie setting did not significantly decrease the volume of intraoperatively transfused blood. Limitations include the dissections performed are the same among the groups, but the constructs and anesthesiology philosophy varied. The effect of these variables is unknown.

Trunk Flexibility and Activity/Function are Significantly Less with Lumbar Fusion in Patients with Lenke 1&2 Curve Types

D'Andrea, Linda P.; Guille, James T.; Letko, Lynn; Newton, Peter O.; Lonner, Baron; Crawford, Alvin; Betz, Randal R.

SUMMARY: There is a statistically significant reduction, as much as 21%, in trunk flexibility, activity & function with fusion to L1 & below versus T12 & above in AIS patients with Lenke 1&2 curve types.

INTRODUCTION: It has not been demonstrated that spinal fusion below T12 would result in a loss of trunk flexibility. Maintaining trunk flexibility after scoliosis fusion surgery is an important goal for some patients. The purpose of this study was to evaluate this preop to postop change in trunk flexibility, and clinical outcomes as measured by SRS domain scores.

METHODS: Prospectively collected data for 196 AIS patients with Lenke 1&2 curve was evaluated. Patients were separated into two groups based on the lowest instrumented vertebra (LIV) of fusion: T12 & above (N= 101) [T8 N=1, T9 N=1, T10 N=4, T11 N=29, T12 N=66], or L1 & below (N= 95) [L1 N=37, L2 N=28, L3 N=22, L4 N=8]. Two year post-operative trunk flexibility (represented as a percent of the pre-operative baseline value) was compared between the LIV groups. Clinical measurements included: thoracolumbar flexion & extension; right & left lateral bending; right & left trunk rotation. The two groups were also analyzed for differences in SRS questionnaire domains & total score preop & at 2 years.

RESULTS: Patients fused T12 & above maintained a much higher percentage of preoperative flexibility in all clinical measures except for right trunk rotation as compared to those fused L1 & below (Table 1). This is most significant with 21% more trunk extension, 11.3% greater flexion, & 13.7% greater left lateral flexion in patients fused T12 or higher. Patients fused T12 or higher reported higher general activity scores (4.77$\pm$ 0.37) compared to the L1 & below group (4.61 $\pm$ 0.55, p=0.015). They also reported increased function after surgery (3.33 $\pm$ 0.84) compared to the L1 & below patients (3.02 $\pm$ 1.14, p=0.036).

CONCLUSION: While it has been shown that longer fusions may yield increased correction in the coronal plane, these findings show that fusion to T12 & higher, maintains a much greater percentage of preoperative trunk flexibility. This is clinically and statistically significant when compared to patients fused to L1 & below for Lenke 1&2 curves. Careful evaluation of surgical goals (radiographic superiority vs. motion/function preservation) must be considered for each individual patient.

SIGNIFICANCE: A significant loss of trunk flexibility results from fusion to L1 & below in patients with Lenke 1&2 curve types.

Table 1. Two-year Postoperative Clinical Measures of Trunk Flexibility represented as a percent of the pre-operative baseline value

CLINICAL MEASURE OF TRUNK FLEXIBILITY	LIV T12 & ABOVE MEAN (STD DEV)	LIV L1 & BELOW MEAN (STD DEV)	P-VALUE
Flexion	90.09 (24.21)	78.83 (30.39)	**0.007**
Extension	86.71 (32.88)	65.72 (37.04)	**<0.001**
Right Lateral Flexion	87.60 (19.11)	80.60 (27.32)	**0.046**
Left Lateral Flexion	85.61 (21.93)	71.89 (22.66)	**<0.001**
Right Rotation	92.38 (24.02)	87.67 (23.93)	0.182
Left Rotation	93.18 (25.11)	84.67 (23.55)	**0.017**

"Don't End Your Fusion at T12 in Idiopathic Scoliosis": Wisdom or Myth?

John Flynn, Tracey Bastrom, Peter Newton, Lawrence Lenke, Alvin Crawford, Thomas Lowe, Randall Betz, David Clements, Baron Lonner, Michelle Marks, and the Harms Study Group

SUMMARY: When T12 is the LIV, curve correction is less and there are more problems with progressive kyphosis and DJK. Risk is lower when the distal anchor is a pedicle screw, rather than a hook.

INTRODUCTION: The 12th thoracic vertebra has unique facet anatomy, representing a transition between the more rigid thoracic spine and the more flexible lumbar spine. According to conventional wisdom, instrumented posterior fusions ending at T12 have a higher risk of post-operative problems. Is this true? Has it changed now that the distal anchor is typically a pedicle screw?

METHODS: From a multi-center AIS database, we identified every Lenke 1 or 2 PSF, min. 2 yr f/u, in which the last instrumented vertebra (LIV) was T10, T11, T12 or L1. 3 groups (above: T10/11, junction: T12 and below: L1) were analyzed.

RESULTS: 159 cases had 2 yr f/u. See Table. Thoracic curve correction was sig. better when the LIV was L1 v. T12 (p=0.001), despite the pre-op Cobb being sig. larger in the L1 cohort (p=0.03). The change in T10-L2 kyphosis was sig. greater with T12 as the LIV (p=0.026). Repeated measures ANOVA revealed a sig. difference in distal junctional kyphosis (DJK) between the three groups (p=0.04): fusion at all levels was kyphogenic at first f/u; however, with an LIV at T10/T11 or L1, kyphosis decreased or stabilized over 2 yrs, while cases fused to T12 became more kyphotic. At 2 yrs, a higher % of cases were >2cm out of coronal balance when the LIV was thoracic (did not reach significance). When the LIV was T12, anchor choice significantly mitigated the risk of DJK (hook 8° v. screw 4°, p=0.048) and disc angulation (p=0.023). There was no sig. difference in instrument-related complications or re-operation.

CONCLUSION: This data supports conventional wisdom: in Lenke 1 or 2 curves, choosing an LIV of L1, rather than T12, results in less DJK, less T10-L2 kyphosis, better correction of Cobb angle, and perhaps a lower likelihood of poor coronal balance at 2 years post-op. Using screws rather than hooks as the most distal anchor may mitigate some of this risk.

SIGNIFICANCE: When planning a fusion for AIS, choosing T12 as the LIV carries risks that should be balanced against other factors.

		THORACIC CURVE		T10-L2 KYPHOSIS		DJK		PERCENT THAT WERE >2cm OUT OF CORONAL BALANCE 2 YRS POST-OP
LIV	# OF PATIENTS	PRE-OP	2 YRS POST-OP	PRE-OP	2 YRS POST-OP	PRE-OP	2 YRS POST-OF	
T10 / T11	19	52°	21°	-4°	3°	0°	4°	26.3%
T12	50	50°	23°	0°	8°	0°	5°	20.0%
L1	90	55°	20°	-2°	2°	-3°	0°	11.1%

Factors Involved in the Decision to Perform a Selective versus Nonselective Fusion of Lenke 5 Curves in Adolescent Idiopathic Scoliosis

Guille, James T.; D'Andrea, Linda P.; Abel, Mark F.; Bastrom, Tracey P.; Betz, Randal R.; Newton, Peter O.; Crawford, Alvin

SUMMARY: Surgeons tended to perform nonselective fusion (NSF) in patients with overall larger Cobb magnitudes, larger thoracic rib humps, and greater thoracic apical translations.

INTRODUCTION: Most patients with Lenke 5 curves can be treated successfully with selective fusion of the lumbar curve alone. We wanted to know in what instances did surgeons not adhere to the guidelines set forth by Lenke et al. and proceed to fuse both the thoracic and lumbar curves.

METHODS: We reviewed the radiographs and records of 109 patients with Lenke 5 curves from a prospectively collected data base. Eighty-four patients (77%) had a selective fusion (SF) of the primary thoracolumbar/lumbar TL/L, whereas 25 patients (23%) had fusion of the thoracic curves as well as the TL/L curve. Mean preoperative sagittal parameters did not statistically differ between the two groups, nor did skeletal maturity or mean age at the time of operation (15.1 vs. 15.5 years).

RESULTS: The mean preoperative PT/MT/L Cobb angles for the NSF group were significantly larger than in the SF group (11/37/51 degrees vs. 7/25/46 degrees ($p<0.001$). The mean thoracic rib hump was significantly larger in the NSF group versus the SF group (9.2 in the NSF group and 4.7 in the SF group) ($p<0.001$). Mean preoperative thoracic apical translation was greater in the NSF group (NSF = 0.47, SF = -0.46) and approached statistical significance. The NSF group had a mean of twice as many levels fused than the SF group (12 vs. 5 levels) ($p<0.001$). Twelve percent of the SF patients were fused to L4 versus 52% of the NSF patients ($p<0.001$). At two years, the % correction of the lumbar Cobb angle was similar, but the % correction of the thoracic curve in the NSF group (63%) was significantly better than the SF group (35%) ($p<0.001$). SRS scores at 2-year-follow-up were similar, except that the NSF group reported less function than the SF group ($p<0.02$).

CONCLUSION: Surgeons tended to break the rules of the Lenke et al. classification and fused both the thoracic and thoracolumbar/lumbar curves in patients with larger curve magnitudes, large thoracic rib humps, and greater thoracic apical translations.

SIGNIFICANCE: Surgeons tended to fuse both curves when the overall thoracic deformity was considered large. The results of doing such was not shown to be superior to fusion of the lumbar curve alone.

Does the Occurrence of Postoperative Complications Adversely Affect SRS Scores?

Guille, James T.; D'Andrea, Linda P.; Petcharaporn, Maty; Bastrom, Tracey P.; Newton, Peter O.

SUMMARY: Patients who experience a major complication following surgery for adolescent idiopathic scoliosis (AIS) have significantly lower SRS scores at 2-year follow-up than patients without complications.

INTRODUCTION: We wanted to test our hypothesis that patients who incurred a postoperative complication after corrective AIS surgery would have lower SRS scores 2 years after surgery than patients who did not have a complication.

METHODS: We reviewed the complication data on 323 patients with AIS who had been followed for a minimum of 2 years and had a complete chart review. Patients were placed into 3 groups: those with a major complication, those with a minor complication, or neither. Major complications included severe medical conditions (e.g., pulmonary embolism), neurologic problems, deep infections, and problems requiring reoperation. Minor complications included easily treated medical conditions (e.g., ileus, atelectasis), instrumentation failures not requiring revision, and superficial wound problems.

RESULTS: Sixteen patients (5%) had a major complication, 56 (17%) had a minor complication, and 251 (78%) had no complications. Mean age at operation was 15 years and was not significantly different amongst the groups. Interestingly, and without explanation, the patients with no complications had significantly higher preoperative function scores ($p<0.001$) than the other two groups. Otherwise, there were no significant differences in the preoperative domains of pain, self-image, activity, or total scores for all groups. There was no significant difference in the final Cobb magnitude amongst the groups. At 2-year follow-up, the patients with a major complication had significantly lower reported self-image ($p<0.03$) and activity ($p<0.02$) scores than patients with no complications. This difference was also seen when compared with patients who had a minor complication and approached statistical significance ($p<0.07$ and $p<0.09$, respectively).

CONCLUSION: In future outcome studies on the operative treatment of AIS, the occurrence of a major postoperative complication needs to be taken into consideration, as it may adversely skew the results of the SRS scores of an otherwise successful procedure.

SIGNIFICANCE: The occurrence of a major postoperative complication significantly decreases SRS scores.

The Role of Halo Extension in the Treatment of AIS

Jensen, Rubens; Harms, Jurgen; Daye, Aziz; Letko, Lynn

SUMMARY: Retrospective single center study of 20 patients with severe (>80°) or rigid (flexibility <35%) AIS treated pre-operatively with halo traction and instrumented with thoracic pedicle screws compared to a multicenter matched control group treated without traction and hybrid instrumentation.

INTRODUCTION: The results of halo traction in spinal deformities is well documented. The literature regarding its use in AIS is scant. This study assesses the degree of correction achieved by halo traction in AIS curves and the effect on final correction.

METHODS: Retrospective review of 40 patients with AIS, minimum 2 year follow-up, who underwent spinal fusion. 20 halo traction patients had a mean age at surgery 16+7 yrs (11+8-24+3). 1 surgery was required in 8 patients. 12 patients required staged surgeries. The mean age of the 20 non-halo patients was 13+11 yrs (10+10-19+2). 1 surgery was required in 12 patients; staged surgeries in 8 patients. X-rays pre-op, in traction, post-op and at last follow-up were reviewed.

RESULTS: Pre-operative halo traction (n=18) time was 50 days (16-104). Between surgeries, (n=12) it was 29 days (18-40). The major curve Cobb angle improved 31% (SD: 14, range: 0-53) with halo traction. The degree of correction achieved with halo traction, compared with the pre-op bending flexibility, was slightly more 31% vs. 23% (p= 0.036). In halo group, the mean major curve was 83° (SD: 10°, range 63°-110°). This was significantly larger than the non-halo group: 72° (SD: 13°, range: 45°-89°)

(p= 0.003). Halo group mean flexibility was 23% (SD: 13%, range 0-47%). This was not significantly different from the non-halo: 32% (SD: 18%, range: 0-69%) (p= 0.09). The percentage post-operative mean major curve correction was significantly more in halo group: 84% (SD: 10%, range: 63-100%) vs the non-halo group: 63% (SD: 16%, range: 22-85%) (p=0.001). Two minor halo pin complications occurred. Both resolved with pin exchange.

CONCLUSION: Halo traction is a safe, well tolerated method, to allow for gradual curve reduction in an awake patient. Preoperative halo traction allowed posterior only surgery in 5 cases. When compared to the non-halo group, a greater final curve correction was achieved; however, the surgical results are aided by but not accomplished by the halo traction alone. The primary disadvantage to halo traction is length of hospitalization.

SIGNIFICANCE: Halo traction is a safe and effective adjuvant modality in the treatment of AIS.

One Size Does Not Fit All: Variations in Pelvic and Other Sagittal Parameters as a Function of Race in AIS

Baron Lonner, M.D., Joshua Auerbach, M.D., Paul Sponseller, Michael O'Brien, Peter Newton, M.D.

SUMMARY: Differences in pelvic parameters and lumbar lordosis were found in this AIS population between Black and White races.

INTRODUCTION: Increasingly, the importance of spinopelvic alignment and balance is appreciated as a major factor in the energy-efficient posture of the individual in the normal and diseased states. Pelvic incidence determines the lordosis of the patient and equations defining the interplay of pelvic parameters, lordosis, and kyphosis have been developed to guide surgical decision-making for spinal deformity. Pelvic incidence and thoracic lordosis have been previously shown to be increased in the AIS population. Racial differences of these measurements in this patient group have not been evaluated and is the purpose of this study.

METHODS: Data on pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis, thoracic kyphosis, and global sagittal balance were obtained from a multicenter AIS database. The two racial groups, caucasian and black were compared. Anova was used to compare differences in the pelvic and sagittal measures between groups.

RESULTS: There were 421 White and 115 Black patients evaluated. The average major curve Cobb angles were similar (White: 56 deg, Black: 57 deg) The pelvic incidence was significantly greater for the Black patients, as was the pelvic tilt and lumbar lordosis.

CONCLUSIONS: Differences in pelvic parameters and lumbar lordosis were found in this AIS population between Black and White races. There were insufficient numbers of patients of other races in the database to make other comparisons. The differences in these measures are small although statistically significant. The surgeon should take into account the individual's inherent sagittal alignment when reconstructing the spine in the scoliotic patient, particularly in the lumbar spine. Greater pelvic incidence requires greater lumbar lordosis.

	PELVIC INCIDENCE*	PELVIC TILT*	SACRAL SLOPE	LORDOSIS*	KYPHOSIS	C7-CSVL
Black (115)	**56.0**	**13.9**	42.5	**-63.6**	24.7	-0.2
White (421)	**52.5**	**10.8**	42.2	**-59.1**	22.9	-0.6

*Significant difference $p<0.05$

Multivariate Analysis of Factors Associated with Kyphosis Maintenance in AIS Surgery

Lonner, Baron; Shah, Suken A.; Bastrom, Tracey P.; Auerbach, Joshua D.; Sponseller, Paul D.; O'Brien, Michael; Newton, Peter O.

SUMMARY: Kyphosis maintenance or restoration is an important goal of AIS surgery. In a multivariate analysis we noted anterior approach and lesser magnitude of kyphosis preoperatively were associated with greater increases in kyphosis and longer fusions were associated with loss of kyphosis.

INTRODUCTION: Sagittal contour of the thoracic spine following surgery for AIS may have implications for long-term health of proximal and distal junctional spinal segments. The use of segmental pedicle screw instrumentation has called into question the ability to restore or maintain thoracic kyphosis. The purpose of this study was to analyze factors associated with kyphosis restoration in AIS surgery.

METHODS: Data from a multicenter AIS database was analyzed. Lenke 1 and 2 curve types with a minimum 2-year follow-up were evaluated. Multivariate analysis included assessment of approach, anchor type/density, rod diameter, metal type, pre-operative coronal curve magnitude, and pre-operative thoracic kyphosis (T5-12) seeking factors associated with an increase in post-op kyphosis. Of 511 patients identified, 307 that had kyphosis less than the mean kyphosis (25deg) for the whole group were analyzed so as to evaluate patients in whom the desired goal was to increase kyphosis. Correlation and multivariate linear stepwise regression were performed.

RESULTS: 84% of curves were Lenke 1 and 16% were Lenke 2. 56% of surgeries were anterior approaches and 44% were posterior (20 PSF with releases).

Factors associated with increasing kyphosis were lower pre-operative kyphosis $R2 = 0.18$, $p<0.001$, and anterior approach $R2 = 0.014$, $p=0.012$. Increasing levels fused resulted in a hypokyphosing effect ($R2 = 0.15$, $p=0.005$) with this effect being greater for the posterior approach and being approximately a 1deg loss of kyphosis for every level fused. Increasing anchor density had a trend towards decreasing kyphosis. Junctional kyphosis was not significantly impacted by changes in T5-12 kyphosis.

CONCLUSION: The greatest predictor of change in kyphosis was pre-operative kyphosis magnitude: for patients with kyphosis less than 25deg, the less the kyphosis magnitude, the greater the increase found which may be reflective of the surgical goals. Regardless of pre-operative status, this study shows that posterior approaches and longer fusions lead to reduced kyphosis. Anterior approaches lead to increased kyphosis. A trend of decreased kyphosis with increased numbers of screws or hooks utilized was also noted.

SIGNIFICANCE: Factors associated with improvements in kyphosis were found.

	MEAN	STANDARD DEVIATION
Age at surgery	14.2	1.9
Pre T5 to T12	14.4	6.9
Pre Thoracic Curve	52.4	10.2
2-year thoracic curve	20.1	8.9
% thoracic correction	64%	16%

Selection of the Upper Instrumented Vertebra in the Surgical Treatment of Adolescent Idiopathic Scoliosis: Identification of the Most Influential Determinants

Upasani, Vidyadhar V.; Newton, Peter O.; Pawelek, Jeff B.; Bastrom, Tracey P.; Shufflebarger, Harry L.; Sponseller, Paul D.; Lonner, Baron; Shah, Suken A.; Harms Study Group

SUMMARY: The three most influential determinants when selecting the upper instrumented vertebra in the surgical treatment of adolescent idiopathic scoliosis are the coronal proximal thoracic curve magnitude, T1 tilt, and T5 to T12 kyphosis. A proximal thoracic curve magnitude $\geq$ 25° differentiates between patients treated from T1-T3 versus T4-T5.

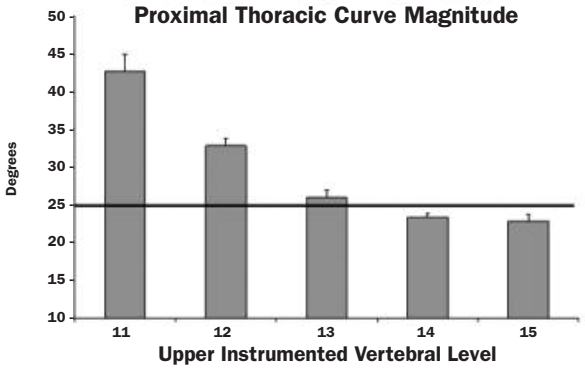
INTRODUCTION: Although the Lenke classification system recommends fusion of minor structural proximal thoracic curves (side bending Cobb $\geq$ 25° or T2-T5 kyphosis $\geq$ 20°); controversy remains over selection of the upper instrumented vertebra (UIV). The purpose of this study was to determine which pre-op variables most strongly influence UIV selection in adolescent idiopathic scoliosis (AIS).

METHODS: A multi-center retrospective analysis of pre-op radiographic and clinical data of AIS patients treated with a posterior spinal fusion (PSF) was performed. Inclusion criteria were: surgical treatment after 2001, UIV from T1 to T5, and a main thoracic apex from the T6/7 disc to the T9/10 disc. Patients were arbitrarily divided into two groups based on UIV (T1-T3 versus T4-T5). Chi-Square, Spearman's correlation, and regression analyses ($p<0.05$) were used to identify the most important independent determinants of UIV.

RESULTS: 473 patients (380 F, age: 15±2 years) treated at one of 10 centers were included in this study. Three radiographic measures were found to be significant predictors of the chosen UIV: proximal thoracic curve magnitude ($R2=0.20$, $p<0.001$), T1 tilt ($R2=0.03$, $p<0.001$), and T5 to T12 kyphosis ($R2=0.02$, $p<0.001$); together accounting for just 25% of the variance in UIV selection. A significantly greater number of patients fused to T1-T3 had a proximal thoracic best bend $\geq$ 25° ($p<0.001$); however this variable was not found to be a significant determinant of UIV ($p=0.10$). Of note, T2 to T5 kyphosis ($\geq$ 20°) also did not significantly influence UIV selection ($p=0.15$).

CONCLUSION: Selection of the UIV is dependent on multiple variables; the three most influential were identified in this study. A greater proximal thoracic curve magnitude, T1 tilt, and T5 to T12 kyphosis correlated with a more proximal UIV. Although a proximal thoracic curve magnitude $\geq$ 25° differentiated between patients treated from T1-T3 versus T4-T5 (Fig 1), this x-ray measure only accounted for 20% of the variability in how surgeons chose the UIV. Many curves greater than 25°, independent of side bending flexibility, were instrumented into the upper thoracic spine.

Figure 1: Distribution of proximal thoracic curve magnitude (degrees) according to the chosen UTV (Average ± SEM).



Risk Factors for Distal Adding-on Identified: What to Watch Out For

Schlechter, John1 Newton, Peter O.; Upasani, Vidyadhar V.; Yaszay, Burt1; Lenke, Lawrence G.; Betz, Randal R.; Lowe, Thomas; Harms Study Group

SUMMARY: A retrospective analysis of 407 adolescent idiopathic scoliosis patients with minimum 2-yr follow-up found that the pre-operative factors associated with "adding on" included: less mature patients, and choosing a lowest instrumented vertebra too proximal to the stable vertebra and deviated too far from the center sacral vertical line.

INTRODUCTION: Considerable research has focused on the selection of fusion levels in the surgical treatment of adolescent idiopathic scoliosis (AIS); however selecting the lowest instrumented vertebra (LIV) continues to be controversial. In some cases, the scoliosis "adds- on" post-operatively (distal primary curve extension). The purpose of this study was to identify the pre-operative curve characteristics that predispose a spinal fusion to add-on.

METHODS: A multi-center, retrospective analysis of pre-op, first-erect, and 2-year post-op radiographs and clinical data was performed. Inclusion criteria were: AIS patients with a Lenke type 1 spinal deformity, minimum 2-year follow-up, and a LIV of L2 or proximal. Distal adding-on was defined as progression of the primary Cobb below the level of instrumentation due to either an increase in the number of vertebra included within the Cobb, or an increase in disc angulation distal to the instrumentation. Spearman's correlation and logistic regression analyses ($p<0.05$) were used to identify pre-op variables associated with adding-on. ANOVA ($p<0.05$) was used to compare 2-yr radiographic data between patients who experienced adding-on, and those who did not.

RESULTS: 52 out of 407 patients reviewed (13%) met the definition for adding-on at 2-years post-op, and experienced a significantly greater change in thoracic Cobb from first erect ($7.4^\circ \pm 8.8^\circ$ vs. $3.6^\circ \pm 5.5^\circ$; $p<0.001$). 5 pre-operative variables were found to be significant independent predictors of adding-on: age ($p=0.04$), Risser stage ($p=0.02$), weight ($p=0.03$), lowest instrumented vertebra (LIV) translation from the center sacral vertical line (CSVL) ($p\leq0.001$), and the number of levels between the stable vertebra and LIV ($p=0.03$) (Table 1).

CONCLUSION: Less mature patients (younger chronologic age, lower Risser stage, and lower weight) are more likely to experience adding on. In addition, when the LIV is more proximal and with greater deviation from the CSVL the chance of adding on also increases. When in doubt, including an extra distal level in the fusion may reduce the risk of adding on especially in younger patients.

Table 1: Pre-operative variables found to correlate significantly with adding-on.

	ADDING-ON	NO ADDING-ON	CORRELATION
Age	14±2 years	15±2 years	r=0.13 (p=0.01)
Risser Stage	2±2	3±2	r=0.16 (p≤0.001)
Weight	48±10 kg	53±12 kg	r=0.14 (p=0.01)
LIV to CSVL	2.1±1.6 cm	1.5±1.0 cm	r=0.18 (p≤0.001)
Stable to LIV	2±2 vertebral levels	1±2 vertebral levels	r=0.19 (p≤0.001)

Increase Patient Satisfaction after Fusion for Adolescent Idiopathic Scoliosis by Minimizing the Deformity-Flexibility Quotient!

Upasani, Vidyadhar V.; Newton, Peter O.; Pawelek, Jeff B.; Bastrom, Tracey P.; Lenke, Lawrence G.; Lowe, Thomas; Clements, David H.; Lonner, Baron; Betz, Randal R.; Harms Study Group

SUMMARY: The deformity-flexibility quotient (DFQ) quantifies two primary, yet competing variables of spinal fusions in patients with adolescent idiopathic scoliosis (AIS); deformity correction and motion preservation. In this study, greater patient satisfaction at 2-years post-op, as determined by the SRS-24 questionnaire, was found to correlate significantly with a lower DFQ; emphasizing the importance of minimizing residual deformity while maximizing the number of lumbar motion segments.

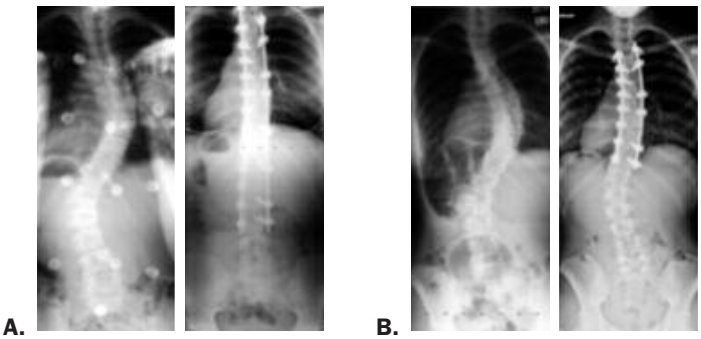
INTRODUCTION: It is unclear whether a selective thoracic fusion which may leave a residual lumbar deformity is preferred to a longer spinal fusion which may improve deformity correction at the expense of lumbar motion. The purpose of this study was to use the SRS-24 questionnaire to determine patient preference between a longer, straighter fusion versus a shorter fusion with a residual lumbar deformity.

METHODS: Peri-op, x-ray, and SRS-24 data were retrospectively reviewed from a consecutively enrolled series. All AIS patients with a Lenke type 1B/C deformity and minimum 2-yr follow-up were analyzed. The DFQ was calculated for each patient by dividing the residual coronal lumbar deformity at 2-yrs post-op by the number of distal unfused motion segments (Fig 1). Spearman's rho test was used to perform a correlation analysis between the DFQ and SRS-24 scores ($p<0.05$). The 2-year coronal lumbar curve deformity and the number of unfused motion segments were also assessed for independent correlation with SRS-24 scores ($p<0.05$).

RESULTS: 155 AIS patients met the inclusion criteria. The average pre-op thoracic and lumbar Cobb angles were $52.3^\circ \pm 9.2^\circ$ and $37.8^\circ \pm 8.2^\circ$; decreasing to $22.4^\circ \pm 9.8^\circ$ and $20.1^\circ \pm 8.8^\circ$, respectively at 2-yrs post-op. The average number of distal unfused motion segments was 5.8 ± 1.4 and the average DFQ was 3.6 ± 1.9 (range:0.2-12.3). Residual lumbar deformity and SRS-24 scores were not significantly correlated at 2-yrs post-op ($p>0.14$); however the number of unfused motion segments did correlate with Functional Level ($r=0.16$, $p=0.04$). Additionally, the DFQ was significantly correlated with Patient Satisfaction ($r=-0.16$, $p=0.04$), and a trend towards a correlation was found with Self Image after Surgery ($r=-0.15$, $p=0.06$).

CONCLUSION: Selective thoracic fusions that preserve motion in the lumbar spine are often associated with a residual lumbar deformity. The current data suggest that despite patients' focus on radiographic correction, residual lumbar deformity by itself did not correlate with SRS-24 scores at 2-yrs post-op. A greater number of unfused lumbar motion segments did correlate with greater function, and a lower DFQ (less deformity and more motion segments of the lumbar spine) correlated with higher 2-year post-op patient satisfaction.

Figure 1: A) Pre-op and 2-yr post-op PA radiographs: 14° residual lumbar curve with 3 infused motion segments (DFQ=4.7). B) Pro-op and 2-yr post-op PA radiographs: 34° residual lumbar curve with 7 unfused motion segments (DFQ=4.9).



Preservation of Thoracic Kyphosis: A Critical Component to Maintaining Post-operative Lumbar Lordosis during the Surgical Treatment of Adolescent Idiopathic Scoliosis

Upasani, Vidyadhar V.; Newton, Peter O.; Pawelek, Jeff B.; Bastrom, Tracey P.; Lenke, Lawrence G.; Lowe, Thomas; Crawford, Alvin; Betz, Randal R.; Lonner, Baron; Harms Study Group

SUMMARY: An analysis of changes in the sagittal profile in surgically treated patients with adolescent idiopathic scoliosis showed that a decrease in post-op thoracic kyphosis results in a decrease in lumbar lordosis. A premature, iatrogenic loss of lumbar lordosis may predispose patients to develop a flat back deformity and an unbalanced forward sagittal alignment.

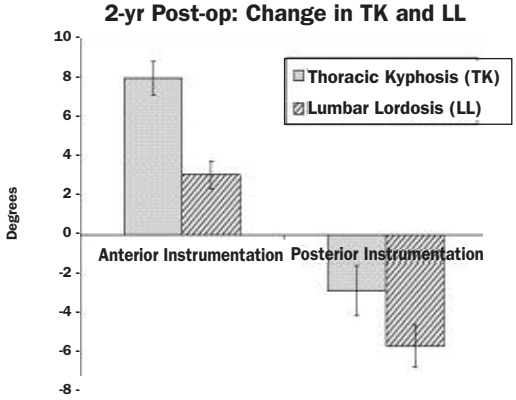
INTRODUCTION: With the increasing popularity of segmental pedicle screw spinal instrumentation, there is a tendency to sacrifice thoracic kyphosis (TK) in order to achieve coronal and axial plane correction. The purpose of this study was to evaluate the sagittal profile of surgically treated adolescent idiopathic scoliosis (AIS) patients.

METHODS: First-erect, one-year and two-year post-op radiographs of AIS patients with a Lenke type 1 deformity and minimum 2-year follow-up after a selective thoracic fusion (lowest instrumented vertebra of T11, T12 or L1) were evaluated. Changes in TK were correlated with changes in lumbar lordosis (LL) at each visit using Pearson's correlation analysis ($p<0.05$). The patients were then sub-divided according to approach (open/thoracoscopic anterior versus posterior) and an ANOVA was used to compare pre- and post-op radiographic measures ($p<0.05$).

RESULTS: 251 patients (age: 14$\pm$2 years) were included in this analysis. 67% of the patients had an anterior surgery (97 open anterior, 71 thoracoscopic) and 33% (83 patients) had a posterior spinal fusion. A decrease in post-op TK was significantly correlated ($p\leq 0.001$) with a decrease in LL at the first-erect ($r=0.3$), one-year ($r=0.4$) and two-year ($r=0.4$) visits, independent of surgical approach. LL decreased significantly at the first-erect visit regardless of approach ($p=0.003$); however at 2-yrs post-op TK and LL were significantly decreased after a posterior approach ($p\leq 0.001$) as compared to an anterior approach which added kyphosis (Fig 1). Of note, the decrease in LL (5.6°$\pm$9.7°) was nearly twice the decrease in TK (2.8°$\pm$11.4°) in the posterior group at 2-years post-op.

CONCLUSION: Given that thoracic AIS is often associated with a preexisting reduction in TK; ideally surgical correction should address this deformity. Procedures which further reduce TK also reduce LL. It is unclear if the loss of LL from thoracic scoliosis correction will compound the loss of LL that occurs with age; leading to further decline in sagittal balance. With this concern, we recommend a posterior column lengthening and/or an anterior column shortening during the surgical correction of thoracic AIS to achieve restoration of normal TK and maximal LL.

Figure 1: 2-year post-op change in thoracic kyphosis (TK) and lumbar lordosis (LL) by surgical approach (average $\pm$ SEM).



Should Post-operative Pulmonary Function be a Criterion that Affects Upper Instrumented Vertebral Body Selection in AIS Surgery?

Schlechter, John; Newton, Peter O.; Upasani, Vidyadhar V.; Pawelek, Jeff B.; Betz, Randal R.; Lenke, Lawrence G.; Lonner, Baron; Crawford, Alvin; Harms Study Group

SUMMARY: Adolescent idiopathic scoliosis (AIS) patients that required a more proximal thoracic fusion were found to have worse pulmonary function 2-years post-op; however, a decreased forced expiratory volume (FEV1) and forced vital capacity (FVC) existed in these patients pre-operatively. Changes in pulmonary function tests (PFT), at 2-years post-op, did not correlate with the selected upper instrumented vertebra.

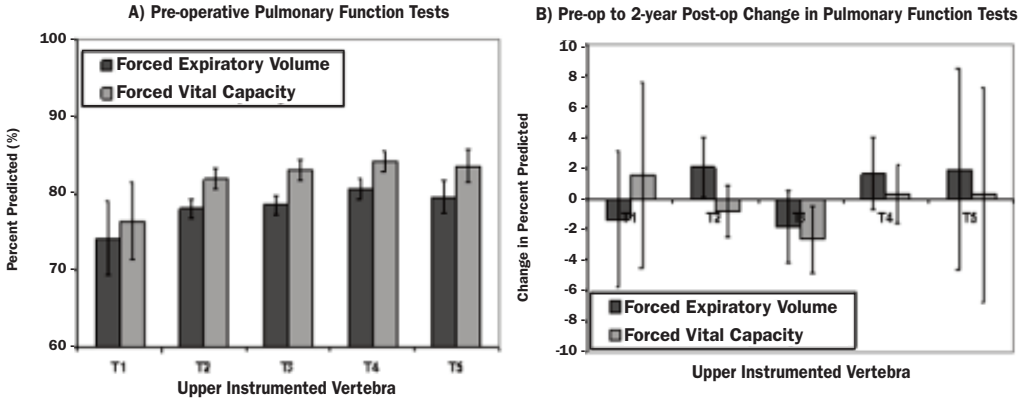
INTRODUCTION: Recent reports suggest limiting the proximal extent of a posterior spinal instrumentation and fusion (PSF) into the upper thoracic spine to optimize post-op pulmonary function in patients with AIS. The purpose of this study was to compare pre- and post-op PFT data to determine whether a more proximal upper instrumented vertebra (UIV) negatively impacts pulmonary function.

METHODS: A multi-center AIS database was used to evaluate pre-op absolute and percent predicted pulmonary function data prior to a PSF, based on the selected UIV. For those patients with 2-year post-op PFT data, an ANOVA ($p<0.05$) was used to compare the change in forced expiratory volume (FEV1) and forced vital capacity (FVC) from pre-op to post-op based on the UIV.

RESULTS: 569 patients (434 females) with main thoracic curves (Lenke type 1-4) and a UIV from T1 to T5 were analyzed. The mean age at surgery was 15±2 years, with a proximal thoracic Cobb of 28.6°±11.1° and a main thoracic Cobb of 57.2°±14.5°. Pre-operatively, patients that eventually underwent fusion to more proximal levels had lower percent predicted PFTs ($p<0.01$; Fig 1A). However, the changes in percent predicted FEV1 and FVC between the pre-op and 2-year follow-up time points (116 patients) were not significantly affected by the chosen UIV ($p>0.76$; Fig 1B).

CONCLUSION: Although patients who require fusion more proximally into the thoracic spine seem to have lower PFTs, this exists pre-operatively and is not altered by surgery. There is no justification for limiting the proximal extent of surgery based on concerns of reducing pulmonary function in AIS. Choosing the most appropriate level of fusion in AIS requires a careful analysis of the risks and benefits for the patient in both the long and short term. There is no evidence that concern of limiting pulmonary function should enter into the decision making process when selecting the UIV in AIS.

Figure 1: A) Pre-op percent predicted FEV_1 and FVC based on UTV based on UIV; (B) 2-yr post-op changes in FEV_1 and FVC based on UIV (average + SEM).



Grading Apical Vertebral Rotation without a CT Scan: A Simple System Based on the Radiographic Appearance of Bilateral Pedicle Screws

Upasani, Vidyadhar V.; Chambers, Reid; Shah, Suken A.; Lehman, Ronald; Ugrinow, Valerie; Mahar, Andrew; Newton, Peter O.

SUMMARY: A trigonometric model to measure vertebral rotation based on the radiographic appearance of bilateral pedicle screws was found to significantly correlate with CT measures of vertebral rotation ($r=0.96$, $p \leq 0.001$), and was used to develop a simple, post-operative grading system for apical vertebral rotation in patients with adolescent idiopathic scoliosis (AIS).

INTRODUCTION: Assessment of vertebral rotation is important in the treatment of the three-dimensional spinal deformity associated with AIS. The purpose of this study was to develop a simple, clinically relevant, radiographic grading system for evaluating post-operative apical vertebral rotation that would correlate with CT measures of rotation; the current gold standard.

METHODS: Radiographs and CT of 17 AIS patients from 3 different surgeons, all who use anatomic landmarks and the free hand technique for pedicle screw placement, were studied. A trigonometric model was used to calculate vertebral rotation based on the radiographic appearance of bilateral pedicle screws (of known length and assuming equal convergence) from first-erect post-operative PA x-rays. Pearson's correlation analysis ($p<0.05$) compared calculated vertebral rotation to CT vertebral rotation measured post-operatively in the same patients. All measurements were performed digitally using SpineView 2.4 software (Surgiview SA, Paris, France).

RESULTS: Bilateral pedicle screws were used at 131 levels, with x-ray measurements of vertebral rotation possible at 92/131 levels (70%), as both screw tips were visible. For these 92 levels, the average absolute difference in rotation as measured radiographically (based on a trigonometric equation) and by CT was $2^\circ \pm 2^\circ$ ($r=0.96$, $p \leq 0.001$). Of note, for all 131 levels, the average absolute difference in screw convergence measured by CT was found to be $3^\circ \pm 4^\circ$; thus validating the assumption of symmetric screw convergence. Based on the position of the screw tips relative to the rods, a simple radiographic grading system was developed that correlated with CT measures of vertebral rotation (Fig 1).

CONCLUSION: An accurate assessment of vertebral rotation can be performed radiographically using screw lengths and screw tip-to-rod distances of bilateral segmental pedicle screws and a trigonometric calculation. These data support the use of a simple radiographic grading system (Fig 1) to approximate apical vertebral rotation in AIS patients treated with bilateral apical pedicle screw instrumentation. When both screw tips are medial to the rods (Grade 0), apical rotation is generally $< 8^\circ$, while a screw tip lateral to the rods (Grade II) suggests rotation $\geq 13^\circ$.

Figure 1: Radiographic grading system for apical vertebral rotation.

Grade (approx rotation)	**0** (0° to 8°)	**I** (9° to 12°)	**II** (≥13°)
X-ray Image			
Location of screw tips	Both screw tips medial	Right screw tip hidden by the rod	Right screw tip lateral to the rod
Avg CT rotation	1°±7°	10°±1°	16°±3°

Comparison Between 4.0-mm Stainless Steel and 4.75-mm Titanium Alloy Single-Rod Instrumentation Systems for Anterior Thoracoscopic Scoliosis Surgery

Yoon, Seung Hwan; Ugrinow, Valerie L.; Upasani, Vidyadhar V.; Pawelek, Jeff B.; Newton, Peter O.

SUMMARY: A comparison between two single-rod anterior thoracoscopic instrumentation systems found that the 4.75-mm titanium alloy construct resulted in improved maintenance of deformity correction at 2-years post-op and a lower incidence of instrumentation related complications (pseudarthrosis, rod breakage and surgical revisions) compared to the 4.0-mm stainless steel construct.

INTRODUCTION: Advances in anterior thoracoscopic spinal instrumentation have attempted to mitigate the complications of rod failure, pseudarthrosis and deformity progression after instrumentation. The purpose of this study was to compare minimum 2-year clinical and radiographic outcomes between 4.0-mm stainless steel (SS) and 4.75-mm titanium alloy (Ti) systems.

METHODS: A retrospective analysis of a consecutive, single surgeon series of anterior thoracoscopic instrumentation and fusion cases with minimum 2-year follow-up was performed. ANOVA ($p<0.05$) was used to compare peri-operative, radiographic, and post-operative complication data between patients instrumented with a 4.0-mm SS versus a 4.75-mm Ti construct.

RESULTS: 49 patients were included in this analysis. The SS construct was used from 7/00 to 12/01, while the Ti construct was used from 3/02 to 10/04. The average age at surgery, gender ratio, surgical time, number of levels fused, and length of hospitalization were not statistically different between the two groups ($p>0.70$). The pre-op main thoracic Cobb angles were also not statistically different ($p=0.62$); however the 2-year main thoracic Cobb angle was significantly smaller ($p=0.028$), and the percent correction at 2-years was significantly greater in the Ti group ($p=0.025$; Table 1). In addition, 5 patients (21%) in the SS group had a pseudarthrosis, 3 (13%) experienced rod failure, and 3 (13%) required a revision posterior spinal fusion, while in the Ti group, 2 patients (8%) had a pseudarthrosis, and no patients experienced rod failure or required a revision.

CONCLUSION: Although the average follow-up in the Ti group was significantly shorter than in the SS group ($p=0.001$), the 4.75mm titanium construct resulted in improved maintenance of deformity correction at 2-years post-op, and a lower incidence of complications (pseudarthrosis, rod breakage and surgical revisions) compared to the 4.0mm stainless steel construct. Improved clinical outcomes with a single-rod 4.75mm titanium anterior thoracoscopic instrumentation system are likely due to improved mechanical properties of the implant (greater elasticity and fatigue resistance), as well as refined patient selection criteria and greater surgical experience.

Table 1: Selected comparisons between SS and Ti groups (avg ± SD).

	N	FOLLOW-UP	PRE-OP THORACIC	2-YR THORACIC	2-YR % CORRECT
SS	24	4.1±1.5 yrs	54.5°±9.8°	26.4°±8.9°	52%±13%
Ti	25	2.4±1.0 yrs	53.2°±6.8°	20.6°±7.0°	62%±13%
p	-	.001	0.62	0.028	0.025

What is the 'Best' Surgical Approach for a Lenke 1 Main Thoracic Curve? Results of a Prospective, Multi-Center Study

Newton, Peter O.; Marks, Michelle C.; Betz, Randal R.; Clements, David H.; Lonner, Baron; Crawford, Alvin; Shufflebarger, Harry L.; O'Brien, Michael; Bastrom, Tracey P.

SUMMARY: A prospective comparison of outcomes for 3 surgical approaches for primary right thoracic curve pattern (Lenke type 1) showed that 2 year post-op outcomes were similar. There were measurable advantages for both the thoracoscopic and posterior approaches compared to the open anterior technique.

INTRODUCTION: Surgical options for the treatment of the typical right thoracic curve pattern of adolescent idiopathic scoliosis (AIS) include: Thoracoscopic anterior (TASF), Open anterior (OASF) and Posterior (PSF) spinal fusions. The purpose of this prospective consecutively enrolled non-randomized trial was to compare the outcomes for these 3 approaches for the treatment of main thoracic AIS.

METHODS: Patients with a primary right thoracic curve pattern (Lenke type 1) from 5 sites who were candidates for a selective thoracic fusion (LIV of L1 for TASF/OASF or LIV of L2 for PSF) were enrolled in this 2 year follow-up study. Changes in pre to post operative radiographs, pulmonary function tests, SRS questionnaires and rib humps were assessed using an ANOVA ($p<0.05$) to compare outcomes between the 3 approaches.

RESULTS: A total of 188 patients, 156 females and 32 males (age: 14.7±2 years) were included (91% 1 yr and 76% 2 yr FU). The 3 groups were similar preoperatively in thoracic and lumbar curve size. There were 63 patients in the TASF group, 28 patients in the OASF group and 97 patients with a PSF. The fusion included an average of 2 greater levels in PSF than the 2 anterior approaches. Surgical time was longer in the TASF and OASF compared to the PSF, however blood loss and incision length were the least in TASF. At 2 yrs post-op all 3 approaches showed similar improvements in the thoracic Cobb, coronal balance, lumbar Cobb, SRS questionnaires, and rib hump measures. The major and minor complications rates were greater in the TASF group with the majority pulmonary, while the PSF wound complication was highest at 7% compared to none in the TASF patients.

CONCLUSION: All 3 approaches resulted in similarly satisfactory outcomes for the majority of these selective thoracic fusion patients with specific advantages to each technique. The PSF patients had more levels fused, yet with the shortest operative time. The TASF group had the smallest incisions and the lowest blood loss, but with the most complications. The OASF group lost pulmonary function without any advantages compared to the other 2 groups.

SIGNIFICANCE: There were measurable advantages for both the thoracoscopic and posterior approaches compared to the open anterior technique.

	TASF	OASF	PSF	P-VALUE
Number of Patients / %	63 / 33%	28 / 15%	97 / 52%	
Levels Fused	7±1	8±1	10±2	p<0.001
Pre-op Thoracic Curve (deg.)	50±9	51±7	50±7	p=0.89
Pre-op Lumbar Curve (deg.)	32±9	31±7	30±9	p=0.25
Surgical Time (minutes)	359±124	378±99	227±82	p<0.001
EBL (cc)	443±430	921±798	877±856	p=0.014
Incision Length (cm)	11±3	27±9	28±6	p<0.001
Thoracic Cobb Correction %	63±13	69±15	63±16	p=0.17
Pre-2 yr Change in FEV (liters)	0.1±0.3	-0.1±0.4	+0.2±0.3	p<0.001
Pre-2 yr Change in FVC (liters)	+0.0±0.3	-0.2±0.3	+0.2±0.4	p<0.01
Pre-2 yr Change in TLC (liters)	+0.3±0.5	-0.5±0.2	+0.3±0.4	p<0.01
SRS Total Score at 2 Years (scale 1-5)	4.3±0.3	4.2±0.3	4.1±0.4	p=0.18
Pre-2yr Decrease in Rib Hump	7±4	9±4	8±4	p=0.13
Implant Failure Rate (%)	8	4	3	p=0.35
Reoperation Rate (%)	6	4	6	p=0.86
Complication Rate Major/Minor (%)	8/44	4/32	7/23	p=0.01

Post Operative Trunk Flexibility Loss is Modest But Incremental as the Fusion Progresses Distally

Newton, Peter O.; Marks, Michelle C.; Bastrom, Tracey P.; Betz, Randal R.; Clements, David H.; Lonner, Baron; Crawford, Alvin; Letko, Lynn; Shufflebarger, Harry L.; O'Brien, Michael

SUMMARY: An evaluation of post-operative trunk flexibility following spinal fusion revealed that the more distal the fusion progresses, the greater the loss of flexibility. For each distal level fused below T10, 5% of trunk flexibility is sacrificed. 80% of pre-operative flexibility is maintained with fusions to L2.

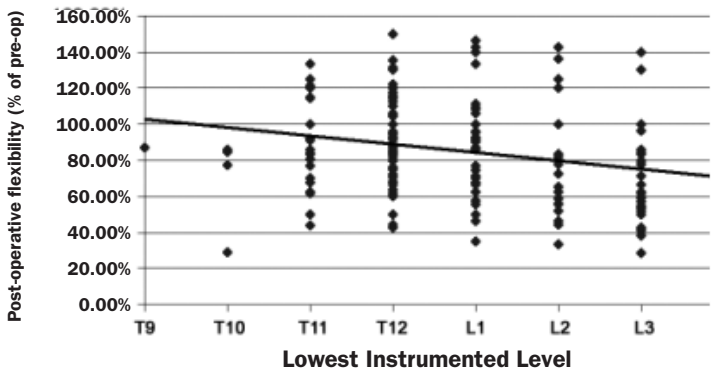
INTRODUCTION: After curve stabilization, motion preservation is a primary aim of spinal fusion. The purpose of this study was to evaluate the relationship between post-operative flexibility and the lowest instrumented vertebrae (LIV) in a spinal fusion.

METHODS: Clinical trunk flexibility measurements were obtained pre-operatively and at 2 years post-operatively on adolescent idiopathic scoliosis (AIS) patients included in a prospective AIS database. The data for patients with Lenke 1, 3, or 6 curve patterns were used to evaluate the relationship between the 2 yr trunk flexibility (expressed as a percentage of the pre-operative measure) and the LIV. Trunk motion was assessed in flexion and lateral bending with a fingertip to floor measurement. Spearman's rho correlation coefficient was employed ($p=0.05$).

RESULTS: The data for 177 patients, 148 females and 29 males (age: 15±2years) were included in this analysis. Despite a wide variation in data, the post-operative trunk flexibility was negatively affected the more distal the instrumentation progressed ($r = -0.28$, $p< 0.001$). For each distal level fused, post-operative trunk flexibility is reduced by 5%. However, post-operative flexibility does not drop to below 80% of pre-operative motion until the LIV reaches L2. Even for patients fused to L4 on average their post-operative flexibility was 65% of pre-operative motion. (Fig.1)

CONCLUSION: It is difficult to quantify the actual loss in function a patient experiences when flexibility is reduced following a spinal fusion. This evaluation of the relationship between post-op flexibility and LIV exhibits reductions in flexibility of roughly 5% for each level fused distal to T10. If the fusion ends at L2 or above, approximately 80% of pre-operative flexibility can be maintained.

SIGNIFICANCE: This evaluation of the relationship between post-op flexibility and LIV exhibits reductions in flexibility of roughly 5% for each level fused distal to T10.



Spearman's rho = -0.28, $p \leq 0.001$

Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis: Guidelines in Selecting the Optimal Lowest Instrumented Vertebra

Takahashi J, Newton P, Ugrinow V, Bastrom T, Harms Study Group

SUMMARY: Three curve patterns were identified according to relative positions of the stable vertebra and the lower end vertebra in Lenke type 1B, 1C and 3C curves. When the stable vertebra was below the end vertebra, the lowest instrumented vertebra should be chosen distal to the end vertebra. If the stable vertebra and the end vertebra are same, we recommend setting the lowest instrumented vertebra one level below the stable vertebra/end vertebra when performing a selective thoracic fusion.

INTRODUCTION: The purpose of this study was to determine how selection of the lowest instrumented vertebra (LIV) relative to stable vertebra (SV) and end vertebra (EV) effects correction of the main thoracic and/or compensatory lumbar curves following selective thoracic fusion.

METHODS: Inclusion criteria were: adolescent idiopathic scoliosis (AIS) patients with Lenke type 1B, 1C or 3C curves that had a selective thoracic fusion with the LIV from T11 to L1 (n=172). The patients were divided into three curve patterns based on the relative position of SV and EV. Group S (n=93) had SV below EV, Group 0 (n=66) SV at the EV, and Group E (n=13) EV below SV. Additionally, each group was divided into six subgroups based on the selected LIV: LIV above SV, at the SV, below SV, above EV, at the EV, and below EV. Each was compared for preoperative and 2-years postoperative radiographic parameters and clinical data.

RESULTS: In Group S, the 2-years postoperative thoracic curve correction rate when the LIV was below the EV (64±16%) was significantly greater than when the LIV was at the EV (54±13% ; $p<0.001$). The 2-years postoperative spontaneous lumbar curve correction (SLCC) rate similarly correlated with the LIV selection subgroups, 52±20% and 43±19%, respectively ($p=0.03$). In group 0, the 2-years postoperative thoracic curve correction rate when the LIV was below the EV/SV (64±14%) was significantly greater than when the LIV was at the EV/SV (52±14%; $p=0.004$). The 2-years postoperative SLCC rate for group 0 similarly correlated with the LIV selection subgroup, 56±16% and 38±21%, respectively ($p<0.01$). In group E, the 2-years postoperative thoracic curve correction and SLCC rate were not significantly different among the LIV selection subgroups; however the incidence of decompensation was 38%.

CONCLUSION: When performing a selective thoracic fusion of Lenke type 1B, 1C and 3C AIS curves in which the SV was at/or below the EV, the greatest correction of the main thoracic and compensatory lumbar curves occurred when the LIV was at least one level distal to the SV. This more distal LIV did not result in an increased rate of truncal imbalance.

KEY WORDS: selective thoracic fusion, lowest instrumented vertebra, stable vertebra, end vertebra

LEVELS OF EVIDENCE: Level 2

Postoperative Left Shoulder Elevation (LSE): An Unexpected Consequence of Surgical Correction of Lenke 1 Main Thoracic Curves

O'Brien, Michael; Shufflebarger, Harry L.; Macagno, Angel; Marks, Michelle C.; Bastrom, Tracey P.; Betz, Randal R.; Newton, Peter O.; Lonner, Baron; Crawford, Alvin; Shah, Suken A.; Harms Study Group

SUMMARY: Surgical correction of right convex, main thoracic (MT) curves in Lenke 1 AIS may result LSE. Risk factors for LSE 2 yrs post-op include: a high or neutral left shoulder preop, a pre-op upper thoracic (UT) curve >25°, a post-op UT >14°, incomplete instrumentation of the UT, and MT that is corrected by >67%. Instrumentation type and surgical approach were not risk factors for LSE.

INTRODUCTION: Lenke 1 curves should be treated with fusion of the MT curve only. Spontaneous correction of the "non-structural" UT and TL/L curves is expected. The purpose of this study was to identify risk factors that predict post-op LSE in Lenke 1 curves.

METHODS: Lenke 1 curves were identified in a prospective surgical AIS database. Using binary logistic regression the data was analyzed. Radiographic measures of shoulder heights were confirmed with clinical photographs of each pt.

RESULTS: 132 Lenke 1 patients with minimum 2 yr f/u, postop x-rays and clinical photos were identified with a mean age of 14±2. 51/132(39%) pts had LSE, 59/132 (45%) had neutral shoulders, 22/132 (17%) had right shoulder elevation (RSE). Instrumentation type and surgical approach were not predictive of LSE post-op. UT >25° pre-op (p=0.015) and post-op UT >14° (p=0.02) were predictive for LSE. Pre-op shoulder height was predictive of LSE post op (p=0.02). 58% of pts with LSE pre-op remained so post-op compared to 20% who started out neutral and 33% who started with RSE. 47% of pts were instrumented into the UT curve. This was predictive of LSE (p=0.03) with a 59% chance that the pt would have LSE at 2 yrs compared to 40% if the fusion ended at or below the MT proximal end vertebra. Pts with a LSE post-op had longer fusions, 9 vs 8 levels, (p=0.02). There was also a trend toward LSE in pts who had higher % correction of the MT curve (>67% p=0.09). Pts with a lumbar "A" modifier had the highest incidence of LSE (p=0.05).

CONCLUSION: Structural criteria of side bending to < 25 degrees is insufficient for defining UT curves that require instrumentation. LSE after surgical correction of Lenke 1 AIS was identified in 39% of pts in spite of the presumed protection afforded by the "non-structural" UT and TL/L curves. Risk factors for LSE post-op are: LSE pre-op, an UT >25°, incomplete instrumentation of the UT, a post-op UT >14° and correction of MT by >67%.

Efficacy of Hemivertebra Resection for Congenital Scoliosis (CS): A Multicenter Retrospective Comparison of Three Surgical Techniques

O'Brien, Michael; Shufflebarger, Harry L.; Newton, Peter O.; Betz, Randal R.; Lonner, Baron; Letko, Lynn; Harms, Jurgen; Crawford, Alvin; Shah, Suken A.; Sponseller, Paul D.; Flynn, John; Boachie-Adjei, Oheneba; Gupta, Munish C.; Macagno, Angel; Abel, Mark F.

SUMMARY: Three surgical treatments for congenital scoliosis (CS) due to hemivertebrae (HV) were evaluated in 76 patients. HV resection with posterior instrumentation (PI) results in, greater % correction with shorter fusions and less EBL. However there is a higher rate of instrumentation failure and neurological complications with HV resection.

INTRODUCTION: We compare the outcomes of 3 surgical treatments for CS due to a HV.

METHODS: A multi-center retrospective study of patients with CS due to 1 or 2 level HV was performed. The surgical treatments were: Group 1: fusion w/o correction (hemi-epiphysiodesis or in-situ fusion without instrumentation), Group 2: correction w/o HV resection (with or w/o anterior or posterior release) with PI, and Group 3, HV resection (anterior and/or posterior) with PI.

RESULTS: 76 patients with minimum 2 year f/u, were evaluated who were treated between 1991 and 2004. The mean age was 8 years (range 1-18). The HV were: fully segmented, non incarcerated (n=51, 67%), incarcerated (n=1, 1 %), and semi-segmented (n=24, 32%). There were 65 patients with single and 11 patients with double HV. There were 14(18.4%) Group 1, 20 (26.3%) Group 2, and 42 (55.3%) Group 3 patients. Group 1(37°) and Group 3(35°) had smaller pre-op curves than Group 2(55°) ($p<0.01$). The overall complication rate for the entire group was 30%: Group 1(23%), Group 2(17%), Group 3(44%). Group 3 had better % correction at 2 years post-op compared to Group 1 and 2 ($p<0.001$). Group 3 had shorter fusion ($p=0.001$), less EBL ($p=0.03$), and a trend toward shorter operative times compared to Group 2 ($p=0.10$). Group 1 and 3 had similar length of fusion. One site adept at posterior HV resection, achieved a mean 84±19% coronal correction at 2 years post-op compared to the other group 3 patients who had a mean 50±25% ($p<0.001$) percent correction suggesting experience with the technique may be important for an optimal result.

CONCLUSION: While HV resection (Group 3) has a higher complication rate than the other two techniques, posterior HV resection (Group 3) in younger patients results in better % correction than either Insitu fusion (Group 1) or Instrumentation without resection (group 2) and it achieves the correction with a shorter fusion than in Group 2.

Table 1. Treatment Groups for Congenital Spinal Deformity.

	N	PRE-OP CURVE SIZE	AGE @ SURGERY	# LEVEL FUSED	COMPLICATIONS	EBL	OPERATIVE TIME	2 YR % CORRECT
Group 1: Fusion without Correction	14	37°±13°	10±6	3 ± 4	1 infection 2 other	344±296	222±104	27±15
Group 2: Correction without HV Resection	20	55°±26°	10±5	7±3	1 infection 1 neurological 1 instrumentation	837±691	324±124	42±20
Group 3: Correction with HV Resection	42	36°±9°	5±4	3±2	3 infection 5 neurological 5 instrumentation 4 other	455±461	255±89	73±21

Cervical Sagittal Plane Decompensation After Pediatric AIS Surgery

Antonacci, M. Darryl; Cahill, Patrick J.; Nydick, Jason; Asghar, JahanGir; Tantorski, Mark; Clements, David H.; Betz, Randal R.; Samdani, Amer F.; Harms Study Group

SUMMARY: Pre- and post-op radiographic sagittal profiles of pediatric patients undergoing scoliosis surgery for Lenke Type 1 and 2 curves was reviewed. Patients with post-op thoracic sagittal profiles <30° had a significantly higher incidence of developing frank cervical kyphosis.

INTRODUCTION: There have been several attempts to characterize the relationship between thoracic kyphosis, lumbar lordosis, and pelvic alignment in sagittal balance. To our knowledge, there has been no attempt to correlate the effect of post-op thoracic kyphosis on the cervical spine.

METHODS: Radiographic parameters were evaluated on patients undergoing pedicle screw posterior spinal instrumentation and fusion (PSIF) for Lenke Type 1 and 2 curves with two year follow-up and adequate C-spine visualization. Parameters included: fusion levels, cervical sagittal balance (C2-C7), thoracic sagittal balance (T2-T12, T5-T12), lumbar sagittal balance, C2 & C7 plumb lines, Risser, Cobb angles, sacral slope, pelvic incidence, tilt, and obliquity.

RESULTS: 22 patients met inclusion criteria. Pre-op, 6 of 22 (Group A) had frank cervical kyphosis (mean +10.5°) and mean pre-op T2-T12 kyphosis of 26.2°. Post-op, Group A remained in cervical kyphosis with mean thoracic kyphosis:19.5 ($p<.05$). Pre-op, 16 of 22 had neutral to lordotic cervical spines (mean -13.75°) with thoracic kyphosis (mean: 45°). Post-op, 8/16 (Group B) developed cervical sagittal decompensation (>5°) with 6 developing frank cervical kyphosis (mean +10.5°, $p<.006$). In Group B, post-op thoracic kyphosis was 25.6°, $p<.004$. The other 8 of 16 (Group C) did not decompensate cervically and had a post-op thoracic kyphosis of 37.5° (vs. Group B., $p<.05$). Of the remaining parameters, only sacral slope demonstrated a statistically significant decrease (mean 46.4 to 37.6) between Groups B and C ($p<.007$).

CONCLUSION: PSIF had a significant hypokyphosing effect on the thoracic spine (19/22 patients). If thoracic kyphosis is decreased to below 30°, the cervical spine decompensates into kyphosis. The long term effect of cervical kyphosis in pediatric scoliosis patients is not well known. The surgeon can influence the sagittal contour of the cervical spine through the construct in the thoracic spine.

	CERVICAL		THORACIC	
GROUP	PRE-OPERATIVE ALIGNMENT	POST-OPERATIVE ALIGNMENT	PRE-OPERATIVE KYPHOSIS	POST-OPERATIVE KYPHOSIS
A	Kyphosis	Kyphosis	26.2	19.5
B	Neutral or Lordosis	Kyphosis	45	25.6
C	Neutral or lordosis	Neutral or Lordosis	44	37.5

How Does Surgeon Experience Affect the Accuracy of Placement of Thoracic Pedicle Screws in Adolescent Idiopathic Scoliosis (AIS)?

Samdani, Amer F.; Ranade, Ashish; Asghar, JahanGir; Cahill, Patrick J.; Antonacci, M. Darryl; Clements, David H.; Betz, Randal R.

SUMMARY: Thoracic screw placement in the deformed spine poses unique challenges, including a steep surgeon learning curve. In this study, we compared pedicle screw breach rates as assessed by postoperative CT for surgeons with varying levels of experience. We established an overall breach rate of 12.5% and found a trend toward fewer breaches for the most experienced surgeons. In addition, this group demonstrated a markedly lower medial breach rate.

INTRODUCTION: The use of pedicle screws for the treatment of AIS has gained widespread popularity. However, placement of thoracic pedicle screws in the deformed spine poses unique challenges, including a steep surgeon learning curve. Few studies have documented the accuracy of pedicle screw placement in AIS as determined by postoperative CT. In this study, we sought to: 1) determine a postoperative CT-based pedicle breach rate in AIS, and 2) determine the relationship between surgeon experience and the rate of pedicle breach.

METHODS: Patients meeting our inclusion criteria (N=45) were randomly selected into one of the following three groups stratified by attending surgeon experience (n=15): A) less than 20 cases of all-pedicle-screw constructs for AIS, B) 20-50 cases, and C) greater than 50 cases. Postoperative CT scans were evaluated by two spine surgeons, and a consensus was established as follows: 1) In: intraosseous placement < or equal to 2 mm breach, and 2) Out: > 2 mm breach, either medial or lateral.

RESULTS: A total of 1,098 screws were evaluated, with an overall group breach rate of 12.5%. When the breach rates were stratified by surgeon experience, there was a trend toward decreased rate of breach after surgical experience exceeded 50 cases, although this did not attain statistical significance (Group A: 13.2%, Group B: 13.7%, Group C: 10.6%, ANOVA p=.41). However, the most experienced group (C) had a markedly decreased rate of medial breaches (3.7% vs. 7.7% and 8.4% for groups A and B, respectively, p=.004). The breach rate for the concave periapical screws was not statistically different both within and among the groups.

CONCLUSION: Accuracy of pedicle screw placement in AIS appears to increase once surgical experience reaches greater than 50 cases. The higher accuracy is most apparent with a decrease in medial breaches, although none of the patients in the study experienced postoperative neurologic complications.

SIGNIFICANCE: Surgeons experience a learning curve when placing thoracic pedicle screws in the deformed spine. This study implies a decreased rate of pedicle screw breaches, particularly medially, once surgeon experience exceeds 50 cases.

SURGEON EXPERIENCE	AGE	MAJOR COBB	BREACH RATE%		
			TOTAL	MEDIAL	LATERAL
Group A: ≤ 20 Cases	13.7	60±12.1	13.2	7.7	5.5
Group B: 20-50 Cases	14.6	62.9±10.3	13.7	8.4	5.3
Group C: ≥50 Cases	14.0	67.5±23.5	10.6	**3.7***	6.9

p=.44 *p<.004

The Uniplanar Screw: A New Tool in the Surgical Treatment of AIS

Suken A. Shah MD, Peter O. Newton MD, Harry L. Shufflebarger MD, Michael F. O'Brien MD, Randal R. Betz MD, Tracey Bastrom MA, Michelle Marks MS, and the Harms Study Group

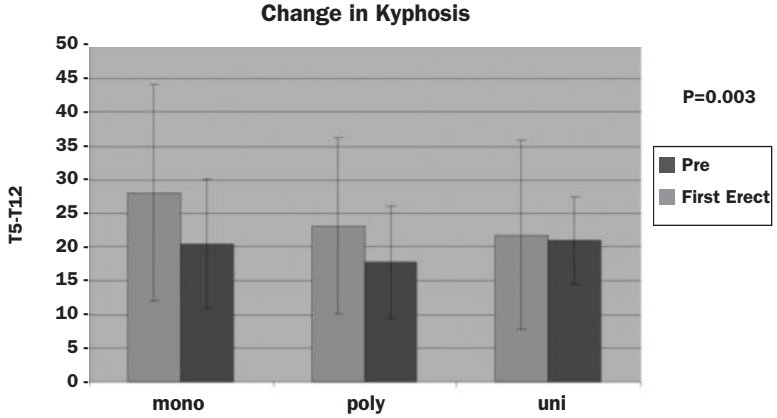
INTRODUCTION: Thoracic pedicle screws are commonly used in the surgical treatment of AIS, with excellent correction of the coronal Cobb angle. Some authors have reported post operative loss of kyphosis suggesting an intrinsic "hypokyphosing" effect of pedicle screw instrumentation. In the three dimensional correction of scoliosis, fixed angle screws achieve superior anchorage of the vertebral body, but do not allow fine control of the sagittal plane and may not restore kyphosis. To address these factors, a new screw was developed which has the advantages of a fixed angle device in the coronal and axial planes, but does articulate in the cephalad/caudad direction. The hypotheses of this study are that uniplanar screws provide similar curve correction in the coronal plane and axial plane as other screws, but provide better preservation/ restoration in the sagittal plane.

METHODS: 141 consecutive patients with main thoracic scoliosis treated with posterior-only surgery from 2004-2006 followed prospectively were identified; they were divided into 3 groups: fixed angle screws, polyaxial screws and uniplanar screws. The group distinctions were based on the type of screw used in 80% of the available apical anchor points. Patients were compared by radiographic and clinical parameters, and SRS-22 outcome scores, preoperatively and after their first erect film postoperatively.

RESULTS: Coronal correction of the main thoracic curve was similar, regardless of the screw used: 77% (mono), 72% (poly), 73% (uni) ($p=0.146$). Postoperatively, in the sagittal plane, there was significant loss of thoracic kyphosis in the mono and poly group; the uniplanar group showed preservation of kyphosis ($p<0.003$, see Graph). SRS 22 outcomes measures at last follow up did not reveal a difference between screw type. A subanalysis indicated that surgeon variability in screw use and rod contouring may also play a significant role in determining postoperative kyphosis.

CONCLUSIONS: The uniplanar screw provides similar coronal plane correction to mono and polyaxial screws, but provides improved ability to restore kyphosis in patients with AIS. The uniplanar screw's ability to articulate in the cephalad/caudad direction allows fine-tuning of the sagittal plane alignment while still ensuring appropriate orientation and secure connection to the rod. The surgeon variability in rod contouring and derotation technique may also play a significant role in restoration of thoracic kyphosis.

SUMMARY: Restoration of thoracic kyphosis in patients who are typically hypokyphotic or lordotic is an important consideration in the surgical correction of AIS. While surgical techniques such as rod contouring and derotation may also be important, the choice of vertebral anchors appears to affect the outcome of post operative thoracic kyphosis. The uniplanar screw provides similar coronal plane correction as fixed angle and polyaxial screws while facilitating improved restoration of thoracic kyphosis.



Pelvic Fixation in Cerebral Palsy Scoliosis Results in Better Restoration of Pelvic Obliquity, Sitting Ability and a Lower Reoperation Rate: Do the Benefits Outweigh the Costs?

Shah SA, Sponseller PD, Abel MF, Newton PO, Letko L, Sucato DJ, Betz RR and the Harms Study Group

SUMMARY: Nonambulatory patients with cerebral palsy (CP) scoliosis and pelvic obliquity are well managed with fixation to the pelvis; this results in better restoration of pelvic obliquity, sitting ability and a lower reoperation rate. Caregiver satisfaction is high and the complication rate is low.

INTRODUCTION: Nonambulatory patients with severe scoliosis due to cerebral palsy frequently have long thoracolumbar curves and pelvic obliquity and are treated with posterior spinal fusion with instrumentation and pelvic fixation. Controversy exists with respect to those children with a mild pelvic obliquity (<10°) but a significant scoliosis: do these children require pelvic fixation? What is the natural history of children with CP scoliosis who were not fused to the pelvis?

METHODS: A multicenter database of children with CP and scoliosis who underwent surgery with minimum 2 year follow up was reviewed and patients were divided into 2 groups: those instrumented to the pelvis and those who were not. Clinical data, radiographic parameters, caregiver utility and complications were assessed.

RESULTS: Of the study population of 157 patients, 129 were instrumented to the pelvis (82%) and 28 were not (18%). Please see table below for full results. Preoperative pelvic obliquity was significantly higher in those patients subsequently instrumented to the pelvis and the change in this group postoperatively was significantly better ($p<0.001$, see table). At follow up, mean pelvic obliquity in both groups was not significantly different (7 vs. 9). Coronal Cobb angle correction was identical in both groups (65%). Instrumenting a patient to the pelvis required an average of 20 minutes more operative time and resulted in 310 cc more blood loss. Caregivers saw significant utility in pelvic fixation: preoperatively, 75% of them rated their children as poor sitters ($p<0.001$) and 94% of them reported a postoperative improvement in their child's sitting ability ($p<0.001$). Infection rates and instrumentation complications were similar in the two groups, but patients fused to the pelvis had a lower reoperation rate (7% vs. 14.3%). Two patients (7%) not originally fused to the pelvis subsequently required pelvic fixation for late pelvic obliquity problems. Reoperations in the pelvic fixation patients were almost all for proximal implant issues; only one patient required removal of pelvic fixation unilaterally for prominence after presumed fusion.

CONCLUSIONS: Patients with sitting difficulties due to pelvic obliquity are well managed by PSF with pelvic fixation to restore pelvic alignment with a low complication rate and the correction is maintained over time. CP patients fused short of the pelvis may develop pelvic obliquity distal to the instrumentation over time.

Table: Summarized Results of Mean Values in the Two Groups.

CRITERIA	PELVIC FIXATION	NO PELVIC FIXATION	
Number of Patients (total N=157)	129	28	
Preop Pelvic Obliquity (°)	25	13	p<0.001
Postop Pelvic Obliquity (°)	7	9	p=0.26
Change in Pelvic Obliquity (°)	18	4	p<000.1
Main Cobb Correction (°)	64.8	64.6	p=0.96
Estimated Blood Loss (cc)	1948	1639	p=0.52
Operative Time (min)	313	294	p=0.33
Preop Sitting Poor (% caregivers)	75	47	p<0.001
Postop Sitting Improved (% caregivers)	94	44	p<0.001
Infection (%)	11	7	p=0.5
Instrumentation Complications (%)	14	13	p=0.88
Re-operations (%)	7	14.3	p=0.25

5-year Clinical and Radiographic Results of Selective Thoracic Fusion with Lumbar Curve >40°

Paul Sponseller MD, Peter O Newton MD, Randal R Betz MD, David Clements MD, Alvin Crawford MD, Michael O'Brien MD, Michelle Marks MS PT, Tracey Bastrom MS

SUMMARY: 5 years after selective thoracic fusion with large lumbar curve, there is more loss of thoracic correction, less lumbar correction, and no difference in SRS scores.

INTRODUCTION: Selective Thoracic Fusion is often employed for motion preservation. This study tested the intermediate-term compensation and clinical benefit in larger lumbar curves.

PATIENTS AND METHODS: Lenke 1-4 curves with a lumbar curve >40° having >5 year follow up were analyzed. Those with LIV > L1 were compared to those fused lower. SRS outcome scores were compared.

RESULTS: 42 patients fused selectively (S) and 33 fused nonselectively (N) were followed to 5 years. Lumbar modifiers for S were 29C and 13B. There was no difference in preop main thoracic curve (57° N vs. 56° S, p<0.08) but lumbar curve was greater in N (55° vs 44°, p<0.01). The most common operation for S was ASF (28/42) while for N it was PSF (23/33). The pattern of change from FE to 5 years was different, with thoracic curves increasing more in S (4 vs 9°, p=0.002) and lumbar curves improving more in S (-1° vs 3° p=0.01). At 5 years the N patients had smaller thoracic curves (20° vs 31°, p=0.01) and lumbar curves (20° NS, 25° S, p=0.04). Reoperation was needed in 6/42 S and 1/33 N (p=0.13). However, four of the 6 revisions in S were for deformity vs. none in N. The SRS subscores and total scores were not different.

Sub-analysis of patients fused posteriorly (12S, 23 N) revealed greater increase in the thoracic curve in S (10° vs 4°, p=0.02) and a difference in the evolution of the lumbar curve (N increased 4° in N, S decreased 1°). There were no differences in T:L correction ratios or reoperation in Lenke B vs C curves. The C-modifier curves had more left-shift of C7-CSVL (-6.2 vs 1.9mm).

CONCLUSIONS: Selective fusion preserves motion at expense of deformity correction. Selective patients have less correction of the thoracic curve at 5 years, with greater loss of thoracic correction even when fused posteriorly, as if to achieve balance. More selective patients required revision for deformity. SRS scores are not demonstrably better at 5 years in the selective patients. Further study is required to perfect this strategy and define its role.

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What Does a Scoliometer Really Measure?

Cahill, Patrick J.; Ranade, Ashish; Samdani, Amer; Asghar, Jahangir; Antonacci, M. Darryl; Clements, David; Betz, Randal R.

SUMMARY: There is no correlation between scoliometer and vertebral rotation on CT scan.

INTRODUCTION: A scoliometer, also know as an inclinometer or level, is a non-invasive and easily applied clinical tool used to measure trunk asymmetry. The most accurate measurement of vertebral rotation is by CT axial imaging. However, concerns exist over the radiation exposure associated with computed tomography. There is a desire to objectively assess the amount of vertebral body derotation correction following surgery for AIS. Research on the efficacy of various surgical derotation maneuvers has used the scoliometer as a way to quantify results without verifying the accuracy of the scoliometer by comparing it to the "gold standard" of CT imaging. This report looks at the mathematical correlation between the two measurements.

METHODS: A retrospective review of 29 patients with AIS was performed. Apical trunk rotation as measured by a scoliometer was obtained in a prospective manner. Rotation of the apical lumbar and thoracic vertebrae were measured on pre-operative CT scan. Statistical correlation analysis between the two measurements was performed.

RESULTS: A statistically significant correlation between vertebral rotation as measured on CT scan and scoliometer could not be established. The Pearson's product moment correlation coefficient for the thoracic curves was 0.266. For lumbar curves, the Pearson's product moment correlation coefficient was -0.388. Neither of these correlations was statistically significant ($p>0.05$).

CONCLUSION: There was no statistically significant correlation between vertebral rotation as measured on CT scan and trunk rotation as measured by scoliometer. Vertebral body rotation is only one factor that contributes to side-to-side trunk asymmetry. Other factors that influence trunk shape may include adipose tissue coverage of bony structures, differences in rib morphology, and muscle mass asymmetry.

SIGNIFICANCE: A scoliometer cannot be used as an alternative to axial CT scans for measurement of vertebral rotation.

Are We Improving Postoperative Sagittal Contour with New Posterior Instrumentation Compared to "Old School" Instrumentation?

Clements, David H.; Betz, Randal R.; Newton, Peter O.; Marks, Michelle C.; Bastrom, Tracey; Harms Study Group

SUMMARY: This is a study comparing the effect of "older" anterior screw versus "old" posterior hybrid versus "new" posterior screw constructs on postoperative sagittal contour in thoracic adolescent idiopathic scoliosis. Anterior screw instrumentation better recreates a normal sagittal contour, posterior hybrid constructs change the contour minimally, and posterior screw constructs worsen the mid thoracic hypokyphosis and exaggerate proximal thoracic kyphosis.

INTRODUCTION: The purpose of this study was to compare the change in sagittal contour after surgical correction of thoracic adolescent idiopathic scoliosis (AIS) using anterior screw versus posterior hybrid versus posterior screw constructs. The study was performed using data entered in a multicenter AIS patient database.

METHODS: Patients with a diagnosis of Lenke 1 AIS who were eligible for surgery were enrolled in this IRB-approved study. Patients were divided into three groups; anterior screw(Group 1), posterior hybrid (Group 2) or posterior screw (Group 3) constructs in the structural thoracic curve. The mean preoperative and minimum 2-year postoperative correction of the sagittal curve measurement was recorded for the levels T2-T5, T2-T12, T5-T12, T10-L2, lumbar lordosis and lateral C7 plumb to the sacrum. Correlation was then made between these measurements for the 3 groups comparing pre-op to 2-year post-op, and comparing pre-op and 2-year post-op curve means between the three groups. 166 patients were available for review in the anterior screw Group 1, 66 in the hybrid anchor Group 2 and 90 in the screw anchor Group 3.

RESULTS: At 2-year follow-up, the anterior Group 1 increased kyphosis significantly from T2-T12 and T5-12 and increased lumbar lordosis. The posterior screw Group 3 saw a significant decrease in kyphosis at T5-T12 and decreased lumbar lordosis, while T2-T5 kyphosis increased. The posterior hybrid Group 2 saw no significant change at T2-T5, T2-T12, and T5-T12 or in lumbar lordosis. T10-L2 did not change significantly in any group. The posterior screw Group 3 was the only group to have a statistically significant, but clinically insignificant, change in C7 plumb to the sacrum.

CONCLUSION: Using "new" posterior screw instrumentation on Lenke 1 curves has had a negative effect on postoperative sagittal contour. The mid thoracic kyphosis and lumbar lordosis decreases in an already flat sagittal deformity, and proximal thoracic kyphosis is increased. "Old" posterior hybrid instrumentation is not as bad, and tends toward minimal change of the sagittal contour. "Older" anterior instrumentation recreates the best sagittal contour. Clearly, the attachment of the anchor in relation to the vertebral axis of rotation has a large effect.

Instrumenting into Non-structural Proximal Thoracic Curves May Significantly Affect Shoulder Balance After Posterior Spinal Fusion

Flynn, John M.; Garner, Matthew; Cody, Stephanie; Bastrom, Tracey; Newton, Peter O.;
Marks, Michelle C.; O'Brien, Michael F.; Harms Study Group

SUMMARY: In AIS patients with nonstructural (Lenke 1 & 3) proximal thoracic (ns-PT) curves, extending the spinal fusion to or above the apex of the PT curve alters shoulder balance significantly more than cases instrumented below the PT apex.

INTRODUCTION: As spinal instrumentation evolves, each generation of increasingly powerful corrective techniques (previously, CD instrumentation; now thoracic pedicle screws) has focused surgeon attention on proximal thoracic curves and shoulder balance. Observing cases of unexpected postoperative shoulder imbalance Lenke 1 & 3, we sought to answer the question: in ns-PT curves, is there a relationship between the upper instrumented vertebra, the apex of the ns-PT curve, and a change in clinical and radiographic shoulder balance measures?

METHODS: From a multi-center AIS database, we identified every Lenke 1 or 3, min. 2 yr f/u, treated with posterior instrumented spinal fusion. We identified the upper instrumented vertebra, the apex of the ns-PT curve, and created 2 cohorts: those instrumented to or above the apex of the PT curve, and those instrumented below the apex of the PT curve. We then analyzed clinical and radiographic measures of shoulder balance in each cohort.

RESULTS: In 95 patients with satisfactory clinical photographs, the change in PA shoulder angle was significantly greater if the instrumentation ended at or above the PT apex, versus below the apex (2.6° vs. 1.7° p=0.035). Analyzing radiographic measures, the T-1 rib angle was altered to a significantly greater extent in those instrumented to or above the UT apex (5.1° vs. 3.6°, p=0.05). The difference in change of radiographic shoulder height also approached statistical significance (0.10).

CONCLUSION: Clinical and radiographic shoulder balance is altered to a significant extent when posterior instrumented spinal fusion is extended to or above the apex of a nonstructural proximal thoracic curve.

SIGNIFICANCE: With powerful posterior correction techniques, there is a risk of creating shoulder imbalance by instrumenting into nonstructural proximal thoracic curves.

The Upper End Vertebral Tilt-Correction Rule: A Valuable Guide to Avoid Shoulder Imbalance After Posterior Spinal Fusion

Flynn, John M.; Garner, Matthew; Cody, Stephanie; Bastrom, Tracey; Newton, Peter O.;
Marks, Michelle C.; O'Brien, Michael F.; Harms Study Group

SUMMARY: There is a risk for creating shoulder imbalance when the upper end vertebral tilt of the main thoracic curve (UEVtilt-MT) is corrected beyond the flexibility of the proximal thoracic curve.

INTRODUCTION: With more powerful correction techniques for posterior spinal fusion, there is an increased risk for creating shoulder imbalance. We studied the relationship between correction of the UEV tilt-MT and the flexibility of the proximal thoracic curve, and correlated these radiographic findings with clinical measures of shoulder balance.

METHODS: From a multi-center AIS database, we identified every patient with a posterior instrumented spinal fusion for thoracic scoliosis, with min. 2 yr f/u. The change in UEVtilt-MT (pre-op to last post-op x-ray) was compared to the flexibility of the proximal thoracic curve (pre-op Cobb minus max. lateral bend), and correlated with clinical and radiographic measures of shoulder balance. 2 cohorts were created: those in which the UEVtilt-MT was corrected less than or equal to the flexibility to the curve above, and those with the UEV corrected greater than the flexibility to the curve above.

RESULTS: 126 cases with adequate radiographs and clinical photographs were analyzed. There was a statistically significant difference in shoulder balance as measured by the AP clavicle angle when the UEV tilt was corrected more than the flexibility of the best bend of the proximal thoracic curve (1.9° vs. 2.6°, p=0.03).

CONCLUSION: Shoulder balance is changed more when the UEVtilt-MT is corrected beyond the flexibility of the proximal thoracic curve.

SIGNIFICANCE: With current techniques that can level the UEV of the main thoracic curve, the surgeon should closely evaluate the flexibility of the proximal thoracic curve to avoid creating shoulder imbalance, especially when the patient's shoulders appear level on the pre-op clinical examination.

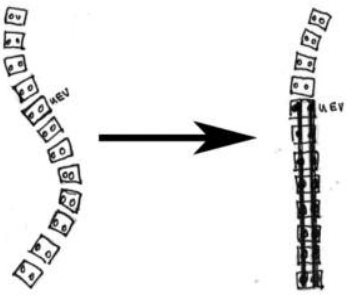


Fig. 1 — Illustration depicting correction of UEV-MT beyond the flexibility of the curve above, with resultant change in shoulder balance.

AP Shoulder Angle: A New Measurement of Shoulder Balance

Flynn, John M.; Garner, Matthew; Cody, Stephanie; Bastrom, Tracey; Newton, Peter O.;
Marks, Michelle C.; O'Brien, Michael F.; Harms Study Group

SUMMARY: We describe a new measurement of shoulder balance, the AP shoulder angle, which correlates well with other previously described radiographic and clinical measures. AP shoulder balance may be more important to patients, because it is what they actually see.

INTRODUCTION: In order to maximize patient benefit from spine deformity surgery, it's necessary to have valid clinical and radiographic measures of trunk deformity. Shoulder balance has been shown to be important patients, but difficult to evaluate. Qiu et al recently correlated several radiographic and clinical measurements of shoulder balance, but did not include any anterior measurements, which may be more relevant to patients, because it is what they see. Our aim was to determine if an anterior measurement (the AP shoulder angle) correlates with other measurements, such that it could be used in subsequent patient-based outcome research.

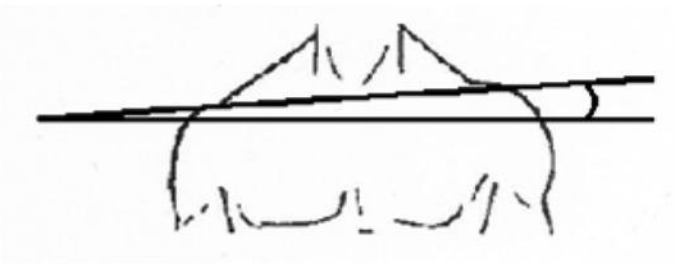
METHODS: From a multi-center AIS database, we identified every Lenke 1-4 PSF, with min. 2 yr f/u. Shoulder balance was analyzed based on the following radiographic and clinical measurements: T1 rib angle, T1 tilt angle, clavicle angle, PA axillary angle, PA shoulder angle and AP shoulder angle.

RESULTS: 127 patients had adequate radiographs, and anterior and posterior pre-op and post-op clinical photos. Correlations between all clinical and radiographic measures of shoulder balance were significant ($r = 0.35$-0.90), which supports previous studies. The strongest correlation was between PA axillary with PA shoulder angles ($r = 0.90$). AP shoulder angle (Figure 1) correlated with all other measures of shoulder balance, and best with PA axillary angle and PA shoulder angle ($r = 0.63$).

CONCLUSION: Our comprehensive analysis of clinical and radiographic measures of shoulder balance corroborates other recent studies, and supports the use of a new measure, AP shoulder angle, which statistically correlates well with the other measures.

SIGNIFICANCE: The use of AP shoulder angles as a measure of shoulder balance is valid, and may be valuable to include in patient-based outcome research tools.

Figure 1: Example of AP shoulder angle measurement



Scheuermann's Kyphosis: Prospective Evaluation of Clinical Presentation and Impact on Quality of Life in 43 Patients

Baron S. Lonner, MD, Kristin E. Kean, BA, Paul Sponseller MD, Harry Shufflebarger MD, Suken Shah MD, Alvin Crawford MD, Michael O'Brien MD, Randy Betz MD, Peter Newton MD

SUMMARY: Body Mass Index and kyphosis magnitude were found to be significantly greater in SK patients presenting with low-apex versus mid-thoracic apex. No differences in pulmonary function, VAS, or SRS-22 scores were noted.

INTRODUCTION: The clinical presentation and impact on health-related quality of life of Scheuermann's Kyphosis (SK) has not been previously evaluated in a prospective manner. The purpose of this study was to identify the different clinical expressions of the pathology based on deformity apex.

METHODS: Prospective analysis of 43 patients with SK from a multicenter database was performed. Patients were divided into two groups according to apical location – low (apex located at or distal to T9, N=18, average age 16.6 years) and mid-thoracic (apex located proximal to T9, N=25, average age 16.8 years). There was no significant difference in age between the groups. Radiographic parameters, pulmonary function, Body Mass Index (BMI), VAS pain scores, and SRS-22 outcomes were assessed. ANOVA was used to detect differences between the groups. Mann-Whitney nonparametric testing assessed differences in VAS.

RESULTS: The greatest sagittal cobb angle was 78.9° for the low apex group and 70.2° for the mid apex group (p=0.008). There were no significant differences detected in coronal deformity. BMI was significantly higher for the low apex group (mean 27.39 versus 22.51, p=0.023). Total SRS scores were 3.66 and 3.71 (best 5), for low and mid-thoracic respectively (p=0.8) and median VAS (worst 10) were 3.00 and 2.00 (p=0.592). Percent predicted FVC and FEV1 were 90.5% and 93.4%, and 102.6% and 95.4%, respectively for the low and mid-thoracic groups (p=0.21, 0.83).

CONCLUSIONS: The varying clinical presentations of patients with SK including impact on pulmonary function, pain, and health impact have been reported for the first time. The magnitude of the deformity as well as BMI was greater in the low apex group but no differences in the other parameters were noted.

SIGNIFICANCE: Increased BMI associated with the low apex presentation of SK may account for the higher kyphosis magnitude then in the mid-apex group due to a delay in detection in the former patients.

Body Mass Index in Scheuermann's Kyphosis (SK): Does BMI Differ in Patients with SK versus Adolescent Idiopathic Scoliosis (AIS)?

Baron S. Lonner, MD; Kristin E. Kean, BA, Paul Sponseller MD, Harry Shufflebarger MD, Suken Shah MD, Alvin Crawford MD; Randy Betz MD, Peter Newton MD

SUMMARY: Body Mass Index (BMI) in a prospective cohort of SK patients was found to be significantly higher than in AIS patients. Overall, self-image, and pain domain scores of the SRS-22 outcome instrument were worse for SK patients than for AIS patients. Higher BMI associated with SK may impact detection of the deformity, clinical effect on the patient, and operative morbidity.

INTRODUCTION: Body Mass Index (BMI) in patients with SK has not been previously reported although clinical observation suggests that it is greater in patients with SK than in the general population and in those with AIS. Increased BMI may impact clinical detection of deformity, self-image reporting, and operative morbidity. The purpose of this study was to assess BMI in SK patients in comparison to AIS patients.

METHODS: 36 patients (16 females, 20 males, average age 16.7 years) from a prospective multicenter study on SK were compared to 241 patients (204 females, 37 males, average age 14.3 years) from a prospectively collected database of AIS. ANOVA was used to detect differences in BMI and SRS-22 scores between the two groups. NIH BMI categories were used to define underweight (<18.5), normal weight (18.5-24.9), overweight (25-29.9), and obese (>/=30).

RESULTS: The mean BMI in the SK group (24.5 +/- 5.5, range: 15.5-38.5) was significantly higher than in the AIS group (20.7 +/- 3.7, range: 14-37, p=0.001). There were no differences in BMI by gender in either group. The SK group had significantly lower (worse) SRS-22 scores in the pain (3.51 vs. 3.86, p=0.004), self image (2.97 vs. 3.80, p=0.001) domains as well as a significantly lower overall score (3.65 vs. 3.98, p=0.001). There were no significant differences in the function and activity domains.

CONCLUSIONS: BMI is higher in patients with SK versus those with AIS. SRS-22 outcome scores are more negatively impacted in the pain, self-image, and overall scores in the SK group than in the AIS group.

Significance: Higher BMI associated with SK may impact detection of the deformity, clinical effect on the patient, and operative morbidity.

Table 1:

*	SK	AIS
Underweight (BMI<18.5)	5.6% (2/36)	31.1% (75/241)
Healthy (BMI=18.5-24.9)	52.8% (19/36)	58.1% (140/241)
Overweight (BMI=25-29.9)	27.8% (10/36)	7.9% (19/241)
Obese (BMI>/=30)	13.9% (5/36)	2.9% (7/241)
Total	36	241

*The distribution across the four BMI groups is significantly different between the SK and the AIS groups p<0.001).

Body Image in patients with adolescent idiopathic scoliosis: Validation of the Body Image Disturbance Questionnaire-Scoliosis Version

Auerbach, Joshua D.; Crerand, Canice E.; Lonner, Baron S.; Shah, Suken A.; Flynn, John M.; Bastrom, Tracey; Bowe, Whitney P.; Newton, Peter O.

SUMMARY: The Body Image Disturbance Questionnaire(BIDQ) is a self-report instrument that assesses dissatisfaction, concern, and distress related to appearance. The BIDQ-S (Scoliosis version) is a modification of the BIDQ with changes specific to the assessment of spinal deformity. We demonstrate construct validity and internal consistency in 31 patients with AIS, with highly significant correlations with each SRS outcomes domain. This user-friendly instrument may be useful in scoliosis research to assess whether a given therapy has a meaningful effect on scoliosis patients.

INTRODUCTION: Appearance concerns in AIS can result in distress and impairment in daily functioning, or body image disturbance. Although there exist studies and validated outcomes measures that have characterized the appearance concerns of adolescents with AIS, no studies have examined body image disturbance in this population. The Body Image Disturbance Questionnaire (BIDQ) is a self-report instrument that measures dissatisfaction, concern and distress that is related to an aspect of appearance, and results in some degree of impairment in social relations, social activities, or occupational functioning. The purpose of this study was to validate a modified version of this measure in a population of adolescents with AIS.

METHODS: Thirty-one patients (mean age: 13.8; 72% female) with AIS were enrolled into a multi-center, cross-sectional study designed to validate the Body Image Disturbance Questionnaire-Scoliosis version (BIDQ-S). Participants completed self-report questionnaires including the Body Image Disturbance Questionnaire-Scoliosis version and had complete SRS outcomes data. Descriptive statistics and Pearson correlations were calculated.

RESULTS: Preliminary results confirmed that the BIDQ was internally consistent (Cronbach's alpha = 0.82), and corrected item total correlations ranged from 0.43-0.67. The BIDQ-S was significantly correlated with each SRS domain and total score (Pearson's coefficient: -0.48 - 0.73, p-value ranges 0.000 – 0.02). Additional validity measurements are under way using measures of depression and body image.

CONCLUSION: The BIDQ has previously been shown to be an accurate instrument that can be used to assess appearance-related distress and impairment in the clinical setting. Based on our results, the BIDQ-S appears to be an internally consistent instrument that correlates with all SRS domains and total SRS scores in a scoliosis population, confirming that quality of life and body image are related psychosocial constructs. This user-friendly instrument is the first to examine body image disturbance in AIS, and provides a more comprehensive evaluation of how altered body image impacts daily functioning.

Left Thoracic Curves Are Not a Mirror Image of Right Thoracic Idiopathic Curves

Valerie Ugrinow, BA; Tracey Bastrom, MA; Eric Varley, DO; Burt Yaszay, MD; Peter O Newton, MD; Harms Study Group

PRECIS: 44 left thoracic curves were compared to 895 right thoracic curves. The coronal plane deformities were similar; however, the sagittal alignment differed between the groups. Right thoracic scoliosis patients had decreased thoracic kyphosis and increased pelvic incidence & sacral slope compared to left thoracic curves. This suggests a different etiology/pathoanatomy between right and left thoracic curves.

PURPOSE: To determine if left thoracic adolescent idiopathic scoliosis (AIS) is merely a mirror image of the common right thoracic curve pattern.

METHODS: A prospective multi-center AIS database was queried to identify 44 left (L) thoracic curves (Lenke 1, 2 or 3). These were compared to 895 right (R) thoracic curves collected over the same time period. The coronal and sagittal measures were compared with ANOVA ($p<0.05$).

RESULTS : The distribution of Lenke types differed slightly between groups (Lenke 1: 79% L, 71% R, Lenke 2: 9% L, 24% R, and Lenke 3: 11% L, 5% R, $p=0.03$), with fewer double thoracic L curves. Age at surgery was similar between the groups (14.8 L, 14.6 R, $p=0.5$). The coronal main thoracic Cobb angle at surgery was also similar between the groups (L: 55 ± 15, R: 54 ± 11, $p=0.5$), suggesting a similar age of onset given the similarity in age at surgery. Sagittal plane differences were noted with thoracic kyphosis (T5-T12) significantly less in the R curves compared to L curves ($p<0.001$). Although the two groups had similar lordosis ($p>0.05$), the R curves also had increased pelvic incidence and sacral slope compared to L curves ($p<0.05$, $p<0.02$ respectively), see Table.

CONCLUSION: Although left and right curves appear nearly as mirror images in the coronal plane, the sagittal profiles were significantly different between these curve patterns. The decreased thoracic kyphosis found in the right thoracic curve patients (especially in the setting of increased pelvic incidence) is consistent with the theory of relative anterior thoracic spinal overgrowth as a cause for thoracic scoliosis. The normal thoracic kyphosis and pelvic incidence found in the left thoracic curve patients is not consistent with the overgrowth theory and may signify another pathomechanism for this curve pattern development. This difference in sagittal alignment should also be kept in mind when planning surgical correction for left thoracic curves.

	LEFT THORACIC	RIGHT THORACIC	P VALUE
n	44	895	
Thoracic Kyphosis	31° + 15	22° ± 13	<0.001
Lumbar Lordosis	63° ± 15	60° ± 12	0.2
Pelvic Incidence	50° ± 13	55° ± 12	<0.05
Sacral Slope	38° ± 9	43° ± 9	<0.02

Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis: Guidelines in Selecting the Optimal Lowest Instrumented Vertebra

Takahashi J, Newton P, Ugrinow V, Bastrom T, Harms Study Group

SUMMARY: Three curve patterns were identified according to relative positions of the stable vertebra and the lower end vertebra in Lenke type 1B, 1C and 3C curves. When the stable vertebra was below the end vertebra, the lowest instrumented vertebra should be chosen distal to the end vertebra. If the stable vertebra and the end vertebra are same, we recommend setting the lowest instrumented vertebra one level below the stable vertebra/end vertebra when performing a selective thoracic fusion.

INTRODUCTION: The purpose of this study was to determine how selection of the lowest instrumented vertebra (LIV) relative to stable vertebra (SV) and end vertebra (EV) effects correction of the main thoracic and/or compensatory lumbar curves following selective thoracic fusion.

METHODS: Inclusion criteria were: adolescent idiopathic scoliosis (AIS) patients with Lenke type 1B, 1C or 3C curves that had a selective thoracic fusion with the LIV from T11 to L1 (n=172). The patients were divided into three curve patterns based on the relative position of SV and EV. Group S (n=93) had SV below EV, Group 0 (n=66) SV at the EV, and Group E (n=13) EV below SV. Additionally, each group was divided into six subgroups based on the selected LIV: LIV above SV, at the SV, below SV, above EV, at the EV, and below EV. Each was compared for preoperative and 2-years postoperative radiographic parameters and clinical data.

RESULTS: In Group S, the 2-years postoperative thoracic curve correction rate when the LIV was below the EV (64±16%) was significantly greater than when the LIV was at the EV (54±13% ; $p<0.001$). The 2-years postoperative spontaneous lumbar curve correction (SLCC) rate similarly correlated with the LIV selection subgroups, 52±20% and 43±19%, respectively ($p=0.03$). In group 0, the 2-years postoperative thoracic curve correction rate when the LIV was below the EV/SV (64±14%) was significantly greater than when the LIV was at the EV/SV (52±14%; $p=0.004$). The 2-years postoperative SLCC rate for group 0 similarly correlated with the LIV selection subgroup, 56±16% and 38±21%, respectively ($p<0.01$). In group E, the 2-years postoperative thoracic curve correction and SLCC rate were not significantly different among the LIV selection subgroups; however the incidence of decompensation was 38%.

CONCLUSION: When performing a selective thoracic fusion of Lenke type 1B, 1C and 3C AIS curves in which the SV was at/or below the EV, the greatest correction of the main thoracic and compensatory lumbar curves occurred when the LIV was at least one level distal to the SV. This more distal LIV did not result in an increased rate of truncal imbalance.

KEY WORDS: selective thoracic fusion, lowest instrumented vertebra, stable vertebra, end vertebra

LEVELS OF EVIDENCE: Level 2

A Novel Method for Assessing the Axial Plane in Scoliosis Demonstrates Uniplanar Screws Outperform Polyaxial Screws

Dalal, Aliasgar; Newton, Peter O.; Upasani, Vidyadhar; Shah, Suken A.; Harms Study Group

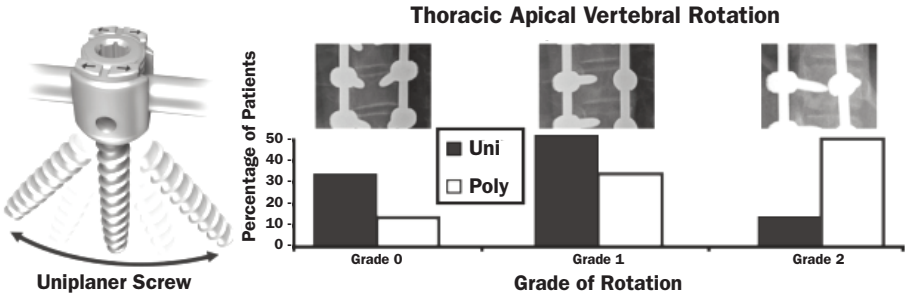
SUMMARY: Thoracic apical vertebral rotation after surgical correction of thoracic AIS was compared between uniplanar and polyaxial pedicle screw constructs. While there was no difference in the correction of the thoracic Cobb angle, the uniplanar screw constructs achieved more complete axial correction than did the polyaxial screw constructs.

INTRODUCTION: The purpose of this study was to compare the correction of axial plane deformity in thoracic adolescent idiopathic scoliosis (AIS) achieved with uniplanar and polyaxial thoracic pedicle screw constructs.

METHODS: A review of a multi-center database of Lenke Type 1-3 AIS patients who underwent surgical correction of thoracic AIS by posterior segmental pedicle screw instrumentation and fusion with either uniplanar or polyaxial pedicle screws and 5.5mm steel rod constructs was performed. Curves > 100° were excluded to control for the propensity to use polyaxial screws to correct larger curves. Apical vertebral rotation of thoracic curves was graded as 0, 1, or 2 based on an innovative CT scan validated radiographic method that uses the relative position of the screw tips to grade apical vertebral rotation at the 6 week and 1 year post-operative visit. By this method, higher grades correspond to greater residual apical vertebral rotation.

RESULTS: 210 patients met inclusion. The uniplanar group included 95 patients while the polyaxial group had 115 patients. The mean pre-operative thoracic Cobb angle of 58±12° and 60±13° (p=0.1), first erect post-op coronal correction of 72% and 74% (p=0.38) and one year correction of 70% and 76% (p=0.07) were not significantly different between the uniplanar and polyaxial groups, respectively. At 6 weeks post-op, the uniplanar group had 34% of patients with grade 0, 52% with grade 1 and only 14% with grade 2 thoracic apical vertebral rotation. In the polyaxial group only 14% of patients were grade 0, 35% were grade 1 and 51% were the most rotated grade 2. This was a significant difference in the distribution of axial rotations (p<0.001), with greater axial correction with uniplanar screws. The same pattern of results was found at 1 year post-op (p<0.001).

CONCLUSION: There was little difference in the coronal plane correction of thoracic curves. However the uniplanar pedicle screw group had a larger proportion of patients with greater thoracic apical vertebral derotation (more complete axial correction) compared to the polyaxial screw group. This is likely attributed to the increase in rotational leverage afforded by uniplanar screws during intraoperative bilateral direct apical vertebral derotation maneuvers.



Surgical Site Infection (SSI) in Spinal Surgery: The Newest "Never" Event

Marks, Michelle C.; Newton, Peter O.; Betz, Randal R.; Sponseller, Paul; Lonner, Baron S.; Shah, Suken A.; Shufflebarger, Harry L.; Harms Study Group

SUMMARY: The timing and severity of surgical site infections were evaluated in a multicenter, prospectively enrolled database of adolescent idiopathic scoliosis patients. In a cohort of 1657 patients, early surgical site infection (within 60 days of surgery) occurred at a rate of 1.7%.

INTRODUCTION: Reduction of surgical site infection (SSI) rates to zero is the new goal and expectation of the US federal government medical payers. An improvement of SSI rates in adolescent idiopathic scoliosis (AIS) may be possible, and the purpose of this study was to define the current SSI rate in a large prospective series of surgical AIS cases.

METHODS: A multicenter, prospectively enrolled database of patients who underwent surgical correction of AIS was reviewed. A secondary chart review of all cases was performed to ensure completeness and accuracy of the data. Early surgical site infections were defined as occurring within the first 60 days following the index operation. The severity of the surgical site infections was classified as those infections requiring an operative debridement (Deep) vs. those treated with local wound care and oral antibiotics (Superficial). Additional wound complications with negative cultures were also compiled.

RESULTS: Of the 1657 patients analyzed, 28 patients were diagnosed with an acute SSI (1.7%). 18 were considered "Superficial" (1.1%) and 10 "Deep" (0.6%). There was no correlation with measured perioperative variables such as: surgical approach (anterior vs posterior), operative time, blood loss, length of hospitalization or implant material (stainless steel vs. titanium) and the SSI rate. There was substantial variation in the rate of SSI among the study group centers ranging from 0 to 3.6%. In addition to these declared SSIs, there were 38 (2.3%) other documented "wound issues" including: dehiscence, seroma and suture reaction.

CONCLUSION: Surgical site infections following AIS surgery occurred in the early post-operative period (first 60 days) at a rate of 1.7% with 0.6% being "Deep". Although specific risk factors could not be identified, the SSI rate among hospitals in this multi-center study varied from 0 to 3.6% and it is possible that some of the "other wound complications" represented minor SSI. The federal mandate to eliminate SSI and the associated lack of reimbursement for the treatment may change clinical practice, and this data provides a benchmark of infection rates for future comparison.

KEYWORDS: Surgical site infection rates, Spinal Surgery, Adolescent Idiopathic Scoliosis, Risk Factors.

A More Distal Fusion is Associated with Increased Motion at L4/L5: A Set up for Degeneration?

Marks, Michelle C.; Newton, Peter O.; Petcharaporn, Maty; Bastrom, Tracey; Shah, Suken A.; Betz, Randal R.; Lonner, Baron S.; Miyanji, Firoz

SUMMARY: Inter-vertebral motion of the unfused distal segments was measured in patients with Adolescent Idiopathic Scoliosis (AIS) who underwent posterior spinal fusion and instrumentation. As the lowest instrumented vertebrae progressed distally, motion at the L4-L5 level increased significantly in lateral bending raising concern about potential early degeneration.

INTRODUCTION: The implications of hyper or hypo-mobility in the un-fused segments of the spine following instrumentation are poorly understood. The purpose of this study was to assess inter-vertebral segmental and cumulative motion in the distal un-fused segments of the spine in patients with AIS following instrumentation as a function of the lowest instrumented level.

METHODS: Patients were offered inclusion into this IRB approved prospective study at their routine 2, 3, 4 or 5 year post-operative visit at one of 5 participating centers. Motion was assessed by standardized radiographs acquired in maximum right, left and forwarding bending positions. The intervertebral angles were measured via digital radiographic measuring software at each level from T12 to S1. The relationship of the vertebral segmental motion for each interspace to the lowest instrumented vertebrae was evaluated with an ANOVA ($p<0.05$). The relationship between the cumulative preserved motion and each domain of the SRS questionnaire were evaluated using a Pearson's correlation coefficient ($p<0.05$).

RESULTS: The data for 57 patients are included. The lowest instrumented vertebrae ranged from T12 to L4. In lateral bending, as the lowest instrumented vertebrae progressed distally, there was significantly greater L4-L5 segment motion ($p=0.001$). A similar trend was appreciated at L5-S1 level. In addition, the summed motion from L3 to S1 also increased with a more distal fusion ($p=0.02$). Similar results were not found in forward bending. None of the domains of the SRS questionnaire correlated with the preserved L3-S1 motion.

CONCLUSION: In a group of post-operative adolescent idiopathic scoliosis patients, evaluation of the distal unfused intervertebral motion showed that preservation of vertebral motion segments allowed greater distribution of functional motion across more levels. The relationship between the increased lateral L4-5 motion and subsequent disc degeneration with a more distal fusion is unknown, but suspected.

Table 1: Lateral bending intervertebral motion in relation to the lowest instrumented vertebrae (degrees).

	Lowest Instrumented Vertebra					
	T2	L1	L2	L3	L4	*P*
Disc Level						
12/1	5±3					
1/2	7±2	7±2				0.64
2/3	9±3	10±3	12±4			0.13
3/4	10±4	10±3	11±6	12±3		0.42
4/5	4±3	7±4	10±5	11±6	12±4	**0.001**
5/1	3±2	4±3	3±2	4±3	9±13	0.09
Measured L3-S1	23±8	24±5	31±12	333±10	N/A	**0.02**

Postoperative Trunk Shift in Lenke 1 Curves: Incidence, Risk Factors, and Correlation with SRS-30

Samdani, Amer F.; Asghar, Jahangir; Cahill, Patrick J.; Clements, David H.; Antonacci, M. Darryl; Newton, Peter O.; Betz, Randal R.; Harms Study Group

SUMMARY: Although attaining truncal balance is one of the primary goals in surgery for AIS, no previous studies have examined its incidence, correlation with SRS-30, and potential risk factors. From a multicenter, prospective database we calculated a 12.6% incidence of postoperative trunk shift (TS) in Lenke 1 curves at two year follow-up. The majority of postoperative TS (64.3%) were iatrogenic. Patients with TS had lower total SRS scores compared to those without TS. Lower % correction of the lumbar curve was an independent risk factor for postoperative TS.

INTRODUCTION: Truncal alignment is one of the primary goals of surgery for AIS. No studies have specifically reported on the incidence of postoperative TS, evaluated its impact on the SRS-30, and assessed potential risk factors.

METHODS: From a multicenter, prospective database of 1,555 patients with AIS, an analysis of pre-op and 2 year post-op radiographs, SRS-30 scores, and clinical data was performed. Inclusion criteria identified 222 pts with AIS and a Lenke 1 curve pattern with minimum 2 yr f/u. To measure TS, apical vertebrae were identified and a line drawn horizontally thru them to mark (a) where left trunk ends and (b) where right trunk ends. When the midpoint of a and b is determined, a perpendicular to that line is drawn (Vertical Trunk Reference Line, VTRL). TS is defined as a greater than 2 cm difference between the VTRL and the CSVL. ANOVA was used to compare 2-year radiographic data and SRS-30 scores between pts with and without postoperative TS. Spearman's correlation and logistic regression analyses ($p<0.05$) were used to identify pre-op variables associated with postoperative TS.

RESULTS: 28 out of 222 (12.6 %) pts with Lenke 1 curve type demonstrated postoperative TS. 18 of these patients (64.3%) had no preoperative TS and were considered iatrogenic. At 2 yr f/u, total SRS-30 scores were significantly lower in the patients with TS (3.99 vs. 4.22, $p=.01$). This difference was most evident in the pain, self image, and functional level of activity domains ($p=.05$, .03, and .01, respectively). The percent correction of the thoracic curve was similar in both groups (TS=61%, No TS=65%, $p=0.18$), whereas, less correction of the lumbar curve was seen in the TS group (49% vs 60%, $p<0.01$). Similarly, % correction of the lumbar curve was identified as an independent risk factor for development of postoperative TS ($r=0.14$, $p=.02$).

CONCLUSION: Postoperative TS is not uncommon after surgery for AIS, occurring in 12.6% of patients with Lenke 1 curves. The majority of these are iatrogenically created and significantly lower SRS-30 scores. Less correction of the lumbar curve is an independent risk factor for development of postoperative TS.

SIGNIFICANCE: Surgeons should be cognizant of iatrogenic creation of postoperative TS as it significantly lowers SRS-30 scores.

	CORRECTION LUMBAR %	CORRECTION THORACIC %	CORONAL BALANCE	SRS-30 TOTAL	SRS-30 PAIN	SRS-30 SELF-IMAGE	SRS-30 FUNC LEVEL ACTIVITY
TS (n=37)	49%*	61%	1.3	3.99*	4.15*	4.07*	4.33*
No TS (n=236)	60%	65%	1.4	4.22	4.38	4.37	4.66

Longer Surgical Times May Increase Your Complication Rate

Shah, Suken A.; Newton, Peter O.; Lonner, Baron S.; Betz, Randal R.; Bastrom, Tracey; Marks, Michelle C.; Harms Study Group

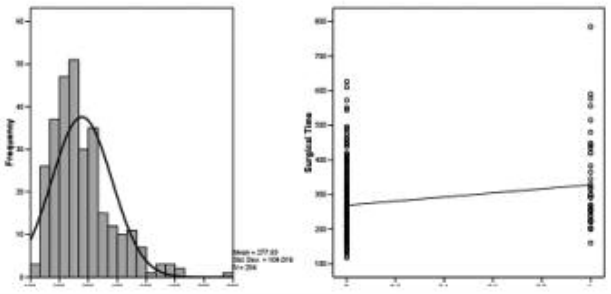
SUMMARY: The duration of surgery was examined as a risk factor for complications in a multicenter, prospectively enrolled database of adolescent idiopathic scoliosis patients with greater than 2 year follow up. In a cohort of 289 patients, 28 patients with a surgical time greater than 420 minutes experienced a complication rate of 32.1%, a rate 3.5 times higher than patients with a surgical time of less than 420 minutes.

INTRODUCTION: Major spinal deformity surgery is stressful on the patient due to prone positioning, blood loss, fluid shifts, anesthetic effects and autonomic deregulation. Longer duration of surgery may lead to adverse outcomes as the patient's reserves are exhausted. The purpose of this study was to examine duration of surgery as a variable on the incidence of complications. Methods: From a multicenter, prospectively enrolled database, patients who underwent surgery for AIS with greater than 2 year follow up were reviewed for surgical time and complications. A secondary review of all cases was performed to ensure completeness and accuracy of complications. Using a histogram analysis of surgical time, long duration of surgery was defined as > 420 minutes and cases were grouped (I – greater than 420 min and II – less than 420 min) and analyzed.

RESULTS: Patients in Group I (28/289) experienced 9 complications: wound infections/dehiscence (4), implant-related (3), neurologic (1) and excessive blood loss (1) for a rate of 32.1%. Patients in Group II (261/289) had 24 complications for a rate of 9.2%. This difference in complication rate related to surgical time was significant (Chi Square p=0.002). There was no significant difference in the preoperative demographics of the groups with regard to curve magnitude or co-morbidities.

CONCLUSION: Surgical duration of greater than 420 minutes resulted in an increased complication rate of 32.1%, a rate 3.5 times higher than cases less than 420 minutes (9.2%). The most frequent complications were wound issues, implant-related problems, neurologic events/alerts and excessive blood loss. Although complex procedures may have long operative times and an increased complication rate in and of themselves, this data may be useful in counseling the patient/family and perhaps in staging procedures when appropriate.

SIGNIFICANCE: In this otherwise healthy population of AIS patients, duration of surgery > 420 minutes was seen to adversely affect outcomes.



Histogram illustrates distribution of surgical time for 289 cases. Scatterplot shows a correlation of complications with increasing surgical time.

Rod Strength: Is it an Important Factor in Coronal and Sagittal Realignment after Surgery for Adolescent Idiopathic Scoliosis?

Shah, Suken A.; Newton, Peter O.; Lonner, Baron S.; Shufflebarger, Harry L.; Bastrom, Tracey; Marks, Michelle C.; Harms Study Group

SUMMARY: Yield strength of rods used in the surgical correction of AIS is an important factor. Higher strength rods are more effective in coronal and sagittal plane restoration of deformities. Stainless steel performs better than titanium when evaluating segmental pedicle screw constructs, even in the challenging scenario of kyphosis restoration with posterior surgical techniques in the hypokyhotic patient.

INTRODUCTION: With modern instrumentation, significant coronal correction of a structural spinal deformity is possible. A side effect of powerful segmental correction of AIS with pedicle screws is induction of hypokyphosis in the thoracic spine. In an effort to mitigate the "hypokyphosing" effect of pedicle screws, surgeons may choose to use rods with higher yield strength in order to pull the spine dorsally into kyphosis with a contoured rod. The hypothesis of this study was that higher strength rods would provide better coronal and sagittal plane restoration in AIS patients.

METHODS: From a multicenter, prospective database, patients with preoperative thoracic kyphosis (T5-T12) less than 20° who underwent PSF for AIS with segmental pedicle screw instrumentation (N = 247) were included in the analysis. Radiographic data preoperatively and postoperatively were compared between groups based on the type of rods used (5.5 mm): titanium (Ti), standard stainless steel (SS), high strength (HS SS), and ultra high strength (UH SS).

RESULTS: When corrected for flexibility, coronal curve correction was similar among the SS groups (74%) and significantly better than Ti (58%) ($p<0.001$). In the sagittal plane, all rod types were able to improve kyphosis ($p<0.01$), especially the ultra high strength stainless steel (UH SS) rods (10.6° to 16.1°), but the difference among rod types was not significant, likely due to variability in the Ti group. There were no complications of the higher strength rods, such as screw pullout or instrumentation failure. In one and two-year follow up, there was no significant of loss of correction in any of the groups.

CONCLUSION: Yield strength of rods used in the surgical correction of AIS is an important biomechanical consideration. While rod contouring and derotation may also be important, the choice of rod strength appears to affect the outcome of postoperative correction. Higher strength rods are more effective in coronal and sagittal plane restoration of deformities. Stainless steel performs better than titanium when evaluating segmental pedicle screw constructs, even in the challenging scenario of kyphosis restoration with posterior surgical techniques in the hypokyhotic patient.

Preop / Postop Kyphosis (T5-T12) Restoration

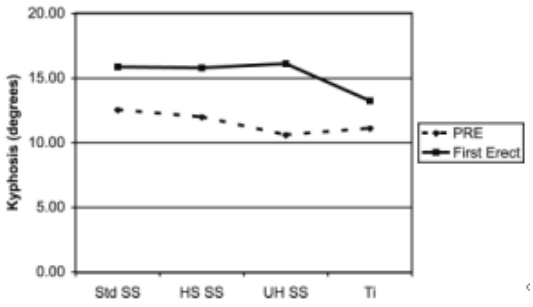


Figure illustrates kyphosis restoration by rod type (Std SS = Standard SS, HS SS = High strength SS, UH SS = Ultra High strength SS, Ti = Titanium).

Lenke Types Select More than Shape

Sponseller, Paul; Newton, Peter O.; Flynn, John M.; Marks, Michelle C.; Bastrom, Tracey; Petcharaporn, Maty; Betz, Randal R.

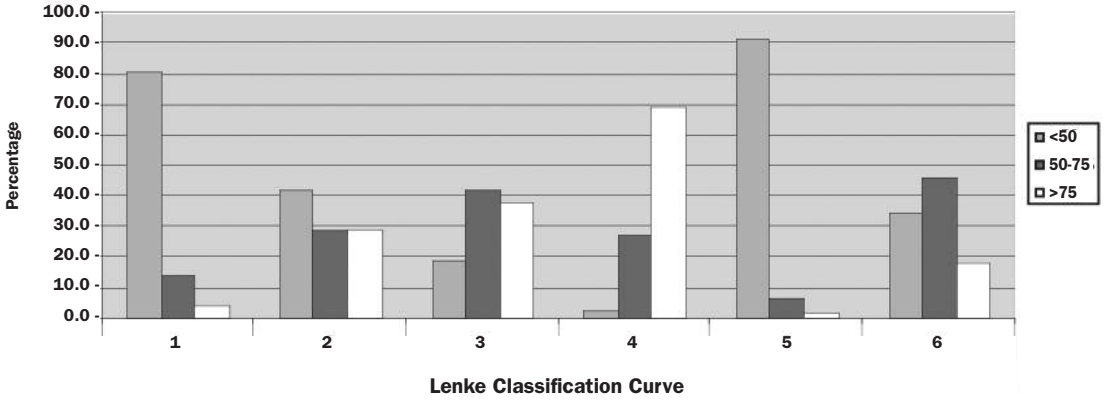
SUMMARY: As a group, Lenke 3 and 4 curves have the largest magnitude; 5 are oldest and smallest. Males have more thoracic curve types.

INTRODUCTION: The Lenke classification addresses curve morphology. Often it defines study inclusion criteria. Our hypothesis was that Lenke types also have differences in magnitude, age and gender which may be relevant to study design.

METHODS: A database of AIS patients <21 years at operation was studied. Lenke type was verified centrally. Curves were stratified as <50°, 50-75° and >75°. Age, primary curve magnitude and gender were compared between types.

RESULTS: 1593 patients were studied. More than half (52%) were Lenke 1; Lenke 3 and 4 were the least common types (4% and 3%). Differences in size among types were significant ($p<0.001$). The majority of smaller curves were Lenke 1 and 5. The type with the greatest percentage of large curves was Lenke 4 (47% > 75°). In Lenke 1 and 5, the greatest number of patients had smaller curves (figure 1). The largest mean curve type was 4 (77°)*, followed by 3 (63°), 2 (60°), 6 (59°), 1 (52°)* and 5 (47°)*(* comparisons $p<0.001$). Lenke 5 curves had the oldest mean age (15.4 versus 14.6 for all others) yet the lowest mean magnitude ($p=0.001$). Curve size was slightly negatively correlated with age ($r=-0.15$). Types 2, 3 and 4 had a significantly higher percentage of males than the others ($p=0.01$). Males were more likely than females to have a major thoracic curve (types 1-4, 22% male) than major TL/L (5 & 6; 15% male) ($p=0.005$), but did not have larger curves. There was a significant relationship between lumbar modifier A-C and % bend flexibility ($p=0.001$).

CONCLUSION: The Lenke classification system assesses curve patterns and flexibility. This necessarily defines some curve types to encompass larger curves. Lenke 1 is by far the commonest type. Lenke 1 and 5 contain a majority of small operative curves; while Lenke 4 contains the largest curves. Lenke 5 patients are oldest. Males have more major thoracic curves. Surgeons designing studies evaluating features of AIS need to realize the characteristics which are co-variates of the classification.



Establishment of a Minimal EMG Threshold for Thoracic Pedicle Screw Placement

Shufflebarger, Harry L.; Dunoyer, Catalina; Harms Study Group

SUMMARY: Each patient serves as the control to determine the minimal acceptable EMG monopolar stimulation threshold. This is determined by superior articular process stimulation.

INTRODUCTION: Various values are reported as acceptable minimums for pedicle screw placement, usually between 8 and 11 mAmps. A better method is presented.

METHODS: A 9mm electrically operated burr was employed to destroy the inferior articular process bilaterally at four contiguous peri-apical thoracic vertebral levels in adolescent idiopathic patients. The cartilage and bone of the superior articular process remained posterior to the exiting intercostal nerve root. Stimulation of this articular process defines minimal acceptable response threshold. 18 adolescent patients were studied. 72 peri-apical articular processes were stimulated. 378 stainless steel screws were placed and stimulated. Recording was from surface electrodes over intercostal muscles.

RESULTS: The mean articular process stimulation threshold for each patient was consistent, ranging from 4-7 mAmp on the concave side, and 4-8 mAmp on the convex. The stimulation threshold for the 378 screws was less than the mean threshold in three instances, resulting in either removal (2) or repositioning (1) of the low threshold screws. No screws required removal after surgery.

CONCLUSION: Each patient may act as the control to determine the minimal acceptable threshold of thoracic pedicle screws in scoliosis. The range of acceptable thresholds was from 3.5-8 mAmp. This is lower than most recommended levels.

SIGNIFICANCE: It is possible to determine an acceptable minimal stimulation threshold for thoracic pedicle screws in each patient.

KEYWORDS: thoracic pedicle screws, EMG stimulation, Minimum threshold.

Multicenter Study of Posterior Vertebral Column Resection for Pediatric Deformity

Shufflebarger, Harry L.; Williams, Seth K.; Newton, Peter O.; Samdani, Amer F.; Betz, Randal R.; Lonner, Baron S.; Sponseller, Paul

SUMMARY: VCR is a valuable method for addressing complex spinal deformity that is associated with substantial potential morbidity.

INTRODUCTION: Vertebral column resection (VCR), consisting of posterior vertebral body excision along with the adjacent disks, is used for correction of severe pediatric deformity. This is the first multicenter study to examine the underlying condition necessitating surgery, immediate correction rates, operative time, blood loss, and neurological complications, to standardize indications and inform surgeons of perioperative neurological morbidities.

METHODS: A retrospective chart review of patients who underwent a VCR for pediatric deformity between 2003 and 2008 was performed. Patients were divided into 5 deformity categories: 1) neuromuscular/paralytic (N/P); 2) complex congenital (CC); 3) adolescent idiopathic (AIS); 4) kyphosis (K); and 5) congenital hemivertebra (CH). Radiographic outcomes and intraoperative data are reported.

RESULTS: Data was available for 31 of 33 consecutive patients. Major curve correction averaged 63° (56%) in the N/P group, 36° (46%) in the CC group, 44° (60%) in the AIS group, 44° (57%) in the K group, and 25° (55%) in the CH group. Operative time averaged 439 minutes in groups 1-4 (N/P, CC, AIS, K) and 249 minutes in group 5 (CH). Blood loss averaged 1870 cc in groups 1-4 and 760 cc in group 5 (CH). Groups 1-4 demonstrated intraoperative spinal cord MEP and/or SSEP monitoring changes in 8 of 18 (44%) patients; 3 postoperative lower extremity (LE) partial motor deficits resulted (1 resolved and 2 with ongoing recovery). Group 5 demonstrated monitoring changes in 2 of 13 (15%) patients; 1 postoperative unilateral LE deficit fully resolved.

CONCLUSION: VCR is a valuable deformity surgery technique with potential neurological complications that can be minimized by the use of spinal cord monitoring to guide intraoperative decisions. VCR risks appear less when performed for hemivertebra excision. Intraoperative neuromonitoring changes are common and the surgeon should be prepared to make adjustments accordingly.

	NEUROMUSCULAR/ PARALYTIC	COMPLEX CONGENITAL	AIS	KYPHOSIS	CONGENITAL HEMIVERTEBRAE
N	4	8	4	2	13
Pre-op major curve Cobb angle (range)	103° (64-138°)	73° (38-127°)	76° (50-93°)	75° (65-84°)	46° (18-81°)
Curve correction	63°	37°	44°	44°	25°
% Curve correction	56%	46%	60%	57%	55%

Lenke 5 Curves: Thresholds for Selecting L3 vs. L4 as the Distal Level of Fusion

Yaszay, Newton, Bastrom, Petcharaporn, Harms Study Group

SUMMARY: Guidelines for selecting the lowest instrumented vertebra (LIV) in Lenke 5 curves treated posteriorly are currently ill-defined. While L3 may be the optimal level to maximize flexibility, L4 may be best to achieve lasting correction. Among similar magnitude curves, L4 was chosen as the LIV when L4 angulation was greater than 20°, L3 translation was greater than 3.6 cm, and L4 translation greater than 2.0 cm.

INTRODUCTION: Controversy exists regarding the selection of the levels of fusion within Lenke 5 curves, particularly the lower level. Fusion to the lower Cobb vertebra has been recommended. The purpose of this study was to evaluate preop radiographic factors that were associated with the selection of either L3 or L4 as the lowest instrumented vertebra (LIV) in posteriorly treated Lenke 5 curves.

METHODS: Posteriorly treated Lenke 5 curves from a prospectively collected multicenter database made up the study population. Preop and postop radiographic features of the curves were compared between patients with an LIV of L3 or L4. Regression analysis ($p < 0.05$) was used to determine the variables that were associated with each LIV group. The cases were also reviewed at a study group meeting by the surgeon members who declared their preferred LIV.

RESULTS: There were 25 posteriorly treated Lenke 5 patients with 2 yr follow-up (13: LIV L3 and 12: LIV L4). Preop lumbar curve magnitude and flexibility were similar. Three preop radiographic variables were significantly associated with the chosen LIV: L3 translation, L4 translation and L4 angulation (Table). The 95% confidence intervals were distinct. The lower Cobb vertebra was not found to be predictive. The postop correction was greater in patients fused to L4 (74% vs 54%, $p<0.01$). While there was an equal distribution in how the cases were treated, the study group members more commonly selected LIV of L3 (83%) than L4 (17%).

CONCLUSION: Selecting the LIV in the posteriorly treated Lenke 5 curves can be difficult. A recent poll of this study group's surgeons suggested a trend toward fusing to L3. This data would suggest choosing L4 as the LIV when the following thresholds are met: L4 angulation greater than 20°, L3 translation greater than 3.6 cm, and L4 translation greater than 2.0 cm.

PRE-OP	LIV=L3	LIV=L4	*p*
Lumbar Cobb	46±5°	47±6°	0.5
Lumbar lordosis	60°±12°	59°±11°	0.5
L3 coronal angulation	26°±6°	24°±6°	0.3
L4 coronal angulation	18°±3° (16-19.9°)	23°±4° (20.6-26°)	**0.001**
L3 translation from CSVL(cm)	3.1±0.8 (2.6-3.6)	4.1±0.6 (3.7-4.4)	**0.001**
L4 translation from CSVL(cm)	1.4±0.7 (0.99-1.8)	2.3±0.5 (1.9-2.6)	**0.001**
L3/4 disc angulation	4.5°±4°	3.6°±4°	0.7
L4/5 disc angulation	5.7°±4°	6.8°±5°	0.4
T/L apical translation(cm)	5.4±1.4	5.2±1.1	0.3
Lower Cobb vertebra (%)	L2 (15%) L3 (54%) L4 (31%)	L2 (0%) L3 (58%) L4 (42%)	0.4

Mean + SD, (95% confidence interval)

Does Maximizing Curve Correction of Lenke 1 Curves in AIS Risk Secondary Decompensation?

Meghan Imrie, Burt Yaszay, Peter Newton, Dennis Wenger, Tracey Bastrom, Harms Study Group

SUMMARY: With proper fusion levels and surgical technique maximal coronal correction of Lenke 1 curves can be achieved without compromising coronal balance, and may result in better residual rib hump and lumbar correction without necessarily sacrificing lumbar levels. However, when compared to curves with less complete correction, kyphosis is lost and SRS scores are not different.

INTRODUCTION: What constitutes optimal thoracic curve correction is controversial. It has been shown that hypercorrection of thoracic curves can result in coronal imbalance, trunk shift, or shoulder imbalance. The purpose of this study was to compare the clinical and radiographic outcomes between Lenke 1 patients with the greatest and least curve correction. Our hypothesis was that greater correction can be done without secondary decompensation.

METHODS: Using a prospective AIS database, Lenke 1 curves with 2 year follow-up (n=385) were ranked by percent coronal correction. The top 15% or high correction group (> 80%) were compared with the bottom 15% or low correction group (<40%). Clinical and radiographic outcomes including parameters of coronal and sagittal balance were compared utilizing ANOVA and chi-square ($p<0.007$).

RESULTS: The High Correction group (n=39) and Low Correction group (n=40) did not differ preoperatively except in lumbar flexibility (Table). In the coronal plane, the High Correction group did not demonstrate clinical imbalance (trunk shift and shoulder height) and had better radiographic balance (C7-CSVL shift). The deformity-flexibility quotient (DFQ) which is the ratio of residual lumbar curve to remaining unfused lumbar segments, was lower (optimal) in the High Correction group. The residual rib hump was also better. In the sagittal plane, the High Correction group had less kyphosis secondary to a loss of kyphosis compared with a gain in the Low Correction group. Despite these differences, SRS scores were not different.

CONCLUSION: Maximizing Lenke 1 curve correction to achieve greater lumbar correction and improved clinical appearance can be done without compromising coronal balance but may be at the expense of sagittal alignment. However, proper preop evaluation, fusion level selection, surgical technique, and surgeon experience are required to achieve relatively complete coronal plane correction without producing shoulder or trunk problems and/or sagittal plane balance issues.

		CORRECTION >80%	CORRECTION <40%	*p*
	Pts (ASF/PSF)	39 (18/21)	40 (19/21)	
Preop	Thoracic Cobb	5±9°	49±8°	0.4
	Lumbar Cobb	31±9°	33±11°	0.3
	Thoracic flexibility	56±16%	48±15%	0.03
	Lumbar flexibility	82±16%	70±+22%	**0.007**
Postop	Lumbar correction	73±20%	33±18%	**0.001**
	DFQ	4.6±1.3	6.0±1.4	**0.001**
	% pts w/ C7-CSVL distance > 2 cm	2.5%	25%	**0.004**
	T5-12 kyphosis	21±10° (avg loss 3°)	28±12° (avg gain 5°)	**0.007**
	Thoracic rib hump	5±4°	10±5°	**0.001**
	Shoulder height > 2 cm	11%	5%	0.6
	Trunk shift (cm)	1.0±0.9	1.3±1.1	0.3
	SRS score	4.2±0.3	4.1±0.4	0.5

A New Indication for Ponte releases in Adolescent Idiopathic Scoliosis: Restoring Thoracic Kyphosis

Yaszay, Newton, Shufflebarger, Shah, Bastrom, Harms Study Group

SUMMARY: Routinely used to decrease kyphosis, Ponte type posterior releases can also be utilized to increase kyphosis by allowing posterior column lengthening. In hypokyphotic thoracic curves treated with pedicle screws, Ponte releases allowed for greater restoration of thoracic kyphosis while maximizing coronal correction. The use of Ponte releases was not associated with a significant increase in blood loss or operative time.

INTRODUCTION: Restoring thoracic kyphosis and achieving optimal coronal correction is a challenge in the hypokyphotic thoracic AIS curve treated with pedicle screws. Ponte osteotomies are routinely used to shorten the posterior column and correct kyphosis. The purpose of this study was to evaluate the novel concept of using Ponte releases to lengthen the posterior column during AIS correction. The hypothesis was a posterior release would allow greater kyphosis creation even with high degrees of coronal/axial correction.

METHODS: Prospectively collected data from a multi-center database where some surgeons used Ponte releases to restore thoracic kyphosis was analyzed. Patients thought to be at greatest risk for postoperative thoracic hypokyphosis made up the study population: structural thoracic scoliosis, pedicle screw instrumentation, $< 20^{\circ}$ T5-T12 kyphosis preoperative and a postoperative scoliosis correction $\geq 60\%$. Radiographic data included coronal and sagittal measures at the 4-6 week postoperative visit. ANOVA ($p<0.05$) was used to identify differences between the patients who had Ponte releases and those who did not.

RESULTS: Of the 1650 patients in the database, 218 patients met the inclusion criteria (84: Ponte and 134: No Ponte). The Ponte group had slightly greater deformity but similar coronal curve correction (75% vs. 76%, respectively, $p=0.3$). A significantly greater increase in T5-12 kyphosis was seen in the Ponte group compared with the no Ponte group (8° vs 3°, respectively, $p<0.001$). There was no difference in the operative time or EBL between the groups.

CONCLUSION: The coronal correction achieved with thoracic pedicle screw instrumentation has been associated with a postoperative reduction in thoracic kyphosis and secondary concerns of junctional kyphosis and reduced lordosis. In hypokyphotic patients, the use of Ponte releases allows for greater lengthening of the posterior column during AIS surgery. This improves thoracic kyphosis restoration despite maximizing coronal correction in thoracic curves treated with pedicle screw instrumentation.

	NO PONTE	PONTE RELEASE	*p*
Preop Thoracic Cobb	53±10	58±12	0.001
Thoracic curve % correction	76±9	75±8	0.3
Sagittal T5-T12 pre-op	12±7	8±9	0.002
Sagittal T5-T12 post-op	15±6	16±7	0.2
Sagittal T5-T12 change	3±7	8±11	≤0.001
EBL (cc)	1034	1108	0.6
Operative time (min)	249	271	0.1

HGS ANNOTATED BIBLIOGRAPHY 2009

Harms Study Group Projects

This is the annotated bibliography of completed Harms Study Group projects. The projects have been organized into the following groups of research:

Completed publications/abstracts have been organized with most recent first, followed by a list of current 2009 projects underway.

DEFORMITY CLASSIFICATION & ASSESSMENT

CLINICAL ASSESSMENT IN AIS

1. *The upper end vertebral tilt-correction rule: a valuable guide to avoid shoulder imbalance after posterior spinal fusion.* Flynn et al. STATUS: Abstract 2009 – Poster @ IMAST. FINDINGS: There is a risk for creating shoulder imbalance when the upper end vertebral tilt of the main thoracic curve (UEVtilt-MT) is corrected beyond the flexibility of the proximal thoracic curve.
2. *AP Shoulder Angle: a New Measurement of Shoulder Balance.* Flynn et al. STATUS: Abstract 2009 – Poster @ IMSAT. FINDINGS: We describe a new measurement of shoulder imbalance, the AP shoulder angle, which correlates well with other previously described radiographic and clinical measures. AP shoulder balance may be more important to patients, because it is what they actually see.
3. *What does a scoliometer really measure?* Cahill (Betz) et al. STATUS: Abstract 2009 – Poster @ SRS. Accepted to Spine 8-09. FINDINGS: There is no correlation between scoliometer and vertebral rotation on CT scan.
4. *Postoperative trunk shift in Lenke 1 curves: incidence, risk factors, and correlation with srs-30.* Samdani et al. STATUS: Abstract 2009 – Poster @ IMAST. FINDINGS: Although attaining truncal balance is one of the primary goals in surgery for AIS, no previous studies have examined its incidence, correlation with SRS-30, and potential risk factors. There is a 12.6% incidence of postoperative TS in Lenke 1 curves at 2 yr f/u. The majority of postoperative TS (64%) were iatrogenic. Patients with TS had lower total SRS scores compared to those without TS. Lower % correction of the lumbar curve was an independent risk factor for postoperative TS.
5. *Postoperative left shoulder elevation (lse): An unexpected consequence of surgical correction of lenke 1 main thoracic curves.* O'Brien et al. STATUS: Abstract 2008 – Podium @ SRS, poster @ IMAST and AAOS. FINDINGS: Risk factors for LSE 2 yrs post-op include: a high or neutral left shoulder preop, a preop upper thoracic (UT) curve>25°, a post-op UT>14°, incomplete instrumentation of the UT, and MT that is corrected by >67%. Instrumentation type and surgical approach were not risk factors for LSE.
6. *Trunk flexibility and activity/function are significantly less with lumbar fusion in patients with lenke 1&2 curve types.* D'Andrea (Betz) et al. STATUS: Abstract 2008 – Poster @ SRS & IMAST. FINDINGS: There is a statistically significant reduction, as much as 21%, in trunk flexibility, activity & function with fusion to L1 & below versus T12 & above in AIS patients with Lenke 1&2 curve types.
7. *Post operative trunk flexibility loss is modest but incremental as the fusion progresses distally.* Newton et al. STATUS: Abstract 2008 – Podium @ SRS, poster @ IMAST & AAOS. FINDINGS: An evaluation of post-operative trunk flexibility following spinal fusion revealed that the more distal the fusion progresses, the greater the loss of flexibility. For each distal level fused below T10, 5% of trunk flexibility is sacrificed. 80% of pre-operative flexibility is maintained with fusions to L2.
8. *Use of the double rib contour sign to determine rib hump correction following scoliosis surgery.* Crawford et al. STATUS: Abstract 2008 submitted – never accepted – Poster @ IMAST, Podium @ AAOS. FINDINGS: The addition of costoplasty to fusion surgeries for AIS improves the correction of the trunk deformity (rib hump).
9. *The majority of initial coronal imbalance following fusion surgery for ais improves within six months.* Asghar (Betz) et al. STATUS: Abstract 2008 – Podium @ SRS, Poster @ IMAST. FINDINGS: Patients with AIS undergoing spinal fusion identified individuals with initial postoperative coronal imbalance. Radiographic follow-up over 24 months reveals that the majority (95%) of patients will eventually obtain balance spontaneously, and the most marked improvement is noted within the first 6 months postoperatively.

10. *Assessment of vertebral body rotation in AIS: correlation between scoliometer and axial ct measurements.* Cahill (Betz) et al. STATUS: Abstract 2008 – not accepted. FINDINGS: In a retrospective study, 29 AIS patients with pre-op CT scans and scoliometer measurements were evaluated. There was no statistically significant correlation between vertebral rotation as measured on CT scan and trunk rotation as measured by scoliometer. The scoliometer may not provide an accurate assessment in the evaluation of surgical derotation maneuvers.
11. *The effect of fusion levels on trunk flexibility and outcome measures in lenke 1&2 curve types.* D'Andrea (Betz) et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: For Lenke 1 & 2 curves, fusion to L1 or above did yield improved outcomes, compared with more distal fusion levels, for postoperative clinical flexibility and trunk motion; however, self image and activity level scores did not decrease with more distal fusion levels.
12 *Are clinical measures of trunk shape sensitive to changes in radiographic measures/scores, or pain and self-image srs-22 scores?* D'Andrea (Betz) et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: Improved post-op clinical trunk shape measures in patients with Lenke 1&2 curves correlated with several radiographic measures but did not correlate with self-image and pain scores.
13. *Return of shoulder girdle function after anterior versus posterior adolescent idiopathic scoliosis surgery.* Ritzman (Newton) et al. STATUS: Abstract 2007 - Published Spine 2008. FINDINGS: Approach related differences in shoulder mobility do exists: OASF imparts a significantly greater magnitude and duration of postoperative shoulder dysfunction than do the TASF or PSF approach, however these effects are transient as shoulder function normalized by the 1 yr post-op time point.
14. *The effects of fusion length on cosmetic and radiographic outcomes on lenke 5 type curves.* D'Andrea (Newton) et al. STATUS: Abstract 2006 – Poster @ IMAST. FINDINGS: Long and short ASF shows similar radiographic and cosmetic outcomes. No variables were found to predict outcomes. Short ASFs may offer good correction, while saving lumbar motion segments.
15. *Trunk shape correction and patient satisfaction in adolescent idiopathic scoliosis.* Clements et al. STATUS: Abstract 2005 – Podium @ IMAST. FINDINGS: In this evaluation of change in trunk shape and patient satisfaction after either anterior or posterior instrumentation results were similar with both approach: both provide a significant improvement in trunk shape.
16. *Post-operative trunk motion in adolescent idiopathic scoliosis: does the region of fusion affect motion?* Marks et al. STATUS: Abstract 2005 – evolved into prospective study in 2007. FINDINGS: A non-invasive clinical assessment of trunk flexibility was utilized to evaluate post-operative motion in patients with AIS. The greatest decreases in post-operative motion were found when both the thoracic and the lumbar regions of the spine were fused.
17. *Do radiographic parameters correlate with clinical outcomes in adolescent idiopathic scoliosis?* D'Andrea (Betz) et al. STATUS: Published Spine 2000. FINDINGS: Radiographic assessment shows a significant improvement between preoperative and 2-year postoperative scores, however, little correlation between the radiographic assessment and the questionnaire scores was found, suggesting that separate analyses of radiographic and clinical outcomes are required when evaluating results of scoliosis surgery.

Current 2009 Projects Underway:

18. *Lumbar curve correction and shoulder balance.* Yaszay et al.
19. *Do pedicle screws improve trunk shape?* Clements et al.

AIS CLASSIFICATION / ASSESSMENT / EVALUATION

1. *Is the lumbar modifier useful in surgical decision making? Defining two distinct Lenke 1A curve patterns.* Miyanji (Newton) et al. STATUS: Published Spine 2008. FINDINGS: Two Lenke 1A curve patterns can be described based on the direction of the L4 tilt. The tilt direction of L4 does allow subdivision of the Lenke 1A curves into 2 distinguishable patterns (1A-R and 1A-L). The 1A-L curves are similar to 1B curves and different in form and treatment from the 1A-R pattern.
2. *Left thoracic curves are not a mirror image of right thoracic idiopathic curves.* Ugrinow (Yaszay) et al. STATUS: Abstract 2008 – Podium SRS. FINDINGS: 44 left curves were compared with 895 right thoracic curves. The coronal plane deformities were similar; however, the sagittal alignment differed between the groups. Right thoracic scoliosis patients had decreased thoracic kyphosis and increased pelvic incidence and sacral slope compared to left thoracic curves. This suggests a different etiology / pathoanatomy between right and left thoracic curves.
3. *Analysis of adherence to the Lenke classification treatment algorithm recommendations.* Clements et al. STATUS: Abstract 2006 – Podium SRS, submitted for publication 2008. FINDINGS: The rules are broken 15% of the time. 6 to 29% of the time (depending on the curve pattern) there are other aspects of the deformity that suggest deviation from the recommendations of the classifications system.
4. *The Role of Stagnara (True Lateral, Plan d' election) X-rays in the Evaluation of the Sagittal Profile pre-operative in AIS.* Letko et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: The Stagnara view proved inaccurate in Lenke 3 and 4 curves with magnitude >80° Thoracic and >70° Thoracolumbar/Lumbar. It is otherwise useful in pre-op sagittal plane assessment of thoracic curves in AIS.

5. *One Size does not fit all: Variations in pelvic and other sagittal parameters as a function of race in AIS.* Lonner et al. STATUS: Abstract 2008 – poster @ IMAST, accepted to Spine 8-09. FINDINGS: Differences in pelvic parameters and lumbar lordosis were found in this AIS population between Black and White races. Black races had a significantly higher pelvic incidence, pelvic tilt and lumbar lordosis. The surgeon should take into account the individual's inherent sagittal alignment when reconstructing the spine in a scoliotic patient. Greater pelvic incidence requires greater lumbar lordosis.
6. *Lenke Types Select more than shape.* Sponseller et al. STATUS: Abstract 2009 – Poster @ IMAST. FINDINGS: Surgeons designing studies evaluating features of AIS need to realize the characteristics which are co-variates of the classification: Lenke 1 & 5 curves contain a majority of small operative curves, while Lenke 4 contains the largest curves. Lenke 5 patients are oldest. Males have more major thoracic curves.
7. *Curve prevalence of a new classification of operative AIS – does classification correlate with treatment?* Lenke et al. STATUS: Published Spine 2002. FINDINGS: The classification system for operative AIS found all 606 consecutive cases or AIS classifiable, with the Type 1, main thoracic curve pattern, the most common type (51%). The system correlates with treatment of surgically structural regions of the spine fused in 90% of cases by the objective radiographic criteria used.
8. *Adolescent Idiopathic Scoliosis – a new classification to determine extent of spinal arthrodesis.* Lenke et al. STATUS: Published JBJS 2001. FINDINGS: This new two-dimensional classification of AIS as tested by 2 groups of surgeons, was shown to be much more reliable than the King system. Additional studies are necessary to determine the versatility, reliability, and accuracy of the classification for defining the vertebrae to be included in an arthrodesis.
9. *Comparison between Left and Right Thoracic Curves in Idiopathic Scoliosis.* Crawford et al. STATUS: Abstract 2005 – Podium @ IMAST, Poster @ SRS. FINDINGS: Pre-operatively and except for the thoracic apical translation, no statistically significant differences were found in patients with AIS regardless of whether they had right or left major thoracic curve.
10. *Can MRI axial rotation measurements in adolescent idiopathic scoliosis correlate with CT?* Samdani et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDING: MRI assessment of vertebral rotation at the apical vertebrae can be reliable and have good correlation with CT as long as the axial images are obtained parallel to the vertebral endplates. Therefore, routine preoperative MRI can be compared to postoperative CT for analysis of rotation correction.

Current 2009 Projects Underway:

11. *Lenke classification: surgeon's thought process with using bends to plan fusion levels.* Yaszay et al.
13. *How does a previous spondy affect treatment planning in AIS?* Yaszay et al.
14. *Disease severity: differences in (1) race and (2) nationality.* Lonner et al.
15. *Psychological effect of bracing.* Lonner / Miyanji et al.
16. *10 yr MRI study assessing disc degeneration below arthrodesis in AIS.* Lonner/Betz/Auerbach et al.
17. *Risk factors for rotation progression (crankshaft).* Cahill et al.
18. *Lenke curve characteristics.* Sponseller et al.
19. *OTRC with posterior pedicle screws.* Sponseller et al.

SAGITTAL PLANE IN AIS

1. *Are we improving postoperative sagittal contour with new posterior instrumentation compared to "old school" instrumentation?* Clements et al. STATUS: Abstract 2009 – Podium SRS & NASS. FINDINGS: When comparing the effect of "older" anterior screw versus "old" posterior hybrid versus "new" posterior screw constructs on postoperative sagittal contour in AIS, anterior better recreates a normal sagittal contour, posterior hybrid constructs change the contour minimally, and posterior screw constructs worsen the mid thoracic hypokyphosis and exaggerate the proximal thoracic kyphosis.
2. *Multivariate analysis of factors associated with kyphosis maintenance in AIS surgery.* Lonner et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: Kyphosis maintenance or restoration is an important goal of AIS surgery. In a multivariate analysis we noted anterior approach and lesser magnitude of kyphosis preoperative were associated with greater increases in kyphosis and longer fusions were associated with loss of kyphosis.
3. *Preservation of thoracic kyphosis: A critical component to maintaining postoperative lumbar lordosis during the surgical treatment of adolescent idiopathic scoliosis.* Upasani (Newton) et al. STATUS: Abstract 2008 – Podium @ SRS & AAOS, Poster @ IMAST, accepted to Spine 8-09. FINDINGS: An analysis of changes in the sagittal profile in surgically treated patients with adolescent idiopathic scoliosis showed that a decrease in post-op thoracic kyphosis results in a decrease in lumbar lordosis. A premature, iatrogenic loss of lumbar lordosis may predispose patients to develop a flat back deformity and an unbalanced forward sagittal alignment.
4. *Cervical sagittal plane decompensation after pediatric AIS surgery.* Antonacci (Betz) et al. STATUS: Abstract 2008 – Poster @ SRS, Podium @ IMAST & NASS. FINDINGS: Pre- and post-op radiographic sagittal profiles of pediatric undergoins scoliosis surgery for Lenke Type 1 and 2 curves was reviewed. Patients with post-op thoracic sagittal profiles <30° had a significantly higher incidence of developing frank cervical kyphosis.

5. *Analysis of sagittal alignment in thoracic and thoracolumbar curves in adolescent idiopathic scoliosis: how do these two curve types differ?* Upasani et al. STATUS: Published Spine 2007. FINDINGS: An increased pelvic incidence, associated with both thoracic and thoracolumbar curves when compared with the normal adolescent population, does not appear to be the potential determinant of the development of the thoracic versus thoracolumbar scoliosis, but may be a risk factor for the development of adolescent idiopathic scoliosis. The theory of anterior overgrowth may be supported by the identification of thoracic hypokyphosis, despite an increased pelvic incidence and lumbar lordosis, in patients with thoracic scoliosis. The association between sagittal measurements and the etiology of thoracolumbar curve formation is less clear; however, regional anterior overgrowth in the lumbar spine may also be responsible for the deformity.
6. *Evaluation of proximal junctional kyphosis in AIS following pedicle screw, hook and hybrid instrumentation.* Helgeson (Shah) et al. STATUS: Abstract 2007 – accepted for publication 10-09. FINDINGS: IN 283 cases of AIS treated with PSF, all pedicle screw constructs had significantly increased proximal level kyphosis when compared to all hook or hybrid constructs at the two year minimum follow-up. However the incidence of PJK among various constructs was not different. A potential solution is the substitution of hooks at the upper-instrumented vertebrae, but further investigation is required.
7. *Sagittal contour correlated with hook versus screw posterior constructs for Lenke 1 curves.* Clements et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: The change in thoracic sagittal alignment that occurs after surgical corrections of thoracic AIS with hook versus screw constructs shows that both implant types correlated to a decrease in sagittal contour and kyphosis T5-T12.
8. *Distal Junctional Kyphosis of Adolescent Idiopathic Thoracic Curves following anterior or posterior instrumented fusion: Incidence, Risk Factors, and Prevention.* Lowe et al. STATUS: Published Spine 2006. FINDINGS: To prevent PJK, the junctional level must be included in both anterior and posterior fusion for thoracic curves.
9. *Lumbar sagittal plane alignment with respect to instrumentation type and surgical technique.* Merola et al. STATUS: Abstract 2005 – Poster @ IMAST & SRS. FINDINGS: The ASF group demonstrated better overall preservation of lumbar sagittal plane contour with respect to lumbar lordosis and thoracic kyphosis.
10. *The effect of continued posterior spinal growth on sagittal contour in patients treated by anterior instrumentation for idiopathic scolisosis.* D'Andrea (Betz) et al. STATUS: Published Spine 2000. FINDINGS: Sagittal progression greater than 10° (average 15°) occurred in 60% in Risser 0 patients. Where only 27% in the riser 1 to 5 patients. Patients treated with anterior instrumentation may be at risk for progressive sagittal kyphosis secondary to growth.
11. *Proximal kyphosis after posterior spinal fusion in patients with idiopathic scoliosis.* Lee (Betz) et al. STATUS: Published Spine 1999. FINDINGS: 46% (32 of 69%) of patients had abnormal proximal kyphosis after undergoing posterior spinal fusion. A pre-op PJK of 5 degrees indicates that extending the fusion to a higher level in the thoracic spine would be beneficial in avoiding this problem.

Current 2009 Projects Underway: (none as of 11-23-09)

RADIOGRAPHIC POSITIONING IN AIS

1. *Which lateral radiographic positioning technique provides the most reliable and functional representation of a patient's sagittal balance?* Marks (Newton) et al. STATUS: Published Spine 2009. FINDINGS: Standing with the hands supported while flexing the shoulders 30° during positioning for lateral spinopelvic radiographic acquisition resulted in an SVA and measures of sagittal plane curvature that were comparable with a functional standing position with arms at the side. This seems to be the best way to move the arms anterior to the spine with the least effect on overall sagittal balance.
2. *Evaluation of a functional position for a lateral radiographic acquisition in AIS.* Faro (Newton) et al. STATUS: Published Spine 2004. FINDINGS: The fists on clavicle position for lateral radiographic acquisition has less negative shift in SVA and in patients with spinal instrumentation, less compensatory posterior rotation of the pelvis. This position allows adequate lateral radiographic visualization of the spine.
3. *Standing lateral radiographic positioning does not represent customary standing balance.* Marks (Newton) et al. STATUS: Published Spine 2003. FINDINGS: The sagittal vertical axis was positive (C7 anterior to S1) for the functional positions (relaxed standing and throughout gait), whereas shoulder flexion resulted in a negative sagittal vertical axis. Adding knee flexion with shoulder flexion resulted in a slight anterior shift of the SVA but was less reliable.

Current 2009 Projects Underway: (none as of 11-23-09)

SURGICAL TECHNIQUES & DECISION MAKING

FUSION LEVEL SELECTION IN AIS

1. *Obesity does not affect fusion levels in adolescent idiopathic scoliosis: a matched cohort analysis.* Cahill et al. STATUS: Abstract 2009 – not accept ed. FINDINGS: Obesity does not play a role in surgeon decision making. An obese patient will likely have the same levels fused as an otherwise similar non-obese patient.
2. *Instrumenting into non-structural proximal thoracic curves may significantly affect shoulder balance after posterior spinal fusion.* Flynn et al. STAUS: Abstract 2009 – Podium SRS. FINDINGS: Shoulder balance is altered to a significant extent when posterior instrumented spinal fusion is extended to or above the apex of a nonstructural proximal thoracic curve.
3. *Selective thoracic fusion in adolescent idiopathic scoliosis: Guidelines in selecting the optimal lowest instrumented vertebrae.* Takahashi (Newton) et al. STATUS: Abstract 2008 – Podium @ SRS & AAOS, Poster @ IMAST & NASS. FINDINGS: When performing a selective thoracic fusion in which the stable vertebrae is at or below the End Vertebrae, the greatest correction of the main thoracic and compensatory lumbar curves occurred when the LIV was at least one level distal the stable vertebrae.
4. *A more distal fusion is associated with increased motion at L4/L5: A set up for degeneration?* Marks (Newton) et al. STATUS: Abstract 2009 – Podium SRS. FINDINGS: As the lowest instrumented vertebrae progressed distally, in lateral bending, there was significantly greater L4-L5 segment motion. The relationship between increased lateral L4-L5 motion and subsequent disc degeneration with a more distal fusion is unknown but suspected.
5. *Lenke 5 Curves: Thresholds for selecting L3 vs L4 as the distal level of fusion.* Yaszay et al. STATUS: Abstract 2009 – Podium @ NASS. FINDINGS: Despite a trend towards fusing to L3, choosing L4 as the LIV when the following thresholds are met: L4 angulation greater than 20°, L3 translation greater than 3.6 cm and L4 translation greater than 2.0 cm.
6. *5 yr clinical and radiographic results of selective thoracic fusions with lumbar curve >40°.* Sponseller et al. STATUS: Submitted for public 10-09. FINDINGS: Selective fusion patients have less correction of the thoracic curve at 5 years with greater loss of thoracic correction even when fused posteriorly. More selective patients required revision for deformity.
7. *"Don't end your fusion at T12 in idiopathic scoliosis": wisdom or myth?* Flynn et al. STATUS: Abstract 2008 – Podium SRS. FINDINGS: In Lenke 1 or 2 curves, choosing an LIV of L1 rather thanks T12 results in less DJK, less T10-L2 Kyphosis, better correction of Cobb angle and lower likelihood of poor coronal balance at 2 yrs post-op. Distal screw versus hook use may mitigate some of this risk.
8. *Factors involved in the decision to perform a selective versus nonselective fusion of Lenke 5 curves in AIS.* Guille et al. STATUS: Abstract 2008 – Poster IMAST. FINDINGS: Surgeons tend to break the rules of the Lenke classification and fused both the thoracic and thoracolumbar/lumbar curves in patients with larger curve magnitudes, large thoracic rib humps, and greater thoracic apical translations.
9. *Selection of the Upper Instrumented Vertebrae in the surgical treatment of adolescent idiopathic scoliosis: identification of the most influential determinants.* Upasani (Newton) et al. STATUS: Abstract 2008 – Poster IMAST, submitted for publication. FINDINGS: Selection of a more proximal UIV is dependent on: proximal thoracic curve magnitude, T1 tilt and T5-T12 Kyphosis. A proximal thoracic curve magnitude > 25° differentiates between patients treated from T1-T3 versus T4-T5.
10. *Risk Factors for Distal Adding-on Identified: What to watch out for.* Schlechter (Newton) et al. STATUS: Abstract 2008 – Podium SRS & AAOS, Poster IMAST & NASS, submitted for publication. FINDINGS: Pre-operative factors associated with "adding on" included: less mature patients, and choosing a lowest instrumented vertebrae too proximal to the stable vertebrae and deviated too far from the center sacral vertical line.
11. *The deformity-flexibility quotient predicts both patient satisfaction and surgeon preference in the treatment of Lenke 1B or 1C curves for adolescent idiopathic scoliosis.* Newton et al. STATUS: Published Spine 2009. FINDINGS: The DFQ was defined to quantify the 2 primary yet competing goals of AIS surgery and is calculated by dividing the residual coronal lumbar deformity by the number of unfused distal motion segments. A lower DFQ was found to significantly correlate with improved patient satisfaction scores. A lower DFQ also predicted the surgeon preferred radiograph in greater than 70% of the pairings. The DFQ quantifies the perceived trade-off between residual deformity and spared motion segments.
12. *A retrospective radiographic and clinical comparison of adolescent idiopathic double thoracic (Lenke II) curves treated by selective anterior instrumentation and fusion of the main thoracic curve versus posterior instrumentation and fusion of both curves.* Lowe et al. STATUS: 2007 Abstract – Poster @ IMAST, submitted to JSDT – rejected. FINDINGS: With a larger MT/PT curve ratio, neutral or negative preoperative T1 tilt, and no positive shoulder asymmetry, selective ASF of the MT curve can be considered. If the converse is true, PSF of both the PT and MT curves is mandated.
13. *Patients who have a selective thoracic fusion for Lenke 1 and 2 curves have similar coronal balance but improved functional outcome scores at two years when compared to those fused into the lumbar spine.* Sucato et al. STATUS: 2007 Abstract – Podium @ SRS, Poster @ IMAST. FINDINGS: Selective thoracic fusion for Lenke 1B, 1C, 2B and 2C curves have similar coronal balance but improved SRS outcome scores when compared to patients fused into the lumbar spine.
14. *Comparison of compensatory curve spontaneous derotation after selective thoracic or lumbar fusions in adolescent idiopathic scoliosis.* Ritzman (Newton) et al. STATUS: Published Spine 2008. FINDINGS: Axial plane correction of the unfused minor curve in patients undergoing selective fusions does occur. Significant spontaneous correction of a thoracic rib hump after a selective lumbar fusion should not be anticipated, whereas an approximate 50% reduction in the lumbar prominence was the average after selective thoracic fusions.

15. *Comparison of lowest instrumented vertebrae (LIV) selection in Lenke 1 main thoracic adolescent idiopathic scoliosis curves by the surgical approach: a minimum 5-year follow-up study.* Lenke et al. STATUS: 2007 abstract – Poster @ IMAST. FINDINGS: ASF patients fused 1 or 2 levels short of the lower end vertebrae will show more loss of correction in the MT cob and specific LIV parameters up to 5 years postoperative than corresponding PSF procedures that were fused principally to 1 or more levels below the LEV.
16. *Radiographic and Surgeon rationale for NOT performing a selective thoracic fusion in Lenke 1C Adolescent Idiopathic Scoliosis Curves.* Lenke et al. STATUS: 2007 abstract – Poster @ IMAST. FINDINGS: The main radiographic difference between patients undergoing ST fusion versus NS fusion was increased TL/L AVT. The main surgeon rationale for a NS fusion was concern for an unacceptable postop lumbar curve; the main clinical reason was nearly-equal preop T & L scoliometer measurements.
17. *Effect of Selective thoracic fusion on trunk flexibility for Lenke 5 Adolescent Idiopathic Scoliosis.* Porter (Betz) et al. STATUS: 2007 abstract – Poster @ IMAST. FINDINGS: Selective anterior fusion had statistically significant better motion in flexion (19%), right bend (32%), and left bend (32%) than the non-selective posterior fusions.
18. *Selective anterior versus Non-selective posterior fusion of Lenke 5C curves: a matched retrospective analysis.* Abel et al. STATUS: Abstract 2006 – Poster @ IMAST. FINDINGS: In 17 matched pairs, there was no difference in radiographic or SRS outcomes in selective vs non-selective. In general, selective fusion is performed more frequently.
19. *Comparison of Selective versus Double major thoracic fusion in patients with thoracic and lumbar scoliosis curves within 5 degrees of each other preoperatively.* Lenke et al. STATUS: Abstract 2005 – not accepted. FINDINGS: Patients with a preop major thoracic and minor lumbar Cobb magnitudes within 5° of each other may still undergo a successful selective selective thoracic fusion when the thoracic and lumbar Cobb measurements are smaller (<60°), and the preop lumbar apical translation is small and less than the thoracic translation.
20. *Factors Involved in the Decision to Perform a Selective Versus Nonselective Fusion of Lenke 1B and 1C (King-Moe II) Curves in Adolescent Idiopathic Scoliosis.* Newton et al. STATUS: Published Spine 2003. FINDINGS : The characteristics of the compensatory "nonstructural" lumbar curve played a significant role in the surgical decision-making process and varied substantially among members of the study group. Side-bending correction of the lumbar curve to <25° (defining these as Lenke 1, nonstructural lumbar curves) was not sufficient criteria to perform a selective fusion in some of these cases. The rate of selective fusion was 92% for the 1B type curves compared to 68% for the 1C curves.
21. *Anterior Single-Rod Instrumentation of the Thoracic and Lumbar Spine: Saving Levels.* Lowe et al. STATUS: Published Spine 2003. FINDINGS: Single-rod anterior instrumentation will often saved one to three distal fusion levels when treating isolated major thoracic, thoracolumbar, or lumbar curves. Fusion levels should include upper to lower Cobb levels. Additionally, anterior single-rod instrumentation because its kyphogenic nature will predictably correct hypokyphosis of the thoracic spine.
22. *Multisurgeon assessment of surgical decision-making in adolescent idiopathic scoliosis – curve classification, operative approach, and fusion levels.* Lenke et al. STATUS: Published Spine 2001. FINDINGS: This case study assessment found a relatively high rate (84-90%) of agreement in curve classification of the individual components of a new classification of the individual components of a new classification system of AIS. This suggests the ability of a group of scoliosis surgeons to identify the specific criteria necessary for this new classification system of AIS. In addition the high variability in selection of both operative approach and fusion levels confirms the current lack of standardized treatment paradigms. This further reinforces the need for a method to critically and objectively evaluate these variable treatments to determine the "best" radiographic and clinical results.
23. *Spontaneous Lumbar curve coronal correction after selective anterior or posterior thoracic fusion in adolescent idiopathic scoliosis.* Lenke et al. STATUS: Published Spine 1999. FINDINGS: Spontaneous lumbar curve correction occurs consistently after both selective anterior and posterior thoracic fusion implying intrinsic ability of the lumbar spine to follow thoracic spine correction. In the current study, using multisegmented hook-rod systems posteriorly with intentional limitation of posterior

Current 2009 Projects Underway:

24. *A single surgeon series of surgical outcomes of all pedicle screws with DIV of T12...should you stop here?* Shufflebarger
25. *Leveling the LIV in selective fusions.* Flynn et al.
26. *Selective fusion of Lenke 3 curves.* Sponseller et al.

SURGICAL APPROACHES IN AIS – COMPARISONS AND PROCEDURES

1. *Adolescent Idiopathic Scoliosis Treated with Open instrumented anterior spinal fusion: Five year follow-up.* Tis (Betz) et al. STATUS: Published Spine 2010. FINDINGS: OASF is a reproducible and safe method to treat thoracic AIS with good coronal and sagittal correction. In skeletally immature children, this technique can cause an increase in kyphosis beyond normal values and less correction of kyphosis should be considered during instrumentation. Pulmonary function is mildly decreased at final follow-up.
2. *Computed tomography evaluation of rotation correction in adolescent idiopathic scoliosis: a comparison of an all pedicle screw construct versus a hook-rod system.* Asghar (Betz) et a. STATUS: Published Spine 2009. FINDINGS: Axial correction using all pedicle screw constructs and a direct vertebral body derotation technique was significantly greater than that obtained with the HR construct.

3. *Second generation ASF vs PSF techniques in the treatment of 30 Lenke 1 AIS patients.* Letko et al. STATUS: Abstract 2009 – not accepted. FINDINGS: Coronal plane correction is similar but kyphosis is reduced with PSF and increased with 2nd generation ASF. Despite changes in kyphosis, there was no difference in the amount of lumbar lordosis at 2 years post-op between the 2 techniques.
4. *Three dimensional correction of severe scoliosis: bringing the anterior release back.* Varley (Newton) et al. STATUS: Abstract 2009 – not accepted FINDINGS: In a matched comparison of posterior alone to posterior with anterior release the 3-D assessment demonstrated comparable coronal correction, but with greater correction in the sagittal and axial planes with an anterior release.
5. *Establishment of a minimal EMG threshold for thoracic pedicle screw placement.* Shufflebarger et al. STATUS: Abstract 2009 – Poster @ IMAST. FINDINGS: Each patient may act as the control to determine the minimal acceptable threshold of thoracic pedicle screws in scoliosis. The range of acceptable threseholds was from 3.5-8 mAmp. This is lower than most recommended levels.
6. *Multicenter study of posterior vertebral column resection for pediatric deformity.* Shufflebarger et al. STATUS: Abstract 2008 – Podium at SRS & NASS. FINDINGS: VCR is a valuable deformity surgery technique with potential neurological complications that can be minimized by the use of spinal cord monitoring to guide intraoperative decisions. VCR risks appear less when performed for hemivertebra excision. Intraoperative neuromonitoring changes are common and the surgeon should be prepared to make adjustments accordingly.
7. *Does maximizing curve correction of Lenke 1 curves in AIS risk secondary decompensation.* Imrie (Yaszay) et al. STATUS: Abstract 2009 – Poster @ IMAST, Podium @ NASS. FINDINGS: Maximizing Lenke 1 curve correction to achieve greater lumbar correction and improved clinical appearance can be done without compromising coronal balance but may be at the expense of sagittal alignment.
8. *A new indication for Ponte releases in Adolescent Idiopathic Scoliosis: Restoring thoracic kyphosis.* Yaszay et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: The ponte group has slightly greater deformity but similar coronal curve correction. A significantly greater increase in T5-T12 kyphosis was seen in the Ponte group compared with the no ponte group. No difference in op time or EBL.
9. *Continued spinal growth in EOIS: Single rod instrumentation without Fusion.* Letko et al. STATUS: Abstract 2008 – not accepted. FINDINGS: A case study of unilateral pedicle screw instrumentation without fusion allows for excellent correction of the spinal deformity and allows for continued growth.
10. *The role of Halo extension in the treatment of AIS.* Jensen (Harms) et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: Treatment of AIS with Halo traction and pedicle screws allowed for greater curve correction when compared to hybrid instrumentation without halo traction.
11. *Grading apical vertebral rotation without a CT scan: A simple system based on the radiographic appearance of bilateral pedicle screws.* Upasani (Newton) et al. STATUS: Published Spine 2009. FINDINGS: A trigonometric model to measure vertebral rotation based on the radiographic appearance of bilateral pedicle screws was found to significantly correlate with CT measures of vertebral rotation which can be used to perform post-operative grading of apical rotation in AIS.
12. *What is the 'best' surgical approach for a Lenke 1 Main thoracic curve? Results of a prospective, multi-center study.* Newton et al. STATUS: Abstract 2008 – Poster @ IMAST, Podium @ AAOS. FINDINGS: A prospective comparison of outcomes for 3 surgical approaches for primary right thoracic curve pattern (Lenke type 1) showed that 2 year post-operative outcomes are similar. There were advantages of T-scope and and posterior over open anterior for example shorter operative time with posterior and smallest incisions and least blood loss with T-scope.
13. *The role of Tranexamic Acid and Increased Bovie setting in blood loss and transfusions during posterior spinal fusions for adolescent idiopathic scoliosis.* Crawford et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: TXA and an increased Bovie setting can significantly decrease intraoperative blood loss in posterior spinal fusion.
14. *Surgical trunk rotation correction in patients with moderate thoracic AIS (<75°): An all pedicle screw construct with derotation is better than thoracoplasty.* Asghar (Betz) et al. STATUS: Abstract 2008 - Poster @ IMAST, Podium @ NASS. FINDINGS: Retrospective comparison of residual rib prominence in patients with direct vertebral body rotation (curves <75° and flexibility >50%) exhibited a larger % correction of the rib prominence at two years than a similar group with thoracoplasty.
15. *Routine postoperative CT scans may detect potentially hazardous thoracic screw breaches in AIS fusion surgery prior to development of clinically significant sequelae.* Samdani et al. STATUS: Abstract 2008 – not accepted. FINDINGS: Review of post-op CT scans in 145 consecutive patients with AIS undergoing fusion identified 2.8% of patients with pedicle screw breaches impinging neighboring neural and vascular structures, leading to subsequent revision. Since these were undetected by standard evaluation routine CT may be beneficial.
16. *Accuracy of free-hand placement of thoracic pedicle screws in adolescent idiopathic scoliosis: how much of a difference does surgeon experience make?* Samdani et al. STATUS: Published Eur Spine 2009. FINDINGS: Pedicle screw breach rates assessed by postoperative CT for surgeons with varying levels of experience were evaluated and found an overall breach rate of 12.5% with a trend toward fewer breaches and less medial breaches for the most experiences surgeons.
17. *Surgical treatment of main thoracic scoliosis with thoracoscopic anterior instrumentation. A five year follow-up study.* Newton et al. STATUS: Published JBJS 2008. FINDINGS: Radiographic findings, pulmonary function, and clinical measures remain stable between the 2 and 5 year follow-up timepoints. The 5 year outcomes are similar to those that have been reported for open anterior and posterior approaches.

18. *Comparison of Severe scoliosis treated with or without Halo traction.* Sponseller et al. STATUS: Published Spine 2009. FINDINGS: Retrospective comparison of large curves with and without preoperative traction showed that curve correction, spinal length and complications were similar but vertebral column resection was more commonly employed in the absence of traction.
19. *Large thoracic AIS curves greater than 70°: do they need an anterior release?* Sucato et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: Similar coronal plane correction of the MT curve was seen when comparing anterior/posterior procedure with a posterior alone procedure. An anterior procedure may improve coronal plane correction if the flexibility of the curve is <40%.
20. *Defining the incidence of complications and risk factors associated with the use of single lung ventilation for thoracoscopic surgery in pediatric spinal deformity.* Sucato et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: The incidence of complications from the use of SLV in a multicenter retrospective study of 501 patients was 8% with only 0.8% of procedures aborted. Younger smaller patients with PFTs <70% predicted are most likely to have these problems with SLV.
21. *Blood loss and operative time in scoliosis surgery as a function of construct type and surgeon experience.* Shufflebarger et al. STATUS: Abstract 2007 – Poster @ SRS & IMAST. FINDINGS: Increasing surgeon experience with all pedicle screw constructs in scoliosis surgery results in decreasing operative time and decreasing blood loss. These important parameters are equivalent to those in all hook constructs.
22. *Spontaneous lumbar curve correction (SLCC) in selective thoracic fusions of idiopathic scoliosis: a comparison of anterior and posterior approaches.* Patel (Newton) et al. STATUS: Published Spine 2008. FINDINGS: Anterior and posterior instrumented fusions performed selectively on the appropriate curves result in equal SLCC when matched by LIV, flexibility of the lumbar curve and percent thoracic curve correction achieved. SLCC is independent of surgical approach.
23. *Ten year trends in the surgical treatment of primary right thoracic adolescent AIS.* Newton et al. STATUS: Abstract 2005 – Poster @ IMAST & SRS. FINDINGS: Between 1995 and 2004 the surgical approach data for 604 patients exhibited a predominance of anterior approaches up until 2003 when posterior approach became more common. Surgical time and EBL have remained stable over time. Thoracoplasty was most common in 1999 and has declined since. Anterior release with PSF has also decreased.
24. *Anterior release prior to a posterior spinal fusion and instrumentation: Is the thoracoscopic approach as effective as an open thoracotomy?* Sucato et al. STATUS: Abstract 2005 – Poster @ IMAST. FINDINGS: At 2 years, no significant differences were seen in the thoracic coronal curve correction, apical translation or coronal plane balance while the incidence of complications was similar for open or thoracoscopic anterior releases performed with a posterior spinal fusion.
25. *Correction of left thoracic curves: a comparison of anterior versus posterior instrumentation.* Crawford et al. STATUS: Abstract 2005 – Podium @ IMAST, Poster @ SRS. FINDINGS: 3 areas achieved statistically significant differences: (1) thoracic curve was greater and more rigid in the posterior group (2) blood loss during surgery was greater in the posterior group (3) an average of 2-3 levels was saved with anterior instrumentation.
26. *Results of screw removal after angiographic verification of aortic impression in 2 of 10 Idiopathic scoliotic VDS patients with >10 year follow-up.* Letko et al. STATUS: Abstract 2005 – Poster @ IMAST. FINDINGS: Results of screw removal after angiographic verification of aortic impression in 2 of 10 patients operated on >13 years ago. Post-op CT showed no evidence of aortic wall changes in either patient.
27. *Prospective evaluation of 50 consecutive scoliosis patients surgically treated with thoracoscopic anterior instrumentation.* Newton et al. STATUS: Published 2005 Spine. FINDINGS: The outcomes of this consecutive series of patients are comparable to prior open and endoscopic series presented in the literature. The technical challenges of this operation are evident in the learning curve effect, which has been demonstrated.
28. *Morbidity of iliac crest bone graft harvesting in adolescent deformity surgery.* Kager (Newton) et al. STATUS: Published JPO 2006. FINDINGS: Site pain associated with IC harvesting in 60 AIS and 11 Scheuermann kyphosis patients showed 12% of AIS and 0% of SK reporting pain. Pain reports are limited in severity <or =3.
29. *A prospective comparison of thoracoscopic vs open anterior instrumentation and spinal fusion for idiopathic scoliosis in children.* Grewal (Betz) et al. STATUS: Published JPO 2005. FINDINGS: At 1 yr follow-up, the thoracic curves were similar and percentage correction of thoracic curves was also similar.
30. *The success of thoracoscopic Anterior spinal fusion in a consecutive series of 112 pediatric spinal deformity cases.* Newton et al. STATUS: Published Spine 2005. FINDINGS: Thoracoscopic anterior release and fusion of the thoracic spine is a safe and effective procedure when combined with posterior instrumentation and fusion. The primary goal of increasing the flexibility of a rigid spine and achieving a solid arthrodesis occurred in the vast majority of cases.
31. *Single-Rod versus Dual-Rod anterior instrumentation for idiopathic scoliosis: a biomechanical study.* Lowe et al. STATUS: Published Spine 2005. FINDINGS: Dual-rod constructs with structural interbody support appear to be the best combination for providing stiffness in anterior instrumentation. The addition of cross-links to anterior constructs does not appear to increase stiffness except in torsion.
32. *Use of a video assisted thoracoscopic surgery to reduce perioperative morbidity in scoliosis surgery.* Newton et al. STATUS: Published Spine 2003. FINDINGS: The thoracoscopic approach for instrumentation of scoliosis has advantages of reduced chest wall morbidity compared with the open thoracotomy method but allows comparable with the open thoracotomy method but allows comparable curve correction.

33. *Anterior single rod instrumentation for thoracolumbar adolescent idiopathic scoliosis with and without the use of structural interbody support.* Lowe et al. STATUS: Published Spine 2003. FINDINGS: The use of interbody structural support does not appear to be necessary to maintain an appropriate sagittal profile or to maximize coronal curve correction when a rigid rod construct with packed morselized bone is used for the treatment of thoracolumbar adolescent idiopathic scoliosis.
34. *Defining the pediatric spinal thoracoplasty learning curve: Sixty-five consecutive cases.* Newton et al. STATUS: Published Spine 2000. FINDINGS: The learning curve for thoracoscopy is substantial but not prohibitive. This technique provides a safe and effective alternative to thoracotomy in the treatment of pediatric spinal deformity.

Current 2009 Projects Underway:

35. *Graft type comparison: Iliac crest vs. combined iliac crest and rib vs. allograft bone grafts.* Lonner et al.
36. *Derotation effects on the sagittal plane.* Cahill et al.
37. *Derotation effects on the coronal plane.* Samdani et al.
38. *What is the role of a thoracoplasty with all pedicle screw constructs.* Samdani et al.
39. *Rod contouring.* Newton et al.
40. *Ponte vs No Ponte.* Newton et al.
41. *Anterior release & Posterior spinal fusion vs. Posterior spinal fusion alone for curves >80°.* Newton et al.
42. *Evolution of t-scope indications.* Newton et al.
43. *Single surgeon series of Anterior vs Posterior for Lenke 5.* Newton et al.

CONSTRUCT / IMPLANT RESEARCH IN AIS

1. *A novel method for assessing the axial plane in scoliosis demonstrates uniplanar screws outperform polyaxial screws.* Dalal (Newton) et al. STATUS: Abstract 2009 – Podium @ SRS & NASS. FINDINGS: Thoracic apical vertebral rotation after surgical correction of thoracic AIS was compared between uniplanar and polyaxial pedicle screw constructs. While there was no difference in the correction of the thoracic Cobb angle, the uniplanar screw constructs achieved more complete axial correction than did the polyaxial screw constructs.
2. *Rod Strength: Is it an important factor in coronal and sagittal realignment after surgery for AIS?* Shah et al. STATUS: Abstract 2009 – Poster @ IMAST, Podium NASS. FINDINGS: Higher strength rods are more effective in coronal and sagittal plane restoration of deformities. Stainless steel performs better than titanium when evaluating segmental pedicle screw constructs, even in the challenging scenario of kyphosis restoration with posterior surgical techniques in the hypokyphotic patient.
3. *The uniplanar screw: a new tool in the surgical treatment of AIS.* Shah et al. STATUS: Abstract 2008 – Podium @ NASS. FINDINGS: The uniplanar screw provides similar coronal plane correction as fixed angle and polyaxial screws while facilitating improved restoration of thoracic kyphosis.
4. *The effect of pedicle screw pullout strength of optimizing pedicle fill using a tool to size and dilate the pedicle.* Clements et al. STATUS: Abstract 2008 – not accepted. FINDINGS: A biomechanical study of the significant increase in pullout strength that occurs when pedicle screw diameter is selected to maximally fill the pedicle by using a tool to size and dilate the pedicle. Screw pullout of the optimally filled pedicle was compared with a standard diameter screw in cadaver spines.
5. *Correlation of scoliosis curve correction with the number and type of fixation anchors.* Clements et al. STATUS: Published Spine 2009. FINDINGS: Major curve correction at 2 years post-op correlates most with the implant density: correction increases with the number of implants used within the measured Cobb levels. Although the absolute number of screws used did not correlate with correction, there was an advantage in lumbar and thoracic curves to using screws compared to hooks. Sagittal contour in the thoracic spine became less kyphotic than the higher the implant density.
6. *Comparison between 4.0 mm stainless steel and 4.75 mm titanium alloy single-rod spinal instrumentation for anterior thoracoscopic scoliosis surgery.* Yoon (Newton) et al. STATUS: Published Spine 2008. FINDINGS: The 4.75 Ti construct resulted in improved maintenance of deformity correction at 2-years postop and a lower incidence of instrumentation related complications. These improved outcomes may be related to mechanical properties of the implant, refined patient selection criteria, and greater experience gained with time.
7. *The interobserver and intraobserver reliability of assessing thoracic pedicle screw position based on computed tomography.* Asghar (Betz) et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: In a review of 20 patients with AIS and a postoperative CT to assess pedicle screw breach, there was poor interobserver reliability with moderate intrarater reliability of the Kim et al. definition for pedicle screw breach. This may call into question the efficacy of these criteria.
8. *Evolution of thoracic pedicle screws in AIS over a ten year period: are the outcomes better?* Shah et al. STATUS: Abstract 2007 – Podium @ SRS, Poster @ IMAST & NASS. FINDINGS: When compared to hook and hybrid cohorts, patients treated with segmental pedicle screw fixation for AIS had improved major Cobb correction, restoration of LIV tilt, rib hump reduction, patient-reported function and self image and shorter fusion.

9. *Treatment of thoracic scoliosis: are monoaxial thoracic pedicle screws the best form of fixation for correction?* Lonner et al. STATUS: Published Spine 2009. FINDINGS: Hybrid, polyaxial and monoaxial segmental constructs were compared and similar coronal and sagittal plane correction was achieved in thoracic AIS. There was a trend toward improved correction of clinical rib hump deformity with Monoaxial screw constructs compared with Poly.
10. *Anterior treatment of structural thoracolumbar and lumbar curves: A comparison of dual versus single rod constructs in 100 patients.* Guille et al. STATUS: Abstract 2007 – Poster @ SRS, Poster @ IMAST, Podium @ NASS. FINDINGS: At 2 yr follow-up, the radiographic results of single versus dual rod instrumentation appear comparable, but with better maintenance of coronal percent correction, shorter operative times and less blood loss in the single rod group.
11. *The variation in how surgeons contour rods for scoliosis correction is substantial.* Pawelek (Newton) et al. STATUS: Abstract 2006 - Poster @ SRS, Podium @ IMAST. FINDINGS: There was substantial variation in rod contouring. The 'ideal' rod contour remains unknown, but it is unlikely a rod contour of 18 degrees will give the same outcome as one contoured 44 degrees (the range within this study).
12. *The effect of rod diameter on scoliosis correction.* Lonner (Newton) et al. STATUS: Abstract 2006 – Poster @ IMAST. FINDINGS: Coronal and sagittal plane correction, maintenance of correction and distal and junctional kyphosis were no different in matched patient's treated with two different rod diameter constructs.

Current 2009 Projects Underway:

13. *Is rod strength a factor in sagittal and coronal correction?* Shah et al.

OUTCOMES & COMPLICATIONS

HEALTH RELATED QUALITY OF LIFE OUTCOME TOOLS IN AIS:

1. *Body Image in patients with AIS: Validation in the Body Image Disturbance Questionnaire – Scoliosis Version.* Auerbach et al. STATUS: Abstract 2009 – poster SRS, podium NASS. FINDINGS: BIDQ is accurate instrument and can be used to assess appearance-related distress and impairment in AIS.
2. *Does the occurrence of postoperative complications adversely affect SRS scores?* Guille et al. STATUS: Abstract 2008 – poster IMAST & SRS. FINDINGS: The occurrence of a major postoperative complication significantly decreases SRS scores.
3. *Adolescent Idiopathic Scoliosis Patients Report Increased Pain at Five Years Compared with Two years after surgical treatment.* Upasani (Newton) et al. STATUS: Published Spine 2008. FINDINGS: The etiology of the worsening pain could not be elucidated.
4. *Dissecting the effects of spinal fusion and deformity magnitude on quality of life in patients with adolescent with adolescent idiopathic scoliosis.* Tsutsui (Newton) et al. STATUS: Published Spine 2009. FINDINGS: Spinal fusion has an isolated negative effect on AIS patient's quality of life (total score) due to a decrease in the activity domain. The overall positive effect of surgery depends on the negative reports and the deformity reduction.
5. *SRS Questionnaire outcomes comparison of posterior pedicle screw instrumentation versus thoracoscopic anterior instrumentation for selective fusion of Lenke 1 Adolescent Idiopathic Curves.* Clements et al. STATUS: Abstract 2006 – Podium @ IMAST, Poster @ SRS. FINDINGS: No significant differences in the SRS questionnaire improvements in between the 2 groups.
6. *The relationship between thoracic hyperkyphosis and the scoliosis research society outcomes instrument.* Petcharaporn (Newton) et al. STATUS: Published Spine 2007. FINDINGS: Higher kyphosis magnitudes were associated lower scores on the SRS questionnaire: the instrument may be even better suited for the evaluation of the hyperkyposis patient.
7. *A Multicenter Study of the Outcomes of the Surgical Treatment of Adolescent Idiopathic Scoliosis Using the Scoliosis Research Society (SRS) Outcome Instrument.* Merola et al. STATUS: Published Spine 2002. FINDINGS: Surgical intervention was associated with improving outcome when compared with pre-operative status; domains of Pain, general self-image, function from back condition, and level of activity all showed significant improvements.
8. *A multicenter study analyzing the relationship of a standardized radiographic scoring system of AIS and the scoliosis research society outcomes.* Wilson (Newton) et al. STATUS: Published Spine 2002. FINDINGS: Significant association existed between pre-op thoracic and lumbar curve magnitude and domains of pain, self image and total scores. However, the low R2 values indicate that variables other than radiographic appearance of the deformity must also be affecting these scores.
9. *Parents' and Patients' preferences and concerns in Idiopathic Adolescent Scoliosis; a cross sectional pre-operative analysis.* Bridwell et al. STATUS: Published Spine 2000. FINDINGS: The greatest concern about the surgery expressed by both parents and patients was neurological deficit. The parents concerns were higher and expectations were greater than the patients.
10. *Do radiographic parameters correlate with clinical outcomes in adolescent idiopathic scoliosis?* D'Andrea (Betz) et al. STATUS: Published Spine 2000. FINDINGS: Radiographic assessment shows a significant improvement between preoperative and 2-year postoperative scores, however, little correlation between the radiographic assessment and the questionnaire score was found, suggesting that separate analyses of radiographic and clinical outcomes are required when evaluating results of scoliosis surgery.
11. *Results of the Scoliosis Research Society Instrument for Evaluation of Surgical Outcome in Adolescent Idiopathic Scoliosis.* Haher et al. STATUS: Published Spine 1999. FINDINGS: The SRS outcomes instrument is a validated tool with good reliability measures. It addresses patients measures for evaluation of outcome in adolescent idiopathic scoliosis by examining several domains.

Current 2009 Projects Underway:

12. *BIDQ further refinement.* Lonner et al.
13. *Anterior chest wall deformity – development of an assessment tool.* Lonner et al.
14. *Patient visualization on radiographs – what is the influence of patient visualization of pre & post radiographs on HRQOL assessment tools.* Lonner et al.
15. *SAQ tool evaluation / potential revision.* Betz et al.
16. *Minimally clinically important difference.* Flynn et al.

PULMONARY FUNCTION TESTING IN AIS

1. *Should post-operative pulmonary function be a criterion that affects upper instrumented vertebral body selection in AIS surgery?* Schlecter (Newton) et al. STATUS: Abstract 2008 – Poster @ SRS & IMAST, submitted for publication. FINDINGS: There is no justification for limiting the proximal extent of surgery based on concerns of reducing pulmonary function in AIS.
2. *Predictors of change in postoperative pulmonary function in AIS – A prospective study of 254 patients.* Newton et al. STATUS: Published Spine 2007. FINDINGS: Pre-op PFT, having an open thoracotomy and thoracoplasty are the variables found to be significant predictors of 2-year pulmonary function (FVC, FEV1, TLC).
3. *Effect of Anterior Approaches for the treatment of Adolescent Idiopathic Scoliosis on Pulmonary Function.* Lonner et al. STATUS: Published JSDT 2009. FINDINGS: Slight declines in pulmonary function at two-year follow-up were noted in both the Video-Assisted Thoracoscopic Surgery and the thoracotomy approach. No significant diminishment was noted for the thoracoabdominal group.
4. *Thoracoscopic Scoliosis Surgery Affects Pulmonary Function Less than thoracotomy at 2 years postsurgery.* Kishan (Newton) et al. STATUS: Published Spine 2007. FINDINGS: There is a clear advantage to the minimally invasive thoracoscopic approach with regards to pulmonary function when compared with the open thoracotomy approaches.
5. *Results of preoperative pulmonary function testing of adolescents with idiopathic scoliosis – as study of 631 patients.* Newton et al. STATUS: Published JBJS 2005. FINDINGS: The degrees of scoliosis that were associated with clinically relevant decreases in pulmonary function were much smaller than previously described, but the majority of variability in pulmonary function was not explained by the radiographic characteristics of the deformity.
6. *Perioperative changes in pulmonary function after anterior scoliosis instrumentation: Thoracoscopic versus open approaches.* Faro (Newton) et al. STATUS: Published Spine 2005. FINDINGS: The thoracoscopic approach causes a smaller decline in pulmonary function 3 months and 1 year after surgery as compared to the more invasive technique of open thoracotomy for anterior spinal instrumentation for correction of adolescent idiopathic scoliosis.
7. *Prospective pulmonary function evaluation following open thoracotomy for anterior spinal fusion in adolescent idiopathic scoliosis.* Graham (Lenke) et al. STATUS: Published Spine 2000. FINDINGS: There was a significant decline in PFT absolute values at 3 months postoperatively with subsequent improvement and no statistical difference between preoperative and 2 year post-op values. For % predicted there was also a significant decline at 3 months which return at 2 year but are still significantly less than pre-op.
8. *Prospective pulmonary function comparison of Open versus Endoscopic Anterior Fusion combined with posterior fusion in adolescent idiopathic scoliosis.* Lenke et al. STATUS: Published Spine 2004. FINDINGS: VAT versus Open release/anterior fusion in association with a PSF for select AIS curves requiring circumferential treatment both demonstrated similar radiographic and pulmonary function test improvement at 2 years postoperative with no significant differences seen between the groups.

Current 2009 Projects Underway: (**none as of 11-23-09**)

COMPLICATIONS IN AIS

1. *Radiographic classification of complications of instrumentation in adolescent idiopathic scoliosis.* Flynn et al. STATUS: Published Clin Orthop Related Research. 2009. FINDINGS: A new system of adverse events based on radiographic findings was used to analyze 466 patients who had surgical management of their AIS. There was no difference in rate between surgical approach or anchor type.
2. *Surgical site infection (SSI) in spinal surgery: The newest "Never" event.* Marks (Newton) et al. STATUS: Abstract 2008 - Podium NASS. FINDINGS: The timing and severity of surgical site infections were evaluated in a multicenter, prospectively enrolled database of adolescent idiopathic scoliosis patients. Deep infections occur at a rate of 0.7%.
3. *Longer Surgical times may increase your complication rate.* Shah et al. STATUS: Abstract 2008 – Poster NASS. FINDINGS: In a cohort of 289 patients, 28 patients with a surgical time greater than 420 minutes experienced a complication rate of 32% a rate of 3.5 times higher than patients with a surgical time of less than 420 minutes.
4. *Complications in the surgical treatment of adolescent idiopathic scoliosis (AIS): A ten year review of a prospective database with 1292 patients.* O'Brien et al. STATUS: Abstract 2007 - Podium @ SRS, Poster @ IMAST. FINDINGS: Overall complication rate was 17.8%. Major complications accounted for 7.5% and minor 10.3%. Posterior complication rates were 13.4% and anterior rates were 24.2%.

5. *The rate of unplanned second surgeries in adolescent idiopathic scoliosis.* Shufflebarger et al. STATUS: Abstract 2007 – submitted for publication in 2009. FINDINGS: The early unplanned second surgery rate was 1.6% irrespective of the approach. Unplanned second surgeries >2 years after the index procedure had an incidence of 7.3%. Implant removal ocured only after index posterior surgery, while pseudoarthorsis repair was more common after anterior index surgery.

Current 2009 Projects Underway:

6. *Define the incidence of neurologic complications and describe their sequelae in AIS.* Yaszay et al.
7. *Reporting of non-neurological complications in AIS.* Yaszay et al.
8. *Descriptive report of neuromonitoring during AIS spinal fusion surgery – define the effectiveness of neuromonitoring.* Yaszay et al.

GLOBAL OUTCOMES IN AIS

1. *Does Obesity affect surgical outcomes in AIS?* Upasani (Newton) et al. STATUS: Published Spine 2008. FINDINGS: Overweight adolescents (BMI% >85) had a greater thoracic kyphosis before surgery compared with their healthy weight peers. Body mass, however, did not affect the ability to achieve coronal or sagittal scoliotic deformity correction, and did not increase perioperative morbidity or mortality.
2. *Double and Triple curvatures in Idiopathic Scoliosis: Incidence and Surgical Outcomes.* Lonner et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: Double and Triple curves compromise a small percentage of the overall AIS population. Improvements in radiographic and clinical outcome measures were demonstrated in most patients with few major complications.
3. *Differences in curve behavior after fusion in adolescent idiopathic scoliosis patients with open triradiate cartilages.* Sponseller et al. STATUS: Published Spine 2009. FINDINGS: Patients with scoliosis and OTRC have a greater risk of adding-on proximally and of loss of correction with anterio-only instrumentation; they may also have less predictable lumbar correction from selective thoracic fusion. However, after combined surgery, they have results similar to those of more skeletally mature patients.
4. *Outcomes of surgical treatment in Male versus Female AIS patients.* Marks (Newton) et al. STATUS: Published Spine 2007. FINDINGS: Male AIS patients had slightly more rigid primary curves compared to females but a similar degree of post-operative scoliosis correction. Differences in the preoperative status and perioperative course did not compromise the outcomes of surgical treatment as in all other measures; the results were comparable between the genders.

Current 2009 Projects Underway:

5. *Are study groups reporting similar or different findings of AIS operative outcomes?* Yaszay et al.
6. *Wait time survey.* Miyanji et al.
7. *BMI > 30 and hyperkyphosis in AIS.* Shah et al.
8. *Return to activity protocol in post-op AIS.* Shah et al.
9. *Outcomes / complications of large curves.* Shah et al.

RESEARCH IN SCHEUERMANN'S KYPHOSIS

1. *Scheuermann's kyphosis: Prospective evaluation of clinical presentation and impact on quality of life in 43 patients.* Lonner et al. STATUS: Abstract 2008 – Poster @ IMAST. FINDINGS: Body mass index and kyphosis magnitude were found to be significantly greater in SK patients presenting with low-apex versus mid-thoracic apex. No differences in pulmonary function, VAS, or SRS - 22 scores were noted.
2. *Body mass index in Scheuermann's Kyphosis (SK): Does BMI differ in patients with SK versus AIS?* Lonner et al. STATUS: Abstract 2008 – Podium @ SRS. FINDINGS: BMI in SK patients was found to be significantly higher than in AIS patients. Overall, self-image, and pain domain scores of the SRS-22 outcome instrument were worse of SK patients than for AIS patients. Higher BMI associated with SK may impact detection of the deformity, clinical effect on the patient and operative morbidity.
3. *Do discs "open" anteriorly with posterior only correction of Scheuermann's kyphosis?* Tsutsui (Newton) et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: SK can be corrected using a posterior construct with or without the addition of an anterior disc release; however, the change in disc shape that accounts for correction has not been well described for either of these procedures. A radiographic comparison between the two procedures revealed no significant difference in the degree of kyphosis correction or the change in disc shape that led to the reduction in kyphosis. Anterior disc heights increased up to 3 mm near the apex for both procedures.
4. *Evaluation of pulmonary function in patients with Scheuermann's Kyphosis.* O'Brien et al. STATUS: Abstract 2005 – Poster @ IMAST. FINDINGS: The pre-operative pulmonary function in patients with SK revealed that patients with kyphosis >85° and with lower apices have better PFT data by several criteria. This information may suggest that moderate rather than a maximum correction of kyphosis is preferred in these patients.
5. *Operative management of Scheuermann's Kyphosis in 78 patients.* Lonner et al. STATUS: Published Spine 2007. FINDINGS: A high rate of proximal junctional kyphosis is associated with surgery using current techniques. PJK is associated with higher magnitude of kyphosis at follow-up, less percent correction; its magnitude correlated directly with pelvic incidence. Loss of correction is less in patients undergoing combined anterior-posterior surgery. Pelvic incidence correlates directly with lordosis but not kyphosis, suggesting that these parameters are not causative of SK.

6. *Results of 2 or more year follow-up in 10 thoracic scheuermann Kyphosis patients treated with Ponte Osteotomies and Segmental Posterior Pedicle screw instrumentation.* Letko, et al. STATUS: Abstract 2005 – Poster @ IMAST. FINDINGS: Retrospective review of 10 patients showed egmental pedicle screw instrumentation in conjunction with Ponte osteotomies allows powerful posterior only correction of SK.

Current 2009 Projects Underway:

7. PSK complications and re-operations as compared to AIS - Lonner

RESEARCH IN CONGENITAL SCOLIOSIS

1. *Efficacy of hemivertebrae resection for congenital scoliosis (CS): A multicenter restrospective comparison for three surgical techniques.* Yaszay et al. STATUS: Abstract 2007 & 2008 – Podium IEOS, Submitted for publication 11-09. FINDINGS: While hemivertebrae resection for congenital scoliosis had a higher complication rate than either hemiepiphysiodesis/in-situ fusion or instrumented fusion without resection, posterior hemivertebrae resection in younger patients resulted in better percent correction than the other two techniques.
2. *The development of scoliosis after hemivertebra resection and instrumentation.* Letko et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: Dorsal hemivertebrae resection and pedicle screw instrumentation provides complete lasting scoliosis correction in almost all single or double hemivertebrae cases. We report 4 cases in which scoliosis developed above and/or below the original surgically corrected deformity.
3. *The development of thoracic hypokyphosis/Lordosis after dorsal hemivertebra resection and intstrumentation in 3 cases of complex thoracic congenital scoliosis.* Letko et al. STATUS: Abstract 2007 – Poster @ IMAST. FINDINGS: 3 patients with complex thoracic congenital scoliosis developed thoracic hypokyphosis/lordosis after dorsal complex resection and pedicle screw instrumentation. Rod removal has resulted in improvement in the thoracic sagittal profile with rod reinsertion required in cases of scoliosis progression.
4. *Results of three classes of surgical treatment for congenital scoliosis due to hemivertebrae: a multicenter retrospective review.* O'Brien et al. STATUS: Abstract 2007 – Yaszay revised and submitted for publication. FINDINGS: 42 patients with hemivertebrae (HV) and congenital scoliosis were compared based on one of three surgical treatments. HV resections with posterior instrumentation results in reduced surgical time, shorter fusions, less blood loss, and improved % correction but slightly higher rates of instrumentation and neurologic complications.

Current 2009 Projects Underway: (none as of 11-23-09)

RESEARCH IN SCOLIOSIS IN CEREBRAL PALSY

1. *Skeletal maturity in cerebral palsy.* Cahill et al. STATUS: Abstract 2009 – not accepted. FINDINGS: The Risser sign is used as a surrogate for predicting skeletal maturity. Little data exist on the use of the Risser sign in cerebral palsy (CP). We have compared the average age of patients with CP to patients with adolescent idiopathic scoliosis (AIS) and stratified them by Risser sign. Patients with CP seem to begin to mature at least a year earlier but reach full maturity at the same age as their AIS cohorts.
2. *Pelvic fixation in cerebral palsy scoliosis results in better restoration of pelvic obliquity, sitting ability and a lower reoperation rate: Do the benefits outweigh the costs?* Shah et al. STATUS: Abstract 2008 – Poster @ IMAST & AAOS. FINDINGS: Nonambulatory patients with cerebral palsy (CP) scoliosis and pelvic obliquity are well managed with fixation to the pelvis; this results in better restoration of pelvic pbliquity, sitting ability and a lower reoperation rate. Caregiver satisfaction is high and the complication rate is low.
3. *Are triggered EMG thresholds reliable for assessing thoracic pedicle screw breach in the cerebral palsy population?* Asghar (Samdani) et al. STATUS: Abstract 2008 – Poster @ SRS & IMAST. FINDINGS: In a retrospective review of 442 thoracic pedicle screws placed in patients with cerebral palsy (CP), our rate of pedicle screw breach was 11%. 79% of medial thoraci pedicle screw breaches triggered at a threshold >6mA with low sensitivity and specificity. Hence, no reliable set of absolute values was identified to delineate pedicle screw placement with triggered EMG.
4. *Infection after spine surgery in cerebral palsy: Risk factors and treatment.* Sponseller et al. STATUS: Published CORR 2009. FINDINGS: A multicenter study revealed a 10% rate of infection after scoliosis surgery in CP. The only predictive patient variable was elevated preoperative white blood cell count.
5. *Scoliosis surgery in cerebral palsy: differences in unit rod and custom rods.* Sponseller et al. STATUS: Published Spine 2009. FINDINGS: Compared with custom-bent rods, unit rods provided superior correction of pelvic obliquity but were associated with higher transfusion requirements, higher infection rates, more proximal fixation problems, and longer intensive care unit and hospital stays.
6. *Anterior / Posterior surgery for cerebral palsy scoliosis: staged or same day?* Shah et al. STATUS: Abstract 2007 – Poster @ SRS, IMAST & NASS. FINDINGS: Anterior and posterior (AP) surgery is occasionally performed for management of scoliosis due to cerebral palsy (CP). When possible, anterior surgery should be performed on the same day, as this results in lower blood loss, operative time and hospital stay without increased complications. AP surgery as compared with posterior surgery for patients with scoliosis due to CP resulted in only modestly better final correction of the major and minor curves, no difference in pelvic obliquity but required longer operative time.

7. *The feasibility of neuromonitoring for cerebral palsy scoliosis and the outcome of neurologic complications.* Shah et al. STATUS: Abstract 2007 – Podium @ SRS, Poster @ IMAST & NASS. FINDINGS: The usefulness of intraoperative neurophysiologic monitoring in scoliosis surgery for patients with CP is questioned by some. The rate, severity and outcome of neurological injuries during surgery in these patients are not well reported. Monitoring of MEP and SSEP in these patients undergoing spinal deformity is feasible and useful to detect impending neurologic deficits. The rate of neurologic adverse events was 4.3% in this series. Most deficits improved over time.

Current 2009 Projects Underway:

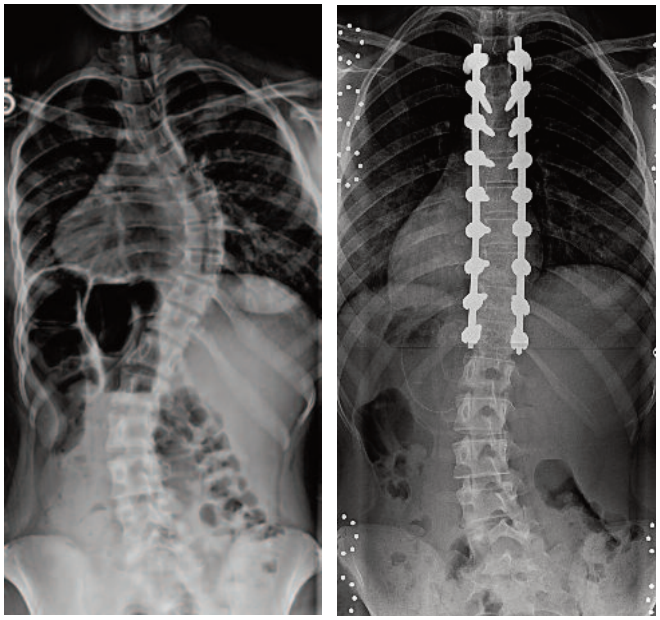
8. *Distal end constructs in Cerebral Palsy.* Cahill / Yaszay.

Potential Areas of Future Research:

- Re-do/add to: Skeletal maturity in cerebral palsy – good idea.
- Write a paper on how to correct pelvic obliquity with iliac screws – look at constructs used with bad vs good outcomes.

FUNDRAISING:

The Harms Study Group Foundation is a not-for-profit foundation that was established in 2008. It was created to enable fundraising efforts by the Harms Study Group membership to further support and advance research in spinal deformities in children and adolescents.



Surgical correction of scoliosis changes lives. Normalizing appearance and preventing progression are the goals that allow teens back to an active life... for the long-term.

Research is the key to unlock future discoveries.

Future research plans and funding requirements of the Harms Study Group:

- Expansion of the study of Scheuermann's Kyphosis study – to evaluate and compare surgical and non-surgical outcomes
- Establishment and maintenance of a non-operative comparison group of adolescent idiopathic scoliosis
- Increased five- and ten-year post-operative follow-up data for adolescent idiopathic scoliosis patients
- Development of a computerized assessment test for health-related quality of life outcomes.

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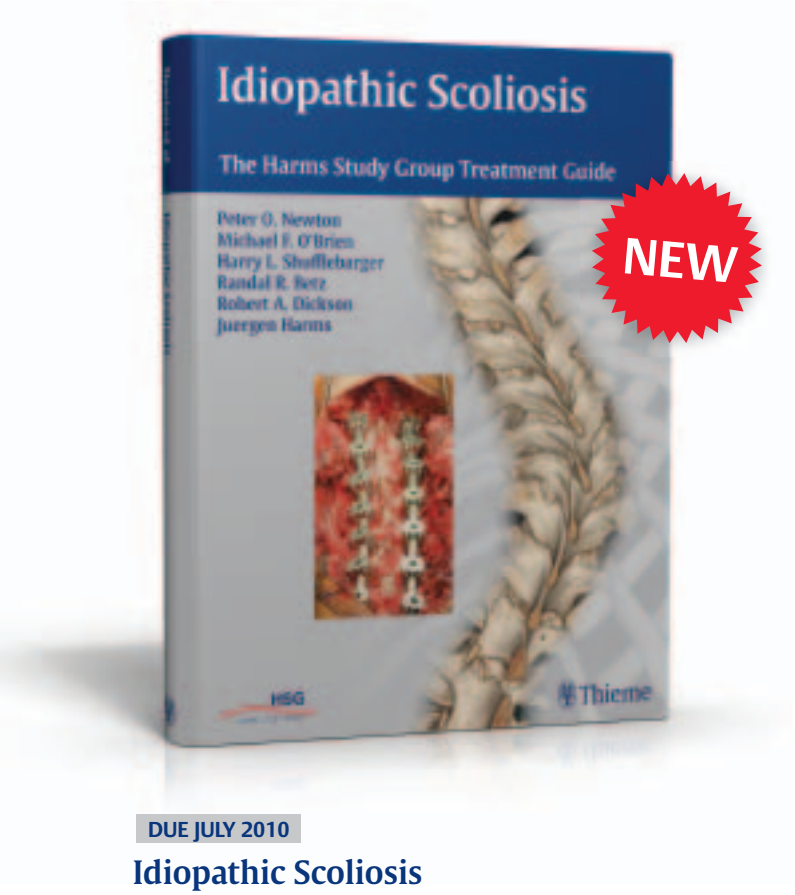
Cutting-edge research from the HSG



"The most up-to-date overview of the condition of idiopathic scoliosis…by recognized authorities in this field. It should be essential reading for all involved in the management of spinal deformities."

—***Robert A. Dickson, FRCS, ChM, DSc, PhD****, Emeritus Professor, Orthopaedic Surgery/Consultant Spine Surgeon, University of Leeds and Leeds General Infirmary, United Kingdom*

DUE JULY 2010

Idiopathic Scoliosis

The Harms Study Group Treatment Guide

Peter O. Newton, MD
Michael F. O'Brien, MD
Harry L. Shufflebarger, MD
Randal R. Betz, MD
Robert A. Dickson, FRCS, ChM, DSc, PhD
Juergen Harms, MD

FEATURES

- **Comprehensive discussion** of pathogenesis and epidemiology, osteobiologics for spinal fusion, anesthesia for scoliosis surgery, surgical complications, and much more
- **Chapters on key treatment decisions,** such as the selection of fusion levels, that teach readers how to critically address clinical questions
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HarmsStudyGroupFoundation@gmail.com

www.HarmsStudyGroupFoundation.com

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