HALF-DAY COURSES

Non-Operative Spinal Deformity Treatment Techniques
Sagittal Plane Deformity Corrective Techniques
Spinal Deformity in Myelomeningocele

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Scoliosis Research Society
48th Annual Meeting & Course
SEPTEMBER 18–21, 2013 • CITÉ CENTRE DE CONGRÈS
Lyon, France

Educational Program

Scoliosis Research Society • Half-Day Courses

Non-Operative Spinal Deformity Treatment Techniques

Room: Forum 4, Forum Level

Sagittal Plane Deformity Corrective Techniques

Room: Forum 5/6, Forum Level

Spinal Deformity in Myelomeningocele

Room: Forum 1, Forum Level

Thursday, September 19th, 2013
1:30 – 4:30pm
Cité Centre De Congrès • Lyon, France

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Course Overview

These interactive courses, presented by internationally renowned faculty, by instructional lecture and case examples, will address principles of improvement and techniques for optimizing outcomes and safety for deformity patients.

Target Audience

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

Disclosure of Conflict of Interest

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Stefano Negrini, MD	Italy	ISICO (c)
Stuart L Weinstein, MD	USA	No Relationships
Josette Bettany-Saltikov, PhD, MSC, MCSP	United Kingdom	No Relationships
Patrick Cahill, MD	USA	DePuy Synthes Spine (b,d,g); Medtronic (b,d,g); Orthopedics (e); Spine Deformity (e); Journal of Bone and Joint Surgery – American (e)
Haemish A. Crawford, FRACS	New Zealand	No Relationships
Jean-Claude deMauroy, MD	France	No Relationships
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Hubert Labelle, MD	Canada	DePuy Synthes Spine (a,f); Spinologics (c); NuVasive (g)
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Eric C. Parent, PhD, MSc, PT	Canada	No Relationships
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Nigel J. Price, MD	USA	No Relationships
Yong Qiu, MD	China	No Relationships
Manuel Rigo, MD	Spain	No Relationships
Michele Romano, PT	Italy	No Relationships
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Daniel J. Sucato, MS	USA	NuVasive (a); DePuy Synthes Spine (a)
Monica Villagrasa-Escudero, PT, MSc, DO	Spain	No Relationships
Michael G. Vitale, MD, MPH	USA	Stryker Spine (b); Biomet (b,g); Synthes Spine (a); OMeGA (a)
James H. Wynne, CPO	USA	Boston Brace (f)
Muharrem Yazici, MD	Turkey	K2M (b); DePuy Synthes Spine (b)
Fabio Zania, MD	Italy	No Relationships
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Shahree Douglas	USA	No Relationships
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Non-Operative Spinal Deformity Treatment Techniques

Course Co- Chairs:

Theodoros B. Grivas, MD, PhD & Nigel Price, MD

Faculty:

Josette A. Bettany-Saltikov, MD; Jean-Claude deMauroy, MD; Patrick T. Knott, PhD, PA-C; Tomasz Kotwicki, MD; Hubert Labelle, MD; Stefano Negrini, MD; Eric C. Parent, PhD; Nigel J. Price, MD; Manuel Rigo, MD; Michele Romano, PT; James O. Sanders, MD; Luke Stikeleather, CO; Mónica Villagrasa-Escudero, PT, MSc, DO; Stuart L. Weinstein, MD; James H. Wynne, CPO; Fabio Zania, MD

Non-Operative Spinal Deformity Treatment Techniques

Co-Chairs: Theodoros B. Grivas, MD, PhD and Nigel J. Price, MD

1:30 – 1:33pm	**Introduction of SRS and International Society on Scoliosis Orthopaedic and Rehabilitation Treatment – Rationale for Combined Presentation** *Nigel J. Price, MD*
1:33 – 1:40pm	**Evidence Based Non-Operative Treatment** *Stefano Negrini, MD (p.7)*
1:40 – 1:47pm	**Scoliosis Classifications Adopted for Non-Operative Approach** *Manuel Rigo, MD (p.11)*
1:47 – 1:54pm	**Imaging Techniques and Patient Evaluation** *Patrick T. Knott, PhD, PA-C (p.13)*
1:54 – 2:05pm	**Discussion**
2:05 – 2:12pm	**Non-Operative Management Using the SOSORT Guidelines** *Tomasz Kotwicki, MD (p.15)*
2:12 – 2:19pm	**European Brace Designs** *Theodoros B. Grivas, MD, PhD (p.17)*
2:19 – 2:26pm	**North American Brace Designs** *Luke Stikeleather, CO (p.23)*
2:26 – 2:33pm	**Brace Fabrication Techniques and Monitoring Devices** *James H. Wynne, CPO (p.24)*
2:33 – 2:40pm	**Panel Discussion: What Specific Lenke Classification Deformities Have the Highest Success with Brace Treatment?** *Nigel J. Price, MD; Theodoros B. Grivas, MD, PhD, et. Al (p.28, p.31)*
2:40 – 2:50pm	**Discussion**
2:50 – 2:57pm	**BrAIST Results** *Stuart L. Weinstein, MD (p.31)*
2:57 – 3:06pm	**European Schools of Physical Therapy for Scoliosis** *Mónica Villagrasa-Escudero, PT, MSc, DO (p.33)*
3:06 – 3:13pm	**Evidence Based Exercises for AIS-Cochrane Review** *Michele Romano, PT (p.37)*
3:13 – 3:20pm	**North American Perspective on Exercises for Scoliosis** *Eric C. Parent, PhD, MSc, PT (p.39)*
3:20 – 3:30pm	**Discussion**
3:30 – 3:37pm	**Role of Education in Non-Operative Treatment** *Josette A. Bettany-Saltikov, MD (p.43)*
3:37 – 3:44pm	**Psychological Support During Non-Operative Treatment** *Fabio Zaina, MD (p.48)*
3:44 – 3:51pm	**Non-Operative Treatment: The Patient's Perspective** *Joseph P. O'Brien, MBA (p.51)*
3:51 – 3:58pm	**SRS School Screening Task Force Report** *Hubert Labelle, MD (p.52)*
3:58 – 4:05pm	**Non-Operative Treatment of Adult Deformity** *Jean-Claude deMauroy, MD (p.53)*
4:05 – 4:20pm	**Panel Discussion: Early Onset Scoliosis: Evidence Based Non-Operative Treatment vs. Operative Methods** *Moderator: James O. Sanders, MD* *Faculty: Nigel J. Price, MD; Theodoros B. Grivas, MD, PhD, et. Al (p.55)*
4:20 – 4:30pm	**Questions**

Evidence Based Non-Operative Treatment

Prof. Stefano Negrini, MD
Chair, Physical and Rehabilitation Medicine, University of Brescia, Viale Europa 11, Brescia, Italy
Research Coordinator, Physical and Rehabilitation Medicine, Care & Research Institute Don Gnocchi, Milan
Scientific Director, Italian Scientific Spine Institute, Via R Bellarmino 11, 20141
Milan, Italy
Chief-Editor, European Journal of Physical and Rehabilitation Medicine

INTRODUCTION: WHAT IS EVIDENCE

Evidence Based Clinical Practice means acting according to the actual best evidence

Theoretically, treatments should be applied only when there is not the reality with traditional treatments established since many years. It is well accepted that, while waiting for higher levels of evidence, clinical decisions should be driven by the actual evidence, even if it is not (yet) of the highest standard: in these cases a low quality of evidence is declared.

Meta-analysis of RCTs did not find any study on parachutes efficacy. Does this mean they are not useful?

Not in all fields it is possible to perform Randomized Controlled Trials (RCTs). In BMJ a meta-analysis showed that it is not possible to find any evidence on the effectiveness of parachutes while falling from airplanes, since there are no RCTs[1]. This was a paradox to explain situations in which RCTs are not appropriate.

The pyramid of evidences is usually climbed step by step

The highest level of evidence is achieved by meta-analysis of RCTs and Cochrane reviews, and the lowest by Clinical Experts Consensuses. Nevertheless, the last can be either the actual best or the only achievable evidence.

RCTs are important, but observational studies as well

If RCTs are not possible for any reason, observational studies are a way to achieve good quality evidence[2,3].These studies have high ecological reliability, since they represents the clinical everyday situation: they should always be applied after RCTs to verify their real applicability.

BRACING

According to a Cochrane systematic review there is evidence in favor of bracing, even if it is of low quality[4]

The paper: Systematic Cochrane review including RCTs and prospective controlled cohort studies. There was very low quality evidence from one prospective cohort study with 286 girls that a brace curbed curve progression at the end of growth (success rate 74% (95% CI: 52% to 84%)), better than observation (success rate 34% (95% CI:16% to 49%)) and electrical stimulation (success rate 33% (95% CI:12% to 60%)). There is low quality evidence from one RCT with 43 girls that a rigid brace is more successful than an elastic one (SpineCor) at curbing curve progression when measured in Cobb degrees, but there were no significant differences between the two groups in the subjective perception of daily difficulties associated with wearing the brace.

Comment: the actual evidence is in favor of bracing, but it is of very low quality since it is not based on an RCT. Similarly, there is evidence of superiority of rigid versus elastic bracing, but of low quality. Until another, higher level of evidence is offered, clinicians should act according to this best evidence.

A meta-analysis shows that bracing does not reduce surgery rates[5], but studies with bracing + exercises were not included and had the highest effectiveness[6-8]

The paper: Systematic review of English language clinical papers including observation or a TLSO (without any adjunctive treatment) in sample closely matching the current indications for bracing (skeletal immaturity, age <15 years, Cobb angle between 20 degrees and 45 degrees). Eighteen studies were included (observation = 3, bracing = 15). All were Level III or IV clinical series. Despite some uniformity in surgical indications, the surgical rates were extremely variable, ranging from 1 surgery of 72 patients (1%) to 51 of 120 patients (43%) after bracing, and from 2 surgeries of 15 patients (13%) to 18 of 47 patients (28%) after observation. When pooled, the bracing surgical rate was 23% compared with 22% in the observation group.

Comment: Four papers by SOSORT members[6-8] (all excluded because exercises had been added to bracing), reported in the same population surgery rates between 2% and 7% (efficacy analysis as those in the meta-analysis). In two of these papers also an Intent-to-treat analysis has been performed, with surgery rates of 12% and 14%[7,8]. These data question the generalizability of this review out of a US/Northern Europe settings, and strengthen the idea of effectiveness of exercises as an adjuvant treatment to bracing.

A meta-analysis shows that full time is better than part-time bracing[9]

The paper: With use of data culled from twenty studies, members of the Prevalence and Natural History Committee of the Scoliosis Research Society conducted a meta-analysis of 1910 patients who had been managed with bracing (1459 patients), lateral electrical surface stimulation (322 patients), or observation (129 patients) because of idiopathic scoliosis. The weighted mean proportion of success was 0.39 for lateral electrical surface stimulation, 0.49 for observation only, 0.60 for bracing for eight hours per day, 0.62 for bracing for sixteen hours per day, and 0.93 for bracing for twenty-three hours per day. The twenty-three-hour regimens were significantly more successful than any other treatment ($p < 0.0001$). The difference between the eight and sixteen-hour regimens was not significant, with the numbers available. The weighted mean proportion of success for the six types of braces included in this review was 0.92, with the highest proportion (0.99) achieved with the Milwaukee brace. Bracing for eight or sixteen hours per day was found to be significantly less effective than bracing for twenty-three hours per day (p < 0.0001).

*Comment: t*his paper is quite old, but give some useful insights still valid.

A meta-analysis (under review) of observational studies following the SRS criteria shows that not all full time rigid bracing are the same: some have the highest effectiveness, others have less than elastic and nighttime bracing

*The paper: T*he SRS criteria give the standard for observational bracing cohorts. A meta-analysis found 9 papers (2 excluded for low quality), 1698 patients (551 included). After 40.5 months of treatment (range 16.4-70.8): progressed >6° 23.4% (0-78), finished >45° 13.4% (0-54), fused 21.6% (0-71); at 2 years follow-up (62.5%): total fused 24%. Striking differences have been found in sub-grouping with either the best results and the worst results in full-time rigid bracing: the best results were in studies following the SOSORT criteria, with exercises added, and with treatment lasting more than 50 months. Intermediate among these two groups were the results of elastic and night-time bracing.

Comment: This paper give indications about the actual predictive factors of good results (i.e. best clinical behaviors) in the worst clinical situation (patients 25-40° Cobb, Risser 0-2).

SOSORT Consensus shows that there is no agreement among experts either on the best braces or on their biomechanical action[10,11]

The paper: Delphi Procedure with final Consensus Conference among SOSORT members. The Chêneau brace was the most frequently recommended. The importance of the three point system mechanism was stressed. Options about proper pad placement on the thoracic convexity were divided 50% for the pad reaching or involving the apical vertebra and 50% for the pad acting caudal to the apical vertebra. There was agreement about the direction of the vector force, 85% selecting a 'dorso lateral to ventro medial' direction but not about the shape of the pad to produce such a force. Principles related to three-dimensional correction achieved high consensus (80%-85%), but suggested methods of correction were quite diverse.
This study reveals there continues to be a strongly held and conflicting if not a contentious opinion regarding brace design and treatment.

Comment: it is not possible today to define the best brace, and the best biomechanical corrective approach.

SOSORT Consensus state that compliance is a matter of clinical more than patients' behavior: there is strong agreement on the management criteria to achieve best results with bracing[10,11]

The paper: Delphi Procedure with final Consensus Conference among SOSORT members. 90% agreement was set as the minimum to be reached. With increasing experience in bracing all numerical criteria tended to become more strict.
A final set of 14 recommendations was given, grouped in 6 Domains (Experience/competence, Behaviours, Prescription, Construction, Brace Check, Follow-up). SOSORT recommends to professionals engaged in patient care to follow the Guidelines of this Consensus in their clinical practice. The SOSORT criteria should also be followed in clinical research studies to achieve a minimum quality of care.

Comment: It is possible to define the best management strategies to help patients achieve a good compliance and perform the best treatment. These strategies can be resumed in specific medical and technical expertise, team approach and clinical behaviours.

Two very important RCTs failed in recruitment, showing that in this field RCTs are not accepted by the patients[12,13]

Paper 1: A randomised controlled trial on the effectiveness of bracing patients with idiopathic scoliosis: failure to include patients and lessons to be learnt. A pilot study on the willingness to participate in such a trial was conducted amongst 21 patients and their parents. A total of four patients were included, and 14 refused to participate in an 18-month period. There were a lot less eligible patients than anticipated (40 instead of 100 per year), and the patients' participation rate was much lower than we had found in our pilot study (21% instead of 70%). The trial failed to include more than a few patients because of an overestimation of the number of eligible patients and because a lot less eligible patients were willing to participate compared to our pilot study. One reason for a low participation rate could be that this trial evaluated a frequently used existing treatment instead of a new treatment, and patients and parents might be afraid of not being treated (despite an intensive secure system for the control arm).

Paper 2: To BrAIST or not to BrAIST: decisions and characteristics of 1131 patients eligible for the Bracing in Adolescent Idiopathic Scoliosis Trial. BrAIST is a partially-randomized trial comparing the outcomes of bracing and observation in children with adolescent idiopathic scoliosis. The purpose of this study is to evaluate 1) whether the BrAIST sample is representative of the target population and 2) whether the treatment arms are equivalent. We addressed these questions by comparing baseline demographic, radiographic and psychosocial characteristics between the groups. Since April 2007, 1131 patients met eligibility criteria; 360 (32%) agreed to participate. There were no statistically significant differences between those who declined and those who agreed to participate in terms of largest Cobb angle, curve type, gender, or age. Blacks/African-Americans were more likely to participate (50%) than other racial groups (p<0.01). Of the 360, 219 (61%) entered into the bracing arm. Before treatment, there were no statistically significant differences in demographics, curve characteristics (Cobb angle, curve type, rotation, kyphosis, lordosis), skeletal maturity, general health, back pain and psychosocial characteristics including body image and quality of life. However, those who were very dissatisfied with their current back condition were more likely to choose a brace (73 vs. 51%, $p<0.01$). Without complete randomization, the equivalence of the two treatment arms is not guaranteed, but the fact that we found no significant differences in this analysis provides some confidence for minimal selection bias in the final results.

Comment: patients and parents perceive the bracing RCTs as parachute trials and prefer a shared decision with their physicians. Classical RCTs cannot be performed. Observational trials are a viable alternative to RCTs, mainly focusing on the SRS criteria.

PHYSIOTHERAPIC SPECIFIC SCOLIOSIS EXERCISES

A Cochrane review shows that there is evidence in favor of exercises as an adjunctive treatment, but of low quality[14]

The paper: Cochrane systematic review on randomized controlled trials and prospective cohort studies with a control group. Two studies (154 participants) were included. There is low-quality evidence from 1 randomized controlled study that exercises as an adjunctive to other conservative treatments to increase the efficacy of these treatments (thoracic curve reduced: mean difference 9.00, [95% confidence interval, 5.47-12.53]; lumbar curve reduced: mean difference 8.00, [95% confidence interval, 5.08-10.92]). There is very low-quality evidence from a prospective controlled cohort study that SSEs structured within an exercise program can reduce brace prescription (risk ratio, 0.24; [95% confidence interval, 0.06-1.04]) as compared with "usual physiotherapy" [many different kinds of general exercises according to the preferences of the single therapists within different facilities]).

Comment: This study shows that there is evidence in favor of exercises effectiveness, even if of low quality.

A systematic review of all the existing studies shows their effectiveness and that auto-correction is the main goal [15]

The paper: Systematic review on all study designs with patients treated exclusively with exercises and outcome Cobb degrees. 19 studies were retrieved, including one RCT and eight controlled studies; 12 studies were prospective. The papers included 1654 treated patients and 688 controls. The highest-quality study (RCT) compared two groups of 40 patients, showing an improvement of curvature in all treated patients after six months. We found three papers on Scoliosis Intensive Rehabilitation (Schroth), five on extrinsic autocorrection-based methods (Schroth, side-shift), four on intrinsic autocorrection-based approaches (Lyon and SEAS) and five with no autocorrection (three asymmetric, two symmetric exercises). Apart from one (no autocorrection, symmetric exercises, very low methodological quality), all studies confirmed the efficacy of exercises in reducing the progression rate (mainly in early puberty) and/or improving the Cobb angles (around the end of growth). Exercises were also shown to be effective in reducing brace prescription.

Comment: Apart the oldest and technically less reliable paper (low methodology and exercises quality), all studies in the literature show the effectiveness of exercises. Specific scoliosis exercises are based on the auto-correction and have the highest effectiveness.

OTHER CONSERVATIVE TREATMENTS

A systematic review shows that there are no studies on manual treatment [16]

The paper: Systematic review of any kind of research on adolescent idiopathic scoliosis patients treated exclusively by chiropractic manipulation, osteopathic techniques, massage, with outcome in Cobb degrees. Only three papers were relevant to our study. However, no one of the three satisfied all the required inclusion criteria because they were characterized by a combination of manual techniques and other therapeutic approaches.

Comment: this paper, and the meta-analysis by Rowe showing no effectiveness of electrical stimulation, exclude evidence on other conservative treatments to control the curve evolution.

CONCLUSIONS

Research on conservative treatment of AIS has continuously decreased since the 80ies [17,18]

SOSORT is born as a cause (or effect) of the renewed interest on research in this field begun with the new millennium.

The SOSORT Guidelines offers the actual standard of conservative care[19]

The SOSORT Guidelines are totally evidence-based. They shows that the existing evidence on conservative treatment today is low: out of 65 recommendations, no one was Level I (strong evidence), 2 were Level II, the remaining were lower. Nevertheless, when importance for patients is considered, 13 were Grade A (to be applied to all patients), and 49 grade B (almost all patients). The correct answer to this situation is research and increased efforts to search for evidence.

REFERENCES

1. Smith GC, Pell JP. Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials. Bmj 2003;327(7429):1459-61.
2. Black N. Why we need observational studies to evaluate the effectiveness of health care. Bmj 1996;312(7040):1215-8.
3. Benson K, Hartz AJ. A comparison of observational studies and randomized, controlled trials. N Engl J Med 2000;342(25):1878-86.
4. Negrini S, Minozzi S, Bettany-Saltikov J, et al. Braces for idiopathic scoliosis in adolescents. Cochrane Database Syst Rev 2010(1):CD006850.

5. Dolan LA, Weinstein SL. Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Spine 2007;32(19 Suppl):S91-S100.

6. Maruyama T, Kitagawa T, Takeshita K, Mochizuki K, Nakamura K. Conservative treatment for adolescent idiopathic scoliosis: can it reduce the incidence of surgical treatment? Pediatr Rehabil 2003;6(3-4):215-9.

7. Rigo M, Reiter C, Weiss HR. Effect of conservative management on the prevalence of surgery in patients with adolescent idiopathic scoliosis. Pediatr Rehabil 2003;6(3-4):209-14.

8. Negrini S, Atanasio S, Zaina F, Romano M, Parzini S, Negrini A. End-growth results of bracing and exercises for adolescent idiopathic scoliosis. Prospective worst-case analysis. Stud Health Technol Inform 2008;135:395-408.

9. Rowe DE, Bernstein SM, Riddick MF, Adler F, Emans JB, Gardner-Bonneau D. A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. J Bone Joint Surg Am 1997;79(5):664-74.

10. Negrini S, Grivas TB, Kotwicki T, Rigo M, Zaina F. Guidelines on "Standards of management of idiopathic scoliosis with corrective braces in everyday clinics and in clinical research": SOSORT Consensus 2008. Scoliosis 2009;4(1):2.

11. Rigo M, Negrini S, Weiss H, Grivas T, Maruyama T, Kotwicki T. 'SOSORT consensus paper on brace action: TLSO biomechanics of correction (investigating the rationale for force vector selection)'. Scoliosis 2006;1:11.

12. Dolan L, Weinstein S. To BrAIST or not to BrAIST: decisions and characteristics of 1131 patients eligible for the Bracing in Adolescent Idiopathic Scoliosis Trial. Scoliosis 2012;7 Suppl 1:O23.

13. Bunge EM, Habbema JD, de Koning HJ. A randomised controlled trial on the effectiveness of bracing patients with idiopathic scoliosis: failure to include patients and lessons to be learnt. Eur Spine J 2010;19(5):747-53.

14. Romano M, Minozzi S, Bettany-Saltikov J, et al. Exercises for adolescent idiopathic scoliosis. Cochrane Database Syst Rev 2012;8:CD007837.

15. Negrini S, Fusco C, Minozzi S, Atanasio S, Zaina F, Romano M. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. Disabil Rehabil 2008;30(10):772-85.

16. Romano M, Negrini S. Are manual therapies effective treatments for adolescent Idiopathic Scoliosis? A systematic review. SOSORT (Society On Scoliosis Orthopaedic and Rehabilitation Treatment) 2006, Poznan (Poland).

17. Negrini S. Approach to scoliosis changed due to causes other than evidence: patients call for conservative (rehabilitation) experts to join in team orthopedic surgeons. Disabil Rehabil 2008;30(10):731-41.

18. Negrini S, Zaina F, O'Brien JP. Evidence on conservative treatments of adolescent idiopathic scoliosis. British Medical Journal 2013;346.

19. Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis 2012;7(1):3.

Notes

Scoliosis Classifications Adopted for Non-Operative Approach

Manuel D. Rigo, MD
Elena Salvá Institut
Vía Augusta 185
08021 Barcelona, Spain
P: +34 932091330

INTRODUCTION

Adolescent Idiopathic Scoliosis is a complex three-dimensional deformity of the spine and the trunk that is usually represented in the coronal and sagittal projections.

Although the coronal projection is a direct one-dimensional view of the deformed spine, it represents indirectly a bi-dimensional one (rotation can be indirectly measured).

The coronal plane projection (AP/PA) has been used to:

1. Select End Vertebrae (UEV and LEV), apical vertebra (AV) and slopes (EVA A, B and C)
2. Define Curve level according to the apex (SRS)
3. Asses curve magnitude (Ferguson angle, Cobb angle)
4. Define progression, stabilization and regression (SRS)
5. Assess spinal balance according to the Central Sacral Line CSL
6. Vertebral rotation (Nash and Moe, Perdriolle, Raimondi and others)
7. Classify: Curve Pattern

In 2001, Lenke et al [1] described a new classification that has become the gold standard. This is a classification to determine extend of spinal arthrodesis in Adolescent Idiopathic Scoliosis (AIS). The new classification was necessary to substitute the old King classification, which was considered to have a poor reliability.

According to their authors the new classification had to:

1. Be comprehensive and include all type of curves
2. Emphasize consideration of sagittal alignment
3. Help to define treatment that could be standardized
4. Be based on objective criteria for each curve type
5. Have good-to-excellent interobserver and intraobserver reliability
6. Be easily understood and of clinical value in the clinical setting

Lenke classification, however, has been rarely used in non-operative treatment. JC De Mauroy [2] has defined brace design according to Lenke types. Reviewing old and recent literature on bracing, curve types are reported when describing the treated population. The most used classifications have been:

The SRS classification according to the curve level:

1. Thoracic: Th2-Th11 (disc Th11-12)
2. Proximal thoracic: Th3-4-5
3. Thoracolumbar: Th12-L1
4. Lumbar: L2-L4 (disc L1-2)

Ponseti and Friedman (1950) [3]

1. Main Lumbar
2. Main Thoracolumbar
3. Combined Lumbar and Thoracic
4. Main Thoracic
5. Cervicothoracic

Moe and Kettleson (1970) [4]

1. Single thoracic
2. Single thoracolumbar
3. Single lumbar
4. Combined thoracic major / Lumbar minor
5. Combined thoracic and lumbar double major
6. Combined thoracic and thoracolumbar double major
7. Combined thoracic double major
8. Multiple

Lee, Denis, Winter and Lonstein (1993) [5]

The authors modified the Moe and Kettleson classification adding the single upper or proximal thoracic type.

King, Moe, Winter and Bradford (1983) [6]

Five thoracic types (I, II, I II, IV, V), simple or combined with lumbar or thoracolumbar.

King classification has a fair reproducibility and poor reliability (Cummings et al 1998) [7]. Also Lenke et al [1] concluded that the King classification does not appear to have sufficient interobserver and intraobserver reliability among scoliosis surgeons to portray curve patterns accurately. However the sources of unreliability are not well understood.

Ideally, a reliable universal classification would be desirable, at least to allow comparison of different non-operative treatment methods. However no specific curve pattern was recommended as an optimal inclusion criteria for AIS brace studies [8]. Reproducibility and reliability of the old classifications has not been studied. Lenke classification could be used, but it is unnecessarily complex for the purpose of describing treatment groups. On the other hand Lenke classification has additional limitations. It is questionable that it can be used in mild scoliosis. Exercises and bracing are indicated in mild to moderate curves. The definition of a structural curve made by Lenke is a residual coronal curve on side-bending radiographs of at least 25º in the proximal thoracic, main thoracic, lumbar and thoracolumbar regions; or +20º of kyphosis in the high thoracic and thoracolumbar regions. From one side, the number of radiographs increases unnecessarily during non-operative management. On the other hand, many real structural curves go down 25º in side bending radiographs when the angle in upright position is 25º- 45º, the classical indication for bracing. Also, lumbar modifiers A, B, C, as well as sagittal modifiers could fail in mild scoliosis and/or be irrelevant for the purpose of describing a population.

There are many brace concepts and different schools for scoliosis rehabilitation. Brace principles and biomechanics are too different to expect that any universal classification can be used for the purpose of treatment specifications.

For example, the Milwaukee brace attempted to obliterate the physiological sagittal curves to correct the lateral deviation by elongation. The Milwaukee brace also prevent forward bending, supposed to be a factor for progression in AIS. Boston brace worked with similar principles originally. Thus, the first generation of Boston brace presented an inversed sagittal shape. Later, in its second generation, it was flat and the last presents a more natural kypho-lordotic shape. The so-called Chêneau type brace is a custom made brace designed to achieve the best 3D correction. Other braces use also the 3D approach but they shown different biomechanics. It has been shown a lack of consensus in describing brace action even for those in agreement with the need to correct in 3D [9].

Some brace concepts use specific classifications to define treatment specifications and brace design. Some others use different criteria than curve pattern. Next picture presents a summary.

Some brace concepts use curve pattern specific classifications:

- SpineCor (Published Blueprints)
- Providence (Published Blueprints)
- Lyon brace (*scoliosis* 2011 6:4)
- Dynamic Derotation Brace (*scoliosis* 2010 5:20)
- Chêneau type and derivates (*scoliosis* 2010 5:1)
- Progressive Action Short Brace PASB (*scoliosis* 2012 7:6)

Some brace concepts use curve use other criteria than curve pattern on brace design:

- Boston (Published Blueprints)
- SPoRT (*scoliosis* 2011 6:8)

Some remarkable criteria used in Boston blueprints:

1. Central Sacral Line to determine spinal balance/unbalance
2. Pelvis tilt
3. Linear deviation and rotation of each vertebral body relative to the CSL

The concept called by Negrini et all SPoRT, is an evolution of the Lyon brace, but considering 3D approach:

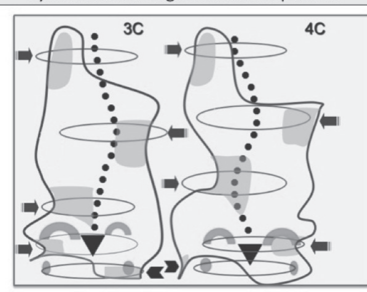
1. Coronal plane. Slopes (the most flexed portion of the curve)
2. Horizontal. Hump localization.
3. Sagittal plane, according to the localization of kyphosis and lordosis.

The brace concepts listed above use specific classifications to define brace design. It is noticeable that even one of the simplest classifications is poorly reproducible. Chêneau, for instances, proposed a, in theory, very simple classification of 3 curves and four curves. The three curves pattern is represented by a simple structural curve associated to two cranial and caudal compensations. The four curves pattern is represented by a double structural curve associated to cranial and caudal compensation. The caudal compensation is defined as lumbo-sacral curve. However, not all the double structural curves are true double and are associated to lumbar/pelvis uncoupling. Chêneau used this simple classification inspired by Schroth, but Schroth used mainly clinical criteria and only secondarily radiological criteria. Some examples are presented to document treatment failures after wrong classification and brace designs. The lack of standard was the reason for the description of a new classification for those using Chêneau type braces and derivates (Rigo et al 2010) [10].

Next figure show the simplest Chêneau classification and the two basic brace designs. Based on these two basic types, Rigo has described 9 different types and brace designs.

Example of brace designs for different curve patterns

Two original Chêneau designs (3 curves and 4 curves) locating at different levels the derotation PADS to form several three-point systems according to the curve pattern



CONCLUSIONS

1. The old classifications (SRS, Ponseti, Moe) are still used to describe populations in brace and physiotherapy studies, but its reproducibility and reliability has not been properly studied
2. Lenke classification has a limited use in non-operative treatment
3. To follow the strict and necessarily complex rules and blueprints for any particular brace concept is essential for success and patient safety

REFERENCES

[1] Lenke L.G. et al (2001) Adolescent Idiopathic Scoliosis. A new classification to determine extent of spinal arthrodesis. The Journal of Bone and Joint Surgery Am 83 (8); 1169-1181

[2] De Mauroy JC et al.: 'Brace technology' thematic series – The lyon brace approach to the conservative treatment of scoliosis. *Scoliosis* 2011, 6:4

[3] Ponseti IV, Friedman B (1950) Prognosis in idiopathic scoliosis. The Journal of Bone and Joint Surgery Am 32: 381-395

[4] Moe JH, Kettleson DN (1970) Idiopathic scoliosis curve patterns and the preliminary results of Milwaukee-brace treatment in hundred sixty-nine patients. The Journal of Bone and Joint Surgery Am 52: 1509-1553

[5] Lee CK, Denis F, Winter RB, Lonstein JE (1993) Analysis of the upper thoracic curve in surgically treated idiopathic scoliosis. A new concept of the double thoracic curve pattern. Spine 18: 1599-1608

[6] King HA, Moe JH, Winter DS, Bradford RB 81983) The selection of fusion levels in thoracic idiopathic scoliosis. The Journal of Bone and Joint Surgery Am 65: 1302-1313

[7] Cummings RJ, et al (1998) Interobserver reliability and intraobserver reproducibility of the system of King et al for the classification of adolescent idiopathic scoliosis. The Journal of Bone and Joint Surgery Am 80: 1107-1111

[8] Richards BS et al (2005) Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. Spine 30(18): 2068-2075

[9] Rigo M et al: SOSORT Consensus paper on brace action: TLSO biomechanics of correction (investigating the rationale for force vector selection). *Scoliosis* 2006 1:11

[10] Rigo M et al: A specific classification correlating with brace treatment: Description and reliability. *Scoliosis* 2010 5:1

Notes

Imaging Techniques and Patient Evaluation

Patrick Knott, PhD, PA-C
Spine and Surface Topography
Professor and Associate Vice President
Study Group, NFP
Rosalind Franklin University of Medicine and Science
www.SSTSG.org
Chicago, IL, USA

1. Radiographic Imaging as a Means of Surveillance in Spinal Deformity
   a. Epidemiologic studies have shown that frequent x-rays has significant risks
      i. Average patient receives 23 full-torso radiographs[1]
      ii. Overall risk of mortality 46% higher[1]
      iii. Cancer rates higher for: breast, lung, ovarian[1, 2]
      iv. Age of patient at time of exposure also critical[3]
   b. Technique during radiographs can lower radiation effect
      i. PA versus AP spinal films result in breast cancer rates that are 1/3 as high[3]
2. MRI as a Non-Radiographic Option
   a. Most MRI's are supine, and deformity changes with loss of gravitational force.
   b. Axial loaded MRI does produce deformity measurements that are similar to standing x-rays.[4]
   c. Cost and imaging time are substantially higher.
3. Ultra Low Dose X-Ray
   a. Slit-scan technology can take simultaneous AP and Lateral x-rays of the spinal column with significantly less radiation exposure.
   b. Radiation dose for spinal images can be reduced to between 1/6 and 1/9 that of a standard dose using traditional x-ray.[5]
4. Surface Topography as a Non-Radiographic Option
   a. ST has been used for years, but recent technology has made it a more reliable modality.
   b. A variety of systems have been tested for reliability and validity, and found to provide accurate 3D spinal reconstructions.[6,7]
   c. Longitudinal surveillance to detect change in shape may be the best use for static ST measurements.[8]
   d. Motion analysis now possible with ST, allowing for assessment of deformity with walking or bending.
   e. Other uses for ST being evaluated, including chest wall deformity, chest volumes, aesthetics, etc.
5. Goals for Patient Management

a. Obtain an initial radiologic image that can show spinal morphology.

b. Obtain a non-radiologic image that can be used repeatedly over time in surveillance.

c. Keep radiation exposure to a minimum, while continuing to provide timely surveillance that will accurately detect a change in the deformity.

References:

1. Ronckers C.M., Land C.E., Miller J.S., Stovall M., Lonstein J.E., Doody M.M. Cancer mortality among women frequently exposed to radiographic examinations for spinal disorders. Radiat Res. 2010 Jul;174(1):83-90.
2. Nash, C.L., Jr., Gregg E.C., Brown R.H., Pillai K. Risks of exposure to X-rays in patients undergoing long-term treatment for scoliosis. *J Bone Joint Surg Am*. Apr 1979; 61(3):371-374.
3. Levy A, Goldberg M, Mayo N, Hanley J, Poitras B. Reducing the Lifetime Risk of Cancer From Spinal Radiographs Among People With Adolescent Idiopathic Scoliosis. *Spine*. 21(13):1540-1547, July 1, 1996.
4. Knott P, Mardjetko S, Kim R, Cotter T, Techy F, Rollet M. Comparing Axial Loaded MRI to Standing Radiographs in the Evaluation of AIS. *Scoliosis* 2010; 5 (Suppl 1): O12 (10 Sept 2010).
5. Deschenes S, Charron G, Beaudoin G, Labelle H, Dubois J, Miron M, Parent S. Diagnostic Imaging of Spinal Deformities: Reducing Patients Radiation Dose With a New Slot-Scanning X-ray Imager. Spine April 2010, 35 (9): 989.
6. Frerich JM, Hertzler K, Knott P, Mardjetko S. Comparison of Radiographic and Surface Topography Measurements in Adolescents with Scoliosis. *The Open Orthopaedic Journal,* (27 July, 2012) 6: 261-265.
7. Liu XC et al. Development of a 3-Dimensional Back Countour Imaging System for Monitoring Scoliosis Progression in Children. Spine Deformity 1 (2013) 102-107.
8. Schulte TL, Hierholzer E, Boerke A, Lerner T, Liljengvist U, Bullmann V, Hackenberg L. Raster stereography versus radiography in the long-term follow-up of idiopathic scoliosis. J Spinal Disord Tech. 2008;21(1):23-28.

Notes

Non-Operative Management Using the SOSORT Guidelines

Tomasz Kotwicki, MD
Department of Pediatric Orthopedics
University of Medical Sciences
Poznan, Poland
kotwicki@ump.edu.pl

What are the SOSORT Guidelines ?

The SOSORT Guidelines represents a series of documents published in Scoliosis Journal (www.scoliosisjournal.com) devoted to define the state-of-the-art policy for non-operative management of idiopathic scoliosis. The most recent Guidelines document published in 2011 by a group of 20 SOSORT experts under the leadership of Stefano Negrini comprises 35 pages and 380 references[1].

The aim of SOSORT Guidelines

The aim is to offer to all professionals engaged in non-operative treatment of idiopathic scoliosis an evidence-based updated review of the actual evidence in the field together with a series of evidence-based recommendations. For the multiple gray areas, important for everyday clinical practice, the recommendations originate as a result of a formal and explicit consensus methodology.

The Guidelines are addressed not only to physicians but also to all health professionals taking care of patients with idiopathic scoliosis. The Guidelines may be used by patients as reference.

Construction of the Guidelines

The Guidelines describe the development methodology and provide general information about scoliosis with up-to-date literature review on non-operative treatment. Practical treatment recommendations with flowcharts covering bracing and physiotherapy are an important part of the Guidelines. For each of the 65 Recommendations published in the SOSORT 2011 Guidelines the Level of Evidence is reported (see Table below).

Level of Evidence of the approved Recommendations

	I	II	III	IV	V	VI	total
Bracing	0	0	2	7	8	3	**20**
Specific exercises to prevent scoliosis progression during growth	0	1	2	0	1	4	**8**
Specific exercises during brace treatment and surgical therapy	0	1	1	2	1	0	**5**
Other conservative treatments	0	0	0	0	1	2	**3**
Respiratory function and exercises	0	0	0	2	1	0	**3**
Sports activities	0	0	2	1	2	1	**6**
Assessment	0	0	0	8	12	0	**20**
Total	**0**	**2**	**7**	**20**	**26**	**10**	**65**

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Main questions the SOSORT Guidelines answer

How to evaluate the patient?

Which non-operative treatment should be performed?

When and how should the brace be applied?

When and how should the exercises be used?

Development of the 2011 SOSORT Guidelines

Review of the literature on the topic up to February 2011, no language limitation.

Review of the previously published guidelines on non-operative scoliosis management (by SOSORT or other local scientific societies).

Delphi procedure developed in multiple stages (see details of the procedure performed on www.scoliosisjournal.com/content/supplementary/1748-7161-7-3-s1.doc)

Classical Level of Evidence table adopted for any Recommendation given (Degrees I through VI, see www.scoliosisjournal.com/content/7/1/3/table/T1).

Strength of Recommendation grading applied (four degrees from the absolute to the low importance, see www.scoliosisjournal.com/content/7/1/3/table/T2).

Evidence-Based Clinical Practice

This represents an approach combining Evidence with Clinical expertise and Patients' preferences. The 2005 SOSORT Consensus paper [2] revealed the basic objectives of idiopathic scoliosis non-operative treatment:

1. to stop curve progression at puberty,
2. to prevent or treat respiratory dysfunctions,
3. to prevent or treat spine pain syndromes and
4. to improve aesthetics via postural correction.

Thus, not only the Cobb degrees are considered but the three general aspects of the impairment induced by spinal deformity: morphology, function and quality of life.

Intensity of Treatment Scheme

The suggested progression of treatments from the least to the most intensive covers twelve therapeutic options from Nothing (minimum) to Surgery (maximum) with the whole spectrum of the non-operative management in between. It comprises: Observation at given intervals of 3, 6 or 12 months, Physiotherapeutic Specific Exercises (PSE, outpatient), Night-time Rigid Brace (NTRB), Specific Inpatient Rehabilitation (SIR), Specific Soft Bracing (SSB), Part Time Rigid Bracing (PTRB) up to Full Time Rigid Bracing (FTRB). These options are considered progressively increasing in power while adjustment to the actual curve size and curve risk of progression should be performed. Thus, for each particular patient, an optimal treatment is searched.

Nothing	Nothing	Minimum
Observation	Ob+months	
Physiotherapeutic Specific Exercises	PSE	
Specific Inpatient Rehabilitation	SIR	
Night-time Rigid Bracing (8-12 hours)	NTRB	
Specific Soft Bracing	SSB	
Part-Time Rigid Bracing (12-20 hours)	PTRB	
Full-Time Rigid Bracing (20-24 hours)	FTRB	
Surgery	Su	Maximum

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Practical Approach Scheme

It is grouping the variety of non-operative therapies in one complex Table (see below), having Cobb degrees expressed in columns while the age and the skeletal maturity indicated by the Risser sign expressed in horizontal lines. For each combination of skeletal maturity and scoliotic curvature severity the minimum and the maximum treatment are defined. All treatments included between the minimum and the maximum can be considered appropriate for a given clinical situation. Example: for an AIS patient having Cobb angle 16-20 degrees and Risser 2, the minimum is Observation every 3 months and the maximum is Part Time Rigid Brace. The Practical Approach Scheme is covering infantile and juvenile idiopathic scoliosis as well as adult and elderly scoliosis with pain.

Practical Approach Scheme (PAS) for an Evidence Based Clinical Practice approach to Idiopathic Scoliosis (Level of Evidence VI - Strength of Recommendation B).

		Cobb	0-10 +hump	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	over 50
Infantile		Min	Ob6	Ob6	Ob3	SSB	SSB	SSB	SSB	SSB	PTRB	FTRB
		Max	Ob3	Ob3	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Juvenile		Min	Ob3	Ob3	Ob3	SSB	SSB	SSB	PTRB	PTRB	PTRB	FTRB
		Max	PSE	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Adolescent	*Risser 0*	Min	Ob6	Ob6	Ob3	PSE	PSE	SSB	PTRB	PTRB	PTRB	FTRB
		Max	Ob3	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
	Risser 1	Min	Ob6	Ob6	Ob3	PSE	PSE	SSB	PTRB	PTRB	PTRB	FTRB
		Max	Ob3	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
	Risser 2	Min	Ob8	Ob6	Ob3	PSE	PSE	SSB	SSB	SSB	SSB	FTRB
		Max	Ob6	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
	Risser 3	Min	Ob12	Ob6	Ob6	Ob6	PSE	SSB	SSB	SSB	SSB	FTRB
		Max	Ob6	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
	Risser 4	Min	No	Ob6	Ob6	Ob6	Ob6	Ob6	Ob6	Ob6	SSB	FTRB
		Max	Ob12	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
	Risser 4-5	Min	No	Ob6	Ob6	Ob6	Ob6	Ob6	Ob6	Ob6	SSB	FTRB
		Max	Ob12	PSE	PTRB	FTRB	FTRB	FTRB	FTRB	FTRB	Su	Su
Adult	*No pain*	Min	No	No	No	No	No	No	No	No	Ob12	Ob12
		Max	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob6	Ob6
	Chronic pain	Min	No	PSE	PSE	PSE	PSE	PSE	PSE	PSE	PSE	PSE
		Max	PTRB	PTRB	PTRB	PTRB	PTRB	Su	Su	Su	Su	Su
Elderly	*No pain*	Min	No	No	No	No	No	No	No	No	Ob12	Ob12
		Max	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob12	Ob6	Ob6
	Chronic pain	Min	No	PSE	PSE	PSE	PSE	PSE	PSE	PSE	PSE	PSE
		Max	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	Su	Su
	Decompensation	*Min*	No	No	PSE	PSE	PSE	PSE	PSE	PSE	PSE	PSE
		Max	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	PTRB	Su	Su

For each single clinical situation reported in any single cell, a minimum and a maximum strength of treatment is listed. The graduation of strength of treatments have been reported in the Strength of Treatments Scheme. Consequently, all treatments included between the minimum and maximum can be considered for that specific clinical situation.

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Quality of non-operative treatment

Recommendations are also provided on the quality of non-operative treatment. The issues of (1) patient evaluation, (2) brace dosage, the compliance and team role, and (3) the quality of orthosis itself are discussed and explained. The 2011 Guidelines updates the previously published SOSORT Consensuses 2009 [3] , 2008 [4] , and 2006 [5], respectively. The dosage of brace is debated according to published evidence [6, 7, 8, 9].

Availability

SOSORT 2011 Guidelines are published in the open access journal "Scoliosis" included in the Thematic series entitled "SOSORT Consensus & Guidelines articles" (www.scoliosisjournal.com/series/SOSORT).

Usefulness

The approach allows clinicians to implement treatment within the actual range of indications while avoiding under-treatment (below the minimum) or over-treatment (above the maximum). Evidence-Based Clinical Practice is postulated to be the best integration of the knowledge offered by Evidence Based Medicine, individual clinical expertise and patients' preferences.

Moreover, several specific practical points are presented: sport activity during non-operative treatment, place of manual therapy, assessment and correction of lower limb discrepancy, use of shoe inserts, and others.

Conclusions

SOSORT 2011 Guidelines represents the state-of-the-art policy for non-operative idiopathic scoliosis treatment. It is based on current evidence and can be considered a handout for everyday practice until next recommendations are published.

The researchers and the clinicians are invited to join the effort of developing new strategies allowing data collection for new evidence.

References

1. Negrini S, Aulisa AG, Aulisa L, Circo AB, de Mauroy JC, Durmala J, Grivas TB, Knott P, Kotwicki T, Maruyama T, Minozzi S, O'Brien J, Papadopoulos D, Rigo M, Rivard Ch, Romano M, Wynne JH, Villagrasa M, Weiss HR, Zaina F. 2011 SOSORT Guidelines: orthopedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis 2012; 7: 3.
2. Negrini S, Grivas TB, Kotwicki T, Maruyama T, Rigo M, Weiss HR. Why do we treat adolescent idiopathic scoliosis? What we want to obtain and to avoid for our patients. SOSORT 2005 Consensus paper. Scoliosis 2006; 1: 4.
3. Kotwicki T, Negrini S, Grivas TB, Rigo M, Maruyama T, Durmala J, Zaina F. Methodology of evaluation of morphology of the spine and the trunk in idiopathic scoliosis and other spinal deformities – 6th SOSORT Consensus Paper. Scoliosis 2009; 4: 26.
4. Negrini S, Grivas TB, Kotwicki T, Rigo M, Zaina F. Guidelines on „Standard of management of idiopathic scoliosis with corrective braces in everyday clinics and in clinical research" : SOSORT Consensus 2008. Scoliosis 2009; 4: 2.
5. Rigo M, Negrini S, Weiss HR, Grivas TB, Maruyama T, Kotwicki T. SOSORT Consensus paper on brace action: TLSO biomechanics of correction (investigating the rationale for force vector selection). Scoliosis 2006; 1: 11.
6. Dolan LA, Weinstein SL. Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence based review. Spine 2007; 32: S91-S100.
7. Rowe DE, Bernstein SM, Riddick MF, Adler F, Emans JB, Gardner-Bonneau D. A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. J Bone Joint Surg Am 1997; 75: 664-674.

8. Allington NJ, Bowe JR. Adolescent idiopathic scoliosis: treatment with the Wilmington brace. A comparison of full time and part time use. J Bone Joint Surg Am 1996; 78: 1056-1062.

9. Katz DE, Herring JA, Browne RH, Kelly DM, Birch JG. Brace wear control of curve progression in adolescent idiopathic scoliosis. J Bone Joint Surg 2010; 92: 1343-1352.

Notes

European Brace Designs

Theodoros B. Grivas, MD, PhD
Orthopaedic and Spinal Surgeon
Director of the Trauma and Orthopaedic Department
"Tzanio" General Hospital
Piraeus, Greece
IRSSD (2009-2010) and SOSORT (2008) Past President
Chief Editor of *Scoliosis*
http://www.scoliosisjournal.com/

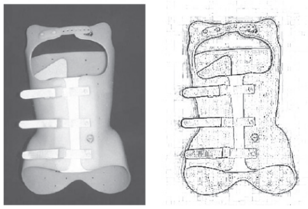
The currently utilised European braces are described. A short history, design rationale, indications, biomechanics, outcomes and comparison between some braces are reported.

Chêneau Brace

Its history starts during the 60's. The brace was initially named Cheneau-Toulouse-Munster Brace. Now it is accepted and used worldwide. It is a rigid brace providing three-dimensional correction. This brace opens anteriorly. The brace is divided in zones and provides large free spaces opposite to pressure sites. The hump should be pressed on 1/3 of the surface of apex. The corresponding dodging site involves 4/5 of the surface of the concave side of curve. Each of the remaining two pressure parts of the *three-point system* presses on 1/5 of the surface of the concave side. They are the apexes of the neighbouring curves. Dodging opposite the latter sites allows movements and straightening of the curve in an active way. It is not permitted to hinder any of the three dodging areas, that is, the middle 4/5 of concave side and the 1/3 over and under the apex.

The mechanisms of Chêneau Brace correction are a) *passive mechanisms*, namely 1) convex to concave tissue transfer, achieved by multiple three-point system acting in 3D, with the aim of curve hypercorrection, 2) elongation and unloading, 3) Derotation of the thorax, 4) bending and b) *active mechanisms*, namely 1) vertebral growth acting as a corrective factor, 2) asymmetrically guided respiratory movements of the rib-cage, 3) repositioning of the spatial arrangement of the trunk muscles to provide their physiological action and 4) anti-gravitational effect.

Outcomes: It was reported that the brace obtains an average primary correction of 41% (thoracic, lumbar, double) and a long term correction of 14.2% thoracic, 9.2% lumbar double curves: 5.5% in thoracic & 5.6% in lumbar. Moreover, at the end of treatment an improvement of Cobb angle correction of about 23% and after 5 years a stabilization of about 15 % (p value < 0.05) are achieved. Therefore, Chêneau brace not only stops progression, but it could also reverse the scoliotic curve. Useful information on the brace and its philosophy can be found in http://cheneau.info



The Chêneau brace

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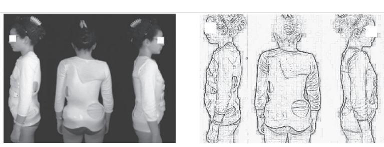
Chêneau Brace derivatives

a) Rigo System Chêneau Brace - RSCB

It was developed during the early 90s. The RSCB is based on the Chêneau Brace, and it is able to produce the required combined forces to correct scoliosis in 3D. The blueprint of the brace is based on the idiopathic scoliosis curve classification introduced for brace treatment by Dr Rigo. The classification includes radiological as well as clinical criteria. *The radiological criteria are utilized to differentiate five basic types of curves including: (I) imbalanced thoracic (or three curves pattern), (II) true double (or four curve pattern), (III) balanced thoracic and false double, (IV) single lumbar and (V) single thoracolumbar. In addition to the radiological criteria, the Rigo Classification incorporates the curve pattern according to SRS terminology, the balance/imbalance at the transitional point, and L4-5 counter-tilting. The principles of correction of the five basic types of curves are also described by Dr. Rigo.* Biomechanically, the RSC brace offers regional derotation. The rib cage and spine are de-rotated. The brace derotates the thoracic section against the lumbar section, with a counter-rotation pad at the upper thoracic region. The brace also produces physiological sagittal profile.

Outcomes: Initial reports using this brace indicated a 31.1% primary Cobb angle correction and 22.2% primary torsion angle correction. At a follow up of 16.8 months 54% of curves were stable, 27% improved and 19% progressed. In patients with long thoracic curves treated with an improved RSC brace design (three-curve-scoliosis brace with pelvis open) there was 76.7 % in-brace Cobb angle correction and 55.9% in-brace axial rotation correction. The latter pattern is easy to correct according to the principles and it can not be compared to "Chêneau light" cohort, which in addition contains double curve patterns which correct least. Please visit http://www.scoliosisjournal.com/content/4/S2/O46 and http://www.scoliosisjournal.com/content/5/1/1 for Rigo System Chêneau Brace details.



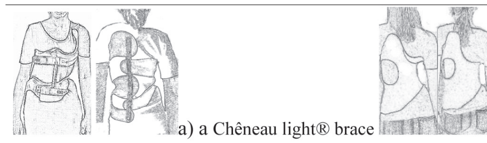
Rigo System Chêneau Brace - RSCB

b) ScoliOlogiC® "Chêneau light"

It was invented by Dr. Hans-Rudolf Weiss and it presented and built in 2005.

Outcomes: Weiss et al, 2007, reported 51% correction of Cobb angle (Cobb angle in the whole group of patients was reduced by an average of 16,4 degrees), 62 % correction for lumbar & thoracolumbar curve pattern, 36 % correction for thoracic scoliosis and 50 % correction for double major curve pattern. The correction effect correlated negatively with age (r = -0,24; p = 0,014), negatively with the Risser stage (-0,29; p = 0,0096) and negatively with Cobb angle before treatment (r = -0,43; p < 0,0001). From the experience obtained through the Chêneau light® brace a new CAD/CAM brace has been designed which is called the Gensingen brace®, described in the 3rd. edition "Best Practice" in conservative scoliosis care. There are blueprints to build a RSC® or a Chêneau light® brace according to the conservative treatment of AIS classification by Dr M. Rigo and Dr. HR Weiss.

Please visit http://www.scoliosisjournal.com/content/5/1/19 for a Chêneau light® brace and http://www.scoliosisjournal.com/content/5/1/22 for a Gensingen brace® details.

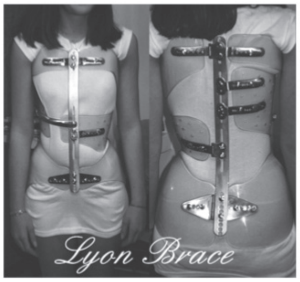


a) a Chêneau light® brace b) a Gensingen brace®

Lyonnaise (Lyon) Brace

It was created by Pierre Stagnara in 1947. Allègre and Lecante modified it to its present form using aluminium bars and plexidur (a high rigidity material) in 1958. It is an adjustable rigid brace, without any collar. The bars of the brace are made of radio see-through duralumin, the faceplate and joint of high steel and the thermo malleable plastic is made of polymetacrylate of methyl. The treatment is based on two main principles of treatment. An initial plaster cast to stretch the deep ligaments before the application of Lyon brace and the subsequent application of the adjustable brace. The blueprint is designed according to Lenke's idiopathic scoliosis classification and there are 14 design types. The indications for this brace are scoliotics of 11-15 years of age. It is not applied earlier to prevent tubular deformation of the thorax.

Outcomes: The reported results detail an effectivity index (results based on SRS - SOSORT treatment criteria 2 years after the weaning of the brace) of 0,97 for lumbar curve, 0,88 for thoraco-lumbar curve and 0,80 for thoracic curve. The Cobb angle correction is reported to be 12% for thoracic correction, 10% and 25% respectively for double major, 24% for thoraco-lumbar, 36% for lumbar. Results are also obtained on cosmesis (hump in mm). The rib hump is better corrected than the Cobb angle, which is reduced by 1/3 at the thoracic level and by more than 50% at the lumbar level. The esthetical aspect is always better than the radiographs. In 1338 treated scoliotics, 67.19 % improved, 27.80 % were stable and 5.00 % deteriorated. Please visit http://www.scoliosisjournal.com/content/6/1/4 for brace details.



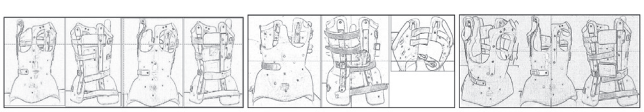
the Lyon Brace

Dynamic Derotating Brace (DDB)

It was developed at Athens, Greece built in 80's. It is made of polypropylene with a soft foam polyethylene lining. It opens posteriorly. This is a TLSO type brace featuring anti-rotatory blades which act as springs - anti-rotatory devices, maintaining constant correcting forces at the pressure areas of the brace and, at the same time, produce movements in opposite directions of the two side-halves of the brace. The derotating metal blades are attached to the rear side of the brace corresponding to the most protruding part of the thorax (hump) or the trunk of the patient.

They become active when their free ends are placed underneath the opposite side of the brace and the brace is tightened using its straps. The forces applied by the de-rotating blades are added to the side forces exerted by the brace, and changing of the backward angle of the blades can modify them.

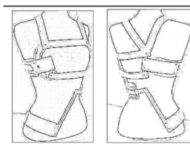
Outcomes: The published reports detail an overall initial Cobb angle correction of 49.54% and at 2 years follow up a correction of 44.10%. It was also reported that the overall 35.70% of curves improved, 46,42% were stable and 7.83% worsened – increased. As far as the cosmesis is concerned (Angle Trunk Inclination – ATI – hump), DDB improves the cosmetic appearance of the back of IS children with all but right thoracic curves. Study on quality of life after conservative treatment of AIS using DDB with the Brace Questionnaire (BrQ), which is specific for brace treatment, revealed an influence on school activity and social functioning, but not on general health perception, physical functioning, emotional functioning, vitality, bodily pain, self-esteem or aesthetics. Please visit http://www.scoliosisjournal.com/content/5/1/20 for DDB brace details.


(a) The thoracic/thoracolumbar module, (b) lumbar module (c) The double curve module

TriaC brace

It was developed by Dr Albert Gerrit Veldhuizen in the Netherlands. The name TriaC derives from the three C's of Comfort, Control, and Cosmesis. The TriaC orthosis has a flexible coupling module connecting a thoracic and a lumbar part.

The TriaC brace exerts a transverse force system, consisting of an anterior progression force counteracted by a posterior force and torque, acts on the vertebrae of a scoliotic spine. In the frontal plane the force system in the TriaC brace is in accordance with the force system of the conventional braces. However, in the sagittal plane the force system only acts in the thoracic region. As a result, there is no pelvic tilt, and it provides flexibility without affecting the correction forces during body motion. The introducers suggest that the inclusion criteria are: IS with a Cobb-angle between 20 and 40 degrees, in skeletally immature scoliotics, with Risser 0–1 status, pre-menarche, post-menarche\1 year, in primary thoracic apex between the 7th and 11th thoracic vertebra and primary lumbar apex between the 2nd and 5th lumbar vertebra, in flexible spinal column as evidenced by at least 40% correction on bending films. Some other studies suggest that the Triac™-Brace represents an alternative exclusively for the correction of lumbar curves. Outcomes: An initial 22% correction is reported for the primary curves within the brace and 35% for the secondary curves. The improvement remained after bracing and in a mean follow up of 1.6 years, as long as it was above a threshold of 20%. In 76% of the patients there was control or net correction of IS curves. It is stated that the TriaC brace significantly alters the predicted natural history of AIS.

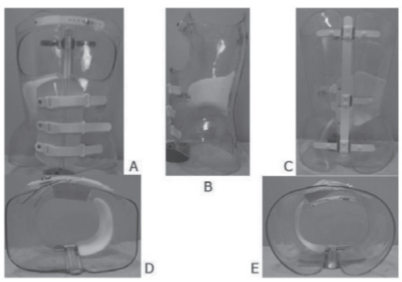

Anterior and posterior view of a TriaC brace

Sforzesco brace

It was developed by Stefano Negrini together with the CPO Gianfranco Marchini in 2004, in Milan, Italy, based on the SPoRT concept (Symmetric, Patient- Oriented, Rigid, Three-Dimensional, Active). The Sforzesco brace combines characteristics of the Risser cast and the Lyon, Chêneau-Sibilla and Milwaukee braces. Its main action is to push scoliosis from the pelvis up, so to deflex, derotate and restore the sagittal plane (three-dimensional action). Results have been published superior to the Lyon brace and similar to the Risser cast with less side-effects, making of the Sforzesco brace, according to authors, an instrument for worst cases. It is based on the efficacy and acceptability correction principles. 1. Efficacy: a) the active brace: the patient is allowed (encouraged) to move freely, b) mechanical efficacy, achieved through pushes, escapes, stops and drivers (the last being a newly developed concept with this brace) c) versatility and adaptability; d) teamwork: MDs, CPOs, PTs patient & family, e) compliance. 2. Acceptability: a) body design and minimal visibility, b) maximal freedom in the Activities of Daily Life, c) assumption of responsibility and d) a cognitive behavioural approach.

Outcomes: This brace is reported to be more effective than the Lyon brace after six months of treatment (38° Cobb curves on average): 80% improved and none worsened vs 53% and 13%, respectively; it is equally effective as the Risser plaster cast to achieve the maximal correction after 18 months of treatment

(40° Cobb average curve); it is more effective than the Risser cast + Lyon brace in treating curves over 45° Cobb reaching the end of growth (45° to 58° Cobb): better results in the thoracic curves without any sagittal plane worsening; it is also able to improve aesthetics in scoliosis patients. Please visit http://www.scoliosisjournal.com/content/6/1/8 for Sforzesco brace details.



Sforzesco brace

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Progressive Action Short Brace (PASB)

This brace is used since 1976, for the treatment of thoraco-lumbar and lumbar idiopathic curves. It is a custom-made thoraco-lumbar-sacral orthosis (TLSO) brace of original design, devised by Dr. Lorenzo Aulisa, in Italy. The PASB is only indicated for the treatment of thoraco-lumbar and lumbar curves. The brace is informed by the principle that a

constrained spine dynamics can achieve correction of a curve, by inverting the abnormal load distribution during growth. The practical application of the biomechanical principles of the PASB is achieved through two operative phases. A plaster cast phase precedes the brace application. At this stage, external forces are exerted to correct the deformity that is elongation, lateral deflection and derotation. This procedure allows obtaining transversal sections represented by asymmetric ellipsis. The finishing touch of the cast establishes the real geometry of the plastic brace. One or sometimes two casts, in relation to the curve rigidity, are manufactured before switching to the custom-made polypropylene orthosis of the second phase of treatment.

Aulisa et al, 2009 reported Cobb angle and Pedriole torsion angle readings of the treated thoraco-lumbar and lumbar curves. The pre treatment Cobb mean value was 29,3 degrees ± 5,16 SD and the initial apical rotation 12.7 degrees ± 6,14 SD. The immediate Cobb correction was 14,67 ± 7,65 SD and the apical rotation correction at follow up 8,95 degrees ± 5,82. Overall curve correction was noted at 94% of patients, curve stabilization in 6% of patients. Please visit http://www.scoliosisjournal.com/content/7/1/6 for BASB brace details.

the **Progressive Action Short Brace (PASB)**

TLI (thoracolumbar lordotic intervention) brace

TLI is developed from its initial stage in 2002 by dr. Piet van Loon, orthopedic surgeon and Jan Munneke, orthotist. TLI is based on the hypothesis that both thoracolumbar kyphotic and scoliotic spinal deformities originate from a dislocation of the thoracolumbar joint from its normal, optimal position at the center. This dislocation (described by M.Jansen in 1913) can occurs gradually in the years before growth spurts by slumping sitting postures. Torque forces by the constant and asymmetric forces of the asymmetric diaphragm can induce scoliosis.

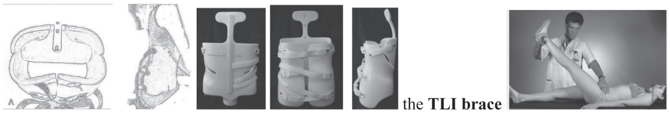
The TLI bracing concept is a Ponseti-type intervention repositioning the joint in its optimal position to reduce shear stress and deformative impulse. TLI is based on this concept of forceful relocating the thoracolumbar joint to its optimal lordotic alignment position. A TLI brace is completely symmetric. Mechanically, TLI is not pushing on the bones of the spine, thorax or pelvis, but is pulling the spine forward by applying extra tension on specific back muscles (erector trunci) as in shortening a bowstring. At the same time the sternal part at the front of the brace functions as an anvil for the forward lordotic force and prevents flexion. There are two versions of TI-braces with different indications: a rigid one (foam lined PE) and in a "soft" version of textiles with bendable paraspinal lordotic bars.

Indication: Scoliosis 10-20 degrees with severe tension (SLR-test), a soft TLI is applied, Scoliosis > 25 degrees before estimated last year of growth a rigid TLI is applied, Kyphosis > 45 degrees or thoracolumbar spine T10-L2 > 10 degrees (Scheuermann II) and tight hamstrings a rigid TLI is applied, kyphosis of thoracolumbar spine T10-L2 < 10 degrees with severe tension problems (Game boy spine) a soft TLI is applied. The principle that forced lordosis by a fulcrum at the thoracolumbar spine shows a statistical relevant instantaneous radiological reduction in both coronal curves of double major scoliosis was published in 2008.

Outcomes: The initial 'in brace' radiographs show a strong reduction of the Cobb angles in different curves in kyphosis and scoliosis groups (sagittal $p < 0.001$, pelvic obliquity $p < 0.001$). After one year of brace treatment in scoliosis and kyphosis group the measurements on radiographs made without brace revealed an improvement in all sagittal and coronal measurements.

Compliance proved high because it is easy to wear (freedom of motion except flexion), little visibility lacking superstructures under shoulder, (auto-) extension of the spine creates space in the brace. The patients see and experience visible progress and are also rewarded because the brace can be made more corrective and smaller at consecutive visits.

Early detection and early start of treatment (including exercises) is a prerequisite in any deformity for successful correction.



REFERENCES

In the open access journal Scoliosis, clicking on the "Article collections" the "Brace Technology Thematic Series" can be found. In this Thematic Series [URL: http://www.scoliosisjournal.com/series/brace_technology] technical papers coming from the different brace schools are published with the aim to improve the knowledge and understanding of brace type and function. This is an established comprehensive source of information about bracing as well. Additionally some more useful references for the present report are cited below.

Danielsson AJ, Hasserius R, Ohlin A, Nachemson AL. A prospective study of brace treatment versus observation alone in adolescent idiopathic scoliosis: a follow-up mean of 16 years after maturity. Spine, 32 (2007), 2198–2207.

Danielsson AJ, Romberg K, Nachemson AL. Spinal range of motion, muscle endurance, and back pain and function at least 20 years after fusion or brace treatment for adolescent idiopathic scoliosis: a case-control study. *Spine,* 31 (2006), 275–283.

Rowe DE. The Scoliosis Research Society Brace Manual. Milwaukee, WI: *Scoliosis Research Society*; (1998), 1–9.

Weinstein SL, Dolan LA, Spratt KF, Peterson KK, Spoonamore MJ, Ponseti IV. Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study. *JAMA,* 289 (2003), 559–567.

Weinstein SL, Ponseti IV. Curve progression in idiopathic scoliosis. *J Bone Joint Surg Am.* 65 (1983), 447–455.

Weinstein SL, Zavala DC, Ponseti IV. Idiopathic scoliosis: longterm follow-up and prognosis in untreated patients. J Bone Joint Surg Am. 63 (1981), 702–712.

Negrini S, Minozzi S, Bettany-Saltikov J, Zaina F, Chockalingam N, Grivas TB, Kotwicki T, Maruyama T, Romano M, Vasiliadis ES. Braces for idiopathic scoliosis in adolescents. Cochrane Database of Systematic Reviews (2009), Issue 1.

Schiller JR, Thakur NA, Eberson CP Brace Management in Adolescent Idiopathic Scoliosis. Clin Orthop Relat Res. (2009) May 30. [Epub ahead of print] PMID: 19484317

Kotwicki T, Cheneau J. Biomechanical action of a corrective brace on thoracic idiopathic scoliosis: Chêneau 2000 orthosis. Disabil Rehabil Assist Technol. 3(3), (2008), 146-53.

Kotwicki T, Chêneau J. Passive and active mechanisms of correction of thoracic idiopathic scoliosis with a rigid brace. Stud Health Technol Inform. 135 (2008), 320-326.

Périé D, Sales De Gauzy J, Sévely A, Hobatho MC. In vivo geometrical evaluation of Cheneau-Toulouse-Munster brace effect on scoliotic spine using MRI method. *Clin Biomech (Bristol, Avon)*. 16(2) (2001), 129-137.

Hopf C, Heine J. Long-term results of the conservative treatment of scoliosis using the Chêneau brace. Z Orthop Ihre Grenzgeb. 123(3) (1985), 312-322.

Cinnella P. Muratore M. Testa E. Bondente P.G. The Treatment of adolescent idiopathic scoliosis with Chêneau brace: long term outcome. Oral Presentation at Lyon 2009 SOSORT Meeting.

Rigo MD and Gallo D (2019): A new RSC brace design to treat single long thoracic scoliosis. Comparison of the in-brace correction in two groups treated with the new and the classical models. *Scoliosis* 2009, 4(Suppl 2):O46 doi:10.1186/1748-7161-4-S2-O46

Rigo MD, Villagrasa M, Gallo D (2010): A specific scoliosis classification correlating with brace treatment: description and reliability. *Scoliosis* (2010) 5:1

Rigo M, Weiss HR 2008 The Chêneau concept of bracing-biomechanical aspects. *Stud Health Technol Inform*. 135 (2008), 303-319

Rigo et al 2002 (Retrospective results in immature idiopathic scoliotic patients treated with a Chêneau brace. Rigo M, Quera-Salvá G, Puigdevall N, Martínez M. *Stud Health Technol Inform*. 88 (2002), 241-245.

Rigo M and Gallo D. 2009 A new RSC brace design to treat single long thoracic scoliosis. Comparison of the in-brace correction in two groups treated with the new and the classical models. Oral Presentation at Lyon 2009 SOSORT Meeting.

Rigo MD, Gallo D and Dallmayer R. (2010): In-brace correction of the Cobb angle with RSC-CAD CAM compared with 'hand made' from the original author . Scoliosis 2010, 5(Suppl 1):O68 doi:10.1186/1748-7161-5-S1-O68

Weiss HR, Werkmann M and Stephan C (2007): Correction effects of the ScoliOlogiC® „Cheneau light" brace inpatients with scoliosis. *Scoliosis* (2007), 2:2 doi:10.1186/1748-7161-2-2

Weiss HR: Best Practice in conservative scoliosis care. 3rd. edition, Pflaum, Munich, 2010.

Weiss HR, Rigo M. The chêneau concept of bracing--actual standards. *Stud Health Technol Inform*. 135 (2008), 291-302.

De Mauroy JC, Lecante C, Barral F, Daureu D, Gualerzi S, Gagliano R. The Lyon brace. *Disabil Rehabil Assist Technol*. 3(3) (2008), 139-145.

De Mauroy JC, Fender P, Tato B, Lusenti P, Ferracane G. Lyon brace. *Stud Health Technol Inform*. 135 (2008), 327-340.

Antoniou D, Valavanis J, Zachariou C, Smyrnis P. 1986 "Dynamic Derotation Brace (DDB). A new aspect for the conservative treatment of Idiopathic Scoliosis" (1986), *Presentation in 21st common meeting of SRS and BSS*.

Valavanis J, Bountis A, Zachariou C, Kokkonis D, Anagnostou D, Giahos D, Daskalakis E. Three-Dimensional Brace Treatment for Idiopathic Scoliosis. In: *Three Dimensional Analysis of Spinal Deformities* M D'Amico et al (Eds.) IOS Press, (1995), 337-341.

Andoniou D, Valavanis J et al: The effectiveness of our bracing system in the conservative treatment of idiopathic scoliosis. *J Bone Joint Surg*, 74-B. Suppl, I, (1992), 86.

Grivas TB, Vasiliadis E, Chatziargiropoulos T, Polyzois VD, Gatos K. The effect of a modified Boston brace with antirotatory blades on the progression of curves in idiopathic scoliosis: aetiologic implications. *Pediatr Rehabil.* 6(3-4) (2003), 237-242.

Grivas TB, Vasiliadis ES. Cosmetic outcome after conservative treatment of idiopathic scoliosis with a dynamic derotation brace. *Stud Health Technol Inform*. 135 (2008), 387-392.

Vasiliadis E, Grivas TB. Quality of life after conservative treatment of adolescent idiopathic scoliosis. *Stud Health Technol Inform*. 135 (2008), 409-413.

Vasiliadis E, Grivas TB, Gkoltsiou K. Development and preliminary validation of Brace Questionnaire (BrQ): a new instrument for measuring quality of life of brace treated scoliotics. *Scoliosis*. (2006) May 20;1:7.

Vasiliadis E, Grivas TB, Savvidou O, Triantafyllopoulos G. The influence of brace on quality of life of adolescents with idiopathic scoliosis. Stud Health Technol Inform. 123 (2006), 352-356.

Grivas TB, Bountis A, Vrasami I, Bardakos NV (2010): Brace technology thematic series: the dynamic derotation brace. Scoliosis 2010, 5:20 (21 September 2010)

Negrini S, Donzelli S, Lusini M, Zaina F. Bracing can reduce high degree curves and improve aesthetics immediately after the end of growth. Final results of a retrospective case series. Stud Health Technol Inform. 2012;176:393-6. PubMed PMID: 22744537.

Donzelli S, Zaina F, Negrini S. In defense of adolescents: They really do use braces for the hours prescribed, if good help is provided. Results from a prospective everyday clinic cohort using thermobrace. Scoliosis. 2012 May 31;7(1):12. doi: 10.1186/1748-7161-7-12. PubMed PMID: 22651570; PubMed Central PMCID: PMC3475113.

Negrini S, Marchini G, Tessadri F. Brace technology thematic series – The Sforzesco and Sibilla braces, and the SPoRT (Symmetric, Patient oriented, Rigid, Three-dimensional, active) concept. Scoliosis. 2011 May 9;6:8. doi: 10.1186/1748-7161-6-8. PubMed PMID: 21554719; PubMed Central PMCID: PMC3115908.

Negrini S, Negrini F, Fusco C, Zaina F. Idiopathic scoliosis patients with curves more than 45 Cobb degrees refusing surgery can be effectively treated through bracing with curve improvements. Spine J. 2011 May;11(5):369-80. doi: 10.1016/j.spinee.2010.12.001. Epub 2011 Feb 2. PubMed PMID: 21292562.

Negrini S, Atanasio S, Fusco C, Zaina F. Effectiveness of complete conservative treatment for adolescent idiopathic scoliosis (bracing and exercises) based on SOSORT management criteria: results according to the SRS criteria for bracing studies - SOSORT Award 2009 Winner. Scoliosis. 2009 Sep 4;4:19. doi: 10.1186/1748-7161-4-19. PubMed PMID: 19732429; PubMed Central PMCID: PMC3224944.

Zaina F, Negrini S, Fusco C, Atanasio S. How to improve aesthetics in patients with Adolescent Idiopathic Scoliosis (AIS): a SPoRT brace treatment according to SOSORT management criteria. Scoliosis. 2009 Sep 1;4:18. doi: 10.1186/1748-7161-4-18. PubMed PMID: 19723337; PubMed Central PMCID: PMC2743641.

Negrini S, Atanasio S, Negrini F, Zaina F, Marchini G. The Sforzesco brace can replace cast in the correction of adolescent idiopathic scoliosis: A controlled prospective cohort study. Scoliosis. 2008 Oct 31;3:15. doi: 10.1186/1748-7161-3-15. PubMed PMID: 18976485; PubMed Central PMCID: PMC2612643.

Negrini S, Atanasio S, Zaina F, Romano M, Parzini S, Negrini A. End-growth results of bracing and exercises for adolescent idiopathic scoliosis. Prospective worst-case analysis. Stud Health Technol Inform. 2008;135:395-408. PubMed PMID: 18401107.

Negrini S, Marchini G. Efficacy of the symmetric, patient-oriented, rigid, three-dimensional, active (SPoRT) concept of bracing for scoliosis: a prospective study of the Sforzesco versus Lyon brace. Eura Medicophys. 2007 Jun;43(2):171-81; discussion 183-4. Epub 2006 Sep 24. PubMed PMID: 16955065.

van Loon PJ, Kühbauch BA, Thunnissen FB.(2008): Forced lordosis on the thoracolumbar junction can correct coronal plane deformity in adolescents with double major curve pattern idiopathic scoliosis. Spine (Phila Pa 1976). 2008 Apr 1;33(7):797-801. doi: 10.1097/BRS.0b013e3181694ff5.

Van Loon PJM, FB Thunnissen, M Roukens, J Munneke (2009): Compliance and satisfaction of TLI-bracing in kyphotic and scoliotic deformities in relation with intrinsic dynamic aspects. Scoliosis 2009, 4(Suppl 2):O63 (14 December 2009)

Van Loon PJM, Roukens M, Kuit JDJ, Thunnissen FB (2012): A new brace treatment similar for adolescent scoliosis and kyphosis based on restoration of thoracolumbar lordosis. Radiological and subjective clinical results after at least one year of treatment. Scoliosis 2012, 7:19 (29 October 2012)

Van Loon PJM (2013): Biological background and biomechanical support explain similar effect in treatment of scoliosis and kyphosis with TLI bracing. Scoliosis 2013, 8(Suppl 1):P4 (3 June 2013)

Van Loon PJM, Thunnissen FB, Roukens M (2013): Adolescent scoliosis and kyphosis treated with TLI (thoracolumbar lordotic intervention) technique in a brace. Mechanism and results .Scoliosis 2013, 8(Suppl 1):P2 (3 June 2013)

Notes

North American Brace Designs

Luke Stikeleather, CO, President
Scoliosis Solutions
Fairfax, VA, USA
Email: luke@orthoticsolutions.com
P: 703-849-9220
F: 703-849-8499

Introduction

In 1998, Dale E. Rowe MD, et al. presented the "**The Scoliosis Research Society Manual of Brace Treatment for Idiopathic Scoliosis** at the 33rd SRS Meeting in New York City.

At the time, it was the most comprehensive compilation of brace related information. The original contents of this manual with updates to some sections are on the SRS website. More recently, in 2009, Reginald Fayssoux MD, Robert Cho MD and Martin Herman MD, published **A History of Bracing for Idiopathic Scoliosis in North America.** While this is a good historical review of the well-known and commonly utilized braces, there are several, "new in North America", brace designs which are attracting attention and gaining traction with more emphasis on addressing three dimensional issues of rotation and sagittal balance.

Design Classifications

Brace classifications typically are either CTLSO's, or TLSO's of thermoplastic construction with either anterior or posterior opening. They are further described as being of symmetrical or asymmetrical design. The SpineCor is distinctly unique and does not lend itself to this classification being of a strap and fabric construction.

This overview highlights design elements and biomechanical principals of each brace type. It is not intended to endorse critique or evaluate the effectiveness of any particular brace.

Overview of Current Brace Designs

Milwaukee
Boston
Wilmington
Charleston
Providence
Spincore
Rosenberger
GOSS
LA Brace
Lyon
Rigo-Cheneau variations

References

Fayssoux RS, Cho RH, Herman MJ. A history of bracing for idiopathic scoliosis in North America. Clin Orthop Relat Res. 2010 Mar;468(3):654-64. doi: 10.1007/s11999-009-0888-5. Epub 2009 May 22

Coillard C, Vachon V, Circo AB, Beauséjour M, Rivard CH. Effectiveness of the SpineCor brace based on the new standardized criteria proposed by the Scoliosis Research Society for adolescent idiopathic scoliosis. J Pediatr Orthop. 2007

D'Amato CR, McCoy B. The Providence Scoliosis System Manual. Milwaukee, WI: Scoliosis Research Society; 2003.

Emans JB. Reference Manual for the Boston Scoliosis Brace. Milwaukee, WI: Scoliosis Research Society; 2003.

Hooper CR, Reed FE, Price CT. The Charleston Brace. An Orthotist's Guide to Scoliosis Management. Milwaukee, WI: Scoliosis Research Society; 2003.

Rigo M, Negrini S, Weiss H, Grivas T, Maruyama T, Kotwicki T: **SOSORT consensus paper on brace action: TLSO biomechanics of correction (investigating the rationale for force vector selection).** *Scoliosis* 2006, **1:**11

Notes

Brace Fabrication Techniques and Monitoring Devices

James H. Wynne, CPO
Vice-President Director of Education
Boston Brace/National Orthotic Prosthetic Company
20 Ledin Drive
Avon, Massachusetts 02322 USA
P: 508-588-6060

M. Timothy Hresko, MD
Boston Children's Hospital
300 Longwood Avenue
Boston, Massachusetts 02155, USA
P: 617-355-6000

Introduction

Brace fabrication techniques have evolved but the goals remained the same:

- Low profile
- Most effective and comfortable
- Maximum reduction of the curve without reducing tolerance

Specific brace designs and materials can be found at:

www.srs.org/professionals/education_materials/SRS_bracing_manual

Thematic series of the Scoliosis Journal (www.scoliosisjournal.com).

Orthotist will utilize different fabrication methods within the same clinic depending on the patient's abilities and presentation. The best method being the one that provides the orthotist the model needed to fabricate the most appropriate orthosis.

Capturing the Shape of the Patient

Care and skill is required all along the fabrication process to ensure a well-designed and fitting orthosis is provided.

- Plaster/ Fiberglass Casting
    - Cotrel and Risser introduced the use of a casting frame
        - ◊ Patient supine, under traction
        - ◊ Corrective forces applied to obtain a corrected model of the patient
    - Vertical frame or bivalve casting techniques developed for those clinics without access to a horizontal frame
    - Model Preparation
        - ◊ Plaster model hand modified, custom TLSO fabricated according to brace type
- Manual Hand Measurements
  It was the observation that many of the plaster models appeared to be the same shape and size that lead to the concept of just taking measurements to obtain a pre-fabricated symmetrical module.
    - Miller and Hall introduced a pre- fabricated symmetrical TLSO in the 1970's

- ◊ Circumferential, width (medial lateral) and depth (anterior posterior) measurements taken at specific land marks
- ◊ Symmetrical shape provides corrective forces, these are supplemented with custom pads added according to brace principles

* Model Preparation
  - ◊ x-ray required for brace design
  - ◊ Orthosis customized according to the Blueprint

- Scanning and Computer-aided Design Computer-aided Manufacturing (CADCAM)
  This technology allows the orthotist to obtain the individual shape of the patient in less time than casting and maintain an electronic copy of the patient's size and shape. Techniques, similar to those used for casting are employed
- Scanners
  * Stationary or hand held; laser (class 1, 2) or white light
  * Commercially available stationary scanners
    - ◊ Capturor, Creaform inc (http://www.creaform3d.com)
    - ◊ Orten (http://orten.fr/)

Stationary scanners require more square footage, limited in the scope of patients they can scan effectively, not portable

* Commercially available handheld laser scanners
  - ◊ The O&P Scan from Rodin4D)(www.rodin4d.com) single camera, class one laser scanner
  - ◊ BioScanner from Biosculpture (www.biosculptor.com) dual camera class two laser
* Commercially available handheld white light scanners
  - ◊ MD4 scanner (www.rodin4d.com)
  - ◊ EVA scanner (Artec.com)

Handheld scanners are able to capture most torsos/ body segments contours and are portable. The White light scanners are less expensive than laser scanners, but require more frequent calibration.

- Model Preparation via CADCAM Software
  Think of the scanner as a digital camera – it captures the image. To modify or manipulate that image it is uploaded into CAD software just like a photo would be loaded into Photoshop (or the like).
  * Commercially available software manufacturers
    - ◊ Rodin4D (www.rodin4d.com); Biosculpture(www.biosculptor.com); Vorum(www.vorum.com)
    - ◊ Orten(http://orten.fr/)

These programs are unique to the orthotic & prosthetic profession, but not specific to scoliosis. The electronic model is now uploaded into the CAD software and modified according to specific bracing strtegies. The x-ray and or the 3D skeleton can be imported into the captured shape. The model can be balanced for systems based on symetry or shifted for asymetrical protocols. Pads or pushes are can be built into the cad model much like they would be for the hand modified models. Timlines can be drawn and the finished brace shape reviewed .(Figure 1)

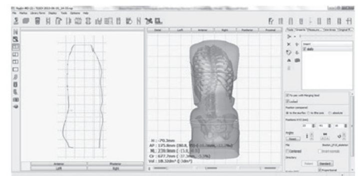


Figure 1 Modified model with skeleton insert, sagittal view on left, Rodin4d software

Once the model is modified, the file is sent to a carver to have the positive model created. Plastic is then vacuum formed over the foam model, trimmed and smoothed and ready for first fit .Cost for this technology is between 15 – 40 thousand US dollars depending on the type of scanner, accessories needed (updated lap tops), type of software and licensing fees.

Fabrication Material

Plastics are available in various thicknesses and rigidity. A thinner more rigid plastic may be selected over a thicker more flexible plastic for cosmetic reasons. Care must be taken that the plastic is strong enough not to deform or fatigue over time. Reiforcments are sometimes added over areas where the forces on the spine are greatest.

Future with CAD

Software is currently being developed that will allow the orhtotist to simulate a brace fitting prior to fabrication. Scans and x-rays will be imported as described. A virtual patient will then be created by the software. The orthotist will have the option of modifying a model or allow the computer to design the most effective design to reduce the curve. Either way, a simulator will allow the virtual brace to be fitted on the virtual patient to test the results. The design can be adjusted to improve results prior to fitting the patient.

Adjustments after fit

Review of the in-brace x-ray is also well accepted as a means to evaluate the patient's response as well as brace construction. By doing so accurate and effective adjustments can be made immediately to maximize the brace's effectiveness. One method of x-ray analysis, termed The Blueprint, first discussed by Watts and updated by Emans gave the orthotist a step by step procedure on x-ray analysis and brace fabrication. More recently, Rigo has described a bracing classification system based on x-ray analysis.

In house fabrication – Central Fabrication Facilities

Many facilities have their own lab where they fabricate the orthosis from start to finish. Other faculties use specialized fabrication facilities called central fabrication. The extent of fabrication depends on the orthotist and the capabilities of the lab. Some central fabrication facilities will specialize in spinal fabrication, most however offer a wide range of fabrication capabilities.

- Central Fabrication Facilities specializing in Scoliosis
  - * Boston Brace (www.bostonbrace.com), the Boston Brace
  - * Spinal Technologies, the Providence Brace
  - * Rodin4d, Cheneau and other European styles

Regardless of where the orthosis is fabricated, the treating orthotist is responsible for the shape capture, design, fitting and follow up adjustments.

Monitors

Brace compliance has always been always a challenge. Lower profile, lighter weight orthoses have been developed in the hope that compliance will improve. A recent study showed the importance of compliance to bracing success. Negrini provided a model of implementing the use of the monitors in the clinical setting. Monitors are a way to eliminate the need to estimate wear by parents/patients and to become aware of habits leading to poor compliance. It is important to make sure the patient understands the monitor is there to help recognize if they are having difficulty adhering to the wear schedule so it can be addressed. It is in identifying the barriers to success that will help the team develop strategies to be successful.

Commercially Available Thermal Sensors

- Tidbit (http://www.onsetcomp.com/products/data-loggers/utbi-001)
- iButton (www. thermodata.us)
- Cricket (http://www.cmdfab.com/embSoft.php)
- Microsensor (www.protech-intl.com)

The Tidbit and iButton are used in various industries and are a volume product. This keeps their cost relatively low. They use a single thermometer, meaning, only the internal temperature of the brace is recorded. The cricket was developed specifically for monitoring brace wear. It has two thermometers, recording both the internal and ambient temperature. Monitors range from 50 – 160 dollars US, the readers from 40 – 2,600 dollars, US.

- Thermal Sensor Features
  - o Ability to set frequency of reads
  - o Internal non-rechargeable battery
  - o Use of a reader to download the data
  - o Software to interpret downloaded data into a clinically relevant report

The Negrini group has developed an algorithm that is available online at no cost. Practitioners log in and copy the raw data into their program and the results are provided. (Figure2) This shows average hours worn, average hours worn per day and by month. The cricket data downloads into an Excel sheet (Figure 3) showing average hours worn and what hours during the 24 hour cycle the brace is worn. The output report needs to be clinically relevant and in a format that resonated with the patients and families. Downloads need to be seamless and quick so that the clinic can run smoothly.

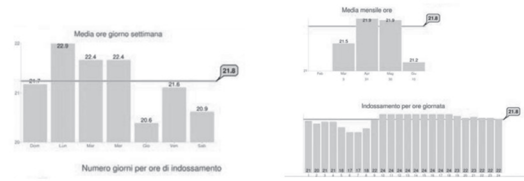


Figure 2 Examples of report available from the Negrini group

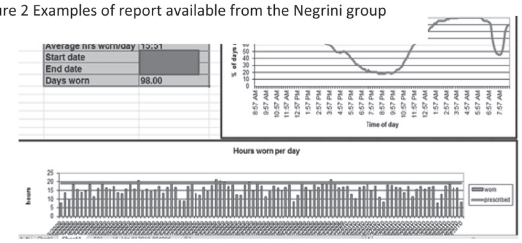


Figure 3 Sample Cricket Report

Experience with monitoring brace wear will help us learn the type of reports patients and families need to assist in improving and maintaining compliance. Future studies should be required to report compliance in order to make conclusions.

Bibliography

1) Emans JB, Kaelin A, Bancel P, Hall JE, Miller ME (1986) The Boston bracing system for idiopathic scoliosis. Follow-up results in 295 patients. Spine 11:792–801

2) Sabrina Donzelli, Fabio Zaina1, and Stefano Negrini, In defense of adolescents: They really do use braces for the hours prescribed, if good help is provided. Results from a prospective everyday clinic cohort using thermobrace, Scoliosis 2012, 7:12

3) Theodoros B Grivas, Achilles Bountis, Irene Vrasami, Nikolaos V Bardakos, Brace technology thematic series: the dynamic derotation brace, Scoliosis 2010, 5:20

4) Angelo G Aulisa1, Giuseppe Mastantuoni, Marco Laineri, Francesco Falciglia, Marco Giordano,Emanuele Marzetti and Vincenzo Guzzanti, Brace technology thematic series: the progressive action short brace (PASB), Scoliosis 2012, 7:6

5) Emans, The Boston Brace Manual

6) Charles d'Amato, Povidence Brace Manual

7) C. Ralph Hooper, Charleston Brace Manual

8) Manual of Brace Treatment for Idiopathic Scoliosis, SRS website, http://www.srs.org/professionals/education_materials/SRS_bracing_manual/

9) Stefano Negrini, Gianfranco Marchini and Fabrizio Tessadri, Brace technology thematic series - The Sforzesco and Sibilla braces, and the SPoRT (Symmetric, Patient oriented, Rigid, Three-dimensional, active) concept, Scoliosis 2011

10) Jean C de Mauroy, Cyril Lecante and Frédéric Barral, "Brace Technology" Thematic Series - The Lyon approach to the conservative treatment of scoliosis,Scoliosis 2011

11) Hans-Rudolf Weiss and Mario Werkmann, "Brace Technology" Thematic Series - The ScoliOlogiC® Chêneau light™ brace in the treatment of scoliosis, Scoliosis 2010

12) Manuel D Rigo, Mónica Villagrasa, Dino Gallo, A specific scoliosis classification correlating with brace treatment: description and reliability, Scoliosis 2010

13) Watts HG, Hall JE, Stanish W: The Boston brace system for the treatment of low thoracic and lumbar scoliosis by the use of a girdle without super structure. Clincal Orthop Relat Res (1977) 87-92

14) Julien Clin, PhD, MScA, Carl-E´ric Aubin, PhD, PEng, Archana Sangole, PhD,Hubert Labelle, MD, and Stefan Parent, MD, PhD, Correlation Between Immediate In-Brace Correction and Biomechanical Effectiveness of Brace Treatment in Adolescent Idiopathic Scoliosis, SPINE Volume 35, Number 18, pp 1706–1713,©2010

15) Julien Clin, Carl-Eric Aubin, Stefan Parent ,Archana Sangole, Hubert Labelle, Comparison of the biomechanical 3D efficiency of different brace designs for the treatment of scoliosis using a finite element model, Eur Spine J, 2009

16) Frederique Desbiens-Blais a,b, Julien Clin a,b, Stefan Parent b, Hubert Labelle b, Carl-Eric Aubin, New brace design combining CAD/CAM and biomechanical simulation for the treatment of adolescent idiopathic scoliosis, Clinical Biomechanics, August 2012

17) Tariq Rahman et al, Electronic monitoring of scoliosis brace wear compliance, J Child Orthop (2010) 4:343–347

18) Donald E. Katz, J. Anthony Herring, Richard H. Browne, Derek M. Kelly, Brace Wear Control of Curve Progression in Adolescent Idiopathic Scoliosis, J Bone Joint Surg Am. 2010;92:1343-1352

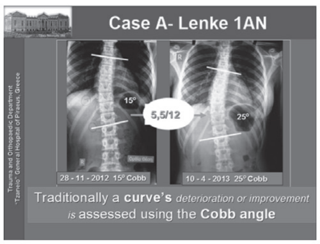
19) Brian M. Benish , CO , * Kristin J. Smith , CO, CTO , * and Michael H. Schwartz , PhD, Validation of a Miniature thermochron for Monitoring Thoracolumbosacral Orthosis Wear Time, SPINE Volume 37, Number 4, pp 309–315 ©2012

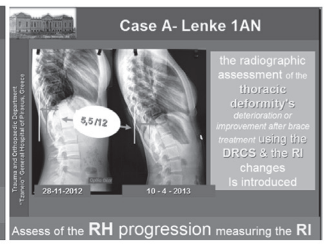
Notes

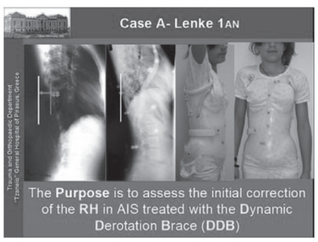
Panel case presentation: Radiological appraisal of thoracic deformity - improvement or deterioration- using the convex/concave rib-hump index ('double rib contour sign') in curves Lenke Type 1, 3, 5 and 6

Dr Theodoros B. Grivas, MD, PhD
Orthopaedic and Spinal Surgeon
Director of the Trauma and Orthopaedic Department
"Tzanio" General Hospital of Piraeus, Greece
IRSSD (2009-2010) and SOSORT (2008) Past President
Chief Editor of *Scoliosis*
http://www.scoliosisjournal.com/

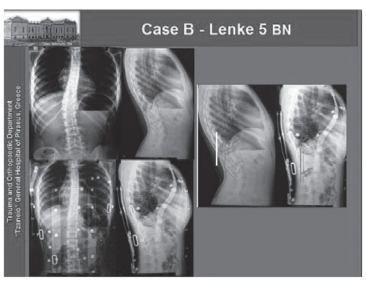
Case presentation







A) Girl 12 years of age, Risser II, and less than one year post menarche, with a Lenke 1AN curve T7-L1 of 15 degrees of Cobb angle, deteriorates to 25 degrees in five and a half months. The rib index also increases from 1,39 to 2,85. Brace treatment using a Dynamic Derotation Brace is commenced. Six weeks later the in-brace Cobb angle is 12 degrees and the rib index becomes 1,80.



B) Girl 12 years of age, Risser II, and less than one year post menarche, with a Lenke 5BN curve T8-L3 of 14 degrees of Cobb angle, deteriorates to 23 degrees in 10 months. The rib index also increases from 1,48 to 1,65. Brace treatment using a Dynamic Derotation Brace is commenced. Four weeks later the in-brace Cobb angle is 7 degrees and the rib index becomes 1,18.

Surface measurements of both girls were documented using the Prujis scoliometer.

Discussion

Traditionally in the setting of the outpatient clinics the assessment of early or late outcomes of brace treatment includes the Cobb angle readings and in a best scenario the assessment of the trunk surface asymmetry, using either a scoliometer or the currently existing surface topography technology facilities.

However the scoliotic children & their parents are very much concerned about the **trunk deformity (TD).** One of the TD components is the **rib hump (RH),** which mainly expresses the rib (thoracic) abnormality. The brace treatment aims not only to stop the progression or correct the scoliotic curve of the central axis - the spine - but also the **TD** in the thorax - the **RH.** The RI can be used in every curve with a thoracic component, as in curves Lenke Type 1, 3, 5 and 6.

Imaging studies assessing thoracic asymmetries include: (1) the segmental rib-vertebra angles (RVA) [1,2,3], (2) the thoracic ratios [4], (3) the convex/concave rib-hump index ('double rib contour sign) [5,6], (4) the ultrasound axial vertebral and rib rotations [7], (5) the ultrasound spine-rib rotation difference (SRRD) [8,9].

The vertebra rotation and the Rib Vertebra Angles (RVAs) are seldom measured on the plane anteroposterior radiographs in the setting of the outpatient clinics. The ultrasound examination is also unusual for the every day clinical praxis. More recently a 3D RVADs study was implemented [10].

A limited number of articles on the RVAs utility have been published. RVAs were used for prognosis of infantile idiopathic scoliosis, [apical RVAD [11], apical RVA [12], for the assessment of brace treatment of juvenile IS [apical RVAD [13] and for the study of the thoracic cage deformity in pre-op & post-op AIS, (T4 to T12) [14, 15, 16, 17, 18].

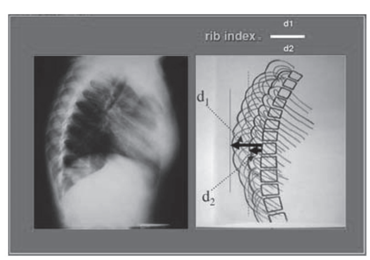
The analysis of segmental RVAs in a cross-sectional study in chest radiographs of nonscoliotics also provided information on the development of the ribcage morphology during growth [19,1].

The reason of the reluctance to do all the above mentioned measurements is that, till now, the aetiological theories for IS were mainly oriented to the central axis, the spine, as this was believed to be the "heart of the problem". Furthermore, in a busy clinical setting it is not very convenient to do all these measurements.

However, the contribution of the thoracic cage deformity is increasingly taken in consideration as a major casual factor for Scoliogeny, based on recent research. Therefore the assessment of the brace treatment impact on the thoracic cage deformity becomes increasingly significant.

One way to assess the thoracic deformity and especially the RH is the use of the convex/concave **rib**-hump **index** - the **double rib contour sign** (**DRCS**) in lateral spinal radiographs. The **RI** is calculated by the ratio of distances d1/d2, where **d1** is the distance between the most extended point of the most extending rib contour and the posterior margin of the corresponding vertebra on the lateral scoliosis films, while **d2** is the distance from the least projection rib contour and the posterior margin of the same vertebra. The **rib-index** is the **ratio d1/d2** [5]. **Figure 1**. The DRCS and the RI were introduced for AIS aetiological reasons.

Figure 1. The DRCS and the rib index



The DRCS and the RI were initially used for clinical reasons, for the assessment of rib hump deformity correction in the operative management of AIS with or without costoplasty [20]. In this publication it was noted that the RI is used due to its simplicity and to the ability to be calculated on the lateral spinal films with no need for special imaging or additional exposure to radiation.

The application of **RI** method for the assessment of thoracic deformity - **RH** - in scoliotics using brace treatment was introduced in Chicago 2013 [21]. It was concluded that the **RI** based on **DRCS** could easily be used to assess any brace effectiveness on the rib hump deformity correction.

Traditionally the early in-brace Cobb angle correction was used to predict the brace treatment outcome. The amount of reduction of the Cobb angle during the early treatment in-brace radiographs was used to predict the brace treatment result. Cobb angle reduction by 25 - 50 percent is reported necessary for a satisfactory outcome [22, 23, 24, 25, 26, 27, 28,29,30,31,32].

Considering that the improvement of the thoracic deformity is as important as that of the spine, in parallel to the study of early in-brace Cobb angle reduction, it is suggested that it is worth measuring the initial in-brace RI correction as well. Further research may confirm that this RI study will be able to predict the brace treatment outcomes on the thoracic cage deformity correction.

Literature

1. Grivas T, Burwell R, Purdue M, Webb J, Moulton A: Segmental patterns of rib-vertebra angles in chest radiographs of children: changes related to rib level, age, sex, side and significance for idiopathic scoliosis. *Clin Anat* 1992, 5(4):272-288.

2. Grivas TB, Samelis P, Chadziargiropoulos T, Polyzois B: Study of the rib cage deformity in children with 10 degrees-20 degrees of Cobb angle late onset idiopathic scoliosis, using rib-vertebra angles – aetiologic implications. *Stud Health Technol Inform* 2002, 91:20-24

3. Burwell RG, Aujla RK, Freeman BJ, Dangerfield PH, Cole AA, Kirby AS, Polak FJ, Pratt RK, Moulton A: The posterior skeletal thorax: rib-vertebral angle and axial vertebral rotation asymmetries in adolescent idiopathic scoliosis. *Stud Health Technol Inform* 2008, 140:263-268.

4. Grivas TB, Burwell RG, Purdue M, Webb JK, Moulton A: A segmental analysis of chest radiographs of children. Changes related to spinal level, age, sex, side and significance for lung growth and scoliosis. *J Anat* 1991, 178:21-38.

5. Grivas TB, Dangas S, Polyzois BD, Samelis P: The double rib contour sign (DRCS) in lateral spinal radiographs: aetiologic implications for scoliosis. *Stud Health Technol Inform* 2002, 88:38-43.

6. Grivas TB, Vasiliadis ES, Mihas C, Savvidou O: The effect of growth on the correlation between the spinal and rib cage deformity: implications on idiopathic scoliosis pathogenesis. *Scoliosis* 2007, 14(2):11.

7. Kirby AS, Burwell RG, Cole AA, Pratt RK, Webb JK, Moulton A: Evaluation of a new real-time ultrasound method for measuring segmental rotation of vertebrae and ribs in scoliosis. *Stud Health Technol Inform* 1999, 59:316-320.

8. Burwell RG, Aujla RK, Cole AA, Kirby AS, Pratt RK, Webb JK, Moulton A: Relation of rib deformity to vertebral deformity in the transverse plane at the curve apex in preoperative adolescent idiopathic scoliosis (AIS): an ultrasound, radiological and surface study of pathomechanisms. In *International Research Society of Spinal Deformities Symposium 2004*. Edited by Sawatzky BJ. University of British Columbia; 2004::302-306.

9. Grivas TB, Burwell RG and Dangerfield PH. Body mass index in relation to truncal asymmetry of healthy adolescents, a physiopathogenetic concept in common with idiopathic scoliosis: summary of an electronic focus group debate of the IBSE. Scoliosis 2013, 8:10 doi:10.1186/1748-7161-8-10

10. Foley G, Aubin CE, Parent S, Labelle H, d'Astous J, Johnston C, Sanders J. Physical Significance of the Rib Vertebra Angle Difference and Its 3-Dimensional Counterpart in Early-Onset Scoliosis. Spine Deformity 1 (2013) 259 - 265

11. Mehta MH: the rib –vertebra angle in the diagnosis between resolving and progressing infantile scoliosis. JBJS, 1972, 54B, 230-243.

12. Kristmundsdottir F, Burwell R G, James J I: The rib-vertebra angles on the convexity and concavity of the spinal curve in infantile idiopathic scoliosis. CORR 1985, (201):205-209.

13. Tolo VT, Gilespie R: the characteristics of juvenile idiopathic scoliosis and results of its treatment. J Bone Joint Surg, 1978, 60-B:181.

14. Wojcic A S, Webb J K, Burwell R G: An analysis of the effect of the Zielke Operation on the rib cage of S-shaped curves in idiopathic scoliosis. Spine, 1990, 15(2):81-86.

15. Wythers DJ, Burwell RG, Webb JK, and Wojcik AS: 1992 . The segmental surface and rib deformity of progressive adolescent idiopathic scoliosis: a preoperative segmental appraisal suggesting aetiological factors in the lumbar spine. In 6th International Symposium on Surface Topography and Spinal Deformity, Hotel Estoril Eden, 19- 20 September 1990. ed. A. Alberti, B. Drerup, and E. Hierholzer (eds.). Stuttgart: Gustav Fischer Verlag, pp. 119-135.

16. Thirlwall, A.S. 1991 The relation of King curve type to the surface and radiological deformity of preoperative scoliosis. Thesis: University of Nottingham

17. Wemyss-Holden SA, Jacobs KJ, Burwell RG, McNeill, Polak FJ, Webb JK, and Moulton A, 1991 The rib cage in adolescent idiopathic scoliosis (AIS): a segmental anal ysis of rib-vertebra angles (RVAs) revealing crossed RVA asymmetry with aetiological implications. Proceedings of a Joint Meeting of the British Association of Clinical Anatomists and the American Association of Clinical Anatomists, Norwich, 8-1 1 July 1991. Clin. Anat.

18. Wemyss-Holden SA, Burwell RG, Polak FJ, Jacobs KJ, McNeill AS, Webb JK, Moulton A, Wojcik AS. Segmental evaluation of the surface and radiological deformity after Cotrel-Dubousset (CD) instrumentation for King type II and III. adolescent idiopathic scoliosis (AIS): surgical and etiological implications. Acta Orthop Belg. 1992;58 Suppl 1:135-8.

19. Grivas TB, Burwell RG Purdue M, Webb JK, Moulton A: The rib cage deformity in idiopathic scoliosis – the funnel shaped upper chest I relation to specific rotation as a prognostic factor. An evaluation of chest shape in progressive scoliosis and control children during growth. Surface Topography and Spinal deformity VI, Alberty, Drerup, Hierholzer (ed). Gustav Fischer Verlag, Stuttgart, Jena, New York, 1992, pp.93-109.

20. Lykissas MG, Sharma V, Crawford AH. Assessment of Rib Hump Deformity Correction in Adolescent Idiopathic Scoliosis With or Without Costoplasty Using the Double Rib Contour Sign. J Spinal Disord Tech. 2012 Sep 28. [Epub ahead of print]

21. Grivas TB, Triantafyllopoulos G, Mazioti C (2013): Assessment of early rib hump deformity correction in adolescent idiopathic scoliosis treated with a dynamic derotation brace using the double rib contour sign. 10th International Conference on Conservative Management of Spinal Deformities, 8th SOSORT Annual Meeting, Chicago, Illinois, USA Wednesday, May 8 through Saturday, May 11, Meeting Proceedings Book, page 37.

22. Rigo E, Negrini S, Weiss HR, Grivas TB, Maruyama T, KotwickiT, SOSORT consensus paper on brace action: TLSO biomechanics of correction (investigating the rationale for force vector selection. Scoliosis 2006, 1:11 doi:10.1186/1748-7161-1-11

23. Emans JB, Kaelin A, Bancel P, Hall JE, Miller ME. The Boston bracing system for idiopathic scoliosis: follow-up results in 295 patients. Spine 1986;11:792–801.

24. Emans, Brace Treatment of Idiopathic Scoliosis: What makes sense in the New Millennium Spine: State of the Art Review, Vol. 14, No.1, January 2000.

25. Rowe, et al SRS Natural History Committee .A Meta-Analysis of the Efficacy of Non-Operative Treatment of AIS JBJS 79:664-74, 1997

26. Katz DE, Durrani AA. Factors that influence outcome in bracing large curves in patients with adolescent idiopathic scoliosis. Spine 2001;26:2354-2361.

27. Katz DE, Richards S, Browne RH, et al. A comparison between the Boston brace and the Charleston bending brace in adolescent idiopathic scoliosis. Spine 1997;22:1302-1312.

28. Katz «Experts debate role of Cobb angle in scoliosis bracing", Biomechanics Magazine May, 2006

29. Landauer F, Wimmer C, Behensky H: Estimating the final outcome of brace treatment for idiopathic thoracic scoliosis at 6-month follow-up. Pediatr Rehabil 2003, 6(3-4):201-7.

30. Clin J, Aubin CE, Sangole A, Labelle H, Parent S: Correlation between immediate in-brace correction and biomechanical effectiveness of brace treatment in adolescent idiopathic scoliosis. Spine 2010, 35(18):1706-13.

31. Weiss HR, Rigo M: Expert-driven Chκneau applications: description and in-brace corrections. Physiother Therory Pract 2011, 27(1):61-67.

32. Zaina F, Donzelli S, Lusini M, Negrini N Correlation between in-brace radiographic correction and short time brace results. Zaina et al. Scoliosis 2012, 7(Suppl 1):O27, http://www.scoliosisjournal.com/content/7/S1/O27

Notes

Case Presentations: What Specific Lenke Classification Deformities Have the Highest Success with Brace Treatment?

Nigel J. Price, MD
Children's Mercy Hospital
Kansas City, MO, USA

Panel discussion on Lenke classification and brace use

CURVE TYPE	PT	MT	TL/L	DESCRIPTION
1	NS	S*	NS	Main Thoracic (MT)
2	S	S*	NS	Double Thoracic (DT)
3	NS	S*	S	Double Major (DM)
4	S	S*	S*	Triple Major (TM)
5	NS	NS	S*	Thoracolumbar/Lumbar (TL/L)
6	NS	S	S*	Thoracolumbar/Lumbar-Main Thoracic (TL/L-MT)

S = Structural
NS = Non-Structural
*Major (largest curve)

COBB ANGLE	MODIFIER
<+10°	-
+10 - +40°	N
>+40°	+

The Lenke classification is primarily used for surgical planning and incorporates sagittal and lumbar modifiers. The panel will use the primary patterns to discuss several cases that are suitable for bracing.

The need for a universally accepted, three dimensional adolescent idiopathic scoliosis classification system amenable to non-operative treatment will be discussed.

Notes

Bracing in Adolescent Idiopathic Scoliosis: Results of the "BrAIST" Clinical trial

Stuart L. Weinstein, MD
Lori A. Dolan, RN, MS, PhD
Department of Orthopaedic Surgery
University of Iowa
Iowa City, Iowa, USA

Bracing: Standard Non Operative Treatment for skeletally immature patients since 1948

- *Expectation*: prevent progression until patient reaches skeletal maturity at which time risk of progression greatly diminishes
- Many studies : Inadequate evidence concerning the effect of bracing on curve progression, rate of surgery, burden of suffering associated with AIS.
- Literature and personal experience has lead some clinicians to conclude that bracing is valuable treatment for AIS; it has led others to conclude the opposite
- *THE STANDARD OF CARE*
- Bracing has never been subjected to a rigorous evaluation of either its efficacy or effectiveness

Primary aim of BrAIST:To compare the risk of curve progression to surgical threshold (≥ 50 degrees) in subjects randomized to a TLSO to those randomized to watchful waiting.

Secondary Aims:

- To compare health and functioning, quality of life, and self-image over time in the two treatment groups.
- To determine the relationship between bracing dose (wear time) and curve response.
- To develop a predictive model for curve progression based on patient characteristics at initial presentation, and after bracing.

First study to combine

- randomization
- objective brace dose monitoring
- standardized radiographic protocols and measurement
- comprehensive radiographic, clinical, and psychosocial testing
- diversity of participating sites
- ad hoc determination of effect size based on consumer input
- 50% reduction in surgical rates

Randomization Simulation

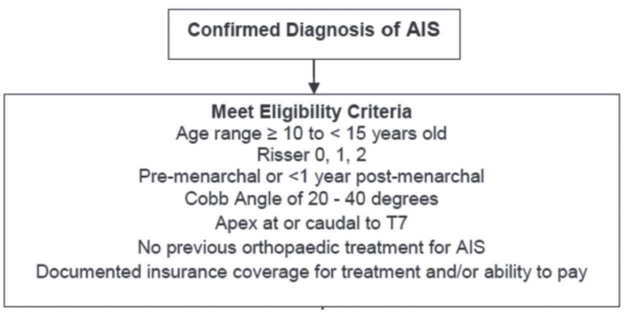
- Overall, 55% of the parents and 45% of the children agreed to participate in the hypothetical trial. 30% of parents and children jointly agreed to participate.

- *Based on these data, we estimate that 25% of all patient/ parent pairs approached during the actual study will agree to participate.*
- Using a 60% surgical rate under observation as the reference, the sufficiently important difference according to parents ranged from 0% (preference for bracing despite no reduction in risk) to 100% (preference for bracing only if the surgical rate could be reduced to 0).
- The median was 50% (reduction in surgical rates from 60 to 30 percent).

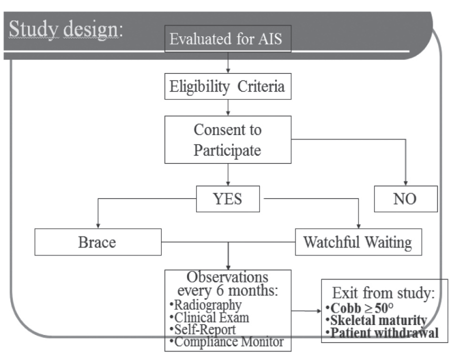
Study population:

- Require 384 subjects to detect a 50% decrease in progression to ≤ 50 degrees
  - * In NIH planning grant; 50% reduction was figure determined by parents and patients
    - ◊ *First clinical trial to let subjects determine what is desired outcome*

Eligibility Criteria



Study Design



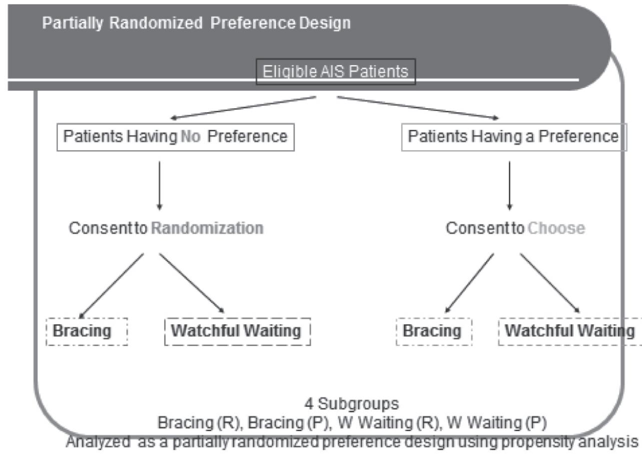
Site Listing and PI's

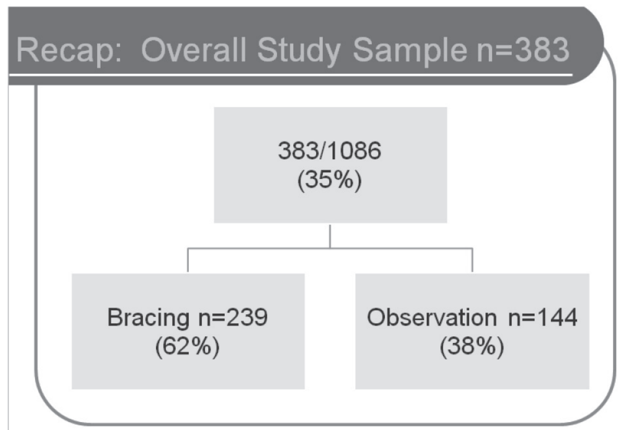
Evidence Based Informed Decision Model

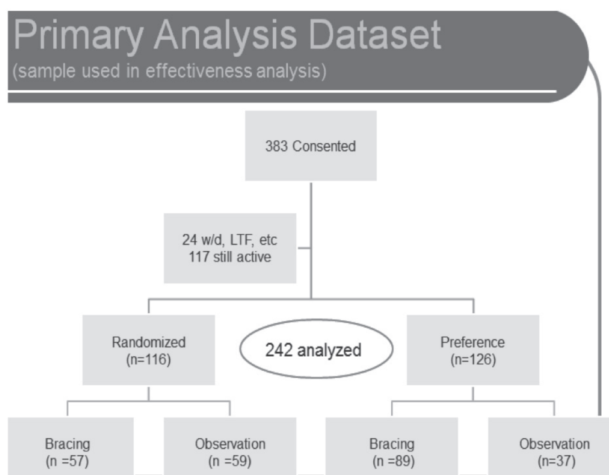
Protocol Modification January 2010

- After 1st three years enrollment goals not reached
  - * Sites had fewer eligible subjects
  - * % patient/parent agreeing to randomization less than predicted 25%
    - ◊ Strong preference for one

Partially randomized preference design:







RESULTS:

Research supported by NIAMS/ NIH 1RO1ARO52113 , CIHR, Shriners Hospitals

References:

Design of the Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST): Weinstein SL; Dolan LA; Wright JG; Dobbs M B; Accepted for Publication Spine

Bracing in Adolescent Idiopathic Scoliosis: Results of the BrAIST Clinical Trial: Weinstein SL; Dolan LA; Wright JG; Dobbs M B.(Submitted for Publication)

Notes

European Schools of Physical Therapy for Scoliosis

Mònica Villagrasa-Escudero, PT, MSc, DO
Elena Salvá Institut
Vía Augusta 185
08021 Barcelona, Spain
P: +34 932091330

INTRODUCTION

Idiopathic Scoliosis can be defined as a complex three-dimentional deformity of the spine and trunk, which appears in apparently healthy children, and can progress in relation to multiple factors during any rapid period of growth [1, 2]. This definition, which is a modification of Weinstein's one[3], combined with the pathogenesis and pathomechanic model described by Burwell et al [4] and Stokes et al [5], as well as, the natural history, guide us into the importance of how health professionals should focus Idiopathic Scoliosis Treatment.

History has taught us that a specialized multidisciplinary working team has more success than an isolated professional. In fact, most of the European schools which have published their results follow this concept. Last year, Tavernaro et al [6] published a case-control retrospective study comparing the results obtained by a specialized multidisciplinary team versus a non specialized one, in an adolescent population with braces, and concluded that the absence of a specialized team increases five times the risk of reduced compliance to bracing and more than 15 times the QoL problems and pain.

This information raises the value of such a team [1,2] which should be comprised of a physiatrist and /or a spinal surgeon specialized in the field, a physiotherapist and an orthotist with specialized knowledge, and the close collaboration of the patient and his/her family. This basic team includes also the collaboration of a psychologist in this field, when is required, and should follow evidence-based principles using the latest research available.

Thereby, we could offer a Scoliosis Rehabilitation model [7] that starts with a correct diagnosis and evaluation of the patient. This allows for the best treatment decision, quality control during treatment delivery, and verification of the results, depending on the characteristics of each patient. Whether the treatment is observation, education, scoliosis specific exercises, bracing or even surgery, all the tools used by this team should be to support the patient.

GOALS OF THE REHABILITATION

Because there is no way to prevent getting IS, the specialists agree with the necessity to prevent curve progression as the main priority of conservative treatment (brace or/and specific exercises) [2,7]. Other goals [2,7] are described, such as to improve cosmetics, general health and breathing function, help in coping with the deformity, to diminish functional limitation and to empower self care.

Physiotherapy can influence and modify these states through the postural component of the scoliosis, decribed by Duval-

Beaupere et al [8], the possibility to interrupt the vicious cycle in a mechanical way and changing the corporal schema of the patient.

Thus, general principles [1] in this field are:

1. Prevent asymmetric compressive forces related to passive posture
2. Reduce secondary muscle imbalance
3. Prevent lordosing reactive forces (passive posture, repeated forward bending movements)
4. Prevent asymmetric torsional forces from gait
5. Produce dynamic de-rotational forces involving breathing mechanics.

All these principles aim to stop the growth-skeletal vicious cycle, the neuronal vicious cycle and the degenerative vicious cycle inherent in IS to change it into a virtuous cycle.

INCLUSION CRITERIA

In 2012, the International Scientific Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) published a guideline about indications for conservative management of scoliosis [2], reviewing the literature published up until 2006 [7]. It is recommended that patients start the Scoliosis Physiotherapeutic Specific Exercises (SPSE) when the patient is an:

1. Immature adolescent (Risser 0) with a risk of progression > 20%
2. Adolescent between Risser 0-3 with a risk of progression ≥ 40%
3. Adolescent in Risser 4 from 20-25 °Cobb
4. Adolescent between Risser 4-5 from 25° Cobb
5. Adult with a Cobb greater than 30°
6. Adolescent or adult patient with chronic pain
7. Elderly patient with pain and/or decompensation

Moreover, some specialists are starting to recommend the SPSE before and after surgery to prepare the patient and get him/her a better condition. It has also been used with bracing (as a preparation for bracing and during brace weaning).

METHODS

For years there was a lack of consensus across professions and countries, as well as a low quality of evidence to support this treatment [9].

The principal problem in the beginning was the lack of knowledge within the Physical Therapy comunity and associated clinical specialists. In fact, in the scientific literature there is no distinction between SPSE and general physical therapy, strengthening activities (yoga, Taichi, Pilates, etc..), osteopathy, chiropractic, and so on.

So part of the work done by SOSORT was to form a consensus regarding the characteristics of the exercises used to treat IS, and to show the difference between SPSE and General Physical Therapy.

Negrini and collaborators [10, 11], have shown in a systematic review that SPSE reduces progression rate (mainly in early puberty) and /or improves the Cobb angles (at the end of growth), as well as reducing brace prescription; at the same time SPSE showed a better effectiveness than General Physical Therapy (electrostimulation, traction and postural training). The same authors [12, 13] concluded that research on SPSE has increased during the last five years, with its level of evidence rising from 2a to 1b. However, better quality research needs to be conducted to recommend it routinely in clinical practice.

The European Physical Therapy Schools involved in the scoliosis field have been developed to address the action mechanisms of scoliosis correction (AM) or to improve brace results (BR).

Italy	France	Germany /BCN	Poland
SEAS (AM, BR)	Lyon School (BR)	Schroth and derivatives (BSPTS) (AM)	DoboMed /FITS (AM)

But all of them, as described in the 2005 SOSORT consensus paper [14], agree on some standard features that contribute to success in the goals previously described:

1. 3D self-correction
2. Stabilization in correction
3. Training in ADL's
4. Patient and family education

PHYSICAL THERAPY SCHOOLS IN EUROPE

There are numerous scoliosis-specific exercise approaches to treat idiopathic scoliosis but we are going to look through the main Schools [9] that have published its work following a scoliosis specific criteria, explaining in a schematic way how they present the method, their principles of correction and their scientific results.

School and its Approach:

SEAS (Scientific Exercise Approach to Scoliosis)
-Improving the patient's awareness of their deformity -Autonomous 3D auto-correction -Active Stabilization through intensive symmetrical activation of all stabilizing muscles -Cognitive-behavioural approach to the patient and family to achieve maximum involvement and compliance -Exercises to stimulate a balance reaction -In-brace SPSE
Principles of correction
-Self-correction in 3D -Improve spinal stability

LYON School
-To complement the Lyon brace -Do not use an original technique specifically but rather a way of approaching and understanding scoliosis - 3 guide elements: patient's age, postural imbalance and Cobb angle -Awareness of trunk deformity (self-elongation) -Exercises avoiding extension in different positions: self-elongation + balance. -Recommendations for the sagittal plane of the spine, deep breathing, derotation of the transversal plane of the spine with pads, strengthening superficial and deep muscles - Sport recommendations
Principles of correction
When bracing (in-brace work): -breathing control -3D mobilization of the spine -Education -Sitting position check

Schroth Method and derivatives *BSPTS (Barcelona Scoliosis Physical Therapy School)*
-3D self-correction -Isometric muscle tension to stabilize the position -Repetition (proprioception) to correct body schema -Breathing mechaniques to re-shape the trunk
Principles of correction
-Self-correction in 3D eventually with external assistance during the training process (self-elongation from a 3D corrected and stable pelvis and trunk + increase of de-rotation by asymmetrical sagittal straightening + increase of deflexion by creating vectors in the frontal plane + breathing mechanics) -Isometric muscular tension to stabilize

DoboMed
-Conservative treatment -Respiratory functional impairment therapy (Klapps's position to increase kyphosis + Schroth to active asymmetrical breathing)
Principles of correction
-Warm-up with non-specific PT -Self-correction in 3D of the spine and ribcage in forward bending in different positions (closed kinematic chains fixing pelvic and shoulder girdle, upright under gravity) -breathing mechanics -isometric tension

FITS (Functional Individual Therapy of Scoliosis)
-Diagnosis and therapy of scoliosis -Complex, asymmetrical and individual therapy used at any age.
Principles of correction
-Release myofascial restrictions which limit a 3D corrective movement -Self-correction in 3D -Stabilization

Most of them include all the standard features. But, does 3D correction mean the same for all Schools? Are they really correcting in 3D? Is there any approach better than another one? We need further consensus and studies to demonstrate and compare the effect of each School of SPSE.

Scientific Results

However, all schools have reported papers where they, in a low level of evidence, obtain some improvements with the rehabilitation treatment. These results demonstrate the relevance of SPSE in the conservative treatment of IS. These papers show that SPSE can:

1. Decrease Cobb angle [15, 16, 17]
2. Reduce (slowly down) curve progression [18, 19]
3. Decrease brace prescription [17, 20]
4. Decrease lose of correction [21]
5. Increase breathing function related to structural flat back [22, 19]
6. Decrease back asymmetry [23, 24]
7. Improve the posture [15]
8. Improve muscular imbalance [25]
9. Improve general exercise efficiency [19]
10. Decrease stress [26]
11. Control curve progression in adult scoliosis [27, 28, 29]
12. Decrease pain in adult scoliosis[27, 28, 29]
13. Improve the posture in adult scoliosis [28, 29]

CONCLUSIONS

1. All schools treat AIS, with the goal of physiological realignment (3D), stabilizing in correction, training ADL's and educating.
2. All schools agree that education of PT professionals in AIS patho-mechanics and its strategy in each individual patient is important.
3. Practicing a specific technique is not enough. The PT needs knowledge and experience gained from participation in a specialized team.
4. There is a lack of consensus of all concepts used as a mechanism of action
5. There is a lack of consensus on the best protocol to use.
6. More research is needed on the effectiveness of all the mechanism of action concepts described in each technique.
7. There must be an increase in SPSE treatment evidence to demonstrate the effectiveness of treatment (quality of life in addition to the change in deformity) in each age group (infants, children, adolescents, young adults and adults, treated with or without brace or with surgery)

REFERENCES

[1] Rigo M, Grivas T. Rehabilitation schools for scoliosis' thematic series : describing the methods and results. *Scoliosis* 2010, 5:27. Available at: http://www.scoliosisjournal.com/content/5/1/27

[2] Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012, 7:3. Available at: http://www.scoliosisjournal.com/content/7/1/3

[2] Weinstein SL. Natural history. *Spine* 1999, 24 (24):2592,600 (15 December 1999)

[3] Burwell RG, Aujla RK, Grevitt MP, et al. Pathogenesis of adolescent idiopathic scoliosis in girls – a double neuro-osseous therory involving disharmony between two nervous systems, somatic and autonomic expressed in the spine and trunk: possible dependency con sympathetic nervous system and hormones with implications for medical therapy. *Scoliosis* 2009, 4:24 Available at: http://www.scoliosisjournal.com/content/4/1/24

[4] Stokes IA, Burwell RG, Dangerfield PH: Biomechanical growth modulation and progressive adolescent scoliosis- a test of the 'vicious cycle' pathogenetic hypothesis: Summary of an electronic focus group debate of the IBSE. *Scoliosis* 2006, 1:16 Available at: http://www.scoliosisjournal.com/content/1/1/16

[5] Tavernaro M, Pellegrini A, Tesadri F, et al. Team care tu cure adolescents with braces (avoiding low quality of life, pain and bad compliance): a case-control retrospective study. *Scoliosis* 2012, 7(1):17. Available at: http://www.scoliosisjournal.com/content/7/1/17

[7] Weiss HR, Negrini S, Rigo M, et al. Indications for conservative management of scoliosis (guidelines). *Scoliosis* 2006, 1:5. Available at: http://www.scoliosisjournal.com/content/1/1/5

[8] Duval-Beaupere G, Lespargot A, Grossiord A. Flexibility of scoliosis. What does it mean? Is this terminology appropiate? *Spine* 1985, 10(5):428-432

[9] Bettany-Saltikov J, et al. Physical therapy for adolescents with idiopathic scoliosis. In: Bettany-Saltikov J, editor. Physical Therapy Perspectives in the 21st Century – Challenges and Possibilities Rijeka: InTech; 2012. p. 3-40.

[10] Negrini S, Antonini G, Carabalona R, et al. Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review. *Pediatr Rehabil* 2003; 6 (3-4):227-35.

[11] Romano M, Minozzi S, et al. Exercises for Adlescent Idiopathic Scoliosis: A Cochrane Systematic Review. *Spine* (Phila Pa 1976) 2013, jun 15; 38(14): E883-E893

[12] Fusco C, Zaina F, Atanasio S, et al. Physical exercises in the treatment of adolescent idiopathic scoliosis: an updated systematic review. *Physiothera Theory Pract* 2011, Jan; 27(1):80-114

[13] Negrini S, Fusco C, Minozzi S, et al. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil Rehabil* 2008; 30(10):772-85

[14] Weiss HR, Negrini S, Hawes CH, Rigo M, Kotwichi T, Grivas TB, Maruyama T, members of the SOSORT: Physical exercises in the treatment of idiopathic scoliosis at risk of brace treatment – SOSORT consensus paper 2005. Scoliosis 2006, 1:6. Available at: http://www.scoliosisjournal.com/content/1/1/6

[15] Bialek M. Conservative treatment of idiopathic scoliosis according to FITS concept: presentation of the method and preliminary, short term radiological and clinical results based on SOSORT and SRS criteria. *Scoliosis* 2011, 6: 25. Available at: http://www.scoliosisjournal.com/content/6/1/25

[16] Weiss HR. Influence of an in-patient exercise program on scoliotic curve. *Ital J Orthop Traumatol* 1992, 18(3): 395-406.

[17] Negrini S, Negrini A, Romano M, et al . A controlled prospective study on the efficacy of SEAS.02 exercises in preventing progression and bracing in mild idiopathic scoliosis. *Stud Health Technol Inform* 2006, 123: 523-6.

[18] Negrini S, Fusco, Minozzi S, et al. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil Rehabil* 2008, 30(10): 772-85.

[19] Dobosiewicz K, Durmala J, Kotwichi T. Dobosiewicz method physiotherapy for idiopathic scoliosis. *Stud Health Technol Inform* 2008, 135:228-36.

[20] Negrini S, Zaina F, Romano M, et al. Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J Rehabil Med* 2008, 40 (6): 451-5

[21] Zaina F, Negrini S, Atanasio S, et al. Specific exercises performed in the period of brace weaning can avoid loss of correction in Adolescent Idiopathic Scoliosis (AIS) patients. *Scoliosis* 2009, 4:8. Available at: http://www.scoliosisjournal.com/content/4/1/8

[22] Weiss HR. The effect of an exercise program on vital capacity and rib mobility in patients with idiopathic scoliosis. *Spine* 1991, 16(1):88-93.

[23] Jelacic M, Villagrasa M, Pou E, et al. Barcelona Scoliosis Physical Therapy School – BSPTS – based on classical Schroth principles : short term effects on back asymmetry in idiopathic scoliosis. Scoliosis 2012, 7(Suppl 1):O57. Available at: http://www.scoliosisjournal.com/content/pdf/1748-7161-7-S1-O57.pdf

[24] Blicharska I, Brzek A, Durmala J. Short-term effect (ATR, Kasperczyk's Scale, chest's mobility) of using of physiotherapy method in the treatment of AIS – pilot study. *Stud Health Technol Inform* 2012, 176:387-92.

[25] Weiss HR. Imbalance of electromyographic activity and physical rehabilitation of patients with idiopathic scoliosis. *Eur Spine J* 1993, 1 (4):240-3.

[26] Weiss HR. Rehabilitation of adolescent patients with scoliosis—wht do we know? A review of the literature. *Pediatr Rehabil* 2003, 6(3-4):183-94.

[27] Negrini A, Parzini S, Negrini MG, et al. Adult scoliosis can be reduced through specific SEAS exercises: a case report. Scoliosis 2008 Dec 16; 3:20. Available at: http://www.scoliosisjournal.com/content/3/1/20

[28] Marti C, et al. Rehabilitation in adult scoliosis: selected case series illustrating options for complexities associated with adult scoliosis. Scoliosis 2010, 5(Suppl 1): O50. Available at: http://www.scoliosisjournal.com/content/5/S1/O50

[29] Villagrasa M, Pou E, Quera-Salvà G, Rigo M. Painful adult scoliosis with kyphosant evolution and sagittal anterior trunk imbalance treated with physical therapy techniques: three case reports. Scoliosis 2009, 4 (Suppl 2): O65. Available at: http://www.scoliosisjournal.com/content/4/S2/O65

Notes

Evidence Based Exercises for AIS-Cochrane Review

Michele Romano, PT
National Rehabilitation Director of ISICO (Italian Scientific Spine Institute)
Milan, Italy
Member of the Scientific Secretariat of the Italian Study Group on Scoliosis and Spinal Diseases (GSS)
SOSORT board member

michele.romano@isico.it
P: +39 3381873884

In the world, for now, the use of exercises for the treatment of AIS (Adolescent idiopathic scoliosis) is controversial. Whilst it is routinely used in several European countries, most centres in the UK, USA and Australia do not advocate its use. One of the reasons is, that many health professionals normally are not acquainted with the difference between SSE and general physiotherapy.

The difference between **generalised physiotherapy** (GPT) and **scoliosis-specific exercises** (SSE) is, that the first type of these motor treatments is more generic and usually consisting in low-impact stretching and strengthening activities like yoga, pilates, ecc. The second type of treatment activity consists in a protocol of exercises individually adapted and performed with the therapeutic aim to reduce the deformity and to stabilize the improvements in order to limit the need of corrective braces or the necessity of surgery.

Specifically, the SSE can be used in three main clinical conditions:

1. **Unique use of exercise** as the primary treatment of AIS for mild curves to try to avoid the use of a brace.
2. **In conjunction with braces**. In this case the aims are to reduce the side effects of wearing a brace (muscle weakness, rigidity, flat back), to improve the efficacy of internal brace pads and to avoid the loss of correction while weaning the brace.
3. **During adulthood if the scoliosis curves exceed certain thresholds**. In this case significant problems such as back pain, breathing dysfunction, contractures and progressive deformity may arise. These problems and the consequent disability can be treated by the help of exercises.

Why do we think it was important to start this review?
A scoping literature search identifyes three previous systematic reviews on the topic, none of which followed Cochrane methodology.

In one of these reviews the 19 papers considered included 1654 treated patients and 688 controls. The highest-quality study (RCT) compared two groups of 40 patients, showing an improvement of curvature in all treated patients after six months. We found three papers on Scoliosis Intensive Rehabilitation (Schroth), five on extrinsic autocorrection-based methods (Schroth, side-shift), four on intrinsic autocorrection-based approaches (Lyon and SEAS) and five with no autocorrection (three asymmetric, two symmetric exercises). Apart from one (no autocorrection, symmetric exercises, very low methodological quality), all studies confirmed the efficacy of exercises in reducing the progression rate (mainly in early puberty) and/or improving the Cobb angles (around the end of growth). Exercises were also shown to be effective in reducing brace prescription.

The evidence that was published in all these previous reviews needs a more rigorous methodology to answer our primary clinical question: "Is a scoliosis-specific exercise therapy effective for reducing the speed of the curve progression?"

In the primary analysis of the Cochrane review the type of studies considered was only **randomised control trials** (RCTs) and **quasi-randomised control trials** (QRCTs) since it was anticipated that very few RCTs would be found. The **non-randomised studies** (NRS) were included in the secondary analysis and was prospective with a control group.

In this review we included studies in which all diagnosed patients had AIS with at least a 10° Cobb angle, and were between the ages of 10 years and the end of bone growth. Studies in which patients presented any type of secondary scoliosis (congenital, neurological, metabolic, post-traumatic, etc) were excluded in according to the SRS criteria.

The experimental interventions in this review included all types of scoliosis-specific exercises and excluded sports, active recreational activities and generalised physiotherapy.

Comparison interventions included no treatment; different types of SSE`s, doses or schedules of exercises; other non-surgical treatments (e.g. braces, electrical stimulation, manual therapy). Comparisons included: exercises versus no treatment, exercises plus another treatment versus the other treatment, exercises versus other treatments, different exercises versus each other, different doses/schedules of exercises versus each other.

The primary outcome to measure the progression of scoliosis was:

- Cobb angle in degrees
- Angle of Trunk Rotation (ATR) in degrees
- Number of patients who have progressed by more than 5° Cobb
- Number of subjects for whom brace or surgery were prescribed

With the bibliographic search performed in the most important electronic databases (like MEDLINE, EMBASE, CINAHL, ecc.), we identified 6683 references. After excluding duplicates we identified 6457 potentially relevant references. 6437 were excluded on the basis of title and abstracts, leaving 20 studies which were acquired in full text for further evaluation. At the end we included only two studies: one randomised controlled trial and one prospective controlled cohort study.

The randomised trial included 80 adolescents, electro-stimulation on the lateral body surface, traction therapy, postural training and postural advice during normal activities were prescribed to both groups. The experimental group also performed SSE.

The prospective controlled cohort study of 74 adolescents prescribed the SEAS exercises (a type of SSE) , which consisted of an individual education session of scoliosis-specific SEAS exercises to be performed every three mounths. SSE were then performed at home two to three time per week. Controls performed usual physiotherapy, which included exercise protocols according to the preferences of their single therapist.

There was very low quality evidence from both the studies and that makes impossible to reach any firm conclusions.

Considered the quality of the available study on this topic, it's not possible to recommend the use of SSE for AIS, according to the Cochrane criteria for the evaluation of the trials. In the previous reviews conducted on the effectiveness of scoliosis-specific exercises, a considerable number of trials of lower methodological quality were included. Although the quality of the included studies was low, results were consistent in favour of the efficacy of SSE. Due to the fact that in the Cochrane review it is necessary to limit the search to only high quality studies, these results could not be confirmed.

REFERENCES

Negrini S, Antonini G, Carabalona R, Minozzi S. Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review. Pediatr Rehabil 2003 Jul-Dec;6(3-4):227-35.

Lenssinck ML, Frijlink AC, Berger MY, Bierman-Zeinstra SM, Verkerk K, Verhagen AP. Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: A systematic review of clinical trials. Phys Ther 2005;85(12):1329-39.

Negrini S, Fusco C, Minozzi S, Atanasio S, Zaina F, Romano M. Exercises reduce the progression rate of adolescent idiopathic scoliosis: Results of a comprehensive systematic review of the literature. Disabil Rehabil 2008;30(10):772-85.

Romano M, Carabalona S, Petrilli S, Sibilla P, Negrini S. Forces exerted during exercises by patients with adolescent idiopathic scoliosis wearing Fiberglass braces. Scoliosis 2006;21:1-12.

Zaina F, Negrini S, Atanasio S, Fusco C, Romano M, Negrini A. Specific exercises performed in the period of brace weaning can avoid loss of correction in Adolescent Idiopathic Scoliosis (AIS) patients. Scoliosis 2009 Apr 7;4(8).

Wan Li, Wang Guo-Xin, Bian Rong. Results of exercise therapy in treatment of essentially S-shaped scoliosis patients: Evaluations of Cobbs angle in the breast and lumbar segment. Chinese Journal of Clinical Rehabilitation 2005;9(34):82-4.

Negrini S, Negrini A, Romano M, Verzini N, Negrini Al, Parzini S. A controlled prospective studiY on the efficacy of SEAS.02 exercises in preventing progression and braces in mild idiopathic scoliosis. Stud Health Technol Inform 2006;123:523-6

Notes

North American Perspective on Exercises for Scoliosis

Eric C. Parent, PT, MSc, PhD, Certified Schroth Therapist
Associate-Professor, Department of Physical Therapy, University of Alberta
Adjunct-Professor, Department of Surgery, University of Alberta
Chair, SOSORT Scientific Committee
2-50 Corbett Hall
Edmonton, AB, T6G2G4, Canada
P: 1-780-492-4429
F: 1 780-492-4429

THEORETICAL INDICATIONS FOR PHYSICAL THERAPY FOR SCOLIOSIS

There are multiple physical and psychosocial impairments, some functional and participation limitations and quality of life deficits that, in theory, could be addressed by exercise-based physical therapy interventions.

There is also some evidence showing some benefits of exercises therapy offered alone, pre-brace, in-brace, pre- and immediately post-operatively. While most of the evidence has focussed on slowing/stopping curve progression, studies on varied general and scoliosis specific exercises have also shown improved pain, improved self-image, improve spinal flexibility, improve spinal strength, improved respiratory measurements and improved motor control to maintain good posture.

The majority of physical therapy curriculums in North America touch briefly on scoliosis detection and describe treatments with bracing and surgery. I am not aware of any Canadian or American programs where physical therapists receive training to use exercises specifically for the management of scoliosis. However, therapists graduating in North America receive training in the use of exercises to address the problems listed above for populations other than scoliosis and, in theory, are prepared to apply their knowledge to scoliosis.

Nevertheless, there is an important difference between **Physiotherapeutic** Scoliosis specific exercises and general physiotherapy exercises. **Scoliosis-specific exercises** consist of individually adapted exercises that are taught to the patients in a centre that is dedicated to scoliosis treatment.[13] Scoliosis-specific exercises include a series of specific physical movements performed with a therapeutic aim of reducing the deformity. Exercises work mechanically by changing the musculature and other soft tissues of the spine. It is also believed that specific exercises can alter the motor control of the spine by affecting neurological changes that interact with each other.[13] On the other hand, generalised physiotherapy is more generic, usually consisting of low-impact stretching and strengthening activities like Yoga, Pilates or Tai chi, but can include different exercise protocols according to the preferences of the therapist.[2]

CONTRAST BETWEEN SRS AND SOSORT RECOMMENDATIONS ON EXERCISES (SRS)

The SRS, which strongly influences practice in NA, did not propose formal treatment guidelines for scoliosis. SRS.org endorses only bracing and surgery and states the following on alternative treatments for AIS:

"Alternative treatments to prevent curve progression … such as **physical therapy… have not demonstrated any scientific value** in the treatment of scoliosis. However, these and other methods can be utilized if they provide some physical benefit to the patient such as core strengthening, symptom relief, etc. **These should not, however, be utilized to formally treat the curvature in hopes of improving the scoliosis."**

CONTRAST BETWEEN SRS AND SOSORT RECOMMENDATIONS ON EXERCISES (SOSORT)

In contrast, the SOSORT 2011 guidelines[6] propose a progression of interventions from least to most intensive to stop curve progression, address respiratory dysfunction, address pain and improve aesthetics. For each combination of baseline curve severity and Risser sign indication of skeletal maturity a range of approaches are proposed. Within the range of intervention, a more aggressive treatment selection depends on the presence of family history, skin and joint laxity, hypokyphosis, trunk inclination in excess of 10^{O} and documented growth spurt.

- **Scoliosis specific Exercise used alone** is among the range of intervention in SOSORT guidelines.
  - from 11° to 30° if Risser <3. and from 11° to 45° if Risser is 4 or 5.
- **Scoliosis specific exercises used alone or combined with bracing** is considered
  - For all combinations of curve severities and Risser signs.
  - Exercises are always recommended with rigid bracing in SOSORT guidelines.

QUALITY APPRAISAL OF EXERCISE STUDIES IN SYSTEMATIC REVIEWS

The differences in recommendations between societies lie in the quality appraisal of the evidence.

Romano's Cochrane review[14] found only 2 studies (1RCT and 1 prospective controlled cohort) meeting their design criteria and concluded: There is a**…"lack of high quality evidence** to recommend the use of Scoliosis Specific Exercises for AIS. … **better quality research needs to be conducted before the use of Scoliosis Specific Exercises can be recommended in clinical practice**. The **risk of bias** in the studies was **very high."**

Similarly, Negrini et al[7] systematically reviewed 19 studies with broader selection criteria and concluded: "Given the **heterogeneity** of the studies and their **weak methodologies**, we did not attempt a real meta-analysis. … solid data coming from RCTs and long-term observational studies will be required."

SOSORT recommends using exercises because the evidence from suboptimal quality studies was generally favorable. The SRS statement may therefore require the following revision: "Alternative treatments to prevent curve progression … such as physical therapy… have shown promising results in the treatment of scoliosis but studies of higher quality are needed before recommending their use."

ARE EXERCISES USED IN NORTH AMERICA? IF YES, HOW?

We reviewed charts from patients with AIS attending our regional scoliosis clinic and found[10] that:

- Only 15% were referred to physical therapy *(mostly for general conditioning or treat pain)*
- Referred patients were 16 yrs old on average and their largest Cobb Angle was an average of 26°

OBJECTIVES TREATMENTS AND OUTCOMES USED BY PT FOR SCOLIOSIS IN ALBERTA

Our survey of all 1599 registered physical therapists in Alberta obtained a response rate of only 12% suggesting possibly a low level of interest/ experience with scoliosis.[10] Among respondents only 69% had treated scoliosis in the past:

- Pain represented the most frequently cited **objective pursued** (80%) followed respectively by stopping curve progression (57%), improving function (53%) and body image (45%).
- Core stabilization exercises (76%) were the **most frequently used treatment technique** followed by postural advice (73%), mobilizations (55%), and yoga stretches (32%).
- Pain (75%) was the **most frequently tracked outcome** followed by subjective perception of posture improvements (73%), spinal range of motion (69%), and muscle strength (64%). (NOT Cobb).

Survey results suggest that Alberta physical therapists are referred a small proportion of all the patients with scoliosis. The sample consulting therapists may have a higher proportion of pain problems that the overall population of patients with scoliosis. This study should be replicated to clarify the generalizability.

To our knowledge only 4 certified Schroth therapists practice in Canada. In the USA and Canada, there has been an increasing number of therapists training in the scoliosis-specific European approaches but this still represents a small minority of all the physical therapist practicing in North America.

CAN REFERRALS AND LACK OF SCREENING EXPLAIN LOW USE OF EXERCISES IN NA?

Beausejour et al from Montréal reviewed charts from 636 patients referred for scoliosis evaluation to examine their characteristics at the initial visit to the scoliosis clinic in a community without school screening.[1]

- **42%** of the suspected cases of AIS had *no* significant deformity (Cobb <10° = inappropriate referrals).

- **32%** of subjects with confirmed AIS were "late referrals" with regards to brace/ex's indications.
  - Skeletally immature (Risser ≤3) + Cobb angle ≥30° or,
  - Cobb angle ≥ 40° (regardless of skeletal maturity).

They concluded that without screening there were fewer case with no scoliosis but much more (20% rather than <1%) of late referral compared to when school screening was offered. If this setting is representative of NA clinics, very few patients are examined that are candidates to receive exercise alone. There are still patients seen that could receive both exercises and bracing but this is very rarely prescribed in NA.

Similarly in the UK, over 80% of the survey respondent at intake in a scoliosis clinic had curves >30^0.[16]

CAN LACK OF AGREEMENT ON THE GOALS OF EXERCISE THERAPY LIMIT EXERCISE USE?

Negrini et al conducted a Delphi consensus study if SOSORT members to identify the goals which should be a priority when treating scoliosis conservatively. They also completed a bibliometric analysis and examined if the goals identified as priority were also the most published about in the literature.[8] There is a discrepancy between ranking of priorities in the consensus and the ranking of topic most published about.

- The top 12 priority goals when using conservative treatments for scoliosis were: Aesthetics, quality of life, psychological well-being, Disability, back pain, rib hump, breathing function, progression into adulthood, need for treatments in adulthood, knowledge and understanding of scoliosis, balance, Scoliosis Cobb Degree, from 1 to 12, respectively. Only the first 11 had over 70% agreement from members.
- The most published topics were: Scoliosis Cobb Degrees (17%) Back pain (8.7%), Kypho-lordosis degrees (8.3%), Self-control of posture (6.9%) and Sensory-motor integration (6.9%) and Perdriolle Degrees.

It is possible that the conservative treatment of scoliosis could be justified by its effect on outcomes others that the traditional radiographic outcomes typically used to monitor the effect of bracing or surgery.

CONSIDERATIONS FOR THE DESIGN OF AN EXERCISE TRIAL FOR SCOLIOSIS IN NA.

As we planned our exercise trial, to select which exercises we wanted to use, we reviewed the exercises used in the scoliosis-specific approaches that had shown some effect on curve progression. There are similarities between the most popular scoliosis-specific approaches.

Nearly all use **side-shift** of the torso towards the concavities (a=Schroth, b=Scoliologic, c=SEAS, d=Dobomed, e=Side-shift and Hitch, f=Lyon "somewhat") and **stabilisation**-type contractions of the torso muscles in a corrected posture (a-f). Further, many approaches involve **derotation** (a-d), and **kyphosing** exercises (b,c,d). In addition there are common use of **self-elongation** (a,b,f) and attempts at derotating the torso in conjunction with exercises involving **controlled breathing** (a,b,d).

Schroth was initially the most published and offered training in English justifying our choice but since, other approaches have also been more widely published and offer standardized training in English.

There is a wide range of dosage of exercises having been used in the literature[7] going from intensive inpatient therapy (e.g Schroth 6 days / wk, 5-6 hrs a day for 3-6 weeks[17]) to infrequent outpatient therapy combined with home programs (e.g. SEAS 1.5 hrs every 2-3 months until maturity with 5 minutes of exercise daily[9]).

NORTH AMERICAN EXERCISE STUDIES FOR SCOLIOSIS

Few exercise studies are published on scoliosis from North America none focused on scoliosis-specific ex's. Mooney et al[4;5] and McIntire et al[3] investigated the rotation strength of patients with scoliosis and the effect of rotation strength training using weight training machines isolating the rotation effort to target the spine muscles.

Patients have varying levels of side to side strength (0-50%) and EMG asymmetries and have weakness when rotating to the concave-left side from the midline of pre-rotated positions compared to healthy controls.[3]

A 4 month supervised training program using the machines (2X/week at 25-55% of lean body weight loads) led to improved strength by 28 to 50%.[3]

The program was followed by 4 months of unsupervised home rotation training (3-5X/week) with elastic bands in 15 subjects strength remained unchanged (gains maintained).[3]

At 8 months, 100% of patients did not progress but after a 2 year follow-up those with curve over 50° progressed and only 64% of patients with curve 20-40° avoided progression.[3]

Zapata et al recently completed their trial (**NCT01550497**) on the effect of core stabilization exercises in patients with AIS and LBP. Results should be available by September.

THE SCHROTH EXERCISE TRIAL FOR SCOLIOSIS (SETS) PILOT (ALBERTA,CANADA)

To address the need for rigorous trials on the effect of exercises and for evidence that the scoliosis-specific approaches widely used in Europe can work in North America we conducted the SETS pilot study.

The SETS Pilot is a RCT comparing the effect of a 6-month supervised outpatient Schroth exercise combined with a home program added to standard care to standard care alone in patients with AIS between 10 and 18 years of with curves from 10 to 45° and all skeletal maturity levels. At 6-months patients randomized to standard care were offered 6 months of exercises. To adjust to the North American context the following was done:

- Therapy limited to no more than 1 visit a week for a total of visit consistent with private insurance plan limits in Canada (up to 24 visits).

Exercise prescription is limited to 3-4 exercises using an algorithm[16] based on difficulty; progressing from passive to active corrections and lying to standing in unstable positions and from static to dynamic corrections. Prescription depends on Schroth curve type using a classification algorithm[15].

Trying to recruit candidate for exercise therapy alone did not work: only 12 eligible candidates over 17 months with none enrolling but 28% agreed to participate in this RCT using the criteria above.[12]

Pilot classic RCT results comparing 11 Schroth patients to 10 Standard care participants.

Attendance to weekly visits and compliance with home ex's over 6 months were adequate(>80%).[12]

The Cohen's d effect sizes favored the Schroth group for the Cobb angle (small =0.32), the Sorensen test (small= 0.28), all domains of the Spinal appearance questionnaire (negligible=0.01 to large =0.92 depending on domains). SRS-22 scores were all small or negligible favoring the standard care for function and pain and the Schroth group for self-image.[12]

The effect sizes for full-torso and back-only surface topography reflecting changes in posture showed favorable outcomes in all planes for Schroth exercises (0.00 to large =0.89).

Pilot cross-over results of 13 subjects completing Schroth exercises after spending 6months with standard care:

Equally, 2 patients dropped out during standard care and 2 during exercises showing feasibility.[11]

Effect sizes for this analysis using the subjects as their own controls were larger favoring Schroth.

For the SRS-22 effect sizes were: pain = 0.6, self-image = 0.92, total score 0.56, function 0.18. [11]

SAQ: 4 domains deemed large effects, 3 deemed small effects and one negligible. [11]

The effect size favoring Schroth for Cobb was negligible but showed generally no progression: 0.13. [11]

The effect size for Sorensen back muscle endurance favored Schroth but was minimal: 0.18. [11]

Posture analyses are underway.

For both the classic RCT and the cross-over comparison, patients receiving exercises felt moderately improved and those receiving standard care felt slight deterioration globally.[11;12]

CONCLUSION

Scoliosis-specific physiotherapeutic exercises did not become part of conservative treatment recommendations in North America while they have in Europe. In Europe, scoliosis specific exercises are used alone for small immature curves and in combination with bracing in larger curve at risk of progression.

Evidence is mounting with promising results on the effects of exercises for scoliosis using prescription adapted for North America's context. Ongoing trials will provide high quality evidence in coming years.

1. Beausejour M, Roy-Beaudry M, Goulet L et al. Patient characteristics at the initial visit to a scoliosis clinic: a cross-sectional study in a community without school screening. *Spine (Phila Pa 1976.)* 2007;32:1349-54.
2. Fusco C, Zaina F, Atanasio S et al. Physical exercises in the treatment of adolescent idiopathic scoliosis: an updated systematic review. *Physiother.Theory.Pract.* 2011;27:80-114.
3. McIntire KL, Asher MA, Burton DC et al. Treatment of adolescent idiopathic scoliosis with quantified trunk rotational strength training: a pilot study. *J.Spinal.Disord. Tech.* 2008;21:349-58.
4. Mooney V, Brigham A. The role of measured resistance exercises in adolescent scoliosis. *Orthopedics* 2003;26:167-71.
5. Mooney V, Gulick J, Pozos R. A preliminary report on the effect of measured strength training in adolescent idiopathic scoliosis. *J.Spinal Disord.* 2000;13:102-7.
6. Negrini S, Aulisa AG, Aulisa L et al. 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012;7:3.
7. Negrini S, Fusco C, Minozzi S et al. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil. Rehabil.* 2008;30:772-85.
8. Negrini S, Grivas TB, Kotwicki T et al. Why do we treat adolescent idiopathic scoliosis? What we want to obtain and to avoid for our patients. SOSORT 2005 Consensus paper. *Scoliosis.* 2006;1:4.
9. Negrini S, Zaina F, Romano M et al. Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J.Rehabil.Med.* 2008;40:451-5.
10. Parent EC, Buyks D, Clough J et al. Therapy objectives, treatments modalities and outcomes used by physiotherapists for adolescent idiopathic scoliosis in Alberta, Canada. SOSORT 9th International Conference on Conservative Management of Spinal Deformities , 38-9. 5-9-2012. Milan, Italy. 5-9-2012.
11. Parent EC, Schreiber S, Hedden D et al. The Effect of a Six-Month Schroth Exercise Program: A pilot study using subjects as their own controls. SOSORT 2013 . 5-11-2013. Chicago, Il, SOSORT. 11-5-2013.

12. Parent EC, Schreiber S, Hedden D et al. Patients with Adolescent Idiopathic Scoliosis and Scroth Curve Type 3c who will respond to Schroth Exercises. Lunchtime Symposia presentation in the Breaking News: Initial Presentations from Recent SRS Grant Winners session. 47th Scoliosis Research Society Chicago. 5-9-2012.
13. Romano M, Fusco C, Minozzi S et al. Physical exercises and adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Stud.Health Technol. Inform.* 2008;140:331.
14. Romano M, Minozzi S, Bettany-Saltikov J et al. Exercises for adolescent idiopathic scoliosis. *Cochrane.Database.Syst. Rev.* 2012;8:CD007837.
15. Schreiber S, Parent E, Watkins E et al. An algorithm for determining scoliosis curve type according to Schroth. *Scoliosis.* 2012;7 Suppl 1:O53.
16. Watkins E, Bosnjak S, Parent E. Algorithms to prescribe Schroth exercises for each of four Schroth curve types. *Scoliosis.* 2012;7 Suppl 1:22.
17. Weiss HR, Weiss G. Curvature progression in patients treated with scoliosis in-patient rehabilitation--a sex and age matched controlled study. *Stud.Health Technol.Inform.* 2002;91:352-6.
16. Betany-Saltikov J., Wellburn S., Watson P. et al. An evaluation of the information needs of people with adolescent idiopathic scoliosis at the point of first diagnosis at the hospital clinic: Final Report. School of Health & Social Care, Teesside University, 2011, P46.

Notes

The Role of Education in the Non-Operative Treatment of Spinal Deformities

Josette Bettany-Saltikov, PhD, MSc, MCSP, PGC[LTHE]
Senior Lecturer in Research Methods and Chartered Physiotherapist
Teesside University
Middlesborough, Tees Valley, United Kingdom
Institute of Health and Social Care
Parkside West Offices, Middlesbrough TS1 3BA
P: 44-1642-342981
j.b.saltikov@tees.ac.uk
http://www.tees.ac.uk/sections/research/health_socialcare/staff_profile_details.cfm?staffprofileid=U0011765
http://tees.academia.edu/josetteBettanySaltikov
http://www.researchgate.net/profile/josette_bettany-saltikov/

What do we mean by Education? Is it the same as data? Information? Or knowledge?

Infogineering model- Here is an excerpt from Dr David Griffiths (2013) website. He describes this very clearly as follows. **Quote:**

"using the **Infogineering defintions** of the three words (data, information, knowledge) "They've been so muddled up over the past few years that the various definitions don't match up. So, let me explain how Infogineering views them all":

Knowledge "Firstly, let's look at Knowledge. **Knowledge is what we know**. Think of this as the map of the World we build inside our brains. Like a physical map, it helps us know *where* things are – but it contains more than that. It also contains our beliefs and expectations. "If I do this, I will probably get that." Crucially, the brain links all these things together into a giant network of ideas, memories, predictions, beliefs, etc. It is from this "map" that we base our decisions, **not the real world itself**. Our brains constantly update this map from the signals coming through our eyes, ears, nose, mouth and skin. You **can't currently store knowledge** in anything other than a brain, because a brain connects it all together. Everything is inter-connected in the brain. Computers are not artificial brains. They don't **understand** what they are processing, and can't make **independent decisions** based upon what you tell them. There are two sources that the brain uses to build this knowledge - information and data."

Data- "Data is/are the **facts of the World**. For example, take yourself. You may be 5ft tall, have brown hair and blue eyes. All of this is "data". You have brown hair whether this is written down somewhere or not. In many ways, data can be thought of as a **description of the World**. We can perceive this data with our senses, and then the brain can process this. Human beings have used data as long as we've existed to form knowledge of the world. Until we started using information, all we could use was data directly. If you wanted to know how tall I was, you would have to come and look at me. Our knowledge was limited by our direct experiences".

Information "Information allows us to expand our knowledge beyond the range of our senses. We can **capture data in information**, then move it about so that other people can access it at different times.Here is a simple analogy for you. If I take a picture of you, **the photograph is information. But what you look like is data.**I can move the photo of you around , send it to other people via e-mail etc. However, I'm not actually moving *you* around – or *what you look like*. I'm simply allowing other people who can't directly see you from where they are to know what you look like. If I lose or destroy the photo, this doesn't change how you look. So, in the case of the lost tax records, the CDs were information. **The information was lost**, but **the data wasn't**. Mrs Jones still lives at 14 Whitewater road, and she was still born on 15th August 1971(end quote)". **http://www.differencebetween.net/language/difference-between-knowledge-and-education/ #ixzz2YS2vkHIm.**

Other model is the Formal versus informal model

1. Education is a formal process whereas knowledge is informally acquired through experiences.
2. Education needs institutions for learning while knowledge has no boundaries.
3. Education has a defined set of rules and curriculum whereas knowledge has no such limitations.
4. Education is learned from books and grows with age while knowledge is free to be acquired from surroundings and has no age limit.

The Importance of Education

"**Education is the most powerful weapon which you can use to change the world.**" Nelson Mandela

"The importance of education cannot be measured. Its value is unmatchable. Without it stems ignorance, frustration, anger, and demise. With it, solutions, alternatives, and new ideas can be brought forth to further improve the evolution of mankind. Without education, improvement and progress would never be achieved. There is no greater purpose than using the mind to everyone's best advantage and that means to put all our minds together to improve the outcomes in the conservative management of spinal deformities for the benefit of patients and service users**."**

SOSORTS Mission Statement on Education- Objectives:

The objectives of this committee are clearly defined in the SOSORT statute. The statute of SOSORT declares in article 4:'- The general aim of the society is: **First, to foster the best conservative management – early detection, prevention, care, education and information - of scoliosis and other spinal deformities.'** Later, in point 4.5 it specifies that one of the aims of the society is: '**To promote specific education and training among professionals creating a body of specialists in this particular area, able to care efficiently for scoliosis patients.'**

Teaching activities undertaken by SOSORT in last 10 years

Informal teaching courses on the different physiotherapy and brace approaches used in different EU countries started in 2006. The more formal Instructional courses were only started 3 years ago in Barcelona. Following feedback from the instructional course it became clear that many participants also wanted instructional courses in research methodology to help them conduct their own research studies in their own practices. So the very first Research Instructional Course was held this May in Chicago for which we had very positive feedback.

Historical Perspective of the conservative management of Spinal deformities

An excerpt from my own PhD thesis demonstrates that spinal deformities have been known for thousands of years. Reference to them is found as far back as prehistoric times, in the ancient Vedic mythological literature, where the spine was the symbolic equivalent of Mount Meru, the traditional centre of the universe (Roaf, 1980).Mention of spinal deformities is also found in the Edward Smith Papyrus, which relates the illnesses and injuries of those who built the great pyramids in the 25th century B.C. and they can also be traced back to the bible. In the 21st chapter of Leviticus, crooked backed individuals were forbidden from offering sacrifices to the Lord (Roaf. R, 1980).The term "Scoliosis" is however usually attributed to Hippocrates. He recommended "succussion" upon a ladder, for cases in which the hump was close to the neck. The patient was bound to a padded ladder, hoisted while still on the ladder to a high tower and extended by manual traction at either end. Treatment in classical greek times was a mixture of gymnastics, faith healing, spa treatments, and applied psychology .In the roman era, the knowledge of mechanics was applied to the treatment of deformities using principles which are still relevant today. Galen in the 2nd century A.D. advocated direct pressure and traction as well as lever pressure and traction. The Asclepion at Pergamun where Galen originally worked, was a combination spa and rehabilitation centre. The arabic cultures also contributed to the medical tradition and it is believed that Mohammed al Gafequi of Cordoba (1265) advocated spinal fusion using fish bones It was not however till the sixteenth century that Ambrose Pare described the deformity that we recognize today. Shortly after, Hildanus (1646) illustrated a scoliotic spine, but it was only in the 18th century that a fuller understanding of spinal deformities was achieved. Two persons of note are Andry (Roaf,1980) who wrote the textbook of orthopaedics and further defined and postulated on the pathogenesis of scoliosis; and Robert Chesher of Leicestershire (1751) who treated spinal deformities by first relaxing contracted muscles by fomentations, friction and machinery and then applying splints. This principle still bears resemblance to some aspects of the range of non operative treatments currently inuse today; relax or stretch muscles to decrease spinal curvature and then hold the spine in this corrected position by means of isometric exercise, plaster jackets or braces (excerpt from Bettany J`s PhD thesis, 1993)

Problems with conducting RCTs in this area

How far have we improved in the treatment of scoliosis with non surgical approaches? What evidence do we have?- As we have heard earlier the two Cochrane reviews on bracing and exercise presented earier have shown low to very low quality evidence for both Scoliosis-specific exercises as well as braces. I believe there are a number of reasons for these results. **One issue may be "Are we asking the right questions"** Perhaps it would be more appropriate to ask more nuanced research questions of the style *"what works, for whom, in what circumstances, and in what respect* (Pawson,2006). So with regards to bracing or PT treatment we should perhaps not just be asking `do braces work? BUT `what types of braces (or PT approach) work under what systems (private vs public) conditions (team treatment vs solo (or silo), where (countries), when (compliance?) how (treatment approach) and for whom (adolescents vs adults). Many of the problems found with the two Cochrane reviews in this area were also related to the poor methodological quality of the included papers. If I remember correctly and speaking as a co-author we had approximately 1000 abstracts for the Bracing review from which only 2 papers in each review met the stringent inclusion criteria. This strongly suggests that further **Advanced level of Education in research methodology for clinicians and researchers in this field is urgently needed.**

There is also the issue of the current medical model of the Hierarchy of Evidence where only RCTs are considered to reflect high quality studies. RCTs are very difficult to conduct in this field - In EU countries where non operative treatment is routine it is unethical NOT to treat patients as part of the control arm of an RCT. So this means any high quality research can only ever be conducted in countries where non operative treatment is not practiced routinely but then the level of PT or brace treatment may be poor as a consequence due to inexperience and lack of team management of patients. There is also the question 'is a poorly conducted RCT better then a very well conducted clinical control trial? We can find very good examples of studies with poor research methodology in the literature but one of significant note is the one included in the Cochrane review by Romano et al (2012).Technically this is considered a Level 1a study but the research methodology in Wan et al`s study (2005) was very poor so can the results actually be applied to clinical practice? Further issues such as patients not agreeing to be in the control arm of an RCT also make them very difficult to conduct. Therefore the complexity and high numbers of variables does not make for a linear relationship. We may perhaps need to be thinking in terms of other theories and methodologies such as the complexity theory (discussed further below) and narrative qualitative research.

Education and Knowledge generation in the area of conservative management is still problematic and publications are few (Brace) to very few (PT) as compared to surgery

Figures provided by PubMed (September 2012) demonstrate the radically different numbers of research articles published within the last five years for surgery, bracing and scoliosis-specific exercises. 2,146 articles were retrieved on scoliosis surgery; the equivalent figure for bracing was 202 articles, and for scoliosis exercises it was 89. The very low number of papers published and the overall low quality of research evidence supporting the effectiveness of SSEs and/or bracing are of great concern. **It is a crucial to address the paucity of researchers and of research undertaken and disseminated in non-surgical management and to increase the knowledge and education in this area.** As the field of non-surgical management researchers and clinicians is small, and their backgrounds and interests tend to be disparate, this reduces the coherence of approaches taken to research and practice. **High quality coherent research conducted by well-qualified clinicians and researchers in the conservative management of spinal deformity is urgently needed.**

This then begs the question – what can we do to address these concerns?

- Currently we hold 1/2 days courses/ lectures/ pre and post annual conference (which SOSORT has done)
- Courses conducted by professional groups mainly for their own members- leads to lack of education and understanding by other professional groups.
- Do we need to improve **Interprofessional education and interprofessional collaborative practice or team work?** Dr. Patty Solomon, PhD: from the School of Rehabilitation Science, McMaster University, Head of Inter-professional education states that this **"occurs when two or more professions learn with, from, and about each other to improve collaboration and the quality of care**." This definition emphasizes an inclusive view of the term "professional" **and includes all learning in academic and clinical settings, before and after qualification.** It is also important to state what inter-professional collaboration is not**. It does not mean that we are being cross-trained to perform others' roles. Nor is it necessarily about developing a team consensus or about thinking alike. It is about taking responsibility for your own area of practice and coordinating it effectively, and with others, as you make decisions about patient management"** (Solomon pg 51).
- A paper published last year by Tavernaro and Negrini et al (2012)- Recently the SOSORT Brace Treatment Management Guidelines (SBTMG) have highlighted the perceived importance of having collaborative multidisciplinary professional teams manage braced patients. They concluded that a **collaborative team approach rather than a solo approach appears to be important for brace treatment, influencing pain, QoL and compliance** (and so, presumably, final results) and suggest that future studies on the topic are advisable.

So what are the barriers to collaboration and changing the culture?

Dr. Patty Solomon, Associate Dean of Health Sciences and Director, School of Rehabilitation Science, Macmasters University states, quote:

"Much has been written about barriers to collaboration such as Rivalry and Turf Wars and the complexity theory and science. We need to see our roles much more broadly, as part of multiple systems and sectors. We need to be mindful **of the need to educate others beyond those in the health care arena about our potential role and scope of practice—there are many living with chronic illness and disability who would benefit from physiotherapy but are not getting referred, or do not know how to access us, or simply are unaware that there could be benefits to physiotherapy care**. If we are to embrace the broader determinants of health, **we need to have strategies to advocate for our patients much more broadly and to collaborate with those whom we may not traditionally have worked with**" (Solomon 2009, pg 51)**. With regards to Rivalry and Turf Wars** "We live in a competitive society. To enter our profession, students have to compete with many other applicants for coveted positions. When we think of the historical roots of the professions, and the structural components of the health care system, I believe we can never eliminate the differences in education, gender, and hierarchy that lead to differences in power and status. Competition is part of our professional and social culture, and to my mind it is naıve to think that we will ever be without it. But this means that we need to learn the skills to allow us to work in situations where power and status prevail. We must learn how to listen, yet advocate for our role. **We must promote what is best for the patient and for quality of care,** not necessarily what is best for ourselves or for the profession at that point in time**. Collaboration isn't about "winning,"** and we may have to choose our battles from time to time. **Collaboration is about coordinating our unique skill set with others as we work together to find the best solutions"** (Solomon 2009, pg 51) end of quote.

The complexity theory and complexity Science (not a new theory but relatively new in the Health sciences)

Solomon states, quote

"This arose from the failure of traditional science to explain some types of complex phenomena. For many years the scientific way was based on a reductionist cause-and-effect model. In the late twentieth century, scientists recognized that this linear way of viewing the world had limitations in trying to explain complex living systems such as the brain, or complex phenomena such as the interactions of people and groups in a community or in a health care setting.(Pelsk and Greenough 2001) These things are complex, in that they are made up of multiple interconnected elements. They are systems that have the ability to internalize information, to learn, and to modify behaviour or evolve as they adapt to changes in the environment. In complexity science, the concept of linear cause and effect goes out the window. The notion that we can understand what happened by reducing things to their components and examining their parts is considered to be old science and an old view of reality.18 Exact outcomes are uncertain, because the interactions among multiple components in a system can produce unpredictable behaviour. When we apply complexity science to trying to institute change in an organization in today's fast-evolving and rapidly changing environment—in this instance, trying to change how we relate to one another in a collaborative way—different strategies are required. **Another rule of complexity science is that small changes can lead to large effects, because of the interdependency and unpredictability of organizations** (Wilson and Holt 2001). When we consider this, suddenly we realize that **the day-to-day and moment-to-moment interactions and conversations that we have with others are meaningful and can lead to change. Communication patterns and interactions among team members can change only if the persisting patterns of communication and interaction among members of the team also change**. So your individual decision to reflect on your actions and communicate with colleagues in a different way can lead to change. **This means that change can occur through many small interactions or strategies. To me this is very empowering, and it is a rule we can apply to patient care, health organizations, or changing collaborative practice." (Solomon 2009, pg 51) end of quote.**

My Vision for Educational Training in non-surgical management of spinal deformities

The goal of a proposed **future conservative educational network** is to provide an integrated post-graduate training package for PTs, Orthotists, osteopaths, chiropractors as well as Physiatrists GPs as well as Surgeons and other health care professionals to address the following concerns:

1. Current differences in practice & treatment pathways

The non-surgical management of idiopathic scoliosis differs considerably across across the world, with some countries having highly specialised dedicated centres and others specialising almost entirely in surgical interventions with minimal non-surgical treatment care (such as the UK). In consequence, some patients are diagnosed early, when the scoliosis curve is small, and receive high level non-surgical management with the aim of reducing the need for surgery later, whilst patients in other EU countries receive either low quality non-surgical care or none at all. **My vision is to develop a post-graduate training course that aims to add coherence of conservative management within different countries by developing high quality evidence and optimising the development of expertise in this increasingly significant field.**

2. Developing an International specialist non-surgical and High Quality Educational training framework

(Ideally at Doctoral levels but can be taken in steps from

certificate through to Doctorate):

Currently, there is no specialised training for physiotherapists or other health care professionals involved in the daily rehabilitation of patients with scoliosis. Furthermore to my knowledge no biomedical or clinical research training programmes exist for postgraduate non-surgical spinal researchers anywhere in Europe. There is demand for expertise within this field and recent years have seen workers from diverse backgrounds come together to work in this area. **There is a clear need for the non-surgical management of idiopathic scoliosis to be recognised as a distinct and important specialism**. With greater recognition of the complications related to spinal surgery, the climate is such that non-medical specialists working from a wide range of disciplines including physiotherapists, exercise scientists, spinal orthotists, spinal nurses, certified osteopaths, biomedical engineers and IT technicians working in the non-surgical management of spinal deformities have the strong potential to become well-defined and recognised specialists within professional practices in the future. The goal of **Developing an International Non surgical specialist Educational training framework** will be to establish a network (**comprised of all health care professions in this area including surgeons**) to **drive this forward by offering a cohesive package of training with strong links between academic, therapeutic and commercial sectors.**

3. The need for increased research & clinical capacity in the non-surgical management of spinal deformities:

The non-surgical management of idiopathic scoliosis is an expanding field of research; however, the overwhelming majority of the published work is focused on surgery, with substantially less based on research into non-surgical techniques. This is partly due to the lack of suitably qualified professional healthcare researchers, and the unavailability of specialised post-graduate non surgical international training programmes in scoliosis and other spinal deformities, despite the potential to significantly increase the impact of non-surgical management on patient care. There are very few specialist researchers in the field of scoliosis-specific exercises and to an even lesser extent in the field of spinal bracing. Researchers and clinicians in this field have been drawn from such diverse backgrounds as physiatrists (medical doctors specializing in physical rehabilitation) or the non- medical specialists described above. In addition, the majority of scoliosis societies within the EU and the rest of the world were founded by surgeons and, consequently, tend to be very surgically focused, with the only society concentrating purely on non-surgical management, research and clinical methods for treating scoliosis, SOSORT (Society of Scoliosis Orthopaedic and Rehabilitation Treatment) founded as recently as 2004. **The aim of developing an International Non-Surgical Spinal Deformity Educational Training Framework** will be to build **research and clinical capacity through networking and the exposure of clinicians and researchers to different sectors, state-of-the art research facilities, clinical settings, techniques and approaches, as well as the development of their own PhD or Professional Doctorate programmes**.

References

Bettany J (1993) **Investigation into the Topographical, kinesiological and Psychological factors in the surgical management of Adolescent Idiopathic Scoliosis**. PhD Thesis, King`s College, University Of London, UK

Cooper H, Braye S, Geyer R (2004). **Complexity and interprofessional education.** Learn Health Soc Care,3, 179–89.

Griffiths D (2013) **Infogeneering: surviving and thriving in an age of information overload**, accessed at http://www.infogineering.net/data-information-knowledge.htm

Pawson R (2006), **Evidence-based policy. A realist perspective.** London.: Sage.

Plesk P, Greenhalgh T. **The challenge of complexity in health care.** Brit Med J. 2001:323:625–8.

Wilson T, Holt T (2001**). Complexity and clinical care**. Brit Med 2001; 323:685–8.

Roaf.R (1980). “ Historical Survey” in Spinal Deformities. 2nd ed. Pitman Medical. 1-5.

Solomon P (2009) **Enid Graham Memorial Lecture- Inter-professional Collaboration: Passing Fad or Way of the Future?** Physiotherapy Canada, Volume 62, Number 1

Tavernaro M, Pellegrini A,Tessadri F, Zaina F, Zonta1 A, and Negrini S (2012)**Team care to cure adolescents with braces (avoiding low quality of life, pain and bad compliance): a case–control retrospective study**. 2011 SOSORT Award winner Scoliosis 2012, 7:17 accessed at http://www.scoliosisjournal.com/content/7/1/17

Notes

Psychological Support During Non-Operative Treatment

Fabio Zaina, MD
ISICO (Italian Scientific Spine Institute)
Milan, Italy
fabio.Zaina@isico.it

Introduction

Psychological impact of the deformity

Spinal deformities have a psychological impact due mainly to abnormalities in body appearance (1). While adolescent patients affected by scoliosis have less social interaction , adults experience more difficulties in creating a family, and have fewer and less satisfying sexual relationships than others (2).

Psychological impact of the treatment

The treatment can often have a negative psychological impact on the patient (3, 4). While scoliosis specific excercises do not usually have negative psychological effects, bracing can have a detrimental impact (5). This impact depends mainly on two aspects: the limitations that the brace creates in movement, and appearance issues with difficulty hiding it under clothes (6). It is well known that the physical appearance of the brace makes adolescent patients unhappy, and makes them feel more self conscious (6). Some studies show that the treatment process can be more stressful than the stress associated with having the deformity (5, 7-9). Of the many braces studied, the Milwaukee brace showed to have the most delitarious psychological impact (6, 10, 11). So, when choosing the treatment, the physician should be aware of these potential psychological issues when prescribing the exercises and braces, and in some cases, may have to compromise between efficacy and psychological impact (12). Moreover, the importance of the physician's own attitude cannot be overstated (13). It can make a major difference in reducing stress and helping the patient accept the prescription and be compliant with the treatment process (13). For this reason, the SOSORT guidelines suggest that "In order to achieve the best possible outcome, conservative treatment should be conducted by an experienced therapeutic team including a physician, a physiotherapist, an orthotist and possibly a psychologist" (12).

Psychological support during an exercise treatment

While using an exercise-only treatment,patients do not experience many psychological issues (5). The most common problem initially relates to anxiety of parents, about whether their son or daughter will eventually need to wear a brace. They are also concerned about how long it will take to see some results, and whether or not this process will be effective in preventing curve progression and preventing surgery (14).

Psychological support during a brace treatment

Many variables can impact the physical and psychological success of brace treatment (8). Having emotional support during this challenging time can make the difference between reaching a good result or causing psychological damage (15-18). The attitude of young patients towards bracing depends mainly on their comfort level and limitation to activites of daily living, as well as the environment they live in and the team approach. When the brace is properly built, allowing free movement of the arms, when the family helps the patient accept the treatment, when the doctor has a positive attitude and explains the necessity of the treatment, when the orthotist makes an effective and comfortably fitting brace, and when the physiotherapist supports the patient, then there is the highest probability of starting and managing a good and effective treatment (5, 13).

Different questionnaires have been created and validated to monitor the impact of the brace treatment (19-21).

The role of the team

A collaborative effort of the treating team, including the doctor, the physiotherapist, the orthotist and possibly a psychologist should work to minimize the psychological impact of the treatment (13).

Why a team? Because each team member has different knowledge and skills needed to manage the patient over the years of treatment. Furthermore, if different professionals give similar and shared messages and instructions to the patient, then the patient is more likely to have better compliance with less psychological problems. On the other hand, professionals not coordinating their efforts in a team approach would undermine the treatment process, potentially damaging the patient and negatively effecting treatment outcomes (13).

SOSORT has published Guidelines to help the team in managing the brace treatment (13).

The role of the doctor

The doctor is the team leader, who selects the appropriate brace design, directs its everyday use, and decides when to reduce or increase hours worn (13). The doctor should spend enough time to explain to the patient the pros and cons of the treatment, the possible alternative scenerios, and make the patient and the family committed to the treament (13). The doctor should strongly believe in the brace!

At the moment of brace fitting, the doctor checks the brace (13). During this visit, many questions usually arise about everyday life with the brace, limitations of activities due to the brace or the pathology. The doctor should spend all the necessary time needed to answer such questions.

The role of the orthotist

The orthotist constructs, fits, and maintains the brace (13). At the first appointment, he or she plays a crucial role in helping the patient during the plaster casting or CAD-CAM scanning. He must emotionally support the patient during the critical phase of brace fitting, when patients tend to be very stressed.

A good orthotist should be skilled not only in "modeling plastic and steel", but in interacting with adolescent patients.

The orthotist must be committed to the kind of brace prescribed. In case he has any doubt about the chosen brace, he should speak with the doctor and reach a shared prescription without alarming the patient or criticizing the doctor's work. When the appropriate prescription is finalized, he must follow it (13).

The role of the physiotherapist

The physiotherapist is also very relevant to the team. The PT is the expert most frequently in contact with the patients, thus having the most potential for positive influence in helping the patient with acceptance of the brace, and treatment protocol (13). They also have the opportunity to recognize possible psychological problems connected to the brace (22). It has been demonstrated that, given the same MD and the same CPO, the therapist can influence the treatment so that with a positive approach to bracing, children can have a better outcome, less pain, more compliance, less psychological distress, and better radiographic and clinical results (22). The PT is an external judge of the brace, and should strongly support this treatment, being careful not to raise doubts in the minds of patients and their families, which may undermine the patient and the best possible results (22).

Special tools for the Psychological Support

Blogs and forums

There are some blogs and forums on the internet dedicated to scoliosis and its treatment.

ISICO has a blog in which patients can ask questions to doctors and physiotherapists, as well as a forum for patient to patient discussion (23).

The National scoliosis foundation has a forum for patients without any medical intervention (24).

Video

Showing a patient playing a sport while wearing a brace is an excellent way to show how managable wearing your brace can be. It is much more effective than the doctor's words!(25)

Patient associations

The National scoliosis foundation was created by patients in the USA (26). It provides information about scoliosis and its treatment, and gives patients the chance to share experiences and support each other. Other associations exist like Curvy Girls, founded to provide a peer to peer and parent to parent support system (27).

Conclusions

The commitment of the team is crucial to help the patient during the treatment.

The psychological impact depends on the brace as well as the environment, and can be significantly influenced by the treating team in order to make it a more positive and pleasant experience, while also addressing the needs of the patient.

The team (MD, PT, CPO) should spend enough time to counsel the patient and the family.

The team should follow the SOSORT Guidelines for the management of the brace treatment.

References

1. Tones M, Moss N, Polly DJ. A review of quality of life and psychosocial issues in scoliosis. Spine (Phila Pa 1976) 2006;15(31):3027-38.
2. Weinstein SL, Dolan LA, Spratt KF, Peterson KK, Spoonamore MJ, Ponseti IV. Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study. Jama 2003;289(5):559-67.
3. Glowacki M, Misterska E, Adamczyk K, Latuszewska J. Prospective Assessment of Scoliosis-Related Anxiety and Impression of Trunk Deformity in Female Adolescents Under Brace Treatment. J Dev Phys Disabil 2013;25(2):203-220.
4. Glowacki M, Misterska E, Adamczyk K, Latuszewska J. Changes in Scoliosis Patient and Parental Assessment of Mental Health in the Course of Cheneau Brace Treatment Based on the Strengths and Difficulties Questionnaire. J Dev Phys Disabil 2013;25(3):325-342.
5. Negrini S, Donzelli S, Dulio M, Zaina F. Is the SRS-22 able to detect Quality of Life (QoL) changes during conservative treatments ? Studies in health technology and informatics 2012;01(176):433-6.
6. Fayssoux R, Cho R, Herman M. A history of bracing for idiopathic scoliosis in North America. Clin Orthop Relat Res 2010;468(3):654-64.
7. Kotwicki T, Kinel E, Stryla W, Szulc A. Estimation of the stress related to conservative scoliosis therapy: an analysis based on BSSQ questionnaires. Scoliosis 2007;2:1.
8. Kinel E, Kotwicki T, Podolska A, Bialek M, Stryla W. Quality of life and stress level in adolescents with idiopathic scoliosis subjected to conservative treatment. Stud Health Technol Inform 2012;176:419-22.
9. Misterska E, Glowacki M, Latuszewska J, Adamczyk K. Perception of stress level, trunk appearance, body function and mental health in females with adolescent idiopathic scoliosis treated conservatively: a longitudinal analysis. Qual Life Res 2012;Nov 28. [Epub ahead of print].
10. Maruyama T TK, Kitagawa T. Milwaukee brace today. Disabil Rehabil Assist Technol 2008;3(3):136-8.
11. Apter A, Morein G, Munitz H, Tyano S, Maoz B, Wijsenbeek H. The psychosocial sequelae of the Milwaukee brace in adolescent girls. Clin Orthop Relat Res 1978;131:156-9.
12. Negrini S, Aulisa AG, Aulisa L, Circo AB, de Mauroy JC, Durmala J, et al. 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis 2012;7(1):3.

13. Negrini S, Grivas TB, Kotwicki T, Rigo M, Zaina F. Guidelines on "Standards of management of idiopathic scoliosis with corrective braces in everyday clinics and in clinical research": SOSORT Consensus 2008. Scoliosis 2009;4:2.

14. Negrini S, Fusco C, Minozzi S, Atanasio S, Zaina F, Romano M. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. Disabil Rehabil 2008;30(10):772-85.

15. Lindeman M, Behm K. Cognitive strategies and self-esteem as predictors of brace-wear noncompliance in patients with idiopathic scoliosis and kyphosis. J Pediatr Orthop 1999;19(4):493-499.

16. Birbaumer N, Flor H, Cevey B, Dworkin B, Miller N. Behavioral treatment of scoliosis and kyphosis. J Psychosom Res 1994;38(6):623-628.

17. MacLean WJ, Green N, Pierre C, Ray D. Stress and coping with scoliosis: psychological effects on adolescents and their families. J Pediatr Orthop 1989 1989;9(3):257-261.

18. Rivett L, Rothberg A, Stewart A, Berkowitz R. The relationship between quality of life and compliance to a brace protocol in adolescents with idiopathic scoliosis: a comparative study. BMC Musculoskelet Disord 2009;10:5.

19. Asher M, Min Lai S, Burton D, Manna B. The reliability and concurrent validity of the scoliosis research society-22 patient questionnaire for idiopathic scoliosis. Spine (Phila Pa 1976) 2003;28(1):63-9.

20. Vasiliadis E, TB G, Gkoltsiou K. Development and preliminary validation of Brace Questionnaire (BrQ): a new instrument for measuring quality of life of brace treated scoliotics. Scoliosis 2006;20(1):7.

21. Vasiliadis E, Grivas TB, Savvidou O, Triantafyllopoulos G. The influence of brace on quality of life of adolescents with idiopathic scoliosis. Stud Health Technol Inform 2006;123:352-6.

22. Tavernaro M, Pellegrini A, Tessadri F, Zaina F, Zonta A, Negrini S. Team care to cure adolescents with braces (avoiding low quality of life, pain and bad compliance): a case-control retrospective study. 2011 SOSORT Award winner. Scoliosis 2012;7(1):17.

23. http://www.scoliosi.org/.

24. http://www.scoliosis.org/forum.php.

25. http://www.isico.it/clinica/scoliosi/247-scoliosi-e-sport.html.

26. http://www.scoliosis.org.

27. http://www.curvygirlsscoliosis.com/.

Notes

Non Operative Treatment: The Patient's Perspective

Joseph P. O'Brien, MBA
President, CEO & Patient - National Scoliosis Foundation (NSF)
President - Society On Scoliosis Orthopedic & Rehabilitative Treatment (SOSORT)
5 Cabot Place
Stoughton, MA 02072 USA
P: 781-341-6333
F: 781-826-5671

INTRODUCTION

Patient care in medicine is a central focus of the various oaths taken by physicians throughout the world as they complete their education and embark on their career. For example;

The Hippocratic Oath [1] reads;

I will prescribe regimens for the good of my patients according to my ability and my judgment and never do harm to anyone.

The Declaration of Geneva [2] states;

- I solemnly pledge to consecrate my life to the service of humanity; the health of my patient will be my first consideration.

These oaths and declarations call the medical professional to maintain their priority on the patient, and provide safe and appropriate treatments within the boundaries of their knowledge, skills, and resources. These responsibilities and commitments to professional ethics are masterfully reflected within the stated mission of the Scoliosis Research Society (SRS); [3]

- To Foster Optimal Care for All Patients with Spinal Deformities.

These oaths are also embodied in the statutes of the Society on Scoliosis Orthopedic & Rehabilitative Treatment (SOSORT); [4]

To Foster the Best Conservative Management of Scoliosis and Other Spinal Deformities; including Early Detection, Prevention, Patient Care, Education & Information and Encourage Multidisciplinary Team Work -including Scientists, Medical and Healthcare Professionals, Patients and their Families.

One of the many physicians who prescribed to the Hippocratic Oath was Nicholas Andry from Lyon. In 1741, he published his book titled, "ORTHOPAEDIA", which was derived from the Greek word, Orthos, which signifies straight, free from deformity; and Pais, a child. [5]

Andry explained the title and the purpose of his book as follows, "Out of these two words I have compounded that of Orthopaedia, to express in one Term the Design I Propose, which is to teach the different Methods of prevention and correction of Deformities of Children."

Nicholas Andry taught both parents, and professionals, to *conservatively manage* spinal deformities through various *non operative methods* in the belief that this provided *optimal care* in his time and space.

The key questions addressed in this presentation are;

- Why is non operative care important to the scoliosis patient and family?
- What is Optimal Care today? What is Best Conservative Management? Are they mutually exclusive?
- How are scoliosis patients' needs best addressed?

References:

[1] Orr, R. D., N. Pang, E. D. Pellegrino, and M. Siegler. 1997. "Use of the Hippocratic Oath: A Review of Twentieth-Century Practice and a Content Analysis of Oaths Administered in Medical Schools in the U.S. and Canada in 1993." *The Journal of Clinical Ethics* 8 (Winter): 377-388.

[2] World Medical Association : "Declaration of Geneva" www.wma.net/en/30publications/10policies/g1/index.html

[3] Kamal N Ibrahim, MD, FRCS(C), MA "2012-2013 President's Message": ww.srs.org/presidential_message.html

[4] International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) "Statutes" June 2011 www.sosort.org

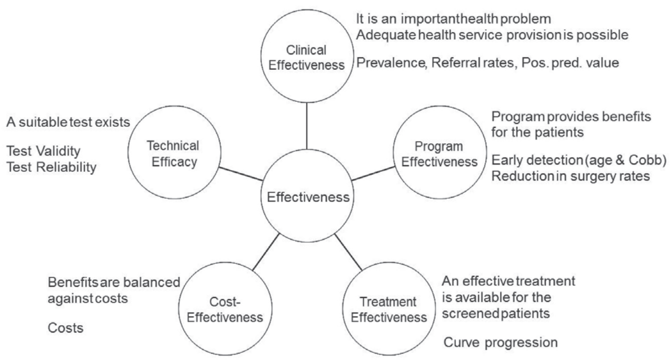
[5] Andry, Nicolas (1743). *Orthopaedia : or, the art of correcting and preventing deformities in children: by such means, as may easily be put in practice by parents themselves, and all such as are employed in educating children. Translated from the French of M. Andry*. London: Printed for A. Millar

Notes

SRS School Screening Task Force Report

Hubert Labelle, MD
B. Stephens Richards, MD; Marinus De Kleuver, MD, PhD; Theodoros B. Grivas, MD, PhD; Keith D. K. Luk, MCh (Orth); Hee Kit Wong, MD; John Thometz, MD; Marie Beauséjour, PhD; Isabelle Turgeon, BSc; Daniel Y. T. Fong, PhD
Hospital Sainte-Justine Ortho Department
Montreal, Canada

The conceptual framework used to analyze scoliosis screening, focusing on *five* main dimensions:



After a review of the current literature, the SRS International Task Force on scoliosis screening, supported by the SRS Board of Directors, makes the following statements regarding scoliosis screening:

1. Scoliosis screening is recommended as valuable in the following domains: technical efficacy, clinical, program and treatment effectiveness. The existing literature does not provide sufficient evidence to make a statement concerning cost effectiveness.
2. Scoliosis screening should aim at identifying suspected cases of scoliosis that will be referred for further evaluation to rule out or confirm a clinically significant scoliosis (>10 degrees of Cobb angle). Females should be screened twice, at age 10 and 12, and boys once, at age 13 or 14[3].
3. The scoliometer is currently the best tool available for scoliosis screening.
4. There is moderate evidence to recommend referral with scoliometer values between 5° and 7°, or greater.
5. There is moderate evidence that the use of scoliosis screening allows for detection and referral of patients with AIS at an earlier stage of the clinical course.
6. There is evidence that scoliosis patients detected by screening are less likely to need surgery than those patients who did not have screening.
7. Prevalence, Referral rates and Positive Predictive Value of current screening tools in screened children reach adequate values (expert opinion), so as to consider scoliosis a condition suitable for screening.
8. There is some evidence to support the value of bracing for the treatment of AIS. More level I and II studies are needed.
9. Continued work to determine minimum standards and targets (referral rates and Positive Predictive Value) is needed for screening programs.
10. Further investigation on cost-effectiveness of screening programs should be obtained by studying comparable settings: one with scoliosis screening, and one without.

Reference:

Labelle H, Richards SB, De Kleuver M, Grivas T, Luk KDK, Wong HK, Thometz J, Beauséjour M, Turgeon I, BSc; Fong DYT, Screening for Adolescent Idiopathic Scoliosis: an Information Statement by the Scoliosis Research Society International Task Force, In Review, The Lancet.

Notes

Non-Operative Treatment of Adult Deformity

Jean-Claude de Mauroy, MD
Spine Orthopedic Department
Clinique du Parc
155 boulevard des Belges
69006 Lyon, France
P: 00 33 4 72448728
demauroy@aol.com

Background

After 65 years 10% of the population has scoliosis. (1)

For ASA (Adolescent Scoliosis in Adult), only lumbar and thoracolumbar scoliosis are evolving in rotary dislocation. (2)

DDS (Degenerative De novo Scoliosis), are also lumbar or thoraco-lumbar patterns. (3)

Non operative treatment with bracing is only discussed for these patients.

Clinical situation

- Pain
  In literature, this is the only indication of bracing
- Imbalance
  Loss of lordosis, pelvic retroversion, thoracolumbar kyphosis, frontal imbalance. These parameters can be measured radiographically. (4)
- Curve progression
  Progression of adult scoliosis is difficult to predict (5) and sometimes refers to a chaotic situation. (6)
- Quality of life
  Abnormal physical appearance, diminished self-esteem, physical limitations are always present. (7)

Lack of evidence for non-operative treatment

- Chiropractic care, physiotherapy, bracing, casting are level IV evidence (8), but surgery is also much discussed. (9-10)
- We must also consider the cost of treatment. (11)

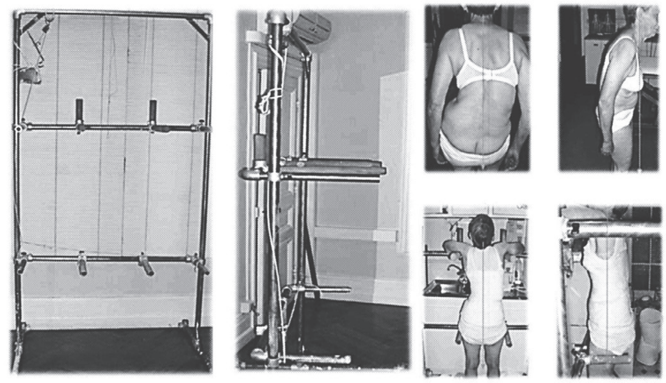
What about bracing?

Bracing is not usual for scoliosis in adults. The only indication is pain.

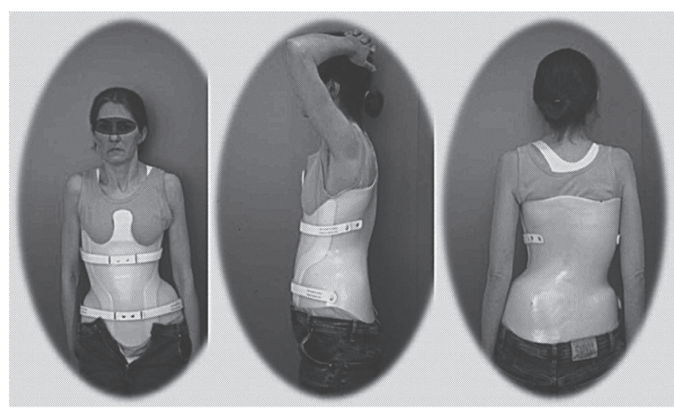
- Soft bracing
  It is an adaptation of the soft brace used during adolescence. It is associated with an appropriate physiotherapy. The advantage is to avoid muscle atrophy. 60 % improvement of pain status (12)
- Rigid bracing
  Using a sagittal realignment brace, we have only short time results (13)
- Casting
  The Lyon Management combines plaster cast, specific adult bracing and physiotherapy (14)

The Lyon Management

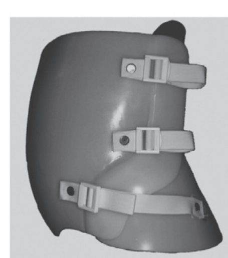
- Plaster cast: 3 weeks
  * A Specific frame with axillary support and under-trochanteric stabilization is necessary to correct imbalance. Sometimes, we can add a cervical suspension.

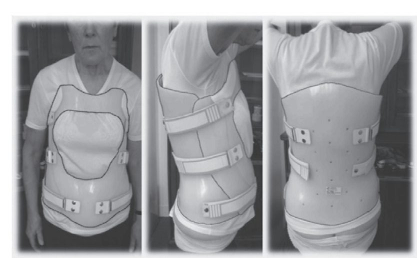


  * Unlike the adolescent scoliotic corrections, we realize only an axial discharge modeling waist as a hourglass and a correction of imbalances.
  * The objective is to adjust the paraspinal muscle tension (creep)
  * The patient continues a normal life in plaster cast to test the efficacy of non-operative treatment
- The polietilene bivalve overlap brace



- 4 to 6 hours per day for a minimum of six months.
- Rigid custom made brace with manual oriented molding in the specific frame or Cad-Cam molding.
- The anterior height is variable depending on the extent of kyphosis: from costochondral to sternoclavicular.



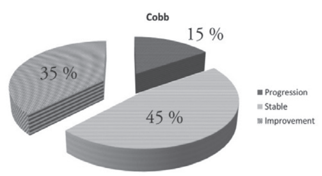


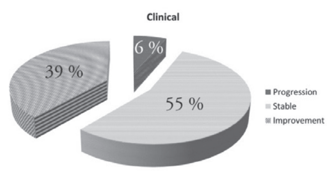
- The 3 mm high density polyethylene can be replaced by a low density for older patients.
- Physiotherapy
    * In plaster cast: respiratory control, under-pelvis mobilization, motion and muscle strengthening
    * After: same exercises without brace, the objective is to strengthen the muscles to prevent brace addiction.

Results of the Lyon management

Retrospective study of 33 patients (30 women and 3 men) treated from 1998 to 2005 with a follow up of more than 5 years after the beginning of the treatment. The average age at the beginning of treatment is 60 years. The average Cobb angle was 37,03°.

- The Cobb angle increased significantly (more than 5°) in 5 patients, 15 are stable, 12 have improved more than 5°.
- Clinical parameters were stable in 17 patients, improved in 12 patients and worsened in 2 patients.





- At the end of the follow-up, 19 patients (60%) are still wearing the brace with an average of five hours per day (One patient night and day).

Discussion

- Due to the complication rates (40-60%) associated with this surgery and the marginal bone quality endemic to this population the indication of a non-operative treatment can be discussed.
- Indications of treatment are for primitive or degenerative adult scoliosis:
    * With severe painful lumbar discal instability.
    * With progressive clinical and radiological imbalance
- The aim of the treatment is a disk protection and a three-dimensional re-equilibration of the spine.
- Muscular atrophy is a common criticism for rigid braces. In fact, the non-operative orthopedic treatment does not suffer approximation. Its teamwork incorporates a specific physical therapy, the continuation of normal activity and the practice of regular physical activity.
- The aesthetic improvement of the rib hump and asymmetrical waist is logical; the orthopedic brace is the best way to remodel a trunk. The cosmetic result continues five years after starting the treatment.
- For non-surgical candidate, the Lyon management is effective in stopping the pejorative evolution of adult scoliosis.
- Casting can immediately verify the effectiveness of non-operative treatment and avoid a delay in surgical management.
- The conservative orthopedic treatment does not have to be an alternative to the surgery. The indications may be progressive: observation, physiotherapy, medicine, non-operative orthopedic Treatment, surgery.
- The good surgical indications concern the lumbar decompensating scoliosis not relieved by the plaster cast, or relieved by the plaster cast, but insufficiently by the brace and especially if there is a spinal stenosis. It can also be used to complete surgery if remaining instability.

Conclusion

There is currently a lack of consensus on the most efficacious non-operative treatments for adult deformity.

When the Conservative orthopaedic treatment is carried out rigorously, it can stabilize the evolution of scoliosis in 85% of cases (28/33). Even if the Cobb angle worsens, patients may feel less pain.

The plaster cast in addition to its ligament lengthening action and unloading the disc is also a test of tolerability and efficacy to avoid an unnecessary rigid brace.

The indication for surgery is facilitated.

Initially reserved for the most severe cases and no-surgical candidates, this protocol deserves to be more widely used for adult scoliosis.

The increase in life expectancy and the incidence of scoliosis with age justifies a more frequent use of these non-operative techniques.

References

1 Schwab FJ, Smith V.A, Biserni M, Gamez L, Farcy JP, Pagala M: Adult scoliosis: a quantitative radiographic and clinical analysis. Spine 2002; 27(4):387-392.

2 Duval-Beaupere G, Dubousset J: Rotatory dislocation of the spine. Common mechanical process for progressive kypho-scoliosis generating neurological disorders. About 16 cases. Rev Chir Orthop, 1972; 58: 323-334.

3 Jimbo S, Kobayashi T, Aono K, Atsuta Y, Matsuno T: Epidemiology of degenerative lumbar scoliosis: a community-based cohort study. Spine (Phila Pa 1976). 2012 Sep 15;37(20):1763-70.

4 Hong JY, Suh SW, Modi HN, Hur CY, Yang JH, Song HR: Correlation of Pelvic Orientation With Adult Scoliosis. J Spinal Disord Tech 2010 Jan 11.

5 Weinstein SL, Zavala DC, Ponseti IV: Long term follow-up and prognosis in untreated patients. J. Bone Jt. Surg,1981; 63-A: 702-712

6 de Mauroy JC: Idiopathic scoliosis and chaos. Stud Health Technol Inform. 2008;135:53-7.

7 O'Brien J: Living with scoliosis: an adult perspective. Scoliosis 2010;5:O43

Akbarnia BA, Ogilvie J.W, Hammerberg KW: Debate: degenerative scoliosis: to operate or not to operate. Spine 2006;31:S195-201.

8 Everett CR, Patel RK: A systematic literature review of nonsurgical treatment in adult scoliosis. Spine. 2007;32:S130-134.

9 Ogilvie JW: Adult scoliosis: evaluation and nonsurgical treatment. Instr Course Lect. 1992;41:251-255.

10 Kluba T, Dikmenli G, Dietz K, Giehl JP, Niemeyer T: Comparison of surgical and conservative treatment for degenerative lumbar scoliosis. Archiv Orthop Trauma Surg; 2009, 129(1):1-5.

11 Glassman SD, Carreon LY, Shaffrey CI, Polly DW, Ondra SL, Berven SH, Bridwell KH: The costs and benefits of nonoperative management for adult scoliosis. Spine (Phila Pa 1976). 2010 Mar 1;35(5):578-82.

12 Marcotte L, Coillard C, Dion P, Rivard CH: The treatment of adult scoliosis utilizing the SpineCor Dynamic Corrective Brace. Scoliosis. 2009; 4(Suppl 2): O52.

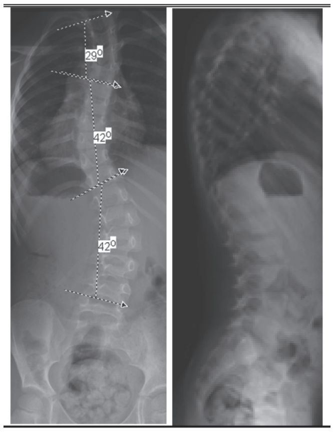
13 Weiss HR, Dallmayer R, Stephan C: First results of pain treatment in scoliosis patients using a sagittal realignment brace. Stud Health Technol Inform. 2006;123:582-5.

14 de Mauroy J.C, Vallèse P, Lalain JJ: Lyon conservative treatment of adult scoliosis. Minerva Ortopedica e Traumatologica 2011 October;62(5):385-96

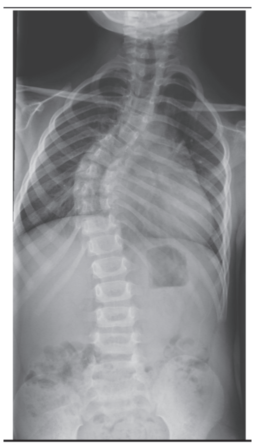
Notes

Panel Discussion: Early Onset Scoliosis: Evidence Based Non-Operative Treatment vs. Operative Methods

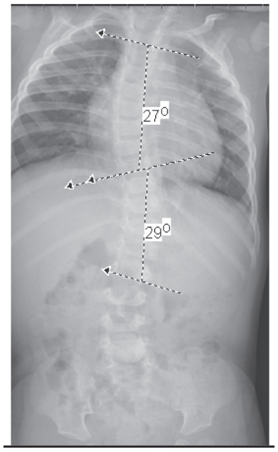
James O. Sanders, MD
University of Rochester
Rochester, NY, USA



4yo asymptomatic girl, double 42 degree curves with a normal MRI



4+4 y.o. girl with Idiopathic Scoliosis Prior treatment with an orthosis since age 2. Curve now 57 degrees and progressing despite bracing



15mo Male with Ehlers-Danlos

Notes

Sagittal Plane Deformity Corrective Techniques

Course Co- Chairs:

Daniel H. Chopin, MD & Frank J. Schwab, MD

Faculty:

Sigured H. Berven, MD; John R. Dimar, II, MD; John C. France, MD; Henry F. H. Halm, MD; Pierre Guigui, MD; Charles E. Johnston, MD; Tyler Koski, MD; Stephen J. Lewis, MD, MSc, FRCS(C); Steven Mardjetko, MD, FAAP; Peter O. Newton, MD; Alberto Ponte, MD; Yong Qiu, MD; Daniel J. Sucato, MD, MS; Michael G. Vitale, MD, MPH

This course is supported, in part, by grants from

Sagittal Plane Deformity Corrective Techniques

Co-Chairs: Daniel H. Chopin, MD & Frank J. Schwab, MD

1:30 – 1:45 pm **Overview of Sagittal Plane Corrective Techniques: Basic Theory, Operative Techniques and Effective Surgical Application**
John R. Dimar, II, MD

1:45 – 1:50 pm **Preoperative Clearance and Preparation to Prevent Perioperative Complications (Bleeding, Neuromonitoring, Infection)**
Tyler Koski, MD

Part I : Osteotomy Techniques

Moderator: Daniel H. Chopin, MD

1:50- 1:58 pm **What is a True Ponte Osteotomy (i.e. Why, Instead of When, is it Not a Smith-Petersen Osteotomy)**
Alberto Ponte, MD

1:58 – 2:06 pm **Pedicular Subtraction Osteotomy**
Stephen J. Lewis, MD, MSc, FRCS(C)

2:06 – 2:14pm **Vertebral Column Resection**
Lawrence G. Lenke

2:14 – 2:22pm **Vertebral Column Decancellation**
Yong Qiu, MD

2:22 – 2:30 pm **Indications for Anterior Based Surgery Techniques for Spinal Deformity**
Henry F.H. Halm, MD

2:30 – 2:50pm **Discussion**

2:50 – 3:10 pm **Case Presentations: Techniques of Sagittal Deformity Correction in Severe Pediatric Kyphosis and Kyphoscoliosis**
Moderator: Peter O. Newton, MD
Panel: Charles E. Johnston, MD; Steven M. Mardjetko, MD, FAAP; Daniel J. Sucato, MD, MS; Michael G. Vitale, MD, MPH

Part II : Application of Osteotomies in Clinical Practice

Moderator: Frank J. Schwab, MD

3:10 – 3: 18 pm **Planification of Sagittal Plane Deformity**
Daniel H. Chopin, MD

3:18 – 3:26 pm **Technical Planning and Intraoperative Execution of Sagittal Plane Correction**
Frank J. Schwab, MD

3:26 – 3:34 pm **Combining Coronal and Sagittal Plane Deformity: Converting the Plan into an Appropriate Operative Technique**
Sigurd H. Berven, MD

3:34 – 3:42 pm **Complications of Osteotomies: How to Recognize and Institute Appropriate Treatment**
Pierre Guigui, MD

3:42– 3:50 pm **Corrective Techniques for the Treatment of Post Traumatic Kyphosis**
John C. France, MD

3:50 – 4:10 pm **Discussion**

4:10 – 4:30 pm **Case Presentations: Adults Thoraco-Lumbar, Lumbar Sagittal Deformities**
Moderator: Stephen J. Lewis, MD, MSc, FRCSC;
Panel: Dennis G. Crandall, MD; Serena S. Hu, MD; Khaled Kebaish, MD; Christopher I. Shaffrey, MD

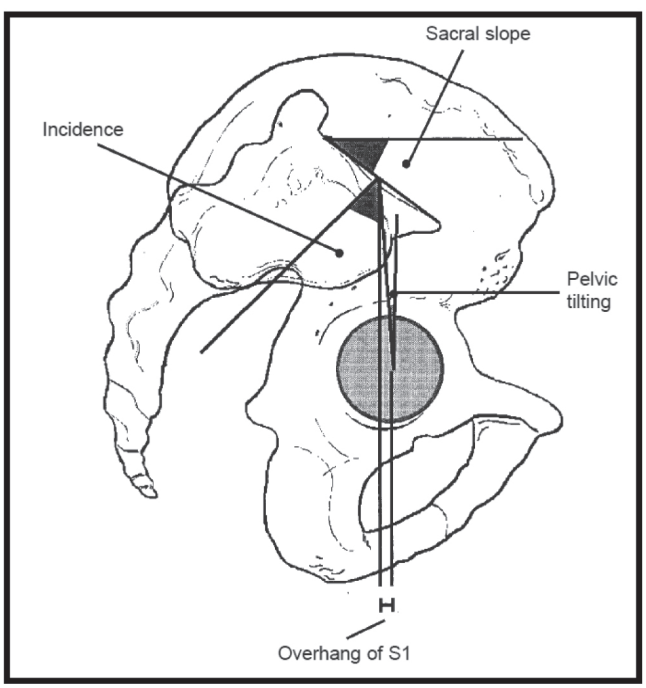
Overview of Sagittal Plane Corrective Techniques: Basic Theory, Operative Techniques and Effective Surgical Application

John R. Dimar II, MD
Clinical Professor or Orthopedics, University of Louisville & The Leatherman Spine Center
Louisville, Kentucky, USA

1. How Important is Positive Sagittal Balance?
    a. In 352 Patients with Positive Sagittal Balance, All Measures of Health Status Showed Significantly Poorer Scores
    b. The Severity of Symptoms Increased in a Linear Fashion With Progressive Sagittal Imbalance
    c. Positive Sagittal Balance was the Most Reliable Predictor of Worse Clinical Symptoms in Patients

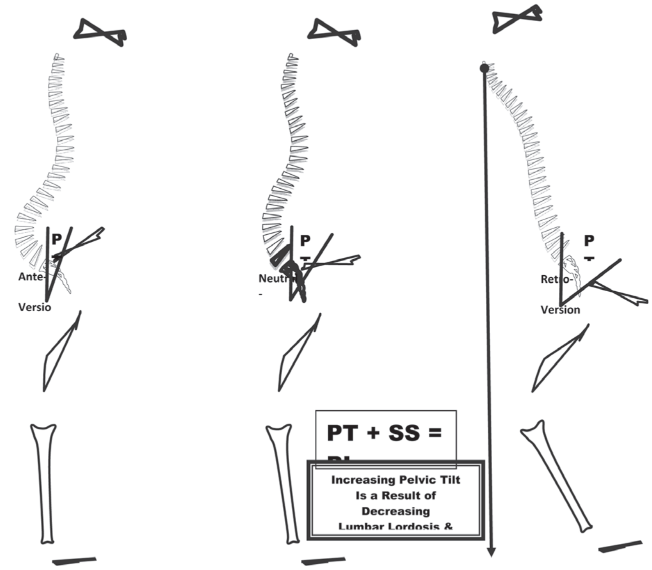
Glassman, Dimar, et al, Spine, Vol. 30, No. 18, pp. 2024-2029, 2006

2. Understanding Sagittal Balance Requires Evaluation of the Global Spine Balance
    a. Economical Sagittal Balance: "This Regulation is Maintained When a Spine Deformity Occurs: It is a Three-Dimensional Relationship between the Pelvis & Spine"
    b. "The Sagittal Balance of the Human Body in The Standing Position is a Compromise Between the Shape of the Pelvis and the Spine"



J. Lagaye, G. Duval-Beupère, et.al., Eur Spine J (1998) 7:99-103

    c. Compensatory Postures of the Spine:
        i. Pelvic **Anteversion** Leads to Increased Compensatory Lordosis
        ii. Pelvic **Neutralversion** Leads to a Normal Balanced Posture
        iii. Pelvic **Retroversion** Results from Loss of Lordosis, Increased Thoracic Kyphosis & Hip Extension in an Effort to Stand Straight



3. Spinal Sagittal Balance Has Been Evaluated From 3 Directions:
    a. From the Occiput Down
    b. Within the Spine by Measuring Thoracic Kyphosis & Lumbar Lordosis
    c. From the Pelvis Up Using Pelvic Parameters
4. Kuntz Evaluated Sagittal Balance From the Occiput Down:
    a. Study Parameters: Review of the Literature of 12 Articles Evaluating the Occiput-Pelvic Alignment by Measuring 23 Different Angles
    b. Occiput-Pelvis In Asymptomatic Adults Showed that Even From the Occiput Sagittal Balance is Maintained in a Narrow Range Over the Pelvis & Femoral Heads

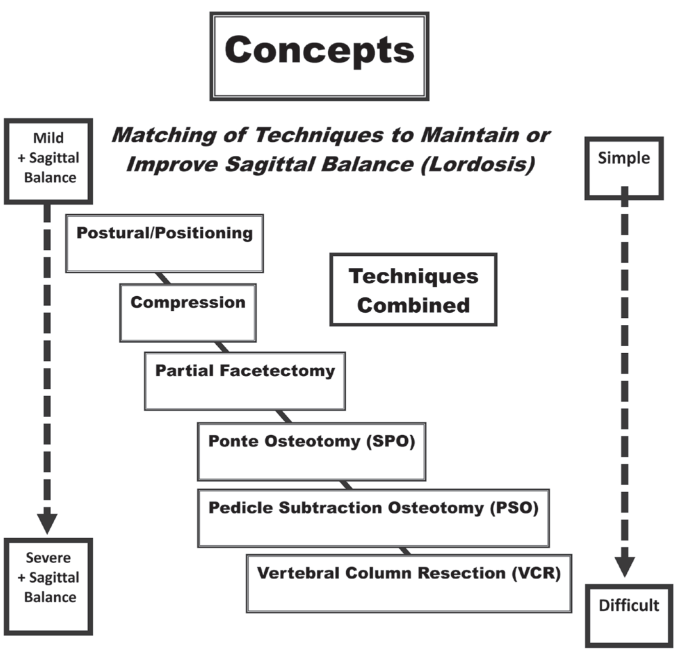
Charles Kuntz IV MD, et. al., J Neurosurg Spine 6: 104-112, 2007

5. Schwab Evaluated Sagittal Balance From The Pelvis Up:
    a. The Pelvis is a Regulator of Balance & Compensates For Positive Sagittal Balance to Maintain Standing Posture
    b. Force Plate Shows Negative Pelvic Tilt Develops To Maintain Balance
    c. Negative Pelvic Tilt = Worse ODI, SF-36, SRSLL = PI + $9^{o} \pm 9$

   d. Pelvic Incidence Can Be Used to Estimate Lumbar Lordosis
   e. Pelvic Retroversion Directly Correlates With Worse Outcome Measures

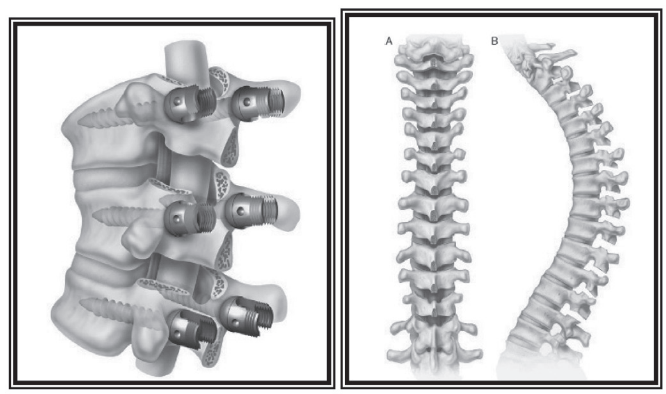
Frank Schwab MD, Virginie Lafage PhD, Spine, Vol. 34, No. 17, pp. 1828-1833, 2009

6. Normal Spinal Parameters:
   a. L4-S1 Contributes Significantly = **40 Degrees**
   b. Total Lumbar Lordosis T12-S1 = **60 Degrees**
   c. Total Thoracic Kyphosis = **40-45 Degrees**
   d. T10-L2 = **0 Degrees**
   e. *Pelvic Incidence = Lumbar Lordosis (Approximately)***
      Thoracic Kyphosis = Lumbar Lordosis
   f. **C7 Plumb Line** Should Fall Behind the Sacrum
   g. **Champagne Glass** Pelvic Outlet Appearance with an AP Pelvis Due to Retroversion
7. Review of Corrective Techniques: Article Reviews the Basics of Osteotomies
   a. **Gill JB, Levin A, Burd T, Longley M,** *Current Concept Review Corrective Osteotomies in Spine Surgery*, JBJS, Volume 90-A, Number 11, pp. 2509-20, November 2008
8. Algorithm of Corrective Techniques to Maintain & Restore Sagittal Balance Locally & Globally:



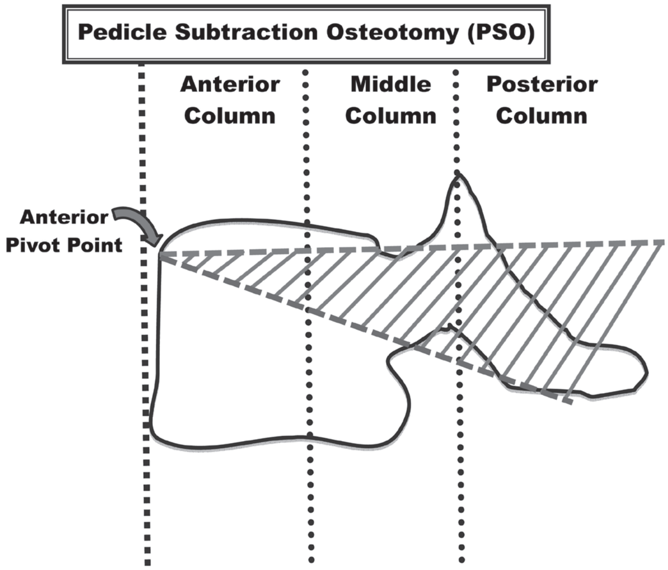
9. Types of Osteotomy Options Available: Selective Article Review
   a. Facetectomy
   b. Ponte Posterior Osteotomy
   c. Costotransversectomy
   d. Thomasen Posterior Subtraction Osteotomy (PSO)
   e. Vertebral Column Resection (VCR)
   f. Smith Petersen Osteotomy (SPO) (Osteoclasis for Ankylosing Spondylitis)
10. Ponte Osteotomy (Incorrectly Called a Smith-Petersen): 1st Described by Dr. Ponte
   a. 46 Consecutive Patients With Scheuermann's
   b. Posterior Osteotomies Resecting Facets
   c. Harrington Compression Hooks
   d. Average Kyphosis Correction: 78.9 to 31°
   e. 2 Patients Developed Neurological Injury & Recovered Following Instrumentation Removal

Geck MJ, Macagno A, Ponte A, Shufflebarger HL, The Ponte Procedure, Posterior Only Treatment of Scheuermann's Kyphosis Using Segmental Posterior Shortening & Pedicle Screw Instrumentation, J Spinal Disord Tec, Vol. 20, No. 8, Dec 2007



11. Posterior Subtraction Osteotomy: Largest Series of PSO with 5 Year Followup
   a. 35 Patients: 29 Females/6 Males, 53.2 Years Old
   b. 5.8 Year F/U (5 to 8 Years)
   c. XR Changes 2 to 5 Years
   d. No Pseudarthrosis at the Osteotomy Sites
   e. Patients With Co-morbidities Did Worse
   f. ODI & SRS Outcomes Same
   g. At 2 Years & 5 Years in 8 Patients Revised
   h. Patients with less than < 8 cm Sagittal Imbalance Did Better

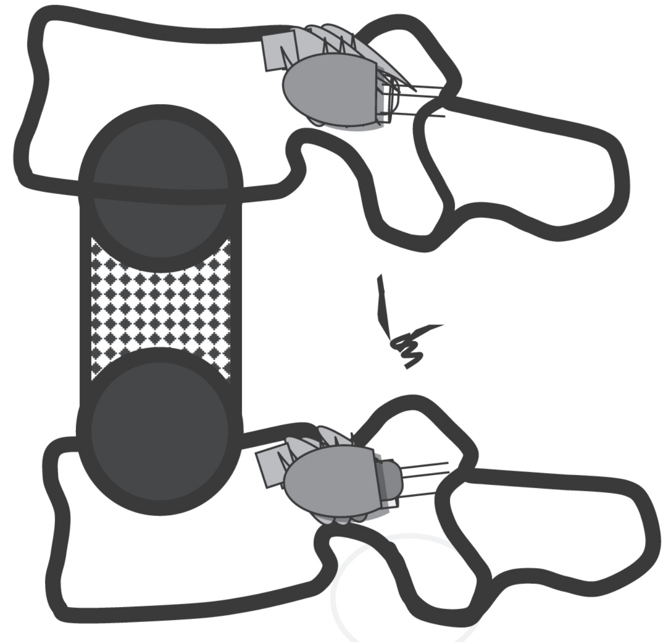
Kim YJ, Bridwell KH, Lenke LG, Cheh G, Baldus C Results of Lumbar Pedicle Subtraction Osteotomies for Fixed Sagittal Imbalance, Spine, Volume 32, Number 20, pp. 2189-2197, 2007



12. 12. Vertebral Column Resection (VCR): Largest Series of VCRs
    a. 43 Patients
    b. 93% Proximal to L1
    c. 18% Lost Potentials- All Recovered
    d. Scoliosis Corrected 69%
    e. Global Kyphosis Corrected 56%
    f. Angular Kyphosis = 63%
    g. Combined Kyphoscoliosis = 56%
    h. Results Better or Equal to Other Techniques in the Literature
    i. "A Posterior-Based VCR is A Safe But Challenging Technique for Treating Severe Primary or Revision Pediatric & Adult Spinal Deformity"

*A Safe But Challenging Technique for Treating Severe Primary or RevisionPediatric & Adult Spinal Deformity" Dr. Larry Lenke

Lenke LG, Sides, BA, Blanke KM, et. al., Vertebral Column Resection for the Treatment of Severe Spinal Deformity, Clin Orthop Relat Res, Vol. 468, No. 3, pp. 687-699, March 2010



Vertebral Column Resection

13. Bibliography:

Glassman SD , Bridwell K, Dimar JD, et al, *The Impact of Positive Sagittal Balance In Adult Spinal Deformity Spine*, **Vol. 30, No. 18, pp. 2024-2029, 2006**

Charles Kuntz IV MD, et. al., *Neutral Upright Sagittal Spinal Alignment from the Occiput to the Pelvis in Asymptomatic Adults: A Review & Resynthesis of the Literature*, **J Neurosurg Spine 6: 104-112, 2007**

Lenke LG, Sides, BA, Blanke KM, et. al., *Vertebral Column Resection for the Treatment of Severe Spinal Deformity*, **Clin Orthop Relat Res, Vol. 468, No. 3, pp. 687-699, March 2010**

Bridwell KH, Lenke LG, Cheh G, Baldus C,*Results of Lumbar Pedicle Subtraction Osteotomies for Fixed Sagittal Imbalance*, **Kim YJ, Spine, Volume 32, Number 20, pp. 2189-2197, 2007**

Geck MJ, Macagno A, Ponte A, Shufflebarger HL, *The Ponte Procedure, Posterior Only Treatment of Scheuermann's Kyphosis Using Segmental Posterior Shortening & Pedicle Screw Instrumentation*, **, J Spinal Disord Tec, Vol. 20, No. 8, Dec 2007**

Gill JB, Levin A, Burd T, Longley M, *Current Concept Review Corrective Osteotomies in Spine Surgery*, JBJS, Volume 90-A, Number 11, pp. 2509-20, November 2

Frank Schwab MD, Virginie Lafage PhD, *Sagittal Plane Considerations & the Pelvis in the Adult Patient, Spine*, **Vol. 34, No. 17, pp. 1828-1833, 2009**

J. Lagaye, G. Duval-Beupère, et.al., Pelvic Incidence: *A Fundamental Pelvic Parameter For Three –dimensional Regulation of Spinal Sagittal Curves,* **Eur Spine J (1998) 7:99-103**

Smith-Petersen MN, Larson CB, Aufranc OE, *Osteotomy of the Spine for Correction of Flexion Deformity in Rheumatoid Arthritis*, **JBJS Am., 1945;27: 1-11**

Bridwell KH, Lewis SJ, Edwards C et. al., *Complications & Outcome of Pedicle Subtraction Osteotomies for Fixed Sagittal Imbalance,* **Spine, Volume 28, Number 18, pp. 2093-2101, 2003**

Cho KJ, Bridwell KH, Lenke LG, et. al., *Comparison of Smith-Peterson Versus Pedicle Subtraction Osteotomy for the Correction of Fixed Sagittal Imbalance,* **Spine, Volume 30, Number 18, pp. 2030-2037, 2005**

Bridwell KJ, Lewis SJ, Rinella A et al., *Pedicle Subtraction Osteotomy for The Treatment of Fixed Sagittal Balance: Surgical Technique*, **J Bone Joint Surg. Am, 86: 44-49, 2004**

Bergin PF, O'Brien JR, Kebaish KM, et. al., *The Use of Spinal Osteotomy in the Treatment Of Spinal Deformity,* **Orthopedics, Volume 33, Number 8, pp. 587-594, August 2010**

Eivind Thomasen, MD, *Vertebral Osteotomy for Correction of Kyphosis*

In Ankylosing Spondylitis, **Clinical Ortho & Rel. Research, Number 194, pp. 142-52, April 1985**

Auerbach JD, Lenke LG, Bridwell KH, et. al., *Major Complications & Comparison Between 3-Column Osteotomy Techniques in 105 Consecutive Spinal Deformity Procedures,* **Spine, June 15, Volume 15, No. 14, pp. 1198-210**

Notes

Preoperative Clearance and Preparation to Prevent Perioperative Complications (Bleeding, Neuromonitoring, Infection)

Tyler R. Koski MD
Northwestern University
Chicago, IL, USA

1. Introduction
2. Predictors of Complications
   a. Patient Factors
      i. Age
      ii. Medical Comorbidities
      iii. Modifiable Risk Factors
   b. Surgical Factors
      i. Blood loss
      ii. Operative time
      iii. Osteotomies
3. Preoperative Evaluation
   a. Medical Evaluation
      i. "High Risk Spine Protocol"
      ii. Laboratory testing
      iii. Involving subspecialists
   b. Surgical Planning
      i. Level selection
      ii. Deformity correction
      iii. Staging procedures
4. Intraoperative Management
   a. Blood management strategies
   b. Staging
      i. Planned
      ii. Unplanned
   c. Neuro-monitoring

Selected References:

1. Halpin RJ, Sugrue PA, Gould RW, Kallas PG, Schafer MF, Ondra SL, **Koski TR**. Standardizing care for high-risk patients in spine surgery. *Spine.* 2010 Dec; 35(23):2232-38.
2. Sugrue PA, Halpin RJ, **Koski TR**. Treatment algorithms and protocol practice in high-risk spine surgery. *Neurosurgery Clinics of North America*. 2013 Apr, 24(2):219-30.

3. Lall RR, Lall RR, Hauptman JS, Munoz C, Cybulski GR, **Koski T**, Ganju A, Fessler RG, Smith ZA. Intraoperative neurophysiological monitoring in spine surgery: indications, efficacy, and role of the preoperative checklist. [Review]. *Neurosurgical Focus*. 2012 Nov, 33(5):E10.

Elgafy H, Bransford RJ, McGuire RA, Dettori JR, Fischer D. Blood Loss in major spine surgery: Are there effective measures to decrease massive hemorrhage in major spine fusion surgery? *Spine. 2010 Apr ,20(35).*

Savage JA, Anderson PW. An update on Modifiable risk factors to reduce the risk of surgical site infections. *Spine J.* 2013. May 24.

Sweet FA, Roh M, Silva C. Intrawound application of vancomycin for prophylaxis in instrumented thoraco-lumbar fusions: efficacy, drug levels, and patient outcomes. *Spine* 2011. Nov 15:36(24).

Sugrue P, McClendon J, Halpin R, Koski TR. Protocol Practice in Perioperative Management of High-Risk Patients Undergoing Complex Spine Surgery. Spine Deformity Preview Issue. Sept. 2012. 15-22.

Notes

What is a True Ponte Osteotomy?

Alberto Ponte, MD
Stuart Clinic
Rome, Italy

Introduction:

There are a number of techniques which developed over time for the correction of spinal deformities. One set of these correction techniques relates to the use of osteotomies. While many ostetotomies were developed around the challenges of specific pathologies they are now commonly used across a wide range of deformity patterns and etiologies.

The purpose of this presentation is to review the history surrounding the Ponte Osteotomy and clarify the clear distinction from the Smith-Petersen osteotomy description. It will thus become evident that these approaches were based on very different pathologies and bear distinctions in their anatomic basis and mechanical implications.

Smith-Petersen: history

Marius Nygaard Smith-Petersen (1886-1953), was born in Grimstad, Norway. He was the son of Morten Smith-Petersen and Kaia Jensine Ursin an acclaimed violinist. The Smith-Petersens were a prominent and influential family. His grandfather Morten Smith-Petersen was a member of Parliament, owned a shipbuilding company.

Marius emigrated with his mother to Milwaukee, Wisc. in 1903, at age 16.He attended the University of Chicago for one year and graduated from the University of Wisconsin, receiving a B.S. in 1910. At the Medical School of the University of Wisconsin,, he worked as a laboratory assistant to physiologist, Dr. Joseph Erlanger. Smith-Petersen then graduated from Harvard Medical School in 1914. He served a surgical internship at the Peter Bent Brigham Hospital, Boston MA under Harvey Williams Cushing, M.D. He was a hospital surgeon in France during WWI. Was awarded the Grand Cross of the Order of St. Olav by the King of Norway. He was considered a brilliant surgeon and a gifted professor.

From 1923 until his death in 1953 he carried on an active orthopedic surgery practice while successively serving as Instructor, Assistant Clinical Professor, and Clinical Professor of Orthopaedic Surgery at Harvard. In 1929 he was appointed Chief of Orthopaedic Surgery at the Massachusetts General Hospital. in 1925, Smith-Petersen introduced the three-flanged steel nail for insertion across the fracture site in hip fractures, an innovation that considerably improved recovery and mortality rates from hip fractures.

1945: An osteotomy of the spine

An osteotomy of the spine described for patients with a kyphotic deformity and an ankylosed spine secondary to rheumatic conditions (ie, ankylosing spondylitis). The technique utilized the posterior vertebral body (middle column) as the fulcrum to obtain deformity correction through the fused disc spaces. Consequently, the anterior column was lengthened and the posterior column shortened in the treatment of "flexion"-type deformity. The technique utilized the posterior vertebral body at lumbar levels (middle column) to obtain correction by gaping of anterior disc spaces, made possible by violating the anterior longitudinal ligament. The result was a marked lengthening of the anterior column, with a high risk of vascular injuries.

Smith-Petersen technique:
- Lumbar spine (1-3 levels)
- Facet joint (articular cartilage) resections
- Ligamentum flavum detached but not removed
- Force lengthening of anterior column

Ponte: development of an osteotomy

Alberto Ponte: background
1953: Medical degree at the University of Turin, Italy.

1953-1969: From orthopaedic residency to full professorship at the University Hospital in Florence, Italy. Fellowship positions in leading orthopaedic and trauma hospitals in Great Britain, Germany, Switzerland and Austria.

1958-1960: In the Unites States: - A one year spine fellowship with John Cobb at Special Surgery in New York, a six month fellowship at the Bone Tumor Service at Memorial Hospital in New York, followed by further training in spine with Joe Risser, Walter Blount and John Moe.

1960 (Florence): The very first scoliosis surgeries in Italy, introducing the methods learned in the United States.

1969-1992: Founder and chief of the first Spine Center in Italy, in Pietra Ligure

Clinical series:

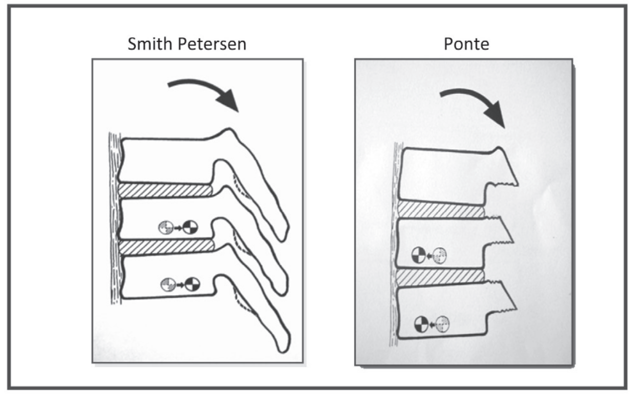
- 506 adult patients (1969-1986) operated on for scoliosis, 101 of them with a vital indication due to short life expectancy and curves over 140 degrees.
- 3025 patients (1969-1992)with thoracic hyperkyphosis treated with plaster casts, over one thousand more with braces. Referrals from all over Italy as well as abroad, explain these large numbers.
- 134 skeletally mature patients (1976-1997) operated on for thoracic hyperkyphosis.
- - 1978: Development of an osteotomy of the spine.

Ponte Osteotomy
Challenges in thoracic spinal deformities, particularly associated with Scheuermann's kyphosis, were not amenable to minor resections as with Smith Petersen approach. More aggressive multilevel bone and ligament resections were necessary to promote a marked shortening of the posterior spine.

- At thoracic levels (11 to 13)
- Complete resection of articular processes, and spinous processes,
- wide resection of laminae
- Complete removal of ligamentum flavum
- In severe cases resections from pedicle to pedicle

Biomechanical Analysis:

30 patients of the above series (15 of each group). Panjabi Method: Biomechanical analysis of the behavior of the COR (Center of Rotation) on pre and post correction lateral x-rays of the thoracic spine.



Posterior shift of COR (Smith-Petersen osteotomy):

- A very **short lever arm** for posterior corrective forces
- (Negative biomechanical advantage)

Anterior shift of COR (Ponte osteotomy):

- A very long lever arm for
- posterior corrective forces
- (Positive biomechanical advantage)

Two principles of Thoracic Kyphosis correction:

- By lengthening the anterior column:
  - Combined ant/post technique
  - Smith-Petersen type of osteotomies
- By shortening the posterior column
  - Ponte type of osteotomies

Lengthening the Anterior Column:

- A high neurological risk!
- interference with anterior medullary blood supply.
  - A single anterior longitudinal artery supplies 2/3 of the anterior spinal cord at mid-thoracic levels.
    - ◊ demontrated by Dommisse on cadaveric spines.

When is a Ponte Osteotomy not a Smith-Petersen Osteotomy?

- When? Never.
- Why? Substantial differences
  - Anatomical

        ◊ larger bone resections at thoracic levels.
    * Mode of correction
        ◊ Shortening of the posterior column vs lengthening of anterior column.
- Integrity of the anterior column support vs disruption of anterior column support.
- A higher grading in the SRS / Schwab Osteotomy Classification:
    * Grade 2 for Ponte osteotomy
    * Grade 1 for Smith-Petersen osteotomy

Notes

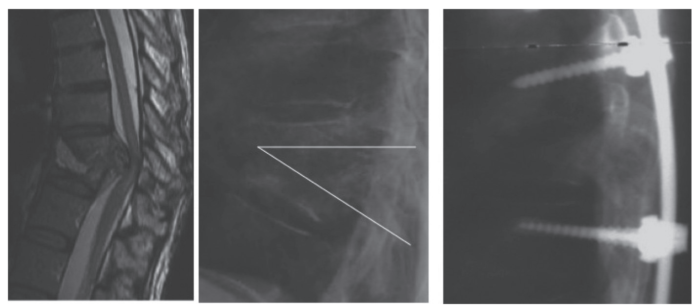
Pedicle Subtraction Osteotomy: Technical Aspects

Stephen Lewis MD, MSc, FRCSC
Toronto Western Hospital, Hospital for Sick Children
University of Toronto
Toronto, Canada

The Pedicle Subtraction Osteotomy (PSO) is a closing wedge osteotomy designed to produce kyphosis correction in the sagittal plane. With the PSO, posterior column shortening is used to achieve correction with the anterior column length remaining unchanged. The middle column shortens as well. The pedicle and adjoining superior articular facet are removed to create a single foramen for the adjacent two nerve roots.

Variations of the osteotomy have been described to achieve the desired correction.

1. Offset PSO: Resection of greater bone on one side compared to the other, will achieve some coronal plane correction.
2. Transdiscal PSO: Resection of the proximal disc space, transdiscal variation, can provide greater sagittal plane correction and provide two bony surface areas for anterior fusion. Especially useful when there is significant disc space involvement in the pathology, such as infection and trauma.



Transdiscal PSO for discitis and cord compression secondary to Tuberculoisis. Note the new vertebra created by resecting the proximal portion of the distal vertebra and the distal portion of the proximal veretbra and reducing the remaining vertebrae together to form a 'new' veretbra

3. Partial or complete vertebral column resection (VCR): the osteotomy is included to resect all or nearly all of the vertebral body to facilitate multi planar corrections

Indications for PSO

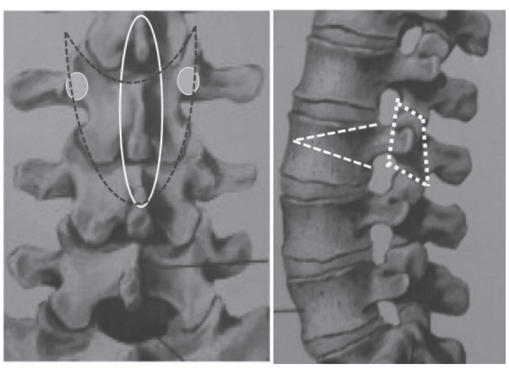
- Fixed sagittal plane deformity greater than 30°
- Stiff or non-mobile anterior column

Bony Attachments of the Pedicle

- Lateral: transverse process
- Medial: lamina
- Proximal: superior facet
- Distal: pars and inferior facet
- Ventral: vertebral body

Osteotomy Steps

- Removal of transverse process
- Removal of medial rib heads (thoracic level PSO)
- Laminectomy
- Isolation of pedicle: removal of superior facet, pars and inferior facet
- Decompression of bilateral nerve roots
- Coagulation of epidural veins
- Angular osteotomy distal and proximal to pedicle into vertebral body
- Removal of pedicle
- Decancellation of vertebral body in a triangular fashion
- Resection of posterior wall of the vertebral body
- Triangular rasping of vertebral body
- Check bone resection
- Closing of the osteotomy with reduction of the inferior facet of the proximal level to the superior facet of the distal level



Regions of resection in a PSO. Note complete posterior column resection of the osteomy level. Reduction of the inferior facet of the proximal vertebra to the superior facet of the distal vertebra will guide the osteotomy reduction and provide posterior bony continuity.

Thoracic level PSO

The PSO can be safely performed in the thoracic spine with an average correction of approximately 20°. Corrections are less than what is achieved with a VCR but approximately 2 to 3 times the correction achieved with a single Ponte or SPO. The PSO is particularly useful when the anterior column is previously fused or not mobile, allowing correction to be achieved without the need for anterior column lengthening.

The exposure of the desired osteotomy level is extended laterally to expose the medial 6 to 7 centimeters of rib. The transverse processes are removed to expose the most medial portion of the rib. The rib is subperiostally dissected and separated from the neurovascular bundle and pleura with curettes, cautery and a rib stripper. The rib is cut laterally and then the medial portion is removed in two parts. A second cut in the rib is made just lateral to the pedicle. The pleura is dissected off the remaining medial rib and rib head. An osteotome or Cobb is then gently tapped between the vertebral body and the rib head to separate the strong ligamentous attachments of the rib head and body. The rib head is then pried from the body and removed. A Penfield 4 and 3 dissectors are used to dissect subperiosteally down the pedicle and proximal portion of the vertebral body to develop the plane between the anterior longitudinal ligament and the mediastinum. The Penfield 3 is replaced with the spoon retractors from the osteotomy set (Medtronic, Memphis, TN), sequentially exchanging the smaller to larger spoon retractor until the appropriate size is secured in place. These steps are repeated on the other side to fully protect the mediastinum during the osteotomy. If a tear in the pleura occurred, a 24 French chest tube was placed just prior to closure.

A decompression is then performed removing the lamina of the osteotomy level as well as the laminae of the levels proximal and distal to the osteotomy level. The complete posterior elements of the desired level are removed. The pedicle is isolated from it's bony attachments to the lamina, pars, and superior facet. The superior facet of the osteotomy level is removed while preserving the inferior facet of the proximal vertebra. Similarly, the inferior facet of the osteotomy level is removed while preserving the superior facet of the distal level. The closure of the osteotomy will be complete when the inferior facet of the proximal level is reduced to the superior facet of the distal level (ie. if a T7 PSO is performed, the inferior facet of T6 is reduced to the superior facet of T8). Following isolation of the pedicle, the pedicle is removed with an L osteotome, the vertebral body is decancellated in a triangular fashion, and the posterior wall is removed. A temporary rod is placed on the pedicle screws on this side to secure the osteotomy and prevent translation and the steps are repeated on the other side. Once the posterior wall is adequately removed, the lateral walls are osteotomized in a triangular fashion. A triangular rasp is then used to rasp the vertebral body in a triangular fashion, rasping sufficiently ventral to allow the osteotomy to close. Prior to osteotomy closure, the dura is inspected and the bone resection, especially the foramens and posterior wall, to ensure the neural elements will not be impinged during closure.

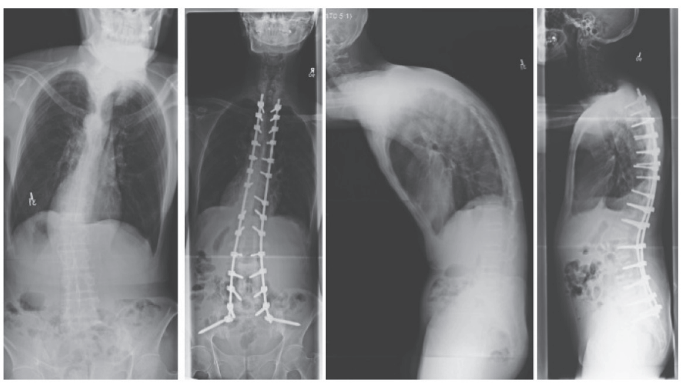
Lumbar PSO

A lumbar PSO is performed in a similar fashion to the thoracic level. Important variations include the need to preserve the nerve roots, as the nerve roots have greater functions compared to the thoracic roots the ability to gently retract the cauda equina, which is not possible in the spinal cord level, and the absence of rib resection.

The transverse process is separated from the lateral pedicle, and dissection along the lateral body at the level of the pedicle is performed to gain access to the lateral vertebral body. Dissection at the pedicle level avoids the large central vessels found on the lateral aspect of the mid body, and puts them on stretch if coagulation of them is required. The osteotomy steps as previously described are then followed.

Closing the Osteotomy with a Central Rod

A supralaminar downgoing ramped hook with a wide blade is placed on the next proximal full lamina. An infralaminar upgoing wide blade ramped hook is placed on the next full lamina distal to the osteotomies. A central rod is then secured to the hooks with the set screws and compression is applied with a multi-hook compressor either between the hooks or to a rod holder placed on the central rod if the distance is too large. Sequential compression is performed until the osteotomies are closed. Leaving the inferior facets intact allows bone on bone contact at the osteotomy sites. The bilateral permanent rods are then secured in place. Further compression through the pedicle screws can be performed if required. The central rod is removed prior to closure to allow greater surface area for fusion and to allow direct contact of the paraspinal muscles to the bone graft region to improve perfusion to the grafted region.



Example of patient with ankylosing spondylitis treated with a T7 and an L2 PSO to correct sagittal malalignment. A central rod was used to close both osteotomies.

Pitfalls

- Difficulty in closing the osteotomy
  * the main reasons the osteotomy will not close is inadequate fixation and inadequate bony resection. Failure to adequately resect sufficient anterior body will prevent the osteotomy from closing. Rechecking the bony resection is indicated.
- Nerve root compression on osteotomy closure
  * Insufficient resection of the superior facet and/or pedicle will result in foraminal compression of the exiting nerve root
- Inadequate correction
  * Sagittal correction is achieved by shortening the posterior column greater than the anterior column. Over resection of the anterior portion of the vertebral body will result in similar front and back shortening, creating a ‘pancaked’ vertebra with little sagittal correction. Attention to the triangular nature of the resection is important to achieve the desired correction.
- Bleeding
  * The course of the epidural veins is predictable and run along the medial border of the pedicle, proximally and distally to the pedicle running laterally into the foramens. Coagulating them is imperative to managing blood loss in the surgery. Bleeding from bone can be managed with judicious use of bone wax. Other hemostatic agents to help control bleeding should be available and used as needed in the important parts of the procedure
- Pseudarthrosis
  * Over resecting the posterior column with a resultant posterior bone gap will result in a failure to achieve a posterior fusion. Preserving the inferior facet of the level proximal to the PSO and reducing it to the superior facet of the level distal to the osteotomy will provide continuous bone across the posterior column. As well, it provides an excellent guide for closure of a single level osteotomy and prevent focal overshortening. If a gap persists in the posterior column following osteotomy closure, press fitting a structural bone graft either from the resected rib, spinous process, lamina, or vertebral body, will provide the necessary structural bone to bridge the defect and promote a posterior column fusion. Alternative methods of obtaining a fusion through the anterior column either through a transdiscal variation or interbody support can be performed. However, because of the focal lordosis creating at the osteotomy site, the posterior column will be under compression and more suitable for fusion.

References:

1. Bridwell KH, Lewis SJ, Rinella A, et al. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. Surgical technique. *The Journal of bone and joint surgery. American volume* 2004;86-A Suppl 1:44-50.
2. Kim KT, Park KJ, Lee JH. Osteotomy of the spine to correct the spinal deformity. *Asian spine journal* 2009;3:113-23.
3. Law WA. Osteotomy of the spine. *Clinical orthopaedics and related research* 1969;66:70-6.
4. Bergin PF, O’Brien JR, Matteini LE, et al. The use of spinal osteotomy in the treatment of spinal deformity. *Orthopedics* 2010;33:586-94.
5. Smith-Petersen MN, Larson CB, Aufranc OE. Osteotomy of the spine for correction of flexion deformity in rheumatoid arthritis. *Clinical orthopaedics and related research* 1969;66:6-9.
6. Emneus H. Wedge osteotomy of spine in ankylosing spondylitis. *Acta orthopaedica Scandinavica* 1968;39:321-6.

7. Hyun SJ, Rhim SC. Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients : a long-term follow-up data. *Journal of Korean Neurosurgical Society* 2010;47:95-101.

8. Lagrone MO, Bradford DS, Moe JH, et al. Treatment of symptomatic flatback after spinal fusion. *The Journal of bone and joint surgery. American volume* 1988;70:569-80.

9. Farcy JP, Schwab FJ. Management of flatback and related kyphotic decompensation syndromes. *Spine* 1997;22:2452-7.

10. Thomasen E. Vertebral osteotomy for correction of kyphosis in ankylosing spondylitis. *Clinical orthopaedics and related research* 1985:142-52.

11. Chen IH, Chien JT, Yu TC. Transpedicular wedge osteotomy for correction of thoracolumbar kyphosis in ankylosing spondylitis: experience with 78 patients. *Spine* 2001;26:E354-60.

12. Danisa OA, Turner D, Richardson WJ. Surgical correction of lumbar kyphotic deformity: posterior reduction "eggshell" osteotomy. *Journal of neurosurgery* 2000;92:50-6.

13. Berven SH, Deviren V, Smith JA, et al. Management of fixed sagittal plane deformity: results of the transpedicular wedge resection osteotomy. *Spine* 2001;26:2036-43.

14. Cho KJ, Bridwell KH, Lenke LG, et al. Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. *Spine* 2005;30:2030-7; discussion 8.

15. O'Shaughnessy B A, Kuklo TR, Hsieh PC, et al. Thoracic pedicle subtraction osteotomy for fixed sagittal spinal deformity. *Spine* 2009;34:2893-9.

16. Kim YJ, Bridwell KH, Lenke LG, et al. Results of lumbar pedicle subtraction osteotomies for fixed sagittal imbalance: a minimum 5-year follow-up study. *Spine* 2007;32:2189-97.

17. Ikenaga M, Shikata J, Takemoto M, et al. Clinical outcomes and complications after pedicle subtraction osteotomy for correction of thoracolumbar kyphosis. *Journal of neurosurgery. Spine* 2007;6:330-6.

18. Yang BP, Ondra SL, Chen LA, et al. Clinical and radiographic outcomes of thoracic and lumbar pedicle subtraction osteotomy for fixed sagittal imbalance. *Journal of neurosurgery. Spine* 2006;5:9-17.

19. Kawahara N, Tomita K, Baba H, et al. Closing-opening wedge osteotomy to correct angular kyphotic deformity by a single posterior approach. *Spine* 2001;26:391-402.

20. Watanabe K, Lenke LG, Daubs MD, et al. A central hook-rod construct for osteotomy closure: a technical note. *Spine* 2008;33:1149-55.

21. Brox JI, Helle A, Sorensen R, et al. Functional outcome after lumbar closing wedge osteotomy in ankylosing spondylitis. *International orthopaedics* 2009;33:1049-53.

22. Jarvis JG, Strantzas S, Lipkus M, et al. Responding to neuromonitoring changes in 3-column posterior spinal osteotomies for rigid pediatric spinal deformities. *Spine* 2013;38:E493-503.

23. Bridwell KH, Lewis SJ, Edwards C, et al. Complications and outcomes of pedicle subtraction osteotomies for fixed sagittal imbalance. *Spine*;28:2093-101.

Notes

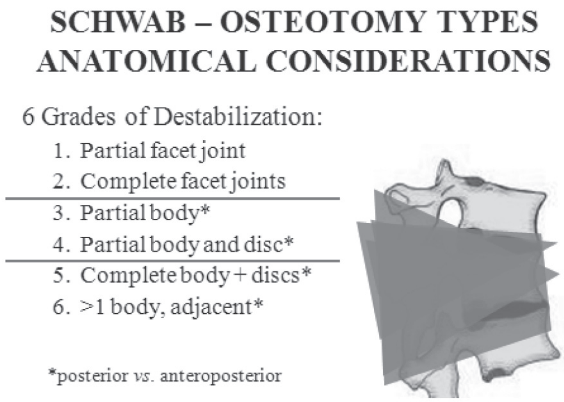
Osteotomy Techniques: VCR

Lawrence G. Lenke, MD
The Jerome J. Gilden Distinguished Professor of Orthopaedic Surgery
Professor of Neurological Surgery
Chief, Spinal Surgery
Co-Chief, Spinal Deformity Service
Director, Complex Spinal Deformity Fellowship
Washington University Medical Center
Saint Louis, Missouri, USA

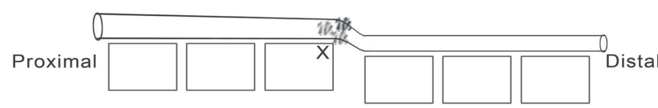
Lyon, France

Osteotomy techniques: VCR

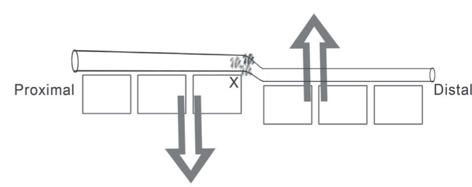
1. Clinical Definition



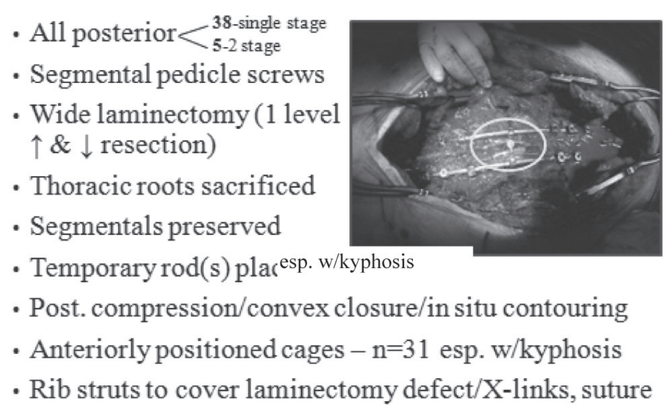
   a. "3-column vertebral osteotomy creating a circumferential segmental defect with sufficient instability to require provisional instrumentation"
   b. Techniques
      i. Procedure of "last resort"
      ii. Severe & stiff deformities/auto-fused spinal columns
      iii. For primary IS → "spine on chest wall" x-rays
      iv. Marked kyphoscoliosis/lordoscoliosis
      v. Performed primarily in thoracic/TL region
      vi. Resection of all post. elements, facet joints ↑/↓, pedicles, nearly all vertebral body and discs ↑/↓
      vii. Tremendous correction ability as spine is disarticulated at apex & proximal/distal limbs slowly brought together
      viii. Performed via staged ant./post. approaches or post.-only (most common)
   c. Indications
      i. Pathology dependent
         1. Type of deformity (scoliosis, kyphosis, lordosis)
         2. Coronal/sagittal/combined imbalance
         3. Curve magnitude
         4. Stiffness (preop & intraop)
         5. Bone density (proxy for PS purchase)
      ii. Surgeon dependent
         1. Operative goals
         2. Surgeon experience/comfort level (PSOs, Post HV excision, costotransversectomy approach)
      iii. Risk dependent
         1. Minimization
         2. Avoid complications
2. Spinal disarticulation inherent to VCR is a double-edge sword that allows *tremendous* correction but has *tremendous* risk
3. Although requires substantial circumferential exposure – it is a useful technique with correction via spinal column/canal SHORTENING via post. compression as main correction mechanism – safe!
4. Intraop spinal column subluxation during post. VCR surgery

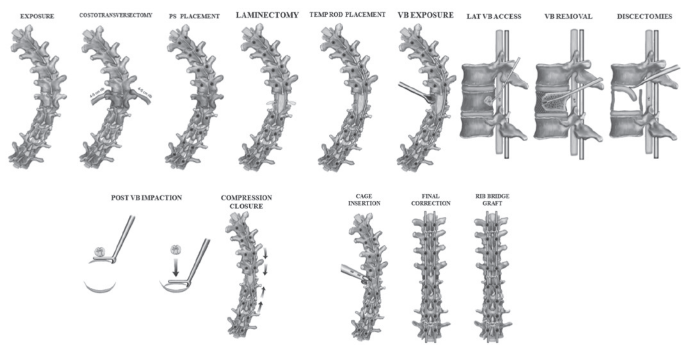


5. Reduce subluxation w/ventral force on proximal segment ± dorsal force on distal segment (MARS!)



6. Technique





7. How to Learn VCR (technique)
    a. Comfortable with screw placement
    b. Comfortable with PCOs, HV excisions & PSOs
    c. Experience with "VCRs" for trauma/tumor pathology
    d. Ideally performing early VCR for someone w/o neuro function preop (i.e., chronic SCI, spina bifida)
    e. Cadaver courses that allow practice
    f. Surgeon visitation to learn finer details
8. OUTCOMES
    a. VCR (data from multicenter pediatric VCR "Fox" Consortium. "Multicenter analysis of 147 consecutive vertebral column resections for severe pediatric spinal deformity". SRS AM, Kyoto, Japan, September 2010, *Spine* 2013;38(2):119–32)
        i. Complications
            1. 86/147 (59%) total complications
            2. 68/147 (46%) intraop
                a. 39/147(26.5%) SCM loss or actual neuro deficit
                b. 33/147(22.4%) EBL >2L
            3. 43/147 = 29% postop
                a. 21/147(14.3%) respiratory
                b. 7/147 (4.8%) infections
        ii. No intraop/postop deaths
    b. Neurologic Highest Risk (data from "Myelopathic Patients Who Lack SCM Data Have the Highest Risk of Spinal Cord Deficits following Posterior VCR Surgery". SRS AM, Kyoto, Japan, September 2010)
        i. Postop Neuro Status
            1. 138 pts./8yrs
            2. 112 with intraop SCM same as preop
            3. 4/26 without intraop SCM – (15%) transient paraplegia
        ii. Characteristics
            1. 3 KS & 1 AK – +116.3°
            2. Apex proximal to midthoracic – T2-7
            3. 3 prior ASF w/segmental vessel ligation
            4. All preop neuro status acute, progressive myelopathy

Age	VCR level(s)	Dx	Secondary Dx	Preop	Postop	F/U
7.7	T6-7	KS	SED	Myelopathy	Paraplegia	Ambulatory in brace
12.8	T5-6	KS	Infant onset scoliosis	Myelopathy	Paraplegia	Ambulatory w/assistance
15.9	T4	KS	Congenital KS	Myelopathy	Paraplegia	Ambulatory
32.6	T2-3	AK	Cervicothoracic syringomyelia	Myelopathy	Paraplegia	Spastic but ambulatory w/assistance

All 4 pts. Regained LE motor function and 4/4 ambulatory

        iii. F/U Neuro Status
    c. Benefit of SCM – multicenter pediatric VCR "Fox" Consortium
        i. Prompt response to SCM changes
            1. 147 pts./7 surgeons
            2. 39/147 (27%) critical change/SCM loss or failed WUT
            3. 19 pts. (13%) worsening neuro status immediate postop
            4. 1 permanent neuro decline
    d. Intraop SCM reliability (data from Can Intraoperative Spine Cord Monitoring Reliably Help Prevent Paraplegia during Posterior VCR Surgery? SRS Annual Meeting, Louisville, KY, September 2011)
        i. Loss of SCM data
            1. 15/90 pts, either lost (n=13) or had degraded data to meet warning criteria (n=2)
            2. All 15 SCM data returned following prompt intervention
            3. All woke with intact LE function! ("SCM SAVES")

Bibliography

1. Lenke LG, O'Leary PT, Bridwell KH, Sides BA, Koester LA, Blanke KM. Posterior vertebral column resection (VCR) for severe pediatric deformity: Minimum 2-year follow-up of 35 consecutive patients. Spine 2009;34(20):2213-21.
2. Lenke LG, Sides BA, Koester LA, Hensley M, Blanke KM. Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res 2010;468(3):687-99.
3. Lenke LG. Posterior vertebral column resection (VCR). Scoliosis Research Society e-Text Spinal Deformity. www.srs.org uploaded May 2011.

4. Suk SI, Chung ER, Kim JH, Kim SS, Lee JS, Choi WK. Posterior vertebral column resection for severe rigid scoliosis. Spine 2005;30(14):1682-7.
5. Suk SI, Kim JH, Kim WJ, Lee SM, Chung ER, Nah KH. Posterior vertebral column resection for severe spinal deformities. Spine 2002;27(21):2374-82.
6. Suk SI, Chung ER, Lee SM, Lee JH, Kim SS, Kim JH. Posterior vertebral column resection in fixed lumbosacral deformity. Spine 2005;30(23):E703-10.
7. Boachie-Adjei O. Role and technique of eggshell osteotomies and vertebral column resections in the treatment of fixed sagittal imbalance. Instr Course Lect 2006;55:583-9.
8. Dorward I, Lenke LG. Osteotomies in the posterior-only treatment of complex adult spinal deformity: a comparative review. Neurosurg Focus 2010;28(3):E4.
9. Powers A, O'Shaughnessy BA, Lenke LG. Posterior thoracic osteotomy (vertebrectomy). In: Wang JC, ed. Advanced Reconstruction: Spine. Instructional Course Lecture 58: North American Spine Society, Rosemont, IL: AAOS, 2011;58(28):265-75.
10. Sponseller PD, Jain A, Lenke LG, Shah SA, Sucato DJ, Emans JB, Newton PO. Vertebral column resection in children with neuromuscular spine deformity. Spine 2012;37(11):E655-E1.
11. Lenke LG, Newton PO, Sucato DJ, Shufflebarger HL, Emans JB, Sponseller PD, Shah SA, Sides BA, Blanke KM. Complications following 147 consecutive vertebral column resections for severe pediatric spinal deformity: A multicenter analysis. Spine 2013;38(2):119-32.
12. Cho SK, Lenke LG, Bolon SM, Kang MM, Zebala LP, Pahys JM, Cho W, Koester LA. Progressive myelopathy patients lacking spinal cord monitoring data have the highest rate of spinal cord deficits following posterior VCR surgery. Spine Deform J (submitted June 2013).

Notes

Vertebral Column Decancellation: Today's Definitions in Thoracolumbar Kyphosis Secondary to Ankylosing Spondylitis

Yong Qiu, MD
The Department of Spine Surgery, the Affiliated Drum Tower Hospital of Nanjing University Medical School, Zhongshan Road 321, Nanjing 210008, China
F: 0086-25-8310-5121
P: 0086-25-8310-5121
scoliosis2002@sina.com

1. Historical review

1.1 Smith-Petersen Osteotomy (SPO)

Smith-Petersen et al[1] originally preformed SPO for the treatment of thoracolumbar kyphosis caused by ankylosing spondylitis (AS) in 1945. This technique involved removing the posterior elements, undercutting the adjacent spinous processes, and closing the osteotomy. The posterior aspect of the disc space is the axis of rotation for the correction. Sagittal correction of thoracolumbar kyphosis was achieved by forceful manual extension of the spine to close the posterior wedge osteotomies. This manipulation disrupted the anterior longitudinal ligament, creating an anterior monosegmental intervertebral opening wedge with elongation of the anterior column. Using this technique, Lagrone et al[2] reported an average correction of 22° in lumbar lordosis and 9° in kyphosis in thoracolumbar junction. However, several complications have been reported, including pseudarthrosis, implant failure, inadequate correction, and loss of correction.[3] Besides, the sharp lordotic angle and elongation of the anterior column may be associated with serious vascular and neurologic complications.[3]

Subsequently, modifications of SPO have been described, such as the polysegmental posterior osteotomies (PPO), which involves removing the facet joints at several levels and compressing the posterior elements to create lordosis. The PPO can results in a gradual correction of the deformity, unlike SPO, which cause an abrupt angular correction. This technique is used most frequently for correction of moderate sagittal imbalance, particularly when there is a flexible component to the deformity. Hehne et al[4] reviewed the outcomes of 177 AS patients treated with PPO. The results of their study showed the average correction was 44°, approximately 9.5° per segment. Complications include 2.3% mortality, 2.3% neurologic deficit, and 18% reversible complications.

1.2 Pedicle Subtraction Osteotomy (PSO)

In 1985, Thomasen advocated the three-column posterior osteotomy for the management of fixed sagittal deformities in AS patients.[5] In this technique, the posterior elements of osteotomized vertebra, including the lamina, articular processes, and pedicles, with the posterior wedge of the vertebral body, are resected. Correction is achieved by passive extension of the lumbar spine to close the posterior osteotomy with an anterior hinge. Moreover, by performing an asymmetrical removal of the posterior elements, correction of both sagittal and coronal plane deformities can be achieved. PSO is typically performed at either L2 or L3, as these vertebrae are the normal apex of lumbar lordosis. In 2002, Kim et al[6] reported the clinical outcomes of 45 AS patients undergoing PSO. They found that an average of 34° increase in lumbar lordosis, and SVA improved from 94mm to 8mm after surgery. Specifically, PSO can achieve greater angular correction than SPO or PPO and is increasingly used for correction of a wide spectrum of conditions associated with severe positive sagittal imbalance.

1.3 Posterior Vertebral Column Resection (PVCR)

In 2002, Suk et al[7] introduced a single-stage PVCR for the correction of rigid complex spinal deformities. The extent of osteotomy includes the resection of posterior elements (spinous process and lamina), pedicles, vertebral body, and discs cephalad and caudad to the vertebral body. Subsequently, a metal cage, structural autograft, or allograft may be used to reconstruct the vertebral column after correction of the deformity. This reconstruction of the vertebral column is supplemented with pedicle screws and rods. Lenke et al[8] reviewed the outcomes of 43 patients underwent PVCR and drew the conclusion that PVCR can offer dramatic correction in both primary and revision surgery of severe spinal deformities. In 2012, Kim et al[9] reported a successful case of PVCR for the AS-related extremely severe kyphotic deformity. Though PCVR is theoretically very appealing, it is a challenging procedure with a great risk of major complications. Therefore, PVCR is the last resort technique in the present armamentarium. It is reserved for the most tenacious spinal deformities that cannot be brought to an acceptable range of correction with other osteotomy techniques such as SPO or PSO.

2. State of art

2.1 Closing-opening Wedge Osteotomy (COWO)

Closing wedge osteotomy (CWO), classically described as PSO, can achieve approximated 35° of lordosis in the lumbar spine.[10] However, in AS patients with severe thoracolumbar kyphosis, when sagittal imbalance requires greater correction at the CWO site, open fracture of the anterior cortex of the osteotomized vertebral body is often needed to achieve the desired correction,[11] transforming a CWO into a COWO. Accordingly, the ideal candidates for COWO are patients with severe thoracolumbar kyphosis requiring more than 35° of correction at 1-level osteotomy.[11,12] It should also be emphasized that in view of the opening of the anterior vertebral cortex and elongation of the anterior column at the osteotomy site during the procedure of COWO,

patients with small scattered calcific deposits in the longitudinal wall of the aorta demonstrated on the preoperative lumbar radiographs should be excluded for COWO to minimize the potential vascular complication.[12] In 2008, Chang et al[11] reviewed the outcomes of 90 patients (including 19 patients of AS) treated with COWO for sagittal imbalance. They found that the mean correction of kyphosis was 81.9°. More recently, Qian et al[12] reviewed 29 AS patients with thoracolumbar kyphosis undergoing COWO, and found that COWO can obtain an extra 10 ° correction than CWO. No pseudarthrosis, delayed union, or nonunion at the level of osteotomy were observed in their study.

2.2 PSO through pseudarthorosis

Surgical treatment is mandatory for spinal pseudarthrosis in advanced AS patients with painful sagittal deformity and/or neurological deficits.[13] However, the most effective and safe surgical procedure for AS-related symptomatic thoracolumbar pseudarthrosis is still controversial. Some authors believe that anterior fusion allows direct access to the anterior lesion,[13,14] whereas others consider that pseudarthrosis can be treated effectively by posterior, transpedicular wedge resection osteotomy at the level of pseudarthrosis and fixation without supplemental anterior fusion.[15,16] Most surgeons recommend combined anterior and posterior approach for the treatment of pseudarthrosis and kyphotic deformity.[13,17] In 2012, Qian et al[18] reviewed the outcomes of seven AS patients with thoracolumbar pseudarthrosis and kyphotic deformity. Results of their study suggested that PSO at the site of pseudarthrosis is a safe and effective method for the treatment of AS patients with pseudarthorosis and kyphotic deformity. After PSO, supplemental anterior fusion is sometimes necessary to support the anterior and middle column and to prevent loss of correction and instrumentation failure, if there is a bone defect in the osteotomy site.

2.3 Skipping two-level PSO

One level PSO can achieve approximately 35° of lordosis at the osteomized site, which is insufficient for severe thoracolumbar kyphosis (Cobb>100°) in advanced AS.[10] In such situation, double PSO is recommended. In 2001, Chen et al[19] reviewed the outcomes of 14 AS patients treated with skipping two-level PSO for thoracolumbar kyphosis. They found that the average correction was 62.6°. Similar improvement in clinical outcomes were also noted in a recent article of Kiaer et al,[20] the authors found that an average 66.9° correction of the lumbar lordosis was obtained in15 patients undergoing two-level PSO. More recently, in a series of 10 AS patients with thoracolumbar kyphosis following two-level PSO, Qian et al[21] reported that the achieved correction of lumbar lordosis was 86°. Of note, there is no serious neurological complication, only one patient had transient brachial plexus paralysis, but resolved after 1 week postoperatively. Based on the results of the previous studies, we can conclude that skipping two-level PSO is an safe and effective treatment for AS patients with extremely severe thoracolumbar kyphosis.

2.4 Vertebral Column Decancellation (VCD)

The potential complications of VCR are disastrous such as spinal column dislocation, greater blood loss, and neurological complications. In 2011, Wang et al[22] introduced a new spinal osteotomy—vertebral column decancellation (VCD), including multilevel vertebral decancellation, removal of residual disc, osteoclasis of the concave cortex, compression of the convex cortex accompanied by posterior instrumentation with pedicle screws. More importantly, residual bone of osteotomy site in VCD may take the place of metal mesh described in the VCR technique, which serves as a "bony cage" and may bring better stability instantly and rapid fusion in the future. For cases with sharp angular spinal deformity, VCD offers a safe and reliable way to achieve good results, including realignment of the deformed spine, decompression of the neurological elements, and potential improvement in neurological function.

Reference

1. Smith-Petersen M, Larson C, Aufranc O. Osteotomy of the spine for cor-rection of flexion deformity in rheumatoid arthritis. J Bone Joint Surg Am 1945;27:1-11.
2. Lagrone MO, Bradford DS, Moe JH, et al. Treatment of symptomatic flatback after spinal fusion. J Bone Joint Surg Am 1988;70:569-80.
3. Van Royen BJ, De Gast A. Lumbar osteotomy for correction of thoracolumbar kyphotic deformity in ankylosing spondylitis. A structured review of three methods of treatment. Ann Rheum Dis 1999;58:399-406.
4. Hehne HJ, Zielke K, Bohm H. Polysegmental lumbar osteotomies and transpedicled fixation for correction of long-curved kyphotic deformities in ankylosing spondylitis. Report on 177 cases. Clin Orthop Relat Res 1990:49-55.
5. Thomasen E. Vertebral osteotomy for correction of kyphosis in ankylosing spondylitis. Clin Orthop Relat Res 1985:142-52.
6. Kim KT, Suk KS, Cho YJ, et al. Clinical outcome results of pedicle subtraction osteotomy in ankylosing spondylitis with kyphotic deformity. Spine 2002;27:612-8.
7. Suk SI, Kim JH, Kim WJ, et al. Posterior vertebral column resection for severe spinal deformities. Spine 2002;27:2374-82.
8. Lenke LG, Sides BA, Koester LA, et al. Vertebral column resection for the treatment of severe spinal deformity. Clin Orthop Relat Res 2010;468:687-99.
9. Kim KT, Lee SH, Son ES, et al. Surgical treatment of "chin-on-pubis" deformity in a patient with ankylosing spondylitis: a case report of consecutive cervical, thoracic, and lumbar corrective osteotomies. Spine 2012;37:E1017-21.
10. Bridwell KH . Decision making regarding Smith-Petersen vs. Pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. Spine 2006; 31: S171-8.
11. Chang KW, Cheng CW, Chen HC, et al. Closing-opening wedge osteotomy for the treatment of sagittal imbalance. Spine 2008; 33: 1470-7.
12. Qian BP, Wang XH, Qiu Y, et al. The influence of closing-opening wedge osteotomy on sagittal balance in thoracolumbar kyphosis secondary to ankylosing spondylitis: a comparison with closing wedge osteotomy. Spine 2012; 37: 1415-23.
13. Kim KT, Lee SH, Suk KS, et al. Spinal pseudarthrosis in advanced ankylosing spondylitis with sagittal plane deformity: clinical characteristics and outcome analysis. Spine 2007; 32:1641–47.
14. Fang D, Leong JC, Ho EK, et al.Spinal pseudoarthrosis in ankylosing spondylitis. Clinicopathological correlation and the results of anterior spinal fusion. J Bone Joint Surg Br 1988; 70:443–7.
15. Chang KW, Tu MY, Huang HH, et al. Posterior correction and fixation without anterior fusion for pseudoarthrosis with kyphotic deformity in ankylosing spondylitis. Spine 2006; 31:E408–13.
16. Van Royen BJ, Kastelijns RC, Noske DP, et al. Transpedicular wedge resection osteotomy for the treatment of a kyphotic Andersson lesion-complicating ankylosing spondylitis. Eur Spine J 2006; 15:246–52.
17. Chen LH, Kao FC, Niu CC, et al. Sugical treatment of spinal pseudoarthrosis in ankylosing spondylitis. Chang Gung Med J 2005; 28:621–8.
18. Qian BP, Qiu Y, Wang B, et al. Pedicle subtraction osteotomy through pseudarthrosis to correct thoracolumbar kyphotic deformity in advanced ankylosing spondylitis. Eur Spine J 2012;21:711-8.
19. Chen IH, Chien JT, Yu TC. Transpedicular wedge osteotomy for correction of thoracolumbar kyphosis in ankylosing spondylitis: experience with 78 patients. Spine 2001;26:E354-60.
20. Kiaer T, Gehrchen M. Transpedicular closed wedge osteotomy in ankylosing spondylitis: results of surgical treatment and prospective outcome analysis. Eur Spine J 2010; 19: 57-64.
21. Qian BP, Qiu Y, Ji ML, et al. Osteotomy for severe thoracolumbar kyphosis in advanced ankylosing spondylitis: skipping two-level pedicle subtraction osteotomy. Zhonghua Yi Xue Za Zhi 2013;93:491-5.
22. Wang Y, Lenke LG. Vertebral column decancellation for the management of sharp angular spinal deformity. Eur Spine J 2011;20:1703-10.

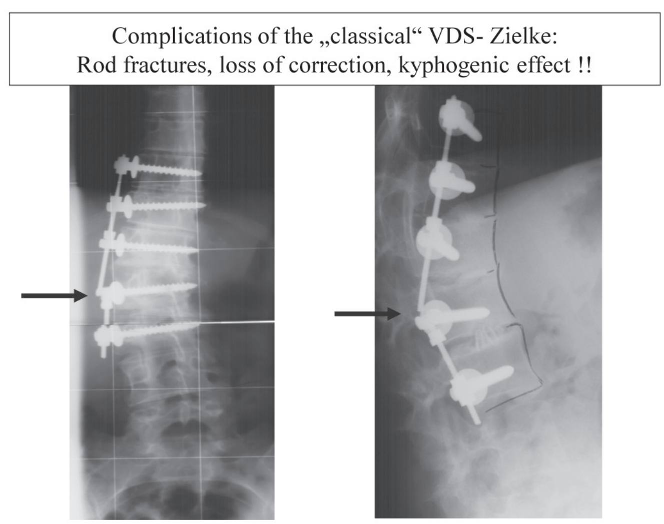
Notes

Indications for Anterior Based Surgery Techniques for Spinal Deformity

Henry F. H. Halm, MD
Center for Spine Surgery and Scoliosis
Neustadt, Germany

Introduction

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



Disadvantage of single screw rod system with a weak 4mm threaded rod: frequent rod fractures with loss of correction due to pseudarthrosis

Biomechanical considerations

Single screw to rod systems with and without cages

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

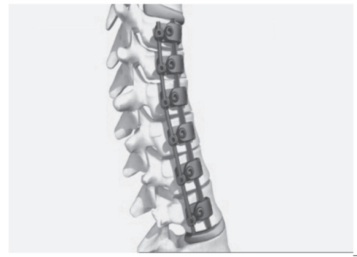
Single screw- rod systems with a solid rod and in combination with cage are capable to restore the stability of the spine to the level of the intact spine, however except for torsional stiffness.

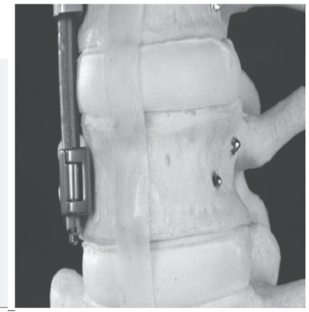
Another weakness of single screw rod systems is the fact that the vertebral body only has one fixation point by one screw. That means that the complications of screw loosening and screw pullout compared to Zielke-VDS are not reduced, which means that with single screw rod systems the bone metal interface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

disadvantage of single screw rod system ist he weak bone metal interface with increased risk of screw pullout, either distally as seen here or at the most cranial level. This also leads to loss of correction and increased pseudarthrosis rates.

Dual rod systems

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





Solid dual rod systems are the most stable construct in terms of bone metal as well as metal metal interface stability. In order to obtain the best possible bone metal interface, bicortical screw fixation is recommended as seen in the picture on the right. Contralateral cortex penetration should be limited to one thread to avoid damage to vascular or visceral structures.

Indications for idiopathic adolescent scoliosis

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

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

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

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

Fusion levels

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

Surgical technique

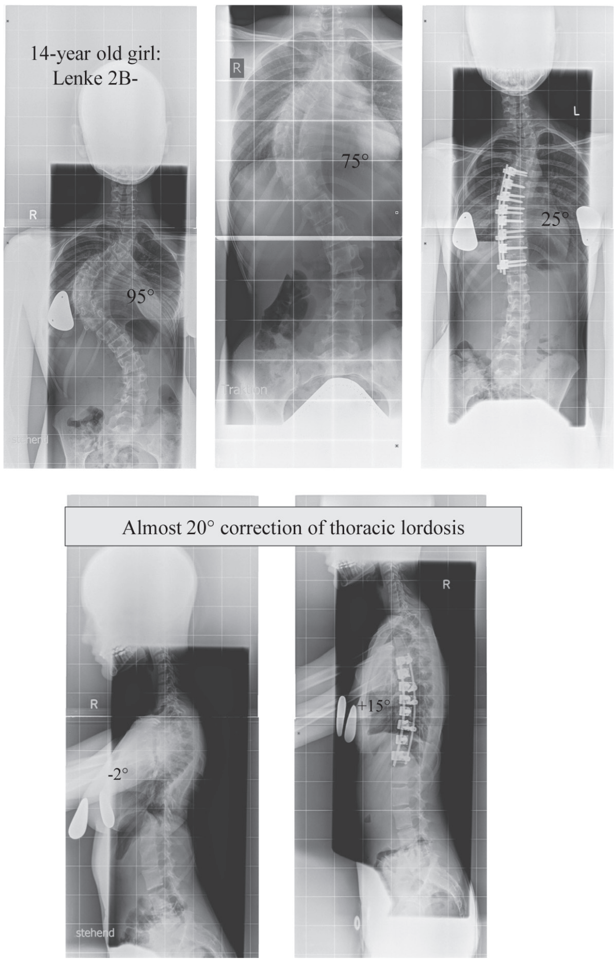
The patient is positioned on the lateral side and on the concavity of the major curve to be instrumented. That means that the spine is typically approached from the convexity.

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

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

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

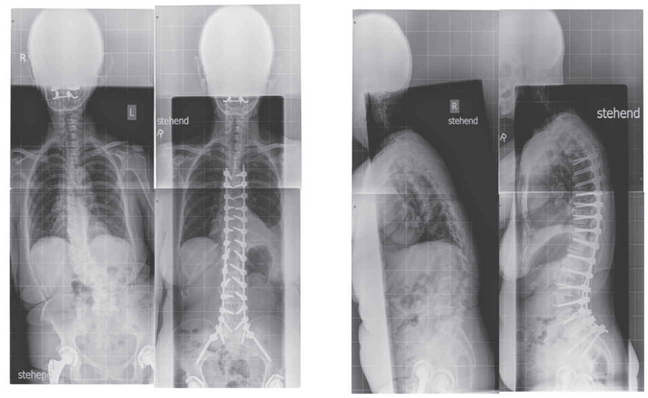
This is followed by instrumentation and instrumented correction and fusion from the convex side, which will be demonstrated with a short video animation.



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

Indications for degenerative adult scoliosis (de novo)

The problem of de novo scoliosis is typically associating lumbar and thoracolumbar kyphosis and this can be nicely addressed with a mini open anterior approach from the concavity either transpsoatic (XLIF type) or anterior to the psoas. Any anterior intersegmental distraction will relordose the spine and also decompress the spinal canal and the foramen indirectly. For the low lumbar and lumbosacral area this can be done through a mini- ALIF approach. After disc resection intersegmental anterior distraction followed by cage insertion can obtain and maintain relordosation with indirect decompression of the spinal canal and the foraminae. This would typically be followed by flipping the patient after the anterior procedure and additional posterior instrumentation and fusion to further increase relordosation by posterior compression and also increase stability with lowering the pseudarthrosis rates. Examples will be shown.



65 year old patient with severe de novo scoliokyphosis. Three level ALIF with excellent relordosation of the lumbar spine followed by long posterior instrumentation and fuion (T5-S1/ Ilium)

Notes

Case Presentations: Techniques of Sagittal Deformity Correction in Severe Pediatric Kyphosis and Kyphoscoliosis

Peter O. Newton, MD
San Diego, CA, USA

This case based panel discussion will address issues in the management of pediatric hyperkyphosis. The cases will include: Scheuermann's kyphosis, Neuromuscular kyphosis, Congenital kyphosis and post infectious kyphosis.

Scheuermann's Kyphosis:

Anterior release vs Posterior only Ponte procedure
Proximal fixation, screw vs hook
Lowest instrumented vertebra selection "rules"

Neuromuscular Kyphosis:

Distal fixation options
Construct strategies

Congenital Kyphosis

Surgical technique tips
Posterior resection, cage use/placement
Risks

Post Infectious Kyphosis

Progressive deformity following implant removal after wound infection
workup and surgical streategies

Notes

Planification of Sagittal Plane Correction

Daniel Chopin, MD
Centre Hospitalier Régional Universitaire de Lille
Pôle Neuroscience et Appareil Locomoteur
Unité Rachis Neuro -Orthopédique
59037 Lille Cedex, France

daniel.chopin@chru-lille.fr

Fixed sagittal imbalance had been identified as a major source of pain and disablilty in adult patients, and restoration of a well balanced spine plays a major role in improvement of reported patient outcome quality. Powerfull and agressive surgical techniques had been described to address the problem, but with higher rate of complications, sometimes without reaching the optimal spinopelvic balance .

Measurement tools, of the sagittal alignment and the compensatory mechanisms, provide the basis for a preoperative planning with corrective simulation, peroperative control, expecting the optimal correction for a particular patient.

I-The References

In standing position every single patient has its own economical posture where the pelvis is the main regulator of chain of correlation between spine curvatures and lower limbs.

On Long Xray including Femoral Heads on a standardized position (« hands on shoulders «).

Global Balance :

- Gravity Line :Vertical line , anterior to the spine, over Femoral Heads (FH) axis(post),knee axis (ant), Heels (constant)

Spine Balance :

- C7 Vertical Line : falls ≈close to postero-superior corner of S1
- SVA (Sagittal Vertical Axis) −20mm± 30mm

Pelvic Parameters :

- Pelvic Incidence (PI) : morphological parameter, constant characteristic of a single patient 52°±10°, but Gaussian repartition in the population from ≈30 to ≈80° with 50% average 52°, 25% low incidence , 25% high incidence.
- Positional parameters : variations according to rotation of the pelvis around the hips, with :
- Pelvic Incidence= Pelvic Tilt+ Sacral Slope.
- On a standing economical posture :
- Pelvic Tilt (PT)≈13°±6,1 (≈−4,5° to 27°)
- Sacral Slope (SS)≈40°±8,5 (17,5° to 63,4°) SS=7,3+0,63 PI

Maximum Lumbar Lordosis (MLL) : ≈60°±10° (30° to 89°)

Maximum Thoracic Kyphosis (MTK≈ 41°±10° (6 to 69°)

T1 Sagittal Tilt(T1ST) ≈−1,4°±2,7

There is a chain of correlations between these parameters , PI being constant for a particular person (MLL and PI, SS and PI, PT and PI, TK)

several simple or multiple regression models had been established some of them :

MLL=PI+9°

MLL= −2,72−1,1PI+1,1PT−0,31MTK

PT=−7+0,37 PI

SS=7,3+0,63 PI

Reciprocal Angular measurements tables by :Stagnara, Bernhardtand Bridwell, Vialle, provide reference angulations for segments of spine.

L4S1 lordosis ≈ 2/3 of MLL

II-Analysis of Sagittal Imbalance

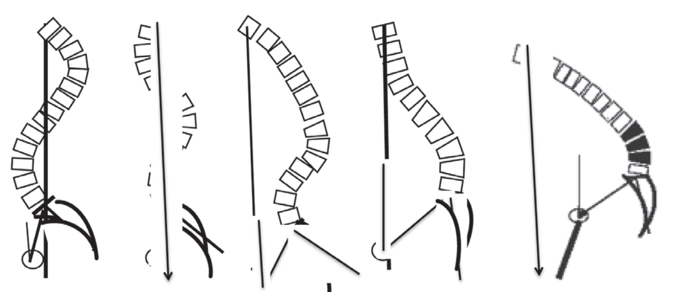
With a fixed Sagittal deformity the patient has to manage in order to keep its center of mass over the 2 feet, but at the price of increasing expenditure energy.

Global : C7 VL according to Sacral Plateau (SP) and FH

- Imbalance : Anterior to SP evaluated by SVA and T1ST
- Compensated imbalance between FH and SP, T1ST negative
- Decompensated Imbalance : anterior to FH, T1ST positive

Site of Fixed deformity and analysis of Compensatory Mechanisms ;

- In the Spine (C7 VL and Pelvic parameters unchanged
- In the Pelvis : retroverted Pelvis, increased PT
- In the Pelvis+Lower Limbs(Knee flexion)
- With Thoracic compensation(thoracic lordosis or relative thoracic kyphosis decrease)
- Without Thoracic compensation (continuing or hyperkyphosis)
  Thoracic area evaluation on standing Xray and clinically
  Anterior Imbalance with normal or reduced PT(anteverted pelvis): Check lower limbs (hip or knee flexion contracture) ,antalgic posture.



a: compensation inside the Spine long lordosis SVA and PT no modification

b : compensation LS and High Thoracic lordosis : SVA and PT no modification

c : LS compensation PT according to PI , but no thoracic compensation

d : Compensation through retroverted Pelvis (increased PT) and Thoracic Lordosis

e : Compensation through retroverted Pelvis and Knee flexion, no thoracic compensation

III- Measurements of Sagittal Imbalance

With Pathological Sagittal Malalignment , PI being constant and not modified, it serves s a reference to evaluate the theoritecal value of the other parameters, and compare to the actual values of the patient.

It allows to tailor the ideal objective of an economical Sagittal SpinoPelvic Balance of a single patient in its specific umbalanced situation.

Some parameters had been recognized to correlate with disability and outcome : PT<25°, SVA<50mm, PI−LL=9°, but evidently, the meaning of these numbers is not the same for low or high PI angle

Measurements can be done manually of with a software.

IV- Planification

- Instrumentation Limits
  Depends on site of fixed Kyphosis and compensatory areas
  - Compensation inside the Spine :
    - ◊ limited to the Kyphotic area according to harmonious sagittal contour and reciprocal angles.
    - ◊ Preserve LS area
    - ◊ Upper limit extended to high thoracic if no upper thoracic compensation.
  - Compensation in the Pelvis (retroverted pelvis)
    - ◊ Include the pelvis (iliac extension fixation)
    - ◊ Upper limit :
      - » High lumbar or Thoracolumbar if thoracic compensation
      - » High thoracic (T1 T2) if thoracic area participates to imbalance,
      - » Covers any kyphotic area .(TL)
      - » Behaviour of uninstrumented thoracic area :
        - Reharmonisation of a Thoracic Lordosis according to quality of lumbar correction.
        - Progression of TK : suboptimal lumbar correction,preoperative hyper or «continuing » Kyphosis, age.

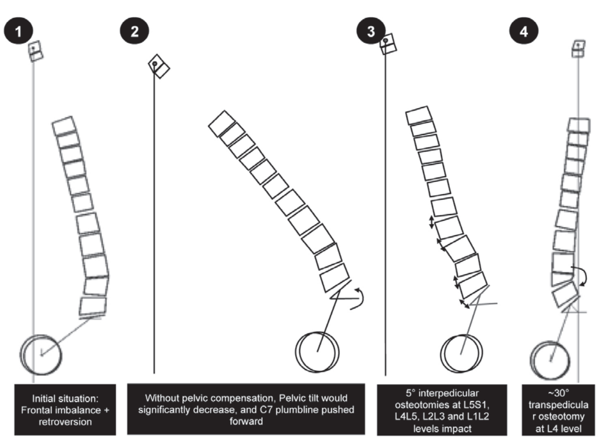
- Contribute to deterioration of the post-operative sagittal balance. Prevented by extension to high thoracic area but increase surgical morbidity.

- b-type of Osteotomy
  - * According to stiffness of the deformity , level, amount of correction needed, patient comorbidities, surgeon experience…
  - * SPO ,Ponte 5° to 10°,PSO up to 20,25°,PSO+adjacent disc 35°to45° ,Close Open Wedge Osteotomy (COWO)<40°, VCR .
    Technically great amount of correction is possible with eventually combined techniques.
- c-Level of osteotomies and amount of correction
  For a Spino Pelvic malalignment the objectives are :
  - * Restoration of MLL according to PI
  - * Restoration of PT according to PI
  - * Restoration of SVA to sacrum
  - * Restoration of L4S1 lordosis (≈2⁄3 of MLL)

On a pragmatic approach simulation can be done eitheir with a paperwork or with a software.

Example:

- Sagittal reconstruction of spine and pelvis, PI,PT,SVA
- Correction of retroverted pelvis with a PT according to PI (pelvic compensation disappear), increasing SVA.
- Restoration of lordosis moving backward C7VL with SPO osteotomies 5° each level L5S1, L4L5, L2L3, L1L2 : suboptimal correction C7VL still anterior, insuffisant L4S1 lordosis
- PSO L4 : 30° necessary to move C7VL to posterior part of S1. Restoration of L4S1 lordosis.
- PSO , COWO, VCD are choosen according to the amount of correction needed.



Importance of level of PSO :

- **Low level** (L4 or L5) better correction of **PT**, restoration of **L4S1 lordosis**, less angulation of **U**pper **I**nstrumented **V**ertebrae : less risk of **P**roximal **J**unctional **K**yphosis or **F**ailure .
- Anterior support of open discs is planed particularly in Lombo-sacral area to avoid pseudarthrosis and loss of correction.

V-Per-0perative control

Planed corrective osteotomies can be controlled during the surgery with measured peroperative Xrays in order to avoid suboptimal (more frequent) or over correction (possible with Low Pelvic Incidence)

Some authors proposed prebended rods according to planed correction.

Better surgical planning may reduce the risk of suboptimal correction and participates to outcome improvement. However it is done from a static view at one time of a complex neuromuscular regulation. Evolution with time and age of unfused segments could be umpredictable and needs more study.

References

9. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine* 2005;30:682– 8.
10. Glassman SD, Bridwell K, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine* 2005;30:2024 –9.
11. Legaye J, Duval-Beaupe`re G. Gravitational forces and sagittal shape of the spine. Clinical estimation of their relations. *Int Orthop* 2008;32:809 –16.
12. Legaye J, Duval-Beaupere G, Hecquet J, et al. Pelvic incidence: a fundamen tal pelvic parameter for three-dimensional regulation of spinal sagittal curves. *Eur Spine J* 1998;7:99–103
13. Vialle R, Levassor N, Rillardon L, et al. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. *J Bone Joint Surg Am* 2005;87:260 –7.
14. Boulay C, Tardieu C, Hecquet J, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. *Eur Spine J* 2006;15:415–22.
15. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size: a prospective controlled clinical study. *Spine* 1994;19:1611–8.
16. Schwab F, Lafage V, Boyce R, et al. Gravity line analysis in adult volunteers: age-related correlation with spinal parameters, pelvic parameters, and foot position. *Spine* 2006;31:E959–67

17. Roussouly P, Gollogly S, Berthonnaud E, Dimnet J (2005) Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. Spine (Phila Pa 1976) 30(3):346–353

18. Kawahara N, Tomita K, Hisatoshi B et al (2001) Closing–opening wedge osteotomy to correct angular kyphotic deformity by a single posterior approach. Spine 26:391–402 .

19. .Sang-Hun Lee, MD,* Ki-Tack Kim, MD,* Kyung-Soo Suk, et al. Sagittal Decompensation After Corrective Osteotomy for Lumbar Degenerative Kyphosis. *Spine* 2011 ; 36, 8, pp E538–E544.

20. Meric Enercan • Cagatay Ozturk • Sinan Kahraman, et al Osteotomies/spinal column resections in adult deformity *Eur spine J* 2012

21. Bridwell K (2006) Decision making regarding Smith-Petersen vs.pedicle subtraction osteotomy vs. vertebral column resection forspinal deformity. Spine 31:S171–S178

22. . Benjamin Blondel, MD,*† Frank Schwab, MD,* Shay Bess, MD,‡ et al Posterior Global Malalignment After Osteotomy for Sagittal Plane Deformity. *Spine* 2013 ;38 : E394–E401.

23. Justin S. Smith, MD, PhD,* Shay Bess, MD,† Christopher I. Shaffrey, MD et al Dynamic Changes of the Pelvis and Spine Are Key to Predicting Postoperative Sagittal Alignment After Pedicle Subtraction Osteotomy *Spine 2012 ;37:* 845–853

24. Stephen J. Lewis, MD, MSc, FRCS(C), Harith Abbas, MD, Sooyong Chua, MD,et alUpper Instrumented Vertebral Fractures in Long Lumbar Fusions *Spine* 2012 ;37 : 1407–1414

25. Kei Watanabe, MD,* Lawrence G. Lenke, MD, et al *(*2010)Proximal Junctional Vertebral Fracture in Adults After Spinal Deformity Surgery Using Pedicle Screw Constructs. *Spine*30 (2) :138-145

26. Kao-Wha Chang, MD, PhD,*†‡ Xiangyang Leng, MD et al. Quality Control of Reconstructed Sagittal Balance for Sagittal Imbalance. *Spine* 2011; 36 :E186–97

27. Virginie Lafage, Ph.D.,1 neiL J. Bharucha,et al (2012) Multicenter validation of a formula predicting postoperative spinopelvic alignment J Neurosurg Spine 16 :15-21,2012

Notes

Technical Planning and Intraoperative Execution of Sagittal Plane Correction

Frank J. Schwab, MD
Clinical Professor, Department of Orthopedic Surgery
New York University Hospital for Joint Diseases
New York, NY, USA

Introduction

Adult spinal deformity (ASD) is a rapidly growing healthcare field due to an aging population and quality of life expectations with aging. While primary deformities are common, some of the most challenging patients present with one or several previous surgeries and spinal malalignment.

Analysis of the sagittal plane in the setting of an asymptomatic population or patients presenting with spinal pathologies was initiated several decades ago_ENREF_1.[10,13,18,25] Key measures of sagittal alignment have been identified, validated and continuously explored by the various study groups focusing on outcomes measures in the setting of ASD (SDSG, ISSG, ESSG etc)(Figure 1)[8,10,18,20,21,23,25]. Alignment objectives have been defined as postoperative SVA<40mm, PT<20˚ and PI-LL≤10˚[2,13,14,22]. . Accordingly, sagittal realignment planning has become a key component of successful adult spinal deformity (ASD) treatment . Realignment procedures for patients with marked sagittal malalignment often require vertebral osteotomies in addition to long posterior fusion[3,4,7,19]. To achieve optimal clinical outcomes, careful attention must be paid to preoperative planning and intra-operative execution of the plan. If realignment is the primary measure of successful ASD procedure, planning and execution of goals are essential.

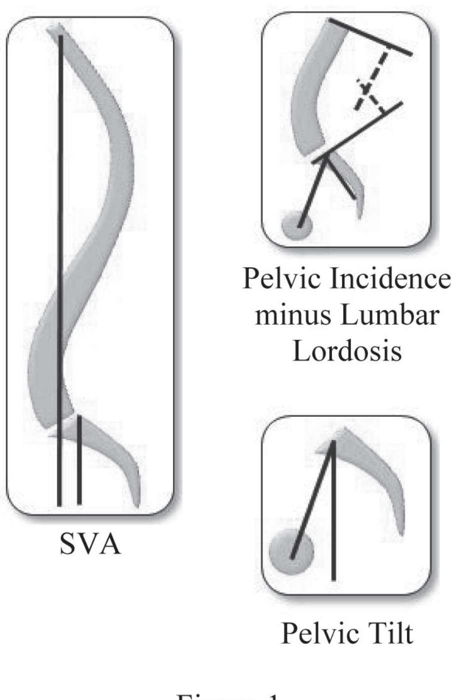


Figure 1

Preoperative Planning

The first critical step in preoperative planning is obtaining standardized full length standing films. These must be obtained in the free-standing position including at minimum C7 –femoral heads, ideally including the head to the feet. All standard measures of sagittal alignment should be applied with realignment goals in mind. Realignment goals should be patient specific. While reference values are helpful, the interplay of regional parameters is most critical (ex. Offset between LL and PI).

Once goals of alignment have been identified, simulation should be performed to identify surgical technique options with radiographic goals in mind. Several tools can be used in order to simulate results of realignment (including anterior cages or posterior osteotomies) in order to assess which preoperative surgical plan is best suited for a given patient. This step is crucial for success and various simulations should be considered in order to have alternative solution if needed during a procedure. Simulation tools may include mathematical formulas[11,12] and visual manipulation and geometric analysis[1,17] with software or tracing paper. The surgical plan should be created with what is feasible in mind, in regards to all aspects of surgery included patient medical health, hospital allowances and surgical team experience and availability. The creation of the plan is most helpful if reviewed with co-surgeons and the rest of the surgical team in the operating room

Intra-op Execution

After developing a surgical plan, it is critical to respect predetermined goals, while being flexible with technique in the operating room. There are many scenarios under which the optimal technique could change at the time of surgery. For example greater flexibility of the spine than expected may obviate a need for larger osteotomies, and patient factors may not permit certain realignment plans due to loss of monitoring potentials or hemodynamic stability. Intraoperative imaging is the primary tool to ensuring execution of the surgical plan. Fluoroscopy can be used for imaging osteotomy sites however, long x-ray, before closure, is the best for assessing lumbar lordosis correction and thoracic alignment related to pre-operative goals .

Image Guided Surgery(IGS), utilizing fluoroscopy based surgical navigation or computed tomography based surgical navigation can be used intraoperatively to provide multiplanar views of the spinal anatomy. These technologies may evolve into powerful surgical planning tools for spinal deformity and ensuring adequate sagittal realignment, though this has not been fully explored[6,9,15].

Proper rod contouring and reduction maneuvers are important tool in sagittal correction, enabling controlled correction and structural support of the newly imposed spinal alignment[5,16]. While rod contouring alone is not sufficient to provide sagittal realignment, ignoring this tactic will nearly ensure a poor radiographic outcome[5,24].

Root Cause Analysis and Early Findings

A prospective root cause analysis, including preoperative, intra-operative and early post-operative time points, was developed to evaluate alignment failures in the setting of adult spinal deformity surgery. Surgical planning was obtained using two different methods, one based on multilinear regression formulas and another based on geometric analysis. Preliminary findings demonstrated that high x-ray quality was essential for generating a surgical plan and evaluating the procedure. Intra-operative x-ray evaluation of lumbar lordosis was representative of post-operative outcomes. Comparison of surgical plan and post-operative results demonstrated that lumbar lordosis was frequently under corrected and thoracic kyphosis compensation poorly anticipated. Overall, target objectives for optimal sagittal realignment could not always be met but improvements in planning and execution are clearly possible.

Conclusions

There is a need for the creation of a standardized and reproducible approach to sagittal spinal realignment surgery and current methods leave room for improvement. In terms of process improvements, the acquisition of high quality full length standing x-rays for all spine patients is obligatory. Additionally, routine use of key radiographic measures should be made for all patients, even those thought of having a primarily degenerative, rather than deformity, pathology. The development of simple clinical tools including a "Surgical Goals" cheat sheet to routinely integrate normative and patient specific acceptable values of sagittal alignment as well as revisiting existing complex formulas to ensure accuracy in their predictions will dually benefit the field.

Optimal patient outcomes in the setting of spinal deformity are critically tied to proper patient assessment and planning however require reconciling preoperative plans with intra-operative execution, while retaining flexibility in technique in order to reach goals. Standard practice must include systematic surgical planning and simulation, with various methods currently available to those seeking to use them. Further work will refine current workflow of surgical planning and new technologies must be developed to drive consistency and reproducibility into intra-operative planning and execution.

Bibliography

1. Akbar M, Terran J, Ames CP, et al. Use of Surgimap Spine in sagittal plane analysis, osteotomy planning, and correction calculation. *Neurosurg Clin N Am* 2013;24:163-72.
2. Boulay C, Tardieu C, Hecquet J, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. *Eur Spine J* 2006;15:415-22.
3. Bridwell KH, Lewis SJ, Lenke LG, et al. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. *The Journal of Bone & Joint Surgery* 2003;85:454-63.
4. Bridwell KH, Lewis SJ, Rinella A, et al. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. Surgical technique. *J Bone Joint Surg Am* 2004;86-A Suppl 1:44-50.
5. Casey MP, Asher MA, Jacobs RR, et al. The effect of Harrington rod contouring on lumbar lordosis. *Spine (Phila Pa 1976)* 1987;12:750-3.
6. Ebmeier K, Giest K, Kalff R. Intraoperative computerized tomography for improved accuracy of spinal navigation in pedicle screw placement of the thoracic spine. *Acta Neurochir Suppl* 2003;85:105-13.
7. Farcy JP, Schwab FJ. Management of flatback and related kyphotic decompensation syndromes. *Spine (Phila Pa 1976)* 1997;22:2452-7.
8. Glassman SD, Bridwell K, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976)* 2005;30:2024-9.
9. Holly LT, Foley KT. Intraoperative spinal navigation. *Spine (Phila Pa 1976)* 2003;28:S54-61.
10. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. *Spine (Phila Pa 1976)* 1994;19:1611-8.
11. Lafage V, Bharucha NJ, Schwab F, et al. Multicenter validation of a formula predicting postoperative spinopelvic alignment. *J Neurosurg Spine* 2012;16:15-21.
12. Lafage V, Schwab F, Vira S, et al. Spino-pelvic parameters after surgery can be predicted: a preliminary formula and validation of standing alignment. *Spine (Phila Pa 1976)* 2011;36:1037-45.
13. Legaye J, Duval-Beaupere G. Sagittal plane alignment of the spine and gravity: a radiological and clinical evaluation. *Acta Orthop Belg* 2005;71:213-20.
14. Legaye J, Duval-Beaupere G, Hecquet J, et al. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. *Eur Spine J* 1998;7:99-103.
15. Nolte LP, Slomczykowski MA, Berlemann U, et al. A new approach to computer-aided spine surgery: fluoroscopy-based surgical navigation. *Eur Spine J* 2000;9 Suppl 1:S78-88.
16. Noshchenko A, Xianfeng Y, Armour GA, et al. Evaluation of spinal instrumentation rod bending characteristics for in-situ contouring. *J Biomed Mater Res B Appl Biomater* 2011;98:192-200.
17. Patwardhan AG, Rimkus A, Gavin TM, et al. Geometric analysis of coronal decompensation in idiopathic scoliosis. *Spine (Phila Pa 1976)* 1996;21:1192-200.

18. Richards BS, Birch JG, Herring JA, et al. Frontal plane and sagittal plane balance following Cotrel-Dubousset instrumentation for idiopathic scoliosis. *Spine (Phila Pa 1976)* 1989;14:733-7.
19. Rose PS, Bridwell KH, Lenke LG, et al. Role of pelvic incidence, thoracic kyphosis, and patient factors on sagittal plane correction following pedicle subtraction osteotomy. *Spine (Phila Pa 1976)* 2009;34:785-91.
20. Schwab F, Lafage V, Patel A, et al. Sagittal plane considerations and the pelvis in the adult patient. *Spine (Phila Pa 1976)* 2009;34:1828-33.
21. Schwab F, Patel A, Ungar B, et al. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. *Spine (Phila Pa 1976)* 2010;35:2224-31.
22. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. *Spine (Phila Pa 1976)* 2012;37:1077-82.
23. Schwab FJ, Blondel B, Bess S, et al. Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: a prospective multicenter analysis. *Spine (Phila Pa 1976)* 2013;38:E803-12.
24. Steib JP, Dumas R, Mitton D, et al. Surgical correction of scoliosis by in situ contouring: a detorsion analysis. *Spine (Phila Pa 1976)* 2004;29:193-9.
25. Vidal J, Marnay T. [Sagittal deviations of the spine, and trial of classification as a function of the pelvic balance]. *Rev Chir Orthop Reparatrice Appar Mot* 1984;70 Suppl 2:124-6.

Notes

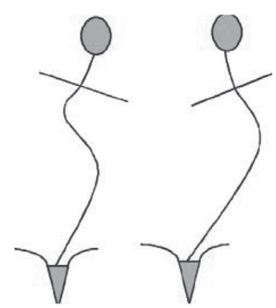
Combined Coronal and Sagittal Plane Deformity: Converting the Plan into an Appropriate Operative Technique

Sigurd Berven, MD
Professor in Orthopaedic Surgery
UC San Francisco
San Francisco, CA, USA

1. Multiplanar Deformity of the Spine
   a. Etiologies
      i. Congenital anomaly
      ii. Iatrogenic:
         1. Flatback Syndrome
         2. Kyphotic Decompensation Syndrome
         3. Adjacent segment pathology
      iii. Degenerative
      iv. Post-traumatic
      v. Infectious
      vi. Neoplastic
      vii. Osteoporotic Compression Fractures
   b. Recognition of patterns in Multiplanar Deformity:

In patients with severe decompensation involving the sagittal and coronal plane, angular osteotomies from a posterior approach or a combined anterior and posterior approach remain with significant limitations:

   c. Distraction of the Spinal Column
      i. Need for a spinal shortening procedure
   d. Trunk shift with shoulder asymmetry
      i. In the figure below in the right, an attempt at deformity correction using conventional angular osteotomies would exacerbate shoulder asymmetry or truncal shift.



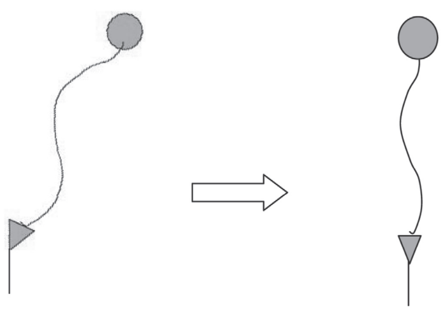
2. **Clinical Assessment of Spinal Imbalance**
      i. Location of the Deformity:
         1. The localization of spinal deformity requires clinical and radiographic assessment.

2. 36" Standing films
3. Bending Films/Push Prone views

a. Clinical Assessment of Deformity:

i. Sagittal Plane:

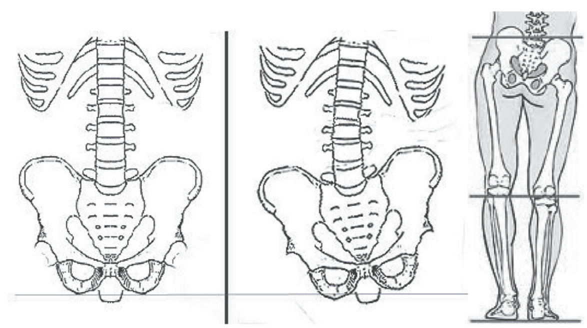
1. Pelvic-femoral axis/Lumbosacral Spine/ Cervicothoracic Spine:
Contractures at the hips may contribute significantly to global imbalance of the spine without any change in the regional or segmental shape of the spine (Figure 1). Flexion of the knees may compensate for sagittal malalignment and therefore care must be taken to examine the patient with knees fully extended.



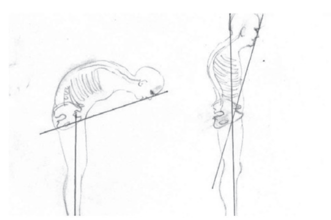
In the sagittal plane, the influence of a hip flexion contracture may be eliminated by examining the patient in the sitting position. A differentiation between spinal deformity that is primarily from the lumbosacral region and deformity primarily from the cervicothoracic region may be made by examining the patient in the supine position. Patients with primary lumbosacral deformity may be able to lie with shoulders flat due to retroversion of the pelvis. In contrast, in the patient with a primary cervicothoracic deformity, the shoulders will remain elevated from the table even in the supine position.

2. Chin-Brow to Vertical Axis:
An assessment of horizontal gaze and the position of the chin-brow axis to the vertical line is an important functional parameter in the clinical assessment of the patient with fixed sagittal plane deformity.

3. Coronal Deformity
Recognition of leg length discrepancy compared and pelvic obliquity is critical for preoperative planning.
Patients with a true leg length discrepancy may require shoe lift or leg length procedure if the spine is normalized to the pelvis post-operatively.
Accomodation of leg length discrepancy with incomplete correction of pelvic tilt may be a pre-operative planning consideration.
Patient choice regarding options for realignment is important for setting expectations regarding post-operative alignment.

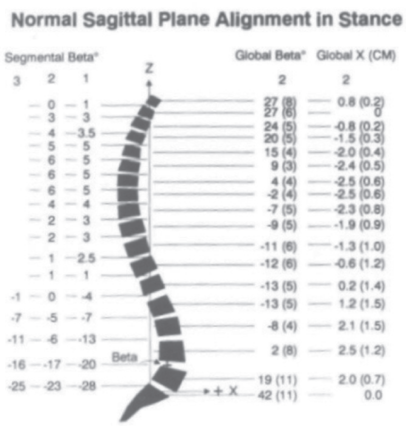


4. Rib-Pelvis Relationship:
The position of the ribs relative to the pelvis is a final consideration in the patient with fixed sagittal plane deformity. Approximation of the ribs and pelvis is an important cause of pain and respiratory and gastrointestinal dysfunction in patients with severe fixed sagittal plane deformity.



b. Radiographic Assessment of Deformity:
Standing 36" PA and Lateral radiographs of the spine are the most important tool in measuring spinal alignment. The patient position is an important consideration in standardizing radiographic measures. The recommended position for an assessment of coronal deformity is a standing film with feet at shoulder width apart, arms at the side and the pelvis level. For the assessment of sagittal alignment, radiographs most accurately and reproducibly reflect sagittal balance with the hips and knees fully extended and the arms at 30degrees forward flexion and the PIP joint in the clavicular fossa.

i. Global Balance:
Global balance of the spine is measured using a plumb line technique to assess the position of the center of C7 to the pelvis. Global balance is influenced by the contour of the spine as well as extraspinal considerations including pelvic obliquity and hip and knee flexion.



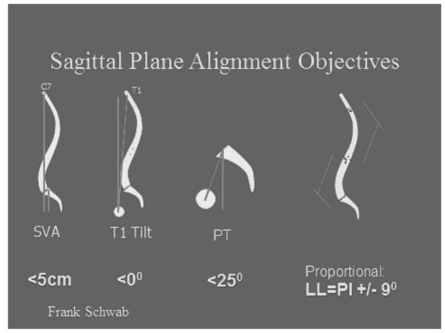
ii. Regional Balance:
Regional balance is measured as the contour of the spine over several segments. Specific regional balance may be defined for the cervical, thoracic, thoracolumbar and lumbar regions. Measurement of regional balance permits a localization of deformity within the spine.

iii. Segmental Balance
Segmental balance is measured as the angle between adjacent segments, and is not influenced by compensation in other areas of the spine. Measurement of segmental balance is most useful in post-traumatic deformity, and short/sharp curves.

3. How Much Correction is Needed?

The amount of correction needed is determined by the goals of deformity correction. Measurable goals in planning correction of deformity include:

a. Restoration of Global Balance
   i. Coronal
   ii. Sagittal
b. Restoration of segmental anatomy (intervertebral disc trapezoidal deformity)
c. Correction of Chin-brow to vertical angle
d. Shift of Line of Weight-bearing posterior to the osteotomy sites.

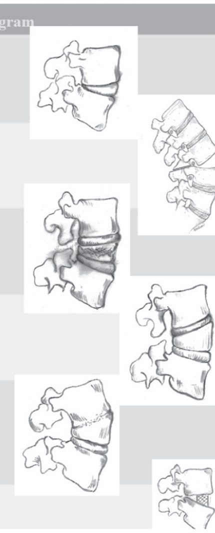


Pre-operative Planning:

1. Assess rigidity of deformity:
   a. Supine Bending Films
   b. Push Prone Films
   c. Extension over a bolster
2. Determine level of intended ostetomies:
   a. Apex of the deformity
   b. Position of the Conus
   c. Preserving at least 3 caudad points of fixation
3. Trigonometric Method:
4. Modeling and Computer-assisted planning:

Spectrum of Posterior-based osteotomies

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



Guidelines for Deformity Correction

Ponte Osteotomy	8-10 degrees per osteotomy 1 degree/mm of posterior resection
Smith-Peterson Osteotomy	10-15 degrees- dependent upon anterior column osteoclasis
Transpedicular wedge	

resection osteotomy:	30-45 degrees per osteotomy
Vertebral Column Resection	60+ degrees and trunk translation

Operative Techniques:
Putting A Plan into Action

1. Combined Anterior and Posterior Surgery
   a. Most useful for patients with fixed obliquity at L4 to S1
   b. Importance of balance of Fractional Curve with thoracolumbar curve
2. Posterior-based Osteotomies: Ponte and Smith-Petersen
   a. Posterior-based facet resection osteotomies may require angular correction techniques for coronal plane deformity correction.
   b. If the shoulder alignment is congruent with the convexity of the deformity then angular correction may permit restoration of shoulder balance.
   c. Incongruity of shoulder alignment with convexity of deformity may require a vertebral column resection for trunk balance
   d. See Figure 1 above
3. Three Column Osteotomies
   a. Three column osteotomies including an asymmetric PSO and vertebral column resection may permit trunk translation and simultaneous correction of coronal and sagittal plane alignment.
   b. Dissociation of the lumbar and thoracic spine at the apex of deformity may permit complex realignment of sagittal, coronal and rotational deformity.
   c. Preoperative planning including biplanar trigonometric calculations is important for estimating resection lengths and volumes
   d. Intraoperative radiographs with assessment of pelvis alignment is important for assessment of final alignment of the spine

Case Examples:

Notes

Case Presentations: Adults Thoraco-Lumbar, Lumbar Sagittal Deformities

Stephen J. Lewis MD, MSc, FRCS(C)
Toronto Western Hospital, University of Toronto
Toronto, Canada

The understanding of global sagittal alignment and balance has greatly improved over the past number of years. The key concepts of sagittal plumb line, pelvic incidence, sacral slope, and relationships between lumbar lordosis and the pelvic parameters have helped surgeons tailor procedures to match their patients' needs.

Posterior based spinal osteotomies are the main procedures performed to restore sagittal alignment. Kyphotic deformities can either be addressed by anterior column lengthening, by posterior column shortening, or a combination of the two. When the anterior column is mobile, there are options for anterior lengthening, however, rigid anterior columns are best managed through posterior based shortening procedures.

Smith Petersen (SPO) or Ponte Osteotomies

Resection of the facets joints following laminotomy with posterior compression can provide up to 10° of sagittal plane correction in the presence of a mobile disc. The terms are often used interchangeably, however, Ponte osteotomies are performed through mobile spines and SPO were originally described through a fused spine. In either case, the osteotomy is quite effective of providing small amounts of correction. They can be used at one or more levels depending on the desired correction and can be used in combination with other osteotomies if greater correction is required. They can be used in the setting of scoliosis, where the release of the facets can allow for better correction of both the sagittal and coronal plane deformities.

Pedicle Subtraction Osteotomies (PSO)

The PSO is the main osteotomy for sagittal plane deformities. It is a posterior based closing wedge osteotomy, where the pedicles are removed along with the superior facet to provide an enlarged foramen to accommodate the two exiting nerve roots. It can be performed safely at most levels below the C6 (where the vertebral arteries begin) and provide from 20° correction in the thoracic spine to 35 to 40° of correction in the lumbar spine. The osteotomy is accomplished by first performing a laminectomy, usually at the intended level and the levels adjacent, and then isolating the pedicle from its bony attachments. These attachments include the transverse processes, the lamina, the pars, and the superior facets. The posterior wall of the vertebral body is then removed, followed by a triangular decancellation of the body. Posterior compression then closes the osteotomy, preferably with lateral bone contact to aide in fusion.

The osteotomy can be modified depending on the needs. If some coronal correction is desired, more bone is resected from the convexity than the concavity. The differential between the posterior and anterior resections will determine the amount of kyphosis correction that will be obtained.

PSO Variants

If greater correction is indicated, the bony resection can be extended proximally to include the proximal disc space. This will have the advantage of providing anterior bony contact across the osteotomy to promote fusion as well as provide greater angular correction. It is particularly useful in deformities secondary to trauma or infection that have significant destruction of the proximal endplate and disc space.

Vertebral Column Resection (VCR)

Resection of the entire posterior elements, vertebral body and adjacent discs can provide the needed mobility to achieve greater deformity correction in multiple planes. Anterior column support in the form of a cage or structural bone graft is required to prevent over shortening and to direct the amount of sagittal plane correction desired. It is particularly useful in severe scoliotic deformities where removing the apical vertebra and shortening of the apex will permit greater overall correction. In non-fused spines, corrections of greater than 60° can be achieved. Careful protection of the mediastinal structures and neural elements are required.

Decision-Making

In this session, we will review the decision making process in determining the appropriate osteotomies and correction maneuvers required for the different cases. Discussions will center around location and type of osteotomy, technical pearls, neuromonitoring and how to manage changes, dealing with previous implants, osteotomy closing techniques, and methods to maximize fusion rates across the osteotomy.

Notes

Spinal Deformity in Myelomeningocele

Course Co- Chairs:

Peter G. Gabos, MD & Muharrem Yazici, MD

Faculty:

Patrick Cahill, MD; Robert H. Cho, MD; Haemish A. Crawford, FRACS;
Lawrence L. Haber, MD; Amer Samdani, MD; Kit M. Song, MD, MHA

This course is supported, in part, by a grant from

DePuy Synthes SPINE

COMPANIES OF Johnson & Johnson

Spinal Deformity in Myelomeningocele

Co- Chairs: Peter G. Gabos, MD and Muharrem Yazici, MD

1:30 – 1:40 pm	**Introduction: Etiology and the Developmental Embryology of Myelomeningocele** *Lawrence L. Haber, MD*
1:40 – 1:50 pm	**How is the Incidence and Epidemiology of Myelomeningocele Different Globally?** *Robert H. Cho, MD*
1:50 – 2:00 pm	**How Do the Indications for Surgical Intervention Differ Globally?** *Muharrem Yazici, MD*
2:00 – 2:15 pm	**Discussion**
2:15 – 2:30 pm	**Pre- and Post-Operative Techniques for Maximizing Soft Tissue Coverage After Spinal Deformity Correction** *Haemish A. Crawford, FRACS*
2:30 – 2:45 pm	**Techniques for Handling the Abnormalities of the Neural Elements in Myelomeningocele** *Amer Samdani, MD*
2:45 – 3:00 pm	**Surgical Treatment of Scoliosis: What Techniques are Available Worldwide?** *Peter G. Gabos, MD*
3:00 – 3:15 pm	**Discussion**
3:15 – 3:30 pm	**Surgical Treatment of Kyphosis: What Techniques are Available Worldwide?** *Kit M. Song, MD, MHA*
3:30 – 3:45 pm	**Management of Postoperative Complications, Infection and Wound Complications** *Patrick Cahill, MD*
3:45 – 4:15 pm	**Case Presentations: Three Cases Including Kyphectomy, Scoliosis Correction, and a Major Complication** *Patrick Cahill, MD, Haemish A. Crawford, FRACS, Lawrence L. Haber, MD*
4:15 – 4:30 pm	**Discussion**

Origins of Myelomeningocele

Lawrence Haber, MD
University of Mississippi Medical Center
Jackson, Mississippi, USA

Epidemiology

Neural tube defects (NTD) 0.5-1.0/1000 births, incudes exposed spinal cerebral neural tissue.

Decreased form 5.9/1000 (CDC) from folic acid/B12 Supplementation

Worldwide phenomenon.

Higher rates in Northeast US, northwest British Isles, Hispanics

Rates vary with accessibility to prenatal care.

15 fold increase in death in the first year of life

9-10 % mortality rate first year of life, includes anencephaly.

Embryology

Neurulation 18-28 days-formation of the neural tube occurs during this process by folding of the neural plate.

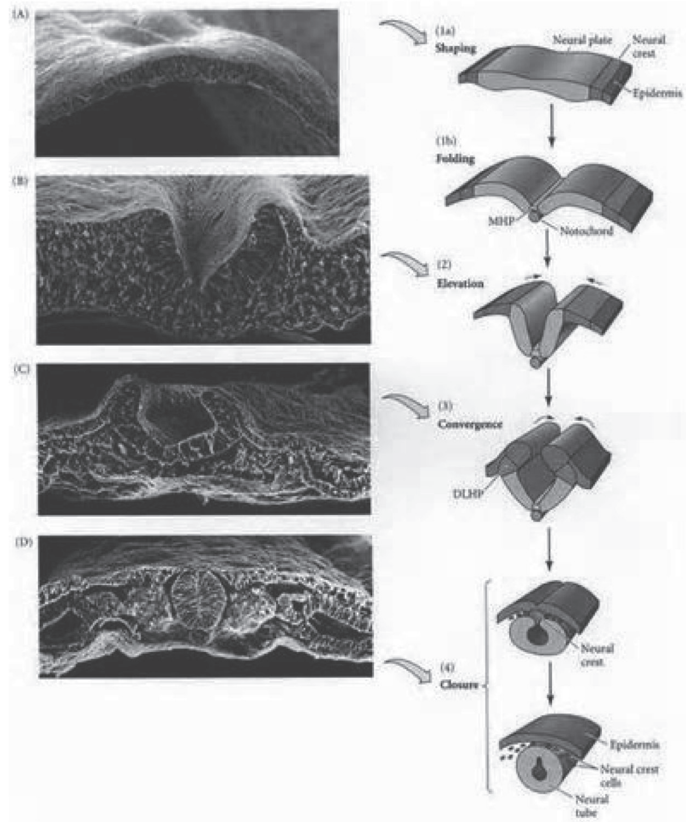
Neural tube closure starts day 22 and extends proximal and distal to complete with closure of the posterior neuropore by day 25-27.

Closure begins in the hind brain and cervical region and spreads bidirectionally and ends at the sacral neuropore around S2. Distal sacral levels close by a different process, canalization.

Canalization follows neurulation-Undifferentiated cells from the primitive streak form the caudal cell mass. This forms the conus, cauda equine and filum terminale.

Canalization ends around day 43-48 with formation of the ventriculus terminalis near the coccyx

Retrogressive differentiation continues until 3 months post gestational and includes ascension of the conus to its normal position.



Etiology

Primary failure of closure of neural tube or secondary rupture of rapidly growing central canal.

Does not follow simple Mendelian genetics. Few multigenerational families.

Recurrence rate sibling 2-5% (50 fold more common than general population).

Likely a multifactorial polygenic disease.

Much focus on genes involved in folic acid metabolism, hyperglycemia and obesity.

Rat studies suggest that genetically predisposed rats rates can be decreased with Folic acid/B12 supplementation but that non susceptible rats do not develop the disease even with severe folic acid/B12 deficiency

Non genetic factors include Valproic acid, carbamazepine, fumonisim (antifugal), trimethoprim (antibiotic)-May be that these block folate metabolism. Any condition that causes Folate or B12 deficiency.

Conclusions

Neural tube defects come from failure of closure of the neural tube early in gestation or a secondary rupture due to a rapidly expanding central canal.

This is a complex disease with many contributing factors.

Most affected individuals likely have a permissive genotype as well as insufficient B12/Folate intake

Vitamin B12 and folic acid supplementation does decrease rates of neural tube defects especially in susceptible individuals.

References

Capp A, Greene, N. Genetics and development of neural tube defects. J.Pathol 220:217-230, 2010

Hertzler D, Depowell J, Stevenson C, et al. Tethered cord syndrome: a review of the literature form embryology to adult presentation. Neurosurg Focus 29 (1): 1-9, 2010.

Wilson A, Platt R, Qing W, et Al. A common variant in methionine synthase reductase combined with low cobalamin (vitamin B12) increases risks for spina bifida. Molecular Genetics and Metabloism 67, 317-323, 1999

Leonard J, Shah M, Kaufman B. (2011)Congenital Intraspinal Anomalies: Spinal Dysraphism-Embryology, Pathology and Treatment. In The Textbook of Spinal Surgery, Third edition (1149-1178). Phlidelphia PA, Lippincott Williams and Wilkins

Smith J L, Schoenwolf G C. Further evidence of extrinsic forces in bending of the neural plate. J. Comp. Neurol. 1991;307:225–236.

Notes

How is the Incidence and Epidemiology of Myelomeningocele Different Globally?

Robert H. Cho, MD
UCLA Clinical Assistant Professor
Pediatric Orthopedic Surgeon
Shriners Hospital for Children
3160 Geneva St.
Los Angeles, CA 90020 USA
P: (213) 388-3151

Introduction

- The observed incidence of myelomeningocele has changed dramatically over the last four decades for many reasons
  - Folic acid supplementation
  - Early screening and recognition
  - Elective termination
- True incidence may be difficult to measure because of lack of registries, or incomplete registries
- The *orthopedic* prevalence has possibly increased because of improvements in medical care leading to increased survival

History

- 1950's—survival rate of ~10%
  - CNS infections
  - Hydrocephalus
  - Older children – renal dysfunction
- 1960's – improvement of survival
  - Holter valves to shunt hydrocephalus
  - Use of antibiotics
  - Elective C-section
  - Improved urinary care
- 1970's – Lorber's criteria
  - Predicted adverse result despite surgical treatment
    - ◊ Severe paraplegia
    - ◊ Gross macrocephaly
    - ◊ Severe kyphosis/scoliosis/birth anomalies
    - ◊ Major birth trauma
- 1980's – Medical advances
  - Discovery of folic acid as major contributor to prevent myelomeningocele
  - Improved prenatal screening
- 1990's/2000's/2010's – fetal (in utero) repair[1]
  - Patients who had in utero repair were half as likely to need VP shunt
  - Chiari malformation less common

* Motor skills markedly improved compared to postnatal repair
* Clinical trial closed after interim analysis of improved outcomes in the fetal repair group

Prenatal Screening

- Serum alpha fetoprotein
  * High false positive rate
  * Only detects ~75% of NTD's
  * If elevated, amniocentesis indicated (amniotic AFP and acetylcholinesterase)
- Ultrasound
  * Three criteria to determine myelomeningocele
    - ◊ Concavity of frontal bones
    - ◊ Ventriculomegaly
    - ◊ Chiari II malformation
  * Macrocephaly determined to be associated with poor outcomes[2]
  * Highly variable sensitivity/specificity

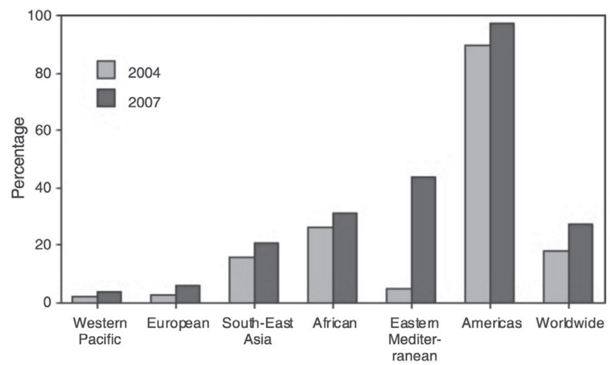
Folic Acid Supplementation

- 1988: Mulinare et al. discovered use of multivatimins in periconceptional period decreased risk of neural tube defects[3]
- 1989: Milunsky et al. identified that folic acid in particular (not multivitamin use) decreased incidence of myelomeningocele [4]
- 1993: Werler et al. found a 60% decrease in relative risk with 0.4 mg folic acid intake during periconceptional period[5]

Fortification programs started in many countries

- 1997 – Costa Rica: fortification of corn and wheat flour with folic acid
  * 74% reduction of NTD's[6]
- 1998 – USA: cereal grains fortified with folic acid
  * Decrease in incidence of 26% noted from 1995-1996 to 1999-2000[7]
- 2007 – over 50 countries have fortified foods with folic acid[8]

FIGURE. Percentage of wheat flour processed in roller mills that was fortified — worldwide and by World Health Organization (WHO) region, 2004 and 2007



Incidence in United States

- Varies significantly
  * 1983-1990 ("pre-folic acid era"): 4.4-4.6 per 10000 live births
    - ◊ Highest rates in East Coast, specifically Appalachia
    - ◊ Lowest rates on West Coast
  * 2005: 1.8 per 10000[9]
  * Seattle[10]
    - ◊ 1981: 5 per 10000 live births
    - ◊ 2001: 0.5 per 10000 live births
  * Race matters
    - ◊ Hispanic descent has the highest rate of NTD's, followed by whites, blacks, then Asians[11]
- Socioeconomic status
  * Lower SES correlates directly with higher incidence of myelomeningocele[12]

Great Britain[13]

- Large decrease in incidence over time
  * 1970: 32 per 10000 live births
  * 1997: 1 per 10000 live births
- Large increase in elective termination rate in NTD pregnancies
  * 1970: 0.2 per 10000
  * 1997: 6.6 per 10000

Japan[14]

- Incidence has not changed over time
  * 1985: 4.3 per 10000 total births
  * 1995: 4.3 per 10000 total births
  * 2005: 4.7 per 10000 total births
- Multiple factors hinted at lack of success

* Failure to educate populace on importance of folic acid during pregnancy
* Reluctance of mothers to take supplements during pregnancy
* Increase in fast food and neglect of traditional Japanese diet

Iran

- 16 per 10000 live births[15]
- Only 24% detection rate from ultrasound[16]
    * Poor or outdated equipment
    * Inadequately trained technicians

South Africa[17]

- Approximately 2.5x more risk for whites than blacks in South Africa for NTD
    * Whites: 25.6 per 10000 total births
    * Blacks: 9.5 per 10000 total births
    * Whites tended to be from higher socioeconomic areas, indicating genetic factors possibly overshadow nutritional factors

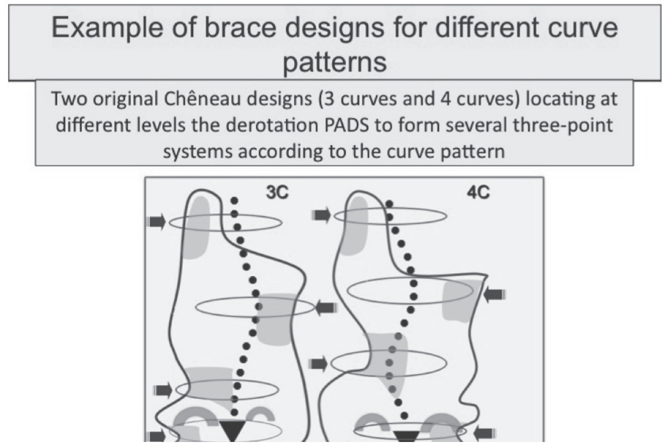
Denmark[18]

- No differences noted after initiation of folic acid supplementation (1997), likely secondary to maternal noncompliance
- Improvements in prenatal ultrasound (2004) increased prenatal elective termination rates, leading to decreased incidence

Netherlands[19]

- Considerations for euthanasia in newborns
    * Predicted extremely poor quality of life
    * Predicted lack of self sufficiency
    * Predicted inability to communicate
    * Expected hospital dependency
    * Long life expectancy
- Euthanasia in newborns considered if Groningen Protocol followed

Incidence per 10000 total births from 8 countries[20]



(Endnotes)

1 Adzick NS, Thom EA, Spong CY, Brock JW 3rd, Burrows PK, Johnson MP, Howell LJ, Farrell JA, Dabrowiak ME, Sutton LN, Gupta N, Tulipan NB, D'Alton ME, Farmer DL; MOMS Investigators. A randomized trial of prenatal versus postnatal repair of myelomeningocele. N Engl J Med. 2011 Mar 17;364(11):993-1004.

2 Brumfield CG, Aronin PA, Cloud GA, Davis RO. Fetal myelomeningocele. Is antenatal ultrasound useful in predicting neonatal outcome? J Reprod Med. 1995 Jan;40(1):26-30.

3 Mulinare J, Cordero JF, Erickson JD, Berry RJ. Periconceptional use of multivitamins and the occurrence of neural tube defects. JAMA 1988;260(21):3141–5.

4 Milunsky A, Jick H, Jick SS, Bruell CL, MacLaughlin DS, Rothman KJ, et al. Multivitamin/folic acid supplementation in early pregnancy reduces the prevalence of neural tube defects [see comments]. JAMA 1989;262(20):2847–52.

5 Werler MM, Shapiro S, Mitchell AA. Periconceptional folic acid exposure and risk of occurrent neural tube defects. JAMA. 1993 Mar 10;269(10):1257-61.

6 Chen LT, Rivera MA. The Costa Rican experience: reduction of neural tube defects following food fortification programs. Nutr Rev. 2004 Jun;62(6 Pt 2):S40-3.

7 Centers for Disease Control and Prevention (CDC). Spina bifida and anencephaly before and after folic acid mandate— United States, 1995–1996 and 1999–2000. MMWR Morb Mortal Wkly Rep 2004;53:362–365.

8 G. Maberly, L. Grummer-Strawn, M. E. Jefferds et al., "Trends in wheat-flour fortification with folic acid and iron— worldwide, 2004 and 2007," Morbidity and Mortality Weekly Report, vol. 57, no. 1, pp. 8–10, 2008.

9 Centers for Disease Control, Prevention. Use of supplements containing folic acid among women of childbearing age–United States, 2007. MMWR. 2008;57(1):5–8.

10 Shurtleff DB. Epidemiology of neural tube defects and folic acid. Cerebrospinal Fluid Res. 2004 Dec 10;1(1):5.

11 Canfield MA, Marengo L, Ramadhani TA, Suarez L, Brender JD, Scheuerle A. The prevalence and predictors of anencephaly and spina bifida in Texas. Paediatr Perinat Epidemiol. 2009 Jan;23(1):41-50.

12 Wasserman CR, Shaw GM, Selvin S, Gould JB, Syme SL. Socioeconomic status, neighborhood social conditions, and neural tube defects. Am J Public Health. 1998 Nov;88(11):1674-80.

13 Morris JK, Wald NJ. Quantifying the decline in the birth prevalence of neural tube defects in England and Wales. J Med Screen. 1999;6(4):182-5.

14 Sumiyoshi Y. How do we react on folic acid deficiency? Brain Spinal Cord 2007; 14: 1–3.

15 Ketabchi SE, Ghodsi SM, Nejat F: Incidence of gross nervous system anomalies in newborns at two obstetric centers in Tehran. J of medical council of Iran 2001, 18(4):277-281.

16 Kazmi SS, Nejat F, Tajik P, Roozbeh H. The prenatal ultrasonographic detection of myelomeningocele in patients referred to Children's Hospital Medical Center: a cross sectional study. Reprod Health. 2006 Jul 18;3:6.

17 Buccimazza SS, Molteno CD, Dunne TT, Viljoen DL. Prevalence of neural tube defects in Cape Town, South Africa. Teratology. 1994 Sep;50(3):194-9.

18 Clemmensen D, Thygesen M, Rasmussen MM, Fenger-Grøn M, Petersen OB, Mosdal C. Decreased incidence of myelomeningocele at birth: effect of folic acid recommendations or prenatal diagnostics? Childs Nerv Syst. 2011 Nov;27(11):1951-5.

19 Verhagen AA, Sauer PJ. End-of-life decisions in newborns: an approach from The Netherlands. Pediatrics. 2005 Sep;116(3):736-9.

20 Kondo A, Kamihira O, Ozawa H. Neural tube defects: prevalence, etiology and prevention. Int J Urol. 2009 Jan;16(1):49-57.

Notes

How Do the Indications for Surgical Intervention Differ Globally?

Muharrem Yazici, MD
Hacettepe University
Ankara, Turkey
mimyazici@gmail.com

Modern world

- Birthrate of children with MMC is quickly decreasing
  - Preventive medicine
  - Prenatal screening
  - Option to terminate

Undeveloped countries

- While MMC birthrate is not decreasing, incidence of children requiring orthopedic care is low
  - Neonatal deaths
    - Sepsis
    - Limited resources of pediatric neurosurgery Inability to effectively control ICP
  - Infancy
    - Urinary problems
    - Systemic infections

Increased incidence of children seeking orthopedic treatment

- Negligent use of routine folic acid
- Insufficient prenatal screening
- Rejection of abortion due to religious/moral causes
- High-quality neonatal care and effective pediatric neurosurgical intervention
  - Early closure
  - Early shunting
  - Effective management of urinary incontinence
  - Education of family
    - CIC-clean intermittent catheterization
    - Skin care

Difference between countries

- Factors related to the patient
- Factors related to social status and peripheral support
- Factors related to living environment
- Factors related to surgery
  - Infrastructure
  - Technique
  - Implant
  - Cost

Case example: Low thoracic or upper lumbar level paraplegic MMC

- Ideal scenario for adult life
    * Relatively long (as much as possible) and aligned spine,
        - ◊ White-collar job
        - ◊ Electrical wheelchair user
        - ◊ Cushioned sitting surface suitable for wheelchair and other surfaces
        - ◊ Hand-controlled car
        - ◊ Wheelchair-friendly environment at home and at work
        - ◊ Self-catheterization training, early and effective intervention for gastrointestinal and urologic problems

Ironically, if patients in a country do not have these medical, social and economic resources, they do not reach the age at which spinal deformity surgery is required.

If most of these resources can be provided in a country, it usually means that everything that is medically necessary can be done. In this case, no serious discrepancies in indications are expected.

Performing surgery to correct spinal surgery and achieving an aligned spine does not mean the patient has been treated.

Before making the incision, if preparation for the following is not sufficient ….

- Implants capable of dealing with osteoporotic and disfigured vertebrae
- Experienced and creative plastic surgery team for possible skin problems
- Infection specialist to deal with postop infections, a health systems which can provide the suitable antibiotics for a suitably long period of time
- Revision strategies prepared to solve problems related to implants and nonunion
- Insurance system that covers a lengthy treatment period and repetitive operations
- ...attempting intervention in these patients is not a prudent or effective course of action.

Notes

Soft Tissue Coverage in Myelomeningocoele Spinal Surgery

Haemish A. Crawford, FRCS
Paediatric Spinal and Orthopaedic Surgeon
Starship Children's Hospital
Auckland, New Zealand
hcrawford@abjs.co.nz

One of the most challenging aspects of spinal surgery in myelomeningocoele patients is the management of the soft tissues. Regardless of how perfect the correction of the deformity is there needs to be a nice closure of the soft tissues to enhance healing and help prevent infection.

The quality of the soft tissue varies between patients. Kyphotic patients can have skin adherent to bone and very little paraspinal musculature. The extent of the defect at birth and the initial closure techniques will also determine future soft tissue quality.

Considerations in planning soft tissue management:

1. Plastic surgeon advice
2. Posterior +/- anterior approach
3. Previous incisions
4. Nutrition
5. Skin condition (acne, pressure areas, infection, thickness …)
6. Potential for skin expander insertion pre spinal correction
7. Low profile spinal implant selection
8. Rotational flaps

Pre operatively it is advisable to have the patient consult with a Plastic Surgeon who can be involved in the surgery as well. Consideration at this stage can be given to skin expander use. Also the incisions can be planned, skin relieving incisions considered, potential rotational flaps designed, and postoperative complications thought about. If necessary it is very helpful to have the plastic surgeon present in the OR when starting the spinal surgery and then at the end to assist during closure.

In cases of severe soft tissue compromise posteriorly or chronic maceration and infection of the skin an anterior only approach may be the most advisable.

Again soft tissue compromise must be considered for the approach as the child may have had a MACE, a feeding tube or a peritoneal shunt inserted previously. An anterior combined with a posterior approach is often the best way to manage the spinal deformity and can help with postoperative soft tissue management. The anterior surgery can be a multilevel discectomy with or without instrumentation. If the posterior wound becomes chronically infected and requires removal of the posterior instrumentation to get soft tissue closure and healing then at least there is some anterior support and fusion.

Previous incisions may determine the surgical incision. A midline approach is preferable however the use of previous incisions close to the midline may devascularise a smaller area. Often an area of devitalised soft tissue will need to be excised.

To prevent infection and promote healing the myelomeningocoele patient should be in the best health prior to surgery. This includes maximising the nutrition preoperatively and then good perioperative nutrition. This often involves nasogastric supplementation and parenteral feeding.

The skin condition preoperatively must be optimised. Any degree of infection needs to be treated with appropriate antibiotics. Pressure areas need to be minimised by custom seating. Acne in the older patients needs to be minimised.

Skin expanders are extremely useful especially in severe kyphotic deformity. We have used them in over 12 patients with excellent results. The skin needs to be in reasonably good condition before insertion to minimise the infection risk. The skin expanders are best inserted through lateral incisions away from the midline scarred area. The incisions for the insertion should also be carefully planned, as they may need to be incorporated into future incisions for soft tissue flaps. They need to be inserted approximately 6 months before the planned spinal surgery as in our study the average length of time from insertion to definitive surgery was 140 days. The expanders are injected with saline through their portals weekly.

Implant selection and surgical technique needs to be carefully considered. Bulky implants both in width and height can make soft tissue closure more difficult.

Rotational flaps may be necessary if primary closure is under too much tension or there is skin break down in the perioperative period. Relieving skin incisions can be made laterally to relieve tension off the suture line. These incisions can result in defects requiring split skin grafting. Rotational musculocutaneous flaps usually utilise buttock and hip tissue. Free tissue transfer is rarely required.

Ideally treat these myelomeningocoele patients early

1. Less obese
2. Less pressure problems
3. Smaller correction required and maybe less metalware required
4. Less acne

Summary

1. Careful assessment of soft tissues is mandatory in spinal surgery on myelomeningocoele patients
2. Get a plastic surgeon involved who can be available on the day of surgery as well
3. Have a closure plan if the suture line is under tension
    a. Relieving incision
    b. Rotation flap

4. Consider skin expanders in severe kyphotic deformity
5. Anterior surgery alone is an option when severe soft tissue deficiency exists

Notes

Techniques for Handling the Abnormalities of the Neural Elements in Myelomeningocele

Amer F. Samdani, MD
Chief of Surgery
Shriners Hospitals for Children-Philadelphia
3551 North Broad Street, Philadelphia, PA 19140, USA
P: 215-430-4250
F: 215-430-4136

Outline:

Definitions - Indications for surgery - Results of surgery - Fetal surgery

Myelomeningocele (MM) [1]

- 4.5 cases per 10,000 live births
- Characterized by defect in caudal neurulation and closure of the neural tube
- Patients present at birth with many neuroanatomical abnormalities, including
    * Small posterior fossa
    * Chiari II malformation
    * Hydrocephalus
        ◊ Up to 80% of patients undergo placement of a VP shunt

Chiari Malformation

- Chiari I
    * Herniation of cerebellar tonsils below foramen magnum
    * Usually asymptomatic
    * Associated syrinx
- Chiari II
    * Almost exclusively seen in children with MM
    * Herniation of tonsils, vermis, 4th ventrical
- Chiari III
- Chiari IV

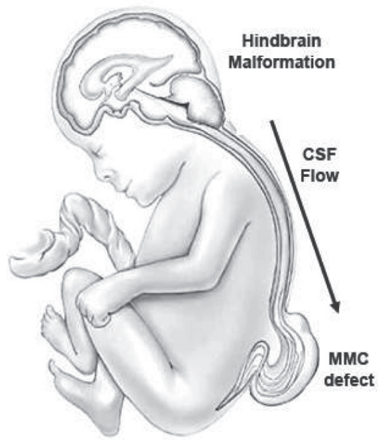
Why do patients with myelomeningocele develop Chiari malformations?

- Chiari in his original description (1892) attributed it to hydrocephalus
- Other theories:
    * Traction theory [2]
    * Low volume posterior fossa [3]

McLone Unified Theory [4]

- Open neural tube in MM does not allow normal distention of ventricular system
- Results in failure of ventricular system to provide development cues to brain and skull

- Hindbrain malformation then obstructs flow and leads to hydrocephalus



Adapted from Sutton et al, 1999 [5]

What are the surgical indications for Chiari decompression in patients with MM?

- Leading cause of death under age two [6]
- Shunt evaluation
  * Increasing pressure on brain stem

Symptoms of Chiari II in Young Children [7]

- Swallowing
  * Cranial nerves 9 and 10
  * Aspiration
- Respiratory
  * Inspiratory stridor
    ◊ Cranial nerve 10
    ◊ Diagnosed with direct laryngoscopy
    ◊ Neurosurgical emergency
- Nystagmus, weak cry

Symptoms of Chiari II in Older Children

- More subtle
  * Weakness
  * Ataxia
  * Occipital headaches

Always consider shunt

Outcomes After Chiari II Decompression

- Resolution of preoperative symptoms
  * Infants: 60% [8]
  * Older children: 80-90% [9]

Tethered Cord [6]

- Conus ends at L1-L2
- Variable etiologies
- Fatty filum
  * Lipoma
  * Myelomeningocele
    ◊ All radiographically tethered BUT
      » 10-30% symptomatic [10]
        - Weakness
        - Gait
        - Pain
        - Scoliosis
        - Worsening of foot and hip deformities
        - Urologic

Outcomes Following Detethering

- Bowman et al, 2009 [11]: 114 patients
- Pierz et al, 2000 [12]: 21 patients
- Herman et al, 1993 [13]: 153 patients
- Fone et al, 1997 [14]: 39 patients
- Reigel et al, 1954 [15]: 262 patients
- Palmer et al, 1998 [16]: 20 patients

Summary of Outcomes

- Pain
  * Best results
  * Up to 100% improved
- Motor and gait
  * Improved in 60-76%
- Urologic
  * Improved in 33-50%
- Scoliosis
  * Equivocal
  * Thoracic level and those with curves > 40° less likely to improve

Detethering in Patients with MM

- Risks
  * Neurologic worsening
  * CSF leak
  * Wound problems
- In a patient who clinically demonstrates no signs of tethered cord syndrome, is a detethering necessary prior to surgical correction

* Samdani et Al., 2010 [17]
  - ◊ Patients N=17
  - ◊ Mean age at surgery 12.4 years
  - ◊ Mean length of follow-up 3.3 years
  - ◊ Untethered 1 year prior to spine correction 0%
  - ◊ New neuro deficit 1 patient
  - ◊ Pre-op major Cobb angle 82°
  - ◊ Post-op major Cobb angle 35°

Syringomyelia

- Etiology
  * Chiari
  * Tethered cord
  * Hydrocephalus
  * Tumor (need MRI with and without gad)
- Size of syrinx
  * Hydromyelia
  * Swelling, spindle, slit
- Present in up to 48% of patients with MM [18]
  * Holocord vs. segmented
- VP shunt
- Consider Chiari decompression or untethering depending on symptomatology

Fetal Surgery for MM Closure [19]

- Performed in utero at 18-25 weeks gestation
- Over 400 patients treated
- Early results suggest:
  * Less severe Chiari
  * Fewer shunts for hydrocephalus
  * No improvement in neurologic outcome
  * Less scarring

Sutton et al, 1999 [5]: "Improvement in Hindbrain Herniation Demonstrated by Serial Fetal Magnetic Resonance Imaging Following Fetal Surgery for Myelomeningocele"

- Case series (n=10)
- Fetal closure at 22-25 weeks gestation
- Similar studies by
  * Bruner et al, 1999 [20]
  * Tulipan et al, 1998 [21]
- Grade 1: visible 4th vent and cisterna magna without cerebellar displacement below foramen magnum
- Grade 2: visible cisterna magna without cerebellar displacement below foramen magnum, no visible 4th vent
- Grade 3: cerebellar displacement below foramen magnum, obliteration PF CSF spaces

Summary

- All patients with MM will have a Chiari II malformation
- Chiari decompression may be urgently needed in young infants
- All patients with MM will have a radiographically tethered cord
  * Only a subset will require detethering
- •Always consider the shunt
  * Pre- and post-op

References

1. Mathews TJ et al: Spina bifida and anencephaly prevalence – United States, 1991-2001. MMWR Recomm Rep 2002;51(RR-13):9-11
2. Penfield W, Coburn DF: Arnold-Chiari malformation and its operative treatment. Arch Neurol Psychiatry 1938;40:328–336
3. Marin-Padilla M, Marin-Padilla TM: Morphogenesis of experimentally induced Arnold-Chiari malformation. J Neurol Sci 1981;50(1):29-55
4. McLone DG and Knepper PA: The cause of Chiari II malformation: a unified theory. Pediatr Neurosci 1989;15(1):1-12
5. Sutton LN et al: Improvement in hindbrain herniation demonstrated by serial fetal magnetic resonance imaging following fetal surgery for myelomeningocele. JAMA 1999;282(19):1826-31
6. McLone DG: Continuing concepts in the management of spina bifida. Pediatr Neurosurg 1992;18(5-6), 254-6
7. Stevenson KL: Chiari Type II malformation: past, present, and future. Neurosurg Focus 2004;16(2):E5
8. Pollack IF et al: Outcome following hindbrain decompression of symptomatic Chiari malformations in children previously treated with myelomeningocele closure and shunts. J Neurosurg 1992;77(6):881-8
9. Oakes WJ et al: Surgical intervention in twenty-nine patients with symptomatic type II Chiari malformations: clinical presentation and outcome. Concepts Pediatr Neurosurg 1988;8:76-85
10. Hudgins RJ, Gilreath CL: Tethered spinal cord following repair of myelomeningocele. Neurosurg Focus 2004;16(2):E7
11. Bowman RM et al: Tethered cord release: a long-term study in 114 patients. J Pediatr Neurosurg 2009;3(3):181-7

12. Pierz K et al: The effect of tethered cord release on scoliosis in myelomeningocele. J Pediatr Orthop 2000;29(3):362-5
13. Herman JM et al: Analysis of 153 patients with myelomeningocele or spinal lipoma reoperated upon for a tethered cord. Presentation, management and outcome. Pediatr Neurosurg 1993;19(5):243-9
14. Fone PD et al: Urodynamic findings in the tethered spinal cord syndrome: does surgical release improve bladder function? J Urol 1997;157(2):604-9
15. Reigel DH et al: Change in spinal curvature following release of tethered spinal cord associated with spina bifida. Pediatr Neurosurg 1994;20(1):30-42
16. Palmer LS et al: Subclinical changes in bladder function in children presenting with nonurological symptoms of the tethered cord syndrome. J Urol 1998;159(1):231-4
17. Samdani AF et al: A patient with myelomeningocele: is untethering necessary prior to scoliosis correction? Neurosurg Focus 29(1):E8, Jul. 2010
18. La Marca F et al: Presentation and management of hydromyelia in children with Chiari type-II malformation. Pediatr Neurosurg 1997;26(2):57-67
19. Sutton LN: Fetal surgery for neural tube defects. Best Pract Res Clin Obstet Gynaecol 2008;22(1):175-88, 2008
20. Bruner JP et al: Fetal surgery for myelomeningocele and the incidence of shunt-dependent hydrocephalus. JAMA 1999;282(19):1819-25
21. Tulipan N et al: Reduced hindbrain herniation after intrauterine myelomeningocele repair: a report of four cases. Pediatr Neurosurg 1998;29(5):274-8

Notes

Surgical Treatment of Scoliosis in Myelomeningocele

Peter G. Gabos, MD
Co-Director, Spine and Scoliosis Center
Alfred I. DuPont Hospital for Children
Wilmington, DE, USA

I. Not "just" Neuromuscular Scoliosis!

While scoliosis in myelomeningocele does share many treatment principles with other types of neuromuscular scoliosis, by its very nature, it presents uniquely different treatment challenges and complexities.

- Anatomic Variations (1)
    * Scoliosis, kyphosis, lordosis
    * Congenital vertebral malformations
    * Absence of posterior elements
    * Subcutaneous dura
    * Altered pedicle trajectory
    * Compromised skin
    * Marked truncal obesity
    * Disuse osteopenia
- Anatomic Variations (2)
    * Chiari malformation
    * Syrinx
    * Tethered cord
    * Diastematomyelia/diplomelia
- Co-Morbidities
    * Shunted hydrocephalus
    * Latex allergy
    * Neurogenic bowel and bladder
    * Bladder augmentation/ACE
    * Thoracic insufficiency syndrome
    * Lower extremity contractures

II. INDICATIONS FOR SURGERY

* Rapidly progressive curvature
* Pulmonary dysfunction/TIS ("marionette sign," diaphragmatic intrusion)
* Decreased sitting tolerance
* Loss of hands-free sitting
* Pressure ulcerations (spine, ischium)
* Effect on pelvic-based lower extremity bracing

- Practice Modifications
    * Antibiotic-impregnated allograft (1500mg vancomycin/320mg gentamicin)

* S2alar-iliac (S2AI) screw fixation
* Posterior lumbar interbody fusion/support (PLIF) at areas of posterior element insufficiency (L5-S1 and L4-L5 minimum)
* Iliac wing osteotomy when needed for pedicle access
* Plastic surgery closure

III. PREOPERATIVE EVALUATION

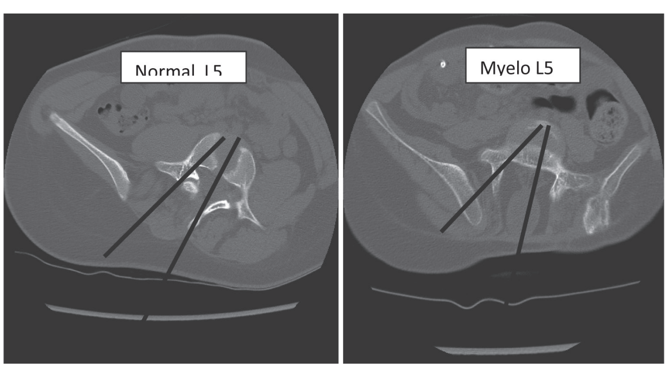
* Characterize all aspects of deformity (physical and radiographic examination)
* Curve flexibility assessments
* Detailed neurologic examination
* Pulmonary evaluation
* Skin evaluation
* Shunt evaluation
* Nutritional assessment
* Mobility assessment
* Truncal obesity
* Lower extremity contractures
* Dentition/overall hygiene
* Social environment

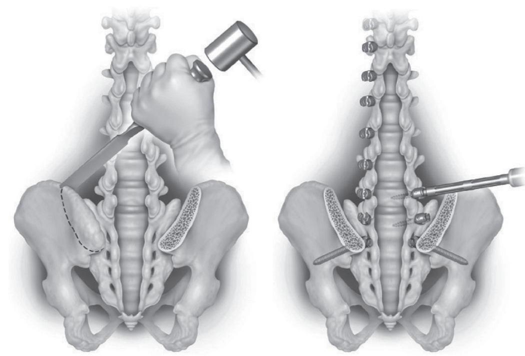
- Radiographic Studies
  * Sitting PA and lateral full-length plain film
  * Supine traction ("pull") film
  * Right and left supine bend film
  * Lateral hyperextension over bolster if kyphotic
  * Shunt study—brain MRI or CT scan if shunt is fractured preop—don't assume "arrested hydrocephalus"!
  * Full-spine MRI
  * Region-specific CT scan with 3D reconstruction (spinal, sacral and pelvic anatomy)
- Pulmonary Evaluation
  * Subjective symptoms
  * "Marionette sign" of Campbell
  * Hemoglobin/hematocrit
  * Pulmonary function testing
  * Radiographic assessment (Space Available for Lung (SAL)/Diaphragm Intrusion Index (DII)
- Skin and Soft Tissue
  * Consultation with Plastic Surgery team
  * Help with planning of incision
  * May dictate how surgical draping is planned
  * Pay attention to skin over PSIS if pelvic screws will be used
  * Gentle handling of skin and soft tissues throughout procedure
- Mobility Assessment
  * Analysis of gait (visual vs. Gait Lab)
  * Assessment of spinopelvic motion with gait
  * Upper extremity use if muscular rotational flaps will be considered (eg. latissimus dorsi)
- Laboratory Studies
  * CBC, PT/PTT, metabolic panel, serum albumin
- Urology Assessment (Alfred I. duPont Hospital for Children Protocol)
  * Urinalysis/ urinary culture and sensitivity (2 weeks prior to surgery)
  * If urinary culture is positive, treat. Repeat 3 days preop. If still positive, and symptomatic, postpone procedure. If asymptomatic, treat IV for 3 days and tailor peri-operative abx.
  * Intra-operative/peri-operative catheter(s) placed by Urologist
  * Intra-operative urinary cultures sent
  * Bladder irrigated with saline/gentamicin solution
  * Re-irrigated POST-positioning to assure patency and access
  * Close attention to urine output during surgery—*watch for clogged catheter* (usually a mucus plug if bladder was reconstructed)
  * *Urosepsis will kill your patient!!*

IV. SURGICAL TECHNIQUES

- **Surgical Approach**
  * Usually posterior-only
  * Anterior release? (plan around previous abdominal procedures/appliances)
  * Pre-op halo traction? (watch shunt!)
  * Osteotomies? (Ponte, wide releases, PSO, VCR)
  * Detethering? (function-dependent)
  * Spinal cord transection?
  * Neuromonitoring? (upper extremity brachial plexopathy)
  * Transfusion management? (cell saver, TXA, etc)
- **Instrumentation/Fusion Principles**
  * Need secure fixation
  * Need screws in areas of deficient posterior elements

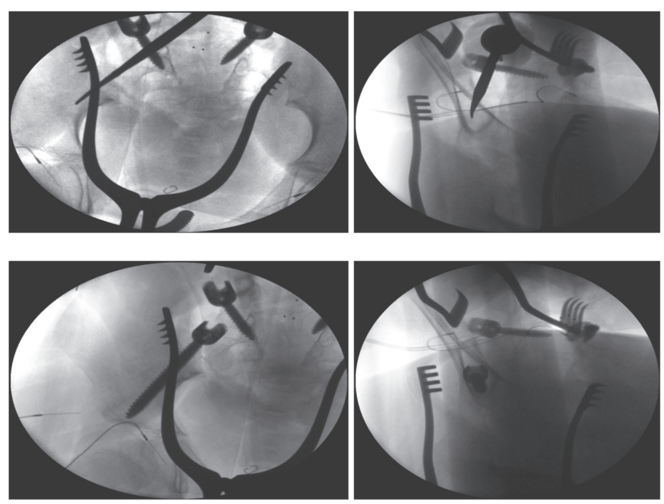
   * Need secure pelvic fixation that isn't prominent
   * Need to maximize surface area for fusion
- **Prior to Incision**
   * Tunneled double lumen subclavian catheter
   * Preoperative Foley placement, irrigation
   * Post-positioning Foley irrigation
   * Pad all soft-tissue prominences
   * Accommodate contractures
   * Hip flexion to decrease lumbar lordosis if needed
   * Femoral/halo traction if needed
   * Pelvic flouroscopic evaluation of unobstructed radiologic access
   * WIDE prep and drape to accommodate any planned (or unplanned) flaps, muscle transfers, etc
- **Surgical Exposure**
   * Careful handling of all soft tissues
   * Work cephalad to caudad over known intact posterior elements
   * Dural sac exposure—establish the "no-fly zone"!
   * Sacro-pelvic exposure
   * Intradural work completed (detethering, etc)
   * Posterior lumbar interbody structural supports placed (L5-S1 always)
- **Instrumentation Sequence**
   * Lower lumbar screws placed first
   * Sacral (S1) screws
   * Sacral alar-iliac (S2AI) screws
   * May need iliac wing osteotomies to place lower lumbar screws due to altered pedicle trajectory (average 30-35 degrees at L5 in myelo)

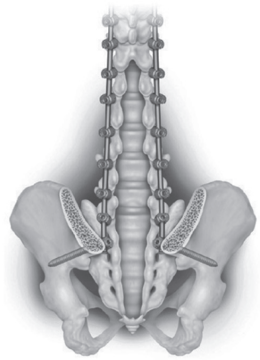




Iliac Wing Osteotomy to gain access to the lower lumbar pedicles may be necessary in cases of marked lumbar lordosis, truncal obesity and altered pedicle trajectory.
From: Gabos, PG. Spinal fusion in myelomeningocele. Neuromuscular Scoliosis Technical Monograph. 2012

- **Pelvic Fixation: Sacral alar-iliac (S2AI) screw pathway[1]**
   * Less prominent fixation (15mm anterior to PSIS screws)
   * Allow in-line rod reduction without the use of lateral connectors





- **Osteotomies**
  * Osteotomy type will affect instrumentation sequence (eg. Ponte osteotomies completed prior to screw placement; screws completed prior to vertebral column resection)
- **Prior to Rod Placement**
  * Radiographic confirmation of screw placement (FlouroScan and/or O-arm CT scan)
  * Local bone graft morselized, mixed with allograft/bonemarrow/antibiotics (1500mg vancomycin, 320mg gentamicin)
  * Rods measured, contoured
  * Facet extirpation, grafting prior to rod placement
- **Correction Principles**
  * Mobilize the spine
  * Load-sharing across all implants
  * Reduction/extended tab screws may be helpful for gradual rod reduction
  * Don't force it! Your screws will pull out.
- **Correction Maneuvers**
  * Depend on surgical goals
  * Cantilever correction with dual rods, linked proximally (great for correction of pelvic obliquity and thoracolumbar/lumbar curvature)
  * Rod rotation
  * Direct vertebral derotation (requires fixed screws (uni- or monoaxial)
  * Distraction/compression for additional coronal and sagittal correction and correction of pelvic obliquity
  * Be cautious with *in situ* rod bending in osteopenic bone
- **Post-Operative Dressings**
  * MUST be *impervious!*
  * Latex-free
  * Closely monitored
  * Changed by YOU (or your designee)

Notes

Kyphosis in Myelomeningocele: Techniques and Methods

Kit M. Song, MD, MHA
Los Angeles, CA, USA

Natural history considerations:

Children born with myelomeningocele (MMC) who do not receive treatment have survivorship to school age of 10%.

- With non-selective closure of the sac and shunting of hydrocephalus, survival rate to young adulthood of 75%.
- Mortality by age 35 = 50%. Respiratory and cardiac events most common cause of mortality.
- Improvements in survivorship largely due to better neurosurgical care and renal care. With in-utero closures and stricter criteria for shunt placements, decreased incidence of hydrocephalus and shunt related problems is being seen. Maternal and fetal risk factors associated with in-utero surgery have limited it's widespread use.
- Declining functional independence has been observed over time. Less than 40% achieve functional independence as young adults.

Kyphosis incidence/natural history:

Kyphosis in (MMC) is a common finding and can be acquired or congenital in nature.

- Thoracic and upper lumbar MMC is most commonly associated with kyphosis deformities
- Newborn kyphosis is seen in 20-50% of patients with MMC.
- Congenital malformations of the spine cause kyphosis in approximately 15% of patients.
- Rates of progression of deformity range from 6° to12° a year

Care and health issues associated with progressive kyphosis:

Several rationales have been widely used to recommend for management of kyphosis deformities in children with MMC.

- Newborn – for closure of the MMC defect with adequate soft tissue coverage
- Loss of neurologic function with progressive deformity
- Skin breakdown over the gibbus
- Sitting difficulties associated with progressive kyphosis
- Diminished FVC secondary to abdominal compression and diaphragm flattening
    - “Marionette's sign” – poor documentation of FVC changes for individual cases and over time
    - Development of “barrel chest” deformity as compensatory strategy
    - Structural correlate – abdominal crowding versus compensatory thoracic lordosis.
    a. Impact of surgery not defined
- Links between progressive deformity and health status impact upon the child are poorly defined. Threshold values associated with the development of any of these rationales have not been established.

Management:

- Non-operative management is believed to be ineffective and bracing is not recommended for most children. In younger children with a flexible deformity, treatment options may be broader and include growing systems. This is, in general uncommon.
- Operative management:
    - Goals:
        - ◊ Seating and sitting improvement – free hands for use
        - ◊ Resolution of skin problems
        - ◊ Optimize respiratory status and development
        - ◊ Stable arthrodesis
    - Risks:
        - ◊ CNS – shunt malfunction and hydrocephalus
            - » Can be acute from intraoperative difficulties
            - » Can be delayed due to altered CSF mechanics
            - » Consider externalization of shunt
        - ◊ Blood loss – high with spinal cord resection
        - ◊ Infection rates – very high
        - ◊ Recurrence of deformity – nonunion rate unknown
        - ◊ Latex allergy – anaphylaxis
        - ◊ Positioning issues secondary lower extremity contractures
- Perio-operative/Intra-operative considerations
    - Advanced imaging to understand deformity, identify neural axis abnormalities
    - Plastic surgery: before, during, after
        - ◊ Tissue expanders is possibility, but muscle coverage better
    - Neurosurgery for management of shunt problems

Surgical Techniques:

- Newborn – kyphosis reduction +/- fusion
    - Good initial correction
    - Gradual recurrence in deformity over time
- Growth sparing systems with stabilization:
    - Beware spinal dysraphisms; tethered cord, diastametomyelia, Chiari malformation
    - Growth modulation – no published reports: overlap with neonatal treatments

- Growing rods: Generally avoided due to skin problems in the midline
- VEPTR: Recent addition for children with flexible kyphosis
  - ◊ Pelvic fixation with Dunn-McCarthy implants
  - ◊ Proximal rib based
- Gravity halo traction with secondary implantation of growth sparing systems – same as above
- Unclear if can avoid later kyphectomy

- Reduction and fusion without vertebrectomy – rarely used due to severity of deformity with soft tissue coverage problems
- Kyphectomy (vertebral resetion) and fusion
  - Preferred method for definitive treatment
  - Anatomical considerations
    - ◊ Obesity
    - ◊ Associated hip contractures: extension and flexion
    - ◊ Aorta/great vessels
    - ◊ Peri-spinous musculature
    - ◊ Spinal cord/CSF flow
    - ◊ Severity of deformity
    - ◊ Distal neurologic function
  - +/- spinal cord resection
    - ◊ Functioning cord versus not
    - ◊ Acute hydrocephalus: Ligation of central canal
    - ◊ Slowly developing hydrocephalus – altered CSF flow and absorption – distal absorption of CSF
    - ◊ Secondary lordosis of thoracic spine
      - » Control of bleeding difficult
      - » Cord resection difficult without proximal laminectomy
    - ◊ Alteration of bladder spasticity – warn patients; not necessarily bad.
  - Infection reduction efforts:
    - ◊ Perioperative antibiotics
      - » Urinary source
      - » Coliforms, gram negatives
      - » Recurrent ulceration/colonization
  - Soft tissue coverage: Muscle mobilization/flap coverage
    - ◊ Presence of decubitus prior to treatment:
      - » Plastic surgical coverage options with resection of decubitus prior to resection and fusion surgery - sequential
      - » Resection and flap coverage – simultaneous, high rate of secondary infection
  - Instrumentation options:
    - ◊ Figure of 8 wiring
    - ◊ Plate fixation – limited if thoracic lordosis
    - ◊ Luque-Galveston
      - » Fackler technique
      - » Dunn-McCarthy technique
      - » Iliac screws/sacral screws
- Aftercare:
  - Very large lever arms if patient obese or mature
  - Bracing options – anecdotal
  - Continuation of antibiotics - anecdotal
  - Surveillance for shunt malfunction due to altered CSF flow

Bibliography

1. Sharrard, W.J., *Spinal osteotomy for congenital kyphosis in myelomeningocele.* J Bone Joint Surg Br, 1968. 50(3): p. 466-71.
2. Eyring, E.J., J.J. Wanken, and M.P. Sayers, *Spine ostectomy for kyphosis in myelomeningocele.* Clin Orthop Relat Res, 1972. 88: p. 24-30.
3. Sharrard, W.J. and J.C. Drennan, *Osteotomy-excision of the spine for lumbar kyphosis in older children with myelomeningocele.* J Bone Joint Surg Br, 1972. 54(1): p. 50-60.
4. Leatherman, K.D. and R.A. Dickson, *Congenital kyphosis in MMC. Vertebral body resection and posterior spine fusion.* Spine (Phila Pa 1976), 1978. 3(3): p. 222-6.
5. Lindseth, R.E. and L. Stelzer, Jr., *Vertebral excision for kyphosis in children with myelomeningocele.* J Bone Joint Surg Am, 1979. 61(5): p. 699-704.
6. Stephen, J.P. and J.G. Bodel, *Luque rod fixation in meningomyelocele kyphosis: a preliminary report.* Aust N Z J Surg, 1983. 53(5): p. 473-7.
7. Christofersen, M.R. and A.L. Brooks, *Excision and wire fixation of rigid myelomeningocele kyphosis.* J Pediatr Orthop, 1985. 5(6): p. 691-6.
8. Heydemann, J.S. and R. Gillespie, *Management of myelomeningocele kyphosis in the older child by kyphectomy and segmental spinal instrumentation.* Spine (Phila Pa 1976), 1987. 12(1): p. 37-41.

9. McMaster, M.J., *The long-term results of kyphectomy and spinal stabilization in children with MMC.* Spine (Phila Pa 1976), 1988. 13(4): p. 417-24.
10. Carstens, C., et al., *Effect of scoliosis surgery on pulmonary function in patients with myelomeningocele.* J Pediatr Orthop, 1991. 11(4): p. 459-64.
11. Kadic, M.A. and A.J. Verbout, *Treatment of severe kyphosis in myelomeningocele by segmental spinal instrumentation with Luque rods.* Acta Orthop Belg, 1991. 57(1): p. 45-51.
12. Paonessa, K.J., et al., *Using tissue expanders in spinal surgery for deficient soft tissue or postirradiation cases.* Spine (Phila Pa 1976), 1991. 16(8 Suppl): p. S324-7.
13. Fromm, B., et al., *Aortography in children with myelomeningocele and lumbar kyphosis.* J Bone Joint Surg Br, 1992. 74(5): p. 691-4.
14. Huang, T.J. and J.P. Lubicky, *Kyphectomy and segmental spinal instrumentation in young children with myelomeningocele kyphosis.* J Formos Med Assoc, 1994. 93(6): p. 503-8.
15. Lintner, S.A. and R.E. Lindseth, *Kyphotic deformity in patients who have a myelomeningocele. Operative treatment and long-term follow-up.* J Bone Joint Surg Am, 1994. 76(9): p. 1301-7.
16. Torode, I. and G. Godette, *Surgical correction of congenital kyphosis in myelomeningocele.* J Pediatr Orthop, 1995. 15(2): p. 202-5.
17. Doers, T., et al., *The progression of untreated lumbar kyphosis and the compensatory thoracic lordosis in myelomeningocele.* Dev Med Child Neurol, 1997. 39(5): p. 326-30.
18. Frank, C.J., J. Brantigan, and J. Cronan, *Bilateral interconnected latissimus dorsi-gluteus maximus muscular cutaneous flaps for closure of subfascial infections in lumbar spinal surgery. A technical note.* Spine (Phila Pa 1976), 1997. 22(5): p. 564-7.
19. McCall, R.E., *Modified luque instrumentation after myelomeningocele kyphectomy.* Spine (Phila Pa 1976), 1998. 23(12): p. 1406-11.
20. Furderer, S., et al., *Sagittal static imbalance in MMC patients: improvement in sitting ability by partial and total gibbus resection.* Eur Spine J, 1999. 8(6): p. 451-7.
21. Geiger, F., D. Parsch, and C. Carstens, *Complications of scoliosis surgery in children with myelomeningocele.* Eur Spine J, 1999. 8(1): p. 22-6.
22. Lalonde, F. and J. Jarvis, *Congenital kyphosis in myelomeningocele: The effect of cordotomy on bladder function.* J Bone Joint Surg Br, 1999. 81: p. 245-9.
23. Sarwark, J.F., *Kyphosis deformity in myelomeningocele.* Orthop Clin North Am, 1999. 30(3): p. 451-5, viii-ix.
24. Dillon, C.M., et al., *Longevity of patients born with myelomeningocele.* Eur J Pediatr Surg, 2000. 10 Suppl 1: p. 33-4.
25. Sponseller, P.D., et al., *Deep wound infections after neuromuscular scoliosis surgery: a multicenter study of risk factors and treatment outcomes.* Spine (Phila Pa 1976), 2000. 25(19): p. 2461-6.
26. Nolden, M.T., et al., *A kyphectomy technique with reduced perioperative morbidity for MMC kyphosis.* Spine (Phila Pa 1976), 2002. 27(16): p. 1807-13.
27. Crawford, A.H., et al., *Neonatal kyphectomy in the patient with myelomeningocele.* Spine (Phila Pa 1976), 2003. 28(3): p. 260-6.
28. Miyamoto, K., et al., *Kyphectomy using a surgical threadwire (T-saw) for kyphotic deformity in a child with myelomeningocele.* Spine (Phila Pa 1976), 2003. 28(10): p. E187-90.
29. Odent, T., et al., *Kyphectomy in myelomeningocele with a modified Dunn-McCarthy technique followed by an anterior inlayed strut graft.* Eur Spine J, 2004. 13(3): p. 206-12.
30. Davis, B.E., et al., *Long-term survival of individuals with myelomeningocele.* Pediatr Neurosurg, 2005. 41(4): p. 186-91.
31. Ozcelik, D., et al., *Soft tissue closure and plastic surgical aspects of large dorsal MMC defects (review of techniques).* Neurosurg Rev, 2005. 28(3): p. 218-25.
32. Preis, K., M. Swiatkowska-Freund, and I. Janczewska, *Spina bifida--a follow-up study of neonates born from 1991 to 2001.* J Perinat Med, 2005. 33(4): p. 353-6.
33. Schoenmakers, M.A., et al., *Spinal fusion in children with spina bifida: influence on ambulation level and functional abilities.* Eur Spine J, 2005. 14(4): p. 415-22.
34. Arnell, K., *Primary and secondary tissue expansion gives high quality skin and subcutaneous coverage in children with a large myelomeningocele and kyphosis.* Acta Neurochir (Wien), 2006. 148(3): p. 293-7; discussion 297.
35. Guille, J.T., et al., *Congenital and developmental deformities of the spine in children with MMC.* J Am Acad Orthop Surg, 2006. 14(5): p. 294-302.
36. Laing, A.J., et al., *Short segment posterior locking cervical plate fixation after kyphectomy for myelomeningocoele-associated kyphosis.* J Spinal Disord Tech, 2006. 19(4): p. 292-4.
37. Ko, A.L., et al., *Retrospective review of multilevel spinal fusion combined with spinal cord transection for treatment of kyphoscoliosis in pediatric myelomeningocele patients.* Spine (Phila Pa 1976), 2007. 32(22): p. 2493-501.
38. Chakraborty, A., et al., *Toward reducing shunt placement rates in patients with myelomeningocele.* J Neurosurg Pediatr, 2008. 1(5): p. 361-5.

39. Cho, A.B., et al., *Treatment of hardware exposure after severe infections in spine surgery with pedicled muscular flaps.* Clinics (Sao Paulo), 2008. 63(2): p. 277-80.

40. Gomez Chavarria, J., A. Cardoso Monterrubio, and E. Garavito Salazar, *[Use of expanders in surgical treatment of kyphosis in patients with myelomeningocele].* Acta Ortop Mex, 2008. 22(3): p. 162-8.

41. Turhan Haktanir, N., et al., *Repair of wide myelomeningocele defects with the bilateral fasciocutaneous flap method.* Turk Neurosurg, 2008. 18(3): p. 311-5.

42. Walick, K.S., et al., *Neuropathic lower extremity pain following Dunn-McCarthy instrumentation.* Spine (Phila Pa 1976), 2008. 33(23): p. E877-80.

43. Woodhouse, C.R., *Myelomeningocele: neglected aspects.* Pediatr Nephrol, 2008. 23(8): p. 1223-31.

44. Bowman, R.M., V. Boshnjaku, and D.G. McLone, *The changing incidence of myelomeningocele and its impact on pediatric neurosurgery: a review from the Children's Memorial Hospital.* Childs Nerv Syst, 2009. 25(7): p. 801-6.

45. Hsieh, P.C., et al., *Posterior vertebral column subtraction osteotomy: a novel surgical approach for the treatment of multiple recurrences of tethered cord syndrome.* J Neurosurg Spine, 2009. 10(4): p. 278-86.

46. Ouellet, J.A., et al., *Pressure mapping as an outcome measure for spinal surgery in patients with myelomeningocele.* Spine (Phila Pa 1976), 2009. 34(24): p. 2679-85.

47. Sponseller, P.D., et al., *Pelvic fixation of growing rods: comparison of constructs.* Spine (Phila Pa 1976), 2009. 34(16): p. 1706-10.

48. Hatlen, T., et al., *Contributory factors to postoperative spinal fusion complications for children with myelomeningocele.* Spine (Phila Pa 1976), 2010. 35(13): p. 1294-9.

49. Piatt, J.H., Jr., *Treatment of myelomeningocele: a review of outcomes and continuing neurosurgical considerations among adults.* J Neurosurg Pediatr, 2010. 6(6): p. 515-25.

50. Samdani, A.F., et al., *A patient with myelomeningocele: is untethering necessary prior to scoliosis correction?* Neurosurg Focus, 2010. 29(1): p. E8.

51. Adzick, N.S., et al., *A randomized trial of prenatal versus postnatal repair of myelomeningocele.* N Engl J Med, 2011. 364(11): p. 993-1004.

52. Flanagan, A., et al., *Activity level, functional health, and quality of life of children with myelomeningocele as perceived by parents.* Clin Orthop Relat Res, 2011. 469(5): p. 1230-5.

53. Hwang, S.W., et al., *Kyphectomy in patients with myelomeningocele treated with pedicle screw-only constructs: case reports and review.* J Neurosurg Pediatr, 2011. 8(1): p. 63-70.

54. Mehta, V.A., et al., *Safety and efficacy of concurrent pediatric spinal cord untethering and deformity correction.* J Spinal Disord Tech, 2011. 24(6): p. 401-5.

55. Murans, G., E.M. Gutierrez-Farewik, and H. Saraste, *Kinematic and kinetic analysis of static sitting of patients with neuropathic spine deformity.* Gait Posture, 2011. 34(4): p. 533-8.

56. Patel, J., et al., *Correlation of spine deformity, lung function, and seat pressure in spina bifida.* Clin Orthop Relat Res, 2011. 469(5): p. 1302-7.

57. Samagh, S.P., et al., *Kyphectomy in the treatment of patients with myelomeningocele.* Spine J, 2011. 11(3): p. e5-11.

58. Schroeder, J.E., et al., *Long-term outcome of surgical correction of congenital kyphosis in patients with myelomeningocele (MMC) with segmental spino-pelvic fixation.* Evid Based Spine Care J, 2011. 2(1): p. 17-22.

59. Helenius, I., J. Serlo, and O. Pajulo, *The incidence and outcomes of vertebral column resection in paediatric patients: a population-based, multicentre, follow-up study.* J Bone Joint Surg Br, 2012. 94(7): p. 950-5.

60. Saadai, P. and D.L. Farmer, *Fetal surgery for myelomeningocele.* Clin Perinatol, 2012. 39(2): p. 279-88.

61. de Amoreira Gepp, R., et al., *Kyphectomy in meningomyelocele children: surgical technique, risk analysis, and improvement of kyphosis.* Childs Nerv Syst, 2013.

Notes

Complications of Spine Surgery in Myelomeningocele

Patrick M. Cahill, MD
Shriner's Hospital for Children
Philadelphia, PA, USA

Spine Surgery in MM

Spinal deformity surgery in MM patients remains problematic in terms of adverse outcomes and complications despite advances in anesthesia, antibiotic prophylaxis, neuromonitoring, implant technology and neuraxis and skeletal imaging that are available in developed countries. These issues are even more challenging in areas of the world where such sophisticated techniques are not available.

The use of folate, genetic counseling and pregnancy termination in many countries has dramatically decreased but not eliminated new cases of MM. However, in other areas of the world, MM incidence remains high, thus the need for spine surgery still exists but will vary among the nations of the world.

Complications of Spine Surgery in MM

Complications are common; MM patients are fragile with multiple co-morbidities & they cannot be avoided completely.

Anticipating and avoiding problems and having a high index of suspicion with an aggressive response to adverse issues when they occur will provide the best chance for salvaging a potential disastrous outcome.

Wound Infection SSI

Predisposing Factors: poor nutrition, remote infections (chronic UTIs, pressure ulcers, osteomyelitis) unstable/tenuous skin coverage, previous wound infection, obesity

THE INCIDENCE OF SSI IN MM REMAINS THE HIGHEST FOR ALL CATEGORIES OF SPINAL DEFORMITY SURGERY IN THE PEDIATRIC POPULATION

Poor Nutrition:

Many etiologies, net effect is poor tissue health, general physiologic malfunction and relative immunosuppresion all of which result in a weakened host response to a infective inoculation.

Correction of nutritional deficiencies should be done pre-op as much as possible.

Remote Infections:

Chronic UTIs, pressure ulcers, unrecognized cuts or injuries to insensate areas

ALL CAN PRODUCE BACTEREMIA THAT CAN SEED THE SURGICAL WOUND at TIME OF SURGERY OR AFTER

Remote infections must be treated before elective spinal surgery and resolved if possible.

Sterilization of chronically infected urine or a chronic osteo may not be possible but responsible organism should be covered with appropriate antibiotic in the perioperative period.

Upper tract UTIs need to be resolved before elective spine surgery.

Unstable/tenuous skin and soft tissue involved in wound closure is a constant threat for wound dehiscence, breakdown and subsequent wound contamination and even exposure of the instrumentation.

Maximization of nutrition, local skin care and evaluation for the need for non-standard wound closure at time of surgery are necessary measures to be done pre-op.

Suspected SSI should be managed aggressively and promptly and assumed deep SSI until proven otherwise.

Thorough I & D, C & S of area, appropriate antibiotics and wound management are needed to salvage instrumentation and promote fusion.

Can use WdVac, suction/irrigation, flaps etc. to achieve wound control/closure.

May need prolonged chronic antibiotic suppression

Obesity:

Large, obese patients have higher rates of infection, massive culture medium, surgery is technically harder, operative times longer, issues w/ mobilization post-op

This is probably an unsolvable problem

Wound/Skin Management Issues

Predisposing Factors:

Poor nutrition, poor/insufficient skin for coverage, bulky implants, infection, previous surgery/incisions, residual pelvic obliquity

Avoidance of Wound/Skin Management Issues

Maximize nutritional status to promote rapid healing of wounds and a normalized immune status

Preliminary soft tissue procedures (e.g. tissue expansion) or planning non-standard closure techniques at time of surgery should be considered in anticipation of managing the surgical wound

Wound/Skin Management Issues

Although the largest size implants that can "fit" should be used for their strength, bulky implants can cause pressure sores, erode through the skin and/or cause discomfort in sensate areas due to tension on the soft tissues. Therefore, the "right size" instrumentation should be chosen so that adequate soft tissue coverage is possible.

Surgical exposure through previous incisions whether previously infected or not can be challenging due to the scar itself or because of adherence of skin and soft tissue to underlying structures as well as reactivating an old infection. These situations may need rescue by previously anticipated non-standard closure techniques

Residual Pelvic Oblquity (RPO):

Results in abnormal pressure distribution in sitting that can cause pressure ulcers.

Rigid, suprapelvic pelvic obliquity requires significant curve correction to level the pelvis.

Fusion to the pelvis with residual, severe RPO may be worse than pre-fusion status

Instrumentation Failure
Predisposing Factors:

Poor implant/bone interface, inadequate construct, large residual deformity, inadequate hip ROM, infection with implant loosening, poor bone stock precludes a solid bone/anchor site and is common in these often debilitated patients.

Hybrid constructs and/or higher implant density may overcome this.

? “Bone Helper” materials (e.g. bone cement)

Screws are not always the answer!

A variety of L-S fixation strategies are available for that need (e.g. very low profile).

Resorbed, infected bone precludes a solid bone/anchor site.

Large residual uncorrected deformity requiring significant rod contouring is not mechanically sound (poor axial support).

Inadequate hip flexion can exert significant flexion forces along the posterior instrumentation when the patient tries to sit and can cause failure by pullout or breakage.

Preliminary hip release/osteotomy is needed in such cases.

Expensive, high tech state of the art instrumentation may not be available to some areas.

REMEMBER, successful spinal surgery was performed on MM patients well before the arrival of pedicle screws. In some areas older type instrumentation in creative, hybrid constructs are good alternatives as long as principles of spinal surgery are adhered to.

Neuraxis Complications
Predisposing Factors: Shunt malfunction

Neuraxis abnormalities:

Tethered spinal cord, Chiari malformation, unrecognized hydrocephalus, dural tears, acute hydrocephalic crisis

Avoidance of Neuraxis Complications
Thorough pre-op clincal neuro evaluation, imaging of neuraxis, correction of neuraxis issues prior to and separate from spinal deformity procedure, skin incisions that help avoid inadvertent dural tears/injuries, intra-op neuromonitoring

Careful assessment of the effects on a neuraxis abnormality by correction of the spinal deformity must include the relative risk of neuro injury from preliminary neurosurgical intervention vs modification of deformity correction techniques that minimize risk of incurring neuro injury.

(e.g. Short segment ASF withASI vs PSF/PSSI)

Complex neuraxis abnormality correction is probably best done PRIOR to spinal deformity correction because the presence of a new neuro deficit after completion of both procedures at the same time may be difficult to sort out and addressing such a problem may be made more difficult (e.g. instrumentation removal as a rescue may not remedy the problem and may actually be dangerous).

Neuromonitoring in patients with thoracic level lesions is unnecessary. Monitoring in patients with at least some LE and/or B/B function should be attempted. However, the “peripheral” deficit plus intracranial abnormalities and seizure disorders and their treatment may make monitoring unreliable or unobtainable.

Monitoring poor, inconsistent signals is unreliable.

Placement of skin incision for deformity correction surgery may help prevent inadvertent dural tears that could lead to chronic CSF leak, meningitis or an intracranial catastrophe.

For most deformity correction procedures, midline exposure over the wide open bifid defect can be problematic in this regard (consider inverted “Y” incision).

Longstanding unshunted hydrocephalus may be problematic if a CSF leak with rapid loss of a large volume CSF occurs.

Simple ligation of SC and dura with a circumferential suture should not be done in cases where caudal SC excision is planned. Careful separate closure of the dural sac below the transected SC is the correct method to avoid an acute hydrocephalic crisis.

Instrumentation and fusion work involves the dysplastic lamina, facet joints and transverse processes that are and quite laterally situated from the midline in the region of the bifid defect.

Working in the midline in these situations is an invitation to potential disaster!

Pseudarthroses
Predisposing Factors:
Inadequate fusion bed, poor fixation/construct stability, poor bone grafting technique (inadequate bed preparation, poor/insufficient grafting material), infection

The midline bifid region of the MM spine provides no bed for bone graft to achieve a fusion.

The dysplastic, small rudimentary laminae, facet joints and TPs may also not be of sufficient size to provide an adequate bed for bone graft.

Discectomy and ASF as a preliminary or same-sitting procedure may help with correction and provide an ample area for bone grafting .

Autogenous iliac bone graft alone is usually insufficient for a stem to stern fusion and may compromise pelvic fixation.

Allograft in various forms as well as other bone substitutes in large quantity are needed in these cases.

BMP is very expensive, may not be appropriate in the pediatric age group and has some deleterious side effects.

Spine Surgery in MM
In 2013, it remains a challenging endeavor even in areas with advanced technology and resources and moreso in regions without such resources. But the keys to making it as successful and safe as well as effective remain the general principles of spinal surgery overall:

Thorough clinical evaluation of the patient

Appropriate, available imaging & lab tests

Medical preparation of the patient including AB's

Meticulous planning of the operation(s) & establishing a team if necessary

Assemble all necessary equipment

Careful surgical technique

Timely Dx of complications and aggressive Rx of them

UNRELENTING ATTENTION TO DETAIL

Notes

Case Presentations: Kyphectomy in Myelomeningocele

Patrick M. Cahill, MD
Shriner's Hospital for Children
Philadelphia, PA, USA

1. Lumbar gibbus in myelomeningocele
   a. Incidence
   b. Etiology
2. Case 1
   a. History
      i. 12 y/o F with thoracic myelo and lumbar gibbus
   b. Imaging
      i. Focal lumbar gibbus
   c. Surgical Challenges
      i. Subcutaneous dura
      ii. Positive sagittal imbalance with inferior rib cage on thighs
      iii. Lack of posterior elements in lumbar spine
         1. Poor fixation
         2. Poor fusion bed
   d. Surgical Plan
      i. Cordectomy
      ii. Excision of multiple lumbar levels
      iii. Bypass fixation across levels without pedicles
   e. Tips/Pearls
      i. Perform posterior based excision of discs before bone resection
      ii. Remove vertebra with oscillating saw or osteotome
      iii. Preserve ALL as a guide for length and for slight stability
3. Case 2
   a. History
      i. 16 y/o male, thoracic level myelo
      ii. Previous PSF
      iii. Thoracolumbar gibbus
   b. Imaging
      i. Distal junctional kyphosis below posterior thoracic construct
   c. Surgical Challenges
      i. Previous instrumentation, fusion mass
      ii. Sagittal imbalance, abdominal impingement problems as previous case
   d. Surgical Plan

i. Extend fusion to pelvis

ii. Replace all instrumentation (avoids connectors at the apex)

e. Tips/Pearls

i. Mid-lumbar fixation with far lateral vertebral body screws to reduce profile

ii. Dunn-McCarthy construct in pelvis

4. Case 3

a. History

i. 20 year-old male, thoracolumbar junction-level myelomeningocele with hydrocephalus

ii. Non-healing ulceration after supine positioning for prolonged (>14 hour) urology procedures.

iii. Intermittent drainage, local wound care for 6 months

b. Imaging

i. Focal lumbar gibbus

c. Indications

i. Osteomyelitis

ii. Risk of meningitis

iii. Difficulty with seating

d. Surgical Challenges

i. Subcutaneous dura

ii. Chronic local infection

iii. GU colonization

iv. Attenuated skin

e. Surgical Plan

i. I&D

ii. Cordectomy ~T11

iii. L2-L4 vertebral column resection

iv. Posterior thoracic (Ponte) osteotomies

v. PSF T5-pelvis

vi. Titanium instrumentation

f. Tips/Pearls

i. Perform VCR with an osteotome or midas rex

ii. Place powdered antibiotics locally

iii. SAI screw fixation - important to decrease prominence when normal muscle layers are absent

5. V. Case 4

a. History

i. 14 y/o male with thoracic myelo and lumbar gibbus

ii. High level sled hockey player

b. Imaging – lumbar gibbus, scoliosis

c. Indications – future pulmonary problems v. current high level function and activities that require trunk motion

d. Audience response – to operate or not

e. Treatment & outcome – revealed after audience survey conducted

Notes