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Sigurd H. Berven and Dean Chou

The Lenke Classification System of Operative Adolescent Idiopathic Scoliosis

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Lawrence G. Lenke

The operative treatment of adolescent idiopathic scoliosis (AIS) is still somewhat controversial regarding selection of the appropriate regions to fuse and selection of the specific upper instrumented vertebra (UIV) and lowest instrumented vertebra (LIV). The Lenke classification system helps to determine the appropriate regions of the spine to be fused. The fused regions include the major curve and any structural minor curves. After this, the approach, anteriorly or, more commonly, posteriorly, and the actual UIV and LIV are selected. Ultimately, multicenter studies evaluating large numbers of similar curve patterns treated differently should help to sort out the best treatment for each particular curve pattern, thus optimizing surgical treatment for patients with AIS.

The Scoliosis Research Society Classification for Adult Spinal Deformity

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Sigurd H. Berven and Thomas Lowe

The management of adult spinal deformity is characterized by significant variability in operative and nonoperative approaches. Adult spinal deformity encompasses a broad spectrum of disorders of the spine, and the disparity observed in reported clinical outcomes of operative and nonoperative care reflects the heterogeneity of the cases studied. A classification of spinal deformity in adults is important in providing a framework for comparison of similar cases and for reporting outcomes on well-defined disorders. Existing classifications of scoliosis are limited in their applicability to adult deformity because they do not include parameters of lumbar degenerative change and regional sagittal alignment that are critical to decision making in surgical care of the adult. The Scoliosis Research Society classification for adult deformity is presented in this article. The purpose of this classification is to provide a framework for reporting similar cases and to contribute to the development of an evidence-based approach to the management of adult spinal deformity.

Radiographic Evaluation of Spinal Deformity

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Timothy R. Kuklo

A complete radiographic evaluation is inherent in the management of the spinal deformity patient; however, a complete evaluation is often not obtained or fully appreciated. This article reviews the proper radiographic methodology for obtaining consistent reproducible radiographs for spinal deformity. In addition, standard radiographic

measurements are reviewed, and the reliability and validity of these measurements are reported. Regional curve flexibility and end, neutral, and stable vertebra selection are also included.

Correlation of Radiographic and Clinical Findings in Spinal Deformities

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Mladen Djurasovic and Steven D. Glassman

Operative treatment for spinal deformities can be undertaken to halt progression of deformity or to treat a patient's clinical complaints. New emerging research using validated health outcomes instruments has begun to investigate which radiographic parameters of spinal deformity correlate with clinical symptoms. Adolescent idiopathic scoliosis tends to present without complaints of pain, and studies have demonstrated that health-related outcomes measures do not correlate with the degree of deformity correction. Clinical complaints in adult scoliosis show a poor correlation with curve magnitude. Studies of adult scoliosis demonstrate that positive sagittal balance is poorly tolerated and correlates with suboptimal health outcomes. Further studies are needed to clarify the clinical significance of radiographic features of spinal deformities further.

Physical Examination in Adolescent Idiopathic Scoliosis

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Mohammad Diab

The following distinguish the physical examination in scoliosis: it is extensive, it is revealing, and it influences treatment. Throughout this discussion, reference frequently is made to evaluation for underlying neural disease. Idiopathic scoliosis is a diagnosis of exclusion, and a neural etiology of spinal deformity must be ruled out in every case.

Low-Grade Spondylolisthesis

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Lionel N. Metz and Vedat Deviren

Spondylolisthesis is an often painful condition affecting millions of people in North America with some ethnic variability. It is characterized by the displacement, usually anterior, of one vertebral body upon another. There are familial predispositions to having the lesion, and a family history of spondylolisthesis may raise one's clinical suspicion. Although the diagnosis is easily made on radiographic evaluation, the pathoetiology and appropriate treatment modality are not always as clear. In the absence of severe neurological symptoms or an unsafe component of instability, a trial of conservative management is reasonable and prudent. Nevertheless, surgical management is more efficacious for enduring symptomatic relief and restoration of physical function. Whereas assessment of postoperative radiographic results lends insight to surgical technique, the true barometer of treatment success is improvement in patient quality of life.

Operative Management of Adult High-Grade Lumbosacral Spondylolisthesis

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Frank L. Acosta, Christopher P. Ames, and Dean Chou

The surgical management of high-grade spondylolisthesis in adults remains challenging and controversial. Symptomatic patients often present with severe pain, neurologic deficits, or deformity. Although there are several surgical options, the decision to proceed with decompression and fusion depends on the patient's presenting symptoms and degree of instability. Posterolateral pedicle screw-rod fixation has improved rates of arthrodesis compared with traditional in situ fusions. Nevertheless, complications with operative management of high-grade spondylolisthesis can be severe.

Adolescent Idiopathic Scoliosis

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Vincent Arlet and Vasantha Reddi

Conservative treatment with a brace continues to remain controversial. A recent study on the efficacy of brace treatment by the Scoliosis Research Society Study Group found it to be efficient, however, and recommends it. Surgical treatment of adolescent idiopathic scoliosis must be tailored to each individual need, type of curve, and surgeon's expertise. A straighter curve does not necessarily mean better for each curve. Recent advances in pedicle screw instrumentation, although powerful in the rate of correction achieved, carry a definitive increase in neurologic risk and must be used only when justified and by experienced teams.

Adolescent Idiopathic Scoliosis: Lenke Type I-VI Case Studies

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Vincent Arlet and Vasantha Reddi

This online material available at www.neurosurgery.theclinics.com.

Brace treatment is effective for selected patients with AIS, but when patients mature or curves progress beyond 40°, surgery may be discussed with the patient and family. The advent of third-generation spinal instrumentation with pedicle screw systems has made extraordinary corrections possible. These posterior corrections must be done cautiously, however. When selecting the fusion level, one should always look at the sagittal plane and include any kyphotic segments. The authors evaluate case examples of Lenke type I through type VI curves with illustrations and radiographic images in this additional content, which is only found on-line.

Operative Management of Degenerative Scoliosis: An Evidence-Based Approach to Surgical Strategies Based on Clinical and Radiographic Outcomes

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Sigurd H. Berven, Vedat Deviren, Brian Mitchell, George Wahba, Serena S. Hu, and David S. Bradford

Degenerative scoliosis is a common and important cause of lumbar spine deformity in the adult. The operative management of degenerative scoliosis encompasses a spectrum of approaches, including decompression alone, or fusion that may include posterior or anterior approaches. There exists significant variability in surgical approaches to degenerative scoliosis, and evidence to support a specific approach is limited. Including the structural thoracic spine in fusions to the thoracolumbar junction has a lower rate of revision than fusions with a cephalad segment at T12 or L1. Short fusions to L5 have a low rate of revision at a minimum follow-up of 2 years. Combined anterior and posterior surgery is more effective in improving lordosis than posterior-only surgery without osteotomies. Clinical outcomes of surgery for degenerative scoliosis are variable, and wct 2 self-reported scores for pain improve more reliably than scores for function. Further investigation, including comparison of randomized or matched cohorts and measurement of outcomes related to specific preoperative complaints, will be useful in the development of an evidence-based approach to degenerative scoliosis.

Anterior Instrumented Arthrodesis for Adult Idiopathic Scoliosis

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Vedat Deviren and Lionel N. Metz

Anterior spinal arthrodesis with instrumentation is a useful alternative to posterior surgery in the management of thoracolumbar deformity in the adolescent and young adult. In adults, flexibility of primary and compensatory curves significantly decreases with increased age and curve magnitude. Curve flexibility is an important determinant of post-operative outcome. Anterior surgery is most appropriate for patients with moderate thoracolumbar or lumbar curves and good flexibility of adjacent segments. Adult patients may develop early degeneration at primary and compensatory curves, and these

curves should be evaluated carefully before surgery and monitored closely during the postoperative period. Good results can be obtained in well-selected patients with a rigid instrumentation system and anterior structural grafts.

The Selection of L5 Versus S1 in Long Fusions for Adult Idiopathic Scoliosis

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Ganesh Swamy, Sigurd H. Berven, and David S. Bradford

The treatment of adult spinal deformities often involves long thoracolumbar fusions into the lower lumbar spine, raising the debate of selecting L5 or S1 as the caudal extent of the fusion. The presence of significant deformity or degenerative pathologic findings at L5-S1 mandates fusion to the sacrum. Fusion to the sacrum is of larger magnitude than fusion to L5 and introduces a higher surgical complication rate. Advantages of ending the fusion at L5 include preservation of motion, avoiding the high complication rate associated with fusion to the sacrum, and possibly avoiding a second operation. Complications with fusion to L5 include possible loss of fixation and subsequent disc degeneration at L5-S1, however, leading to possible pain and loss of sagittal balance and the need for revision surgery. To date, the functional consequences of an open disc space beneath long constructs remain poorly defined, and there is no firm evidence in the literature guiding the surgeon's choice. The issues and evidence guiding the decision to fuse to L5 or S1 are examined in this article.

Flatback Syndrome

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Daniel C. Lu and Dean Chou

Flatback syndrome is characterized by loss of normal lumbar lordosis, resulting in forward tilt of the trunk, inability to stand erect, back pain, and thigh pain from chronic hip flexion and knee bending. The usual etiology is iatrogenic, through previous fusions or with extension instrumentation. Surgical treatments described include extension osteotomy (Smith-Petersen), pedicle subtraction osteotomy, and polysegmental osteotomies.

Complex Deformities of the Cervical Spine

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John H. Chi, Bobby Tay, David Stahl, and Ryan Lee

Cervical deformities arise from a multitude of causes, including genetic, congenital, inflammatory, degenerative, and iatrogenic etiologies. They often require surgical intervention for treatment of pain, progressive structural decompensation, and neurologic deterioration. Although congenital and hereditary causes of cervical deformity require specialized attention to particular clinical features and operative considerations, postsurgical (iatrogenic) cervical deformity after surgery is the most common single cause. Appropriate treatment involves careful selection of conservative and aggressive measures and familiarity with advanced surgical techniques that allow for the safe correction of these challenging deformities. Flexible deformities can be managed with single-staged procedures, whereas fixed deformities require two-staged or even three-staged procedures. Staged surgery for fixed cervical deformities can achieve up to 28° of angular correction and 31% translational correction.

Scheuermann's Kyphosis

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Thomas G. Lowe

Scheuermann's disease is the most common cause of structural kyphosis in adolescents. The kyphotic deformity is frequently attributed to "poor posture," resulting in delayed diagnosis and treatment. Indications for treatment remain somewhat debated, because the true natural history of the disease has not been clearly defined. Brace treatment is almost always successful in patients with kyphosis between 55° and 80° if the diagnosis

is made before skeletal maturity. Kyphosis greater than 80° in the thoracic spine or 65° in the thoracolumbar spine is almost never treated successfully without surgery in symptomatic patients. Surgical treatment in adolescents and young adults should be considered if there is documented progression, refractory pain, loss of sagittal balance, or neurologic deficit. The major postoperative complication after surgical treatment is junctional kyphosis proximally or distally, which is usually related to not including all levels of the kyphosis or overcorrection of the deformity ($\geq 50\%$). With proper patient selection, excellent outcomes can be expected with nonoperative or operative treatment in patients with Scheuermann's disease.

Other Causes of Pediatric Deformity

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Amer F. Samdani and Phillip B. Storm

Pediatric spine deformity can result from a variety of conditions. The etiologies include idiopathic, congenital, neuromuscular, traumatic, iatrogenic, and radiation-induced spine deformities. The spine deformity may manifest as scoliosis, kyphosis, lordosis, or a mixed deformity. In this article, the authors discuss the classification, natural history, and management of congenital scoliosis. They conclude with a discussion of the various etiologies for neuromuscular scoliosis.

Concepts of Surgical Correction-Segmental Derotation and Translation Techniques

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John H. Chi, Ryan Lee, and Praveen V. Mummaneni

Current surgical tools and techniques allow for an unprecedented ability to correct even the most severe scoliotic deformities. The development of rigid segmental instrumentation devices (pedicle screw) has revolutionized the spine surgeon's capability to manipulate the spine and reduce its deformity. Rod rotation involves placing a preshaped rod in one or both sides of a curve and rotating it to achieve curve reduction. Rod translation comprises using specialized devices, such as a "persuader," to reduce a curve sequentially as vertebral segments are translated onto a rod maintained in normal position. Both maneuvers have become popularized to obtain triplanar correction using segmental instrumentation. In this article, the authors discuss and illustrate segmental derotation and translation techniques.

Surgical Strategies and Choosing Levels for Spinal Deformity: How High, How Low, Front and Back

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James M. Mok and Serena S. Hu

The purpose of this article is to describe general strategies in the surgical treatment of adolescent and adult scoliosis, including radiographic evaluation, curve selection, principles guiding the selection of the upper and lower instrumented vertebrae, and indications for anterior surgery. Sagittal plane deformity, including Scheuermann's kyphosis, is discussed. Avoidance and treatment of postoperative flatback deformity is also briefly mentioned. There are multiple and sometimes conflicting considerations that must be reviewed when planning surgical stabilization of spinal deformity. Although there may be significant variation in surgeon decision making, careful adherence to primary principles, such as achieving coronal and sagittal balance in all patients and minimizing fusion levels, particularly in young patients, should be of paramount importance.

Derotation of the Spine

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Suken A. Shah

Idiopathic scoliosis is a three-dimensional deformity: lateral deviation in the coronal plane, thoracic hypokyphosis in the sagittal plane, and rotation in the transverse plane

affecting the ribs and trunk. With pedicle screw fixation and modern corrective techniques, derotation of the spine can now be accomplished. The goals of vertebral derotation are to achieve true three-dimensional correction of the spinal deformity and reverse the torsional asymmetry induced by scoliosis. Intuitively, in typical thoracic adolescent idiopathic scoliosis, this would mean optimal coronal correction, restoration of thoracic kyphosis, and realignment of thoracic torsion by lifting the concavity out of the chest and reducing the convex rib deformity without the need for thoracoplasty.

Measuring, Preserving, and Restoring Sagittal Spinal Balance

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Brian A. O'Shaughnessy and Stephen L. Ondra

The past decade has witnessed dramatic improvement in understanding and treatment of sagittal plane deformity. The authors have reviewed several studies that have clarified normative values for sagittal plane geometry as well as the role of the pelvis as we understand it today. In the treatment of lumbar degenerative disease with a fusion procedure, proper patient positioning and adherence to a thoughtful surgical plan are critical in the preservation of sagittal balance. In the event that restoration of sagittal alignment is required, it is best accomplished by the use of osteotomies, the techniques for which are described.

Kyphectomy for Myelodysplasia

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Lawrence I. Karlin

A progressive kyphotic deformity occurs in 15% of children with myelomeningocele. The more common problems caused by the gibbus are recurrent or recalcitrant skin ulceration and seating difficulties. The only effective treatment is surgery. Excellent correction is possible by vertebrectomy of a portion of the cephalad limb of the deformity. Superior maintenance of the correction is accomplished by segmental spinal instrumentation. Alternative techniques that spare growth are currently being investigated. Vertebral body decancellation is one such method that is less extensive than vertebrectomy and, theoretically, allows continued spinal growth. It seems most appropriate for the younger patient with a less rigid and dramatic deformity.

The Cervicothoracic Junction

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Vincent Y. Wang and Dean Chou

The cervicothoracic junction (CTJ) represents a unique region in the spine because of its biomechanical properties. It is predisposed to various traumatic injuries, tumor, and iatrogenic instability. It is also a difficult region to access anteriorly because of the vital structures ventral to the CTJ. The development of new surgical techniques and new instrumentation has allowed better access and fixation to the CTJ.

Spinopelvic Fixation in Deformity: A Review

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Edward R.G. Santos, Michael K. Rosner, Joseph H. Perra, and David W. Polly

Spinopelvic fixation techniques are evolving and now seem to be converging. Good S1 pedicle fixation is the initial key anchor point. The tricortical technique tests out as the best. Supplemental fixation options are available. The most efficacious seems to be iliac fixation, followed by two-level structural interbody support. Achieving appropriate global sagittal balance also lessens the likelihood of implant pullout and places the fusion mass under relatively more compressive forces than tension forces. Regardless of the method of fixation, the ultimate determinant of long-term implant survival is the achievement of adequate biologic fusion.

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Shane Burch	

Spinal column reconstruction for the management of spinal deformity is technically challenging and has been associated with high complication rates. The purpose of this article is to review the major complications associated with spinal deformity. Major complications include pseudarthrosis, proximal junction kyphosis, sagittal decompensation, deep wound infection, and neurovascular injury. The technology and instrumentation used to treat spinal deformity continue to develop, and the complication rates seem to be decreasing. Although only trends can be identified, complications are to be expected when performing this surgery. Awareness of the occurrence of complications can lead to better information and guidance of the surgeon's expectations as well as the patient's.

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Ivan Cheng, Rayshad Oshtory, and Michael S. Wildstein	

Spinal deformity surgery represents one of the most challenging environments in which to achieve bone fusion. High rates of pseudarthroses, limited quantities of available autograft bone, and the potential morbidity of iliac crest harvest have driven a search for bone graft extenders and substitutes. With expanding knowledge of bone biology, the authors review options in spinal fusion with a particular focus on deformity surgery, including the use of autograft, allograft, demineralized bone matrix, ceramics, and bone morphogenetic proteins.

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Douglas C. Burton and R. Christopher Glattes	

The development of validated health-related quality-of-life instruments that are generic (Short Form-36) or disease-specific (Scoliosis Research Society [SRS]-22) allows physicians and researchers to measure the qualitative impact of spinal deformity and its treatment on their patients quantitatively. Although some further research may be needed in the area of the responsiveness of the SRS-22r, it should be considered a validated instrument that is useful in the research and treatment of pediatric and adult patients with spinal deformity.

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