Treatment Options for Adolescent Idiopathic Scoliosis

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the spine, with an age of onset from 10 years old to maturity. Although the etiology of this disorder is currently unknown, many theories are actively being studied to attempt to discover a unifying reason for its development. For example, asymmetric overgrowth of the anterior spinal column during the adolescent growth spurt has been thought to cause spinal buckling and lead to spinal deformity progression. In addition, several familial studies have demonstrated a clear genetic inheritance pattern. While the particular genes responsible for this spinal disorder are as yet unknown, several regions of the genome appear to be linked to scoliosis development in adolescence.

Patient Evaluation
Most children with scoliosis present to an orthopaedic surgeon after a positive screening exam at school; however, some children may present with complaints of back pain. A careful history and physical examination are essential to exclude the numerous conditions associated with a spinal deformity and arrive at a diagnosis of idiopathic scoliosis. A detailed familial and surgical history, the presence of pain, the patient’s recent growth, and a thorough review of systems should be obtained. On examination, the patient’s trunk shape and balance, pubertal development, limb lengths, and skeletal abnormalities should be evaluated. The Adams forward-bend test can be used to quantify the angle of trunk rotation (ATR) in the upper thoracic, mid-thoracic, and lumbar regions of the spine. An ATR greater than 7° is often indicative of a rotational deformity of the spine; however, the cut-off point for a positive screening has yet to be defined. In addition, a complete neurological examination should be performed to rule out intraspinal involvement.

Radiographical evaluation with standing posteroanterior and lateral radiographs of the entire spine can be used to assess for scoliosis and follow curve progression. Curve magnitude is determined by the Cobb method. If surgical treatment is being considered, lateral-bending radiographs (supine or over a bolster) can be used to assess curve flexibility. Magnetic resonance imaging (MRI) may be indicated in males or patients with an atypical left thoracic curve, neurological abnormalities, or substantial back pain of no obvious etiology.

The development and progression of AIS is associated with the peri-pubertal growth spurt, and the more severe spinal deformities are more commonly seen in girls than in boys. The growth potential of the patient should be assessed to determine the risk of curve progression. The time of peak growth velocity has been closely associated with closure of the triradiate cartilage, menarche, and the Risser stage of the iliac crest.

Non-surgical Management
Orthopaedic management of AIS is based on the natural history of this spinal disorder and on the likelihood of developing a worsening deformity. Long-term studies of untreated scoliosis have identified a poor prognosis, with an increased rate of morbidity associated with worsening cardiopulmonary compromise, increased back pain, and psycho-social issues related to the deformity. Spinal curves less severe than 20° in immature patients should be monitored with clinical examination and radiographs every four to 12 months until skeletal maturity. A curve that progresses during puberty and is greater than 40° for thoracic curves and 30° for thoracolumbar curves at maturity can be monitored approximately every three to five years, as the risk of curve progression in adulthood is reduced.

Although various non-surgical AIS treatment options are available (physical therapy, Botox injections, paraspinal electrostimulation), only bracing has been suggested to alter the natural history of this spinal disorder. Orthotic treatment with a brace or a molded body cast may be considered for a patient with a substantial growth potential (Risser ≥2) and a curve greater than 30° or for a patient with a curve greater than 20–25° with more than...
5° of documented progression.9 The Scoliosis Research Society Prevalence and Natural History Committee found a direct relationship between prevention of curve progression and the number of hours the brace was worn per day, suggesting that the more time a patient spends in the brace, the less likely their curve is to progress. The current recommendations are to encourage brace wear from 16 to 23 hours per day.10 However, despite patient compliance, bracing has been shown to be capable of only maintaining an existing curve, rarely resulting in a lasting reduction of the spinal deformity.8 In addition, orthotics have been relatively unsuccessful in applying corrective forces to the spine of a male patient with a muscular build, or an obese patient with an increased body mass. Controversy about the efficacy of bracing in patients with AIS remains despite the widespread use of orthotics in this population. A multicenter, prospective, randomized trial has been recently funded by the National Institutes of Health and is underway to definitively study the effectiveness of bracing in the skeletally immature AIS population.

Surgical Management

The goals of surgical correction are to improve spinal alignment and balance as well as prevent curve progression. The surgery involves an instrumented fusion of the spinal segments affected by the scoliosis. Such treatment is suggested when the curve size is great enough that the natural history without treatment is likely to lead to relentless deformity progression. Deformity correction and arthrodesis continue to be the primary process measures of surgical success. Surgical planning should be based on the pattern of the curve, as described by the King-Moe11 or Lenke12 classification systems. In addition, curve magnitude, the risk of curve progression (based on skeletal maturity), clinical deformity, and trunk balance/rotation must be considered in deciding whether surgery is indicated.13–15 In general, surgical treatment may be considered in skeletally immature patients with curves greater than 40° and for mature patients with curves over 50°. Although posterior spinal instrumentation and fusion is the most commonly used approach in the surgical treatment of idiopathic scoliosis, combined anterior/posterior procedures and anterior only procedures—both open and thoracoscopic—have proved to be a viable option in specific patients.

Posterior spinal instrumentation has evolved significantly since the Harrington and Cotrel-Dubousset eras and is currently the gold standard in the surgical treatment of AIS. Segmental pedicle screw fixation and instrumentation have improved the ability to consistently achieve greater than 70% deformity correction that is maintained post-operatively in midterm follow-up.16–18 (see Figure 1). These new constructs may also allow greater control of the transverse plane and possibly resist crankshaft growth without requiring an anterior procedure. The primary downside of the posterior approach is the extensive dissection required within the paraspinal musculature.

Combined anterior and posterior scoliosis procedures are primarily indicated in the treatment of large, rigid spinal deformities. The anterior approach enables maximal spinal mobilization prior to posterior instrumentation and fusion by allowing disruption of the main anterior stabilizing structures of the spine (the annulus, the intervertebral disc, and the anterior longitudinal ligament). In the most severe cases, resection of the rib head or even the costovertebral joint may be required to optimize spinal mobility. Another indication for these combined approaches is in the treatment of immature patients. Unbalanced ablation of the posterior growth potential, with continued anterior growth, has been thought to cause spinal ‘buckling’ with the development of a post-operative crankshaft deformity.19,20 To prevent this complication, immature patients often must be treated with an
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Two-year follow-up after thoracoscopic anterior instrumentation has also been reported. In a series of 50 consecutive patients, curve correction averaged 60%, with an average operating time of 5.8 hours. This initial series of patients suggested that thoracoscopic instrumentation was a viable option in the treatment of AIS; however, success remained dependent on patient selection and surgeon technical ability. Eighteen of the first 20 consecutive patients of this series now have more than five-year follow-up, and unpublished data demonstrate that deformity correction and absolute pulmonary function is maintained, and that successful bony fusion has occurred at 92% of the motion segments.

Future Trends
Aggressive research continues in understanding the etiology of idiopathic scoliosis. The promising work of several investigators in the search for genetic markers in this population is gathering momentum, with hope of a clinical test coming in the near term. With regions of the genome responsible identified, coding of the genes and identifying the proteins and pathways that lead to the altered growth of the spine will almost certainly open the way for new therapies.

However, before this new information is gained, we must continue to improve our corrective methods and seek avenues to pursue that do not require spinal fusion. Our operations today clearly allow spectacular deformity correction and spinal realignment, but at the expense of many segments of spinal motion and the risk of accelerated adjacent segment degeneration in the decades that follow for these young patients.

Modulating the growth of the spine with internal means is underway both clinically and in the lab. Altering growth of the vertebrae and discs mechanically without fusion is an attractive concept that should allow early intervention once a progressive curve is identified. Much as many might use a brace today to modify spinal growth, internal ‘braces’ in the form of an anterior growth tether or staple might provide a more direct effect on the spine as growth is completed. Eliminating the fusion component of the corrective strategy for scoliosis certainly must remain a goal we strive to reach.

Summary
AIS is a potentially severe musculoskeletal disorder of the pediatric population. The natural history is for continued progression in many patients whose curves reach 50. The techniques and instrumentation used to treat the spinal deformity continue to evolve.

Recent advances have significantly improved our ability to achieve and maintain curve correction, but numerous questions regarding the etiology of this disorder and long-term surgical outcome remain unanswered.