Surgical Reconstruction of Deformed Spine in Adolescent Idiopathic Scoliosis Review

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ABSTRACT
Adolescent idiopathic scoliosis is one of the spinal deformities. Its etiology remains unclear. However, excellent treatment results have been reported with recent developments in implant technologies. In this study, recent developments in the diagnosis and surgical treatment of adolescent idiopathic scoliosis were reviewed.

KEY WORDS: Adolescent idiopathic scoliosis, Diagnosis, Scoliosis, Surgery

INTRODUCTION
Adolescent idiopathic scoliosis is one of the major topics of interest for spinal surgeons. While its etiology remains unclear, excellent surgical treatment results are reported with recent developments in implant technologies. Whereas correction of cosmetic appearance was the main concern in treatment previously, achieving more functional and detailed results such as total body balance, shoulder balance, symmetry of thoracic cavity, pelvic balance, and walking symmetry are aimed in surgical treatment.

Adolescent idiopathic scoliosis is a sagittal, frontal, and horizontal plane deformity of the vertebral column. It is nine times more frequently seen in girls than boys, and the age at diagnosis is usually between 11 and 16 years. Scoliotic curves can be seen in many different forms although thoracic curves are the most common. Curves are most commonly measured in the frontal plane and a curve and a magnitude of more than 10 degrees is considered a scoliotic curve (1,2). Curves less than 10 degrees have no clinical significance. Curves are measured in the frontal plane in follow-up.

ETIOLOGY AND NATURAL HISTORY
The etiology of adolescent idiopathic scoliosis remains obscure. Many theories have been developed to date but none of these have been able to describe the pathology precisely. Neuromuscular and locomotor systems were the main area of interest for theories of etiology. It has been reported that relatively faster growth of the anterior than posterior column of the spine during the rapid growth peak can result in scoliosis (3,4). Adolescents with a more rapid growth peak and who are taller have greater risk for scoliosis, but the amount of risk is yet to be determined. Decrease in type II fibers in muscles around the vertebral column and disorganization of muscle fibers are among other mechanisms described for possible etiologies but have also not been proven.

Deteriorations of neural anatomy (5), impairment of calmodulin in trombocytes (6), or impairment in melatonin metabolism (7) were also proposed as etiological factors. It is a common clinical practice to encounter a familial tendency for adolescent idiopathic scoliosis. Kesling et al. performed a meta-analysis and showed that the concordance for adolescent idiopathic scoliosis in
The natural history of adolescent idiopathic scoliosis has been emphasized in many studies. Risk factors for curve progression must be taken into consideration before a prediction about the prognosis of a scoliotic curve is made. Maturity of the spine at the onset of scoliosis, curve magnitude at admission, location of the apex of the curve, and other accompanying pathologies can be risk factors for curve progression. Assessment of the maturity of the spine is very important. Sexual maturity, age at menarche, the Risser sign and closure of the triradiate cartilage can all be used for determination of the maturity of the spine. Curve progression up to 100 degrees can be seen in untreated high risk patients in adulthood. The main complaints of scoliosis patients with an untreated curve at adulthood are back pain, early fatigue, respiratory problems, and cosmesis – psychological problems. Many parents of scoliosis patients believe that deaths may occur at adulthood because of respiratory problems. In fact, life-threatening respiratory problems are extremely rare.

TREATMENT

The choice of treatment in adolescent idiopathic scoliosis is a subject of debate. Curve magnitude measured by the Cobb method is widely used for guidance of treatment. Surgical treatment is usually recommended for curves with over 45 degrees frontal plane Cobb angle to limit progression of the curve and for deformities that can limit function in adulthood. For curves with less Cobb angle than 45 degrees, conservative treatment is usually recommended. One of the conservative treatment methods is observation. Mild curves near maturity can be observed. Brace treatment is another conservative treatment method and can be used for flexible curves where the apex is at the middle-lower thoracic area, before maturity, and with a magnitude near the surgical limit. There are many types of braces described in the literature for scoliosis. The evaluation of the effectiveness of brace treatment is a matter of debate. The effect of brace treatment on the natural history, in other words, the brace treatment's influence on the curve has not been determined so far.

SURGICAL TREATMENT

The main objectives of surgical treatment are to limit the progression, decrease the curve magnitude, and maintain a well-balanced trunk and cranium over the pelvis. The commonly accepted indication for surgical treatment is a Cobb angle larger than 45 degrees in the frontal plane. As previously described, some other factors are also important besides the Cobb angle magnitude. A child before skeletal maturity and peak growth with 30 degrees can be observed. Nevertheless, surgical treatment could be considered before 45 degrees in a case of rapid progression of the curve.

Posterior fusion techniques are basic for surgical treatment of scoliosis. Limiting the progression of the curve is the main aim of surgical treatment before the implant era. Long time bed-rest or casts were used following posterior in-situ fusions. The search for better treatment methods continued because of high complication rates. The biggest step taken in scoliosis treatment is the start of curve correction with spinal instrumentation. Correction with instrumentation in scoliosis started with the hooks and rods of Harrington in 1960s, and this technique was used for many years in many centers. In the Harrington system, the stable vertebrae and stable zone were determined first and distraction forces were applied to this area with hooks and rods. In time, some revisions were made, and wires were used for translation of the apex toward the midline. Correction of the curves in three planes with the screw-hook and rod combination of the Cotrel-Dubousset system was another big step in scoliosis surgery. With this system, derotation maneuvers were introduced and sagittal plane deformities were addressed as well as frontal plane deformity. Wires were also used in combination with the Cotrel-Dubousset system. After reports about the effectiveness of this method, different systems based on the same principle were introduced.

Preoperative evaluation of the patient is of utmost importance in posterior instrumentation. Trunk balance, pelvic obliquity, and total walking balance must be evaluated before the operation. Radiograms must be in the standing position and include the cranium and pelvis. In the antero-posterior radiogram, trunk symmetry, frontal Cobb angle of the curves, pelvic obliquity must be assessed. In lateral radiograms, kyphosis and lordosis deformities at the thoraco-lumbar and lumbo-sacral junction areas as well as sagittal plane balance must be determined.
Supine bending graphies are helpful in determining the mobility of the intervertebral discs, and thus the primary and secondary curves. Also supine traction and supine traction under general anesthesia x-rays can be used for determining the flexibility (21). Determination of the upper and lower levels of instrumentation is also very crucial. Choosing a wrong level, specifically a lower level, may result in decompensation. Determination of the apex, upper and lower levels of the curve and stable vertebra are important (22). According to preoperative planning, instrumentation systems with derotation, translation, distraction-compression or any combination systems may be used (Figure 1A,B).

It is considered that additional intraspinal pathologies are not expected in idiopathic scoliosis. Some problems such as diastomatomyelia, syringomyelia, intraspinal lipomas or asymptomatic tethered cord can rarely be seen. These types of curves should be considered congenital. Computerized tomography and magnetic resonance imaging are useful for the diagnosis of intraspinal pathologies (5). Intraspinal problems are not common in the curves accepted as idiopathic but the results can be devastating both for the patient and the surgeon if they occur. Some hints and tips may be helpful to suspect intraspinal pathologies. Left thoracic curves, acute angled curves, huge curves without rotation can be a sign of underlying pathologies. In these situations, MRI is the gold standard method. CT scan is also an available method but it can show the bony details instead of the neural tissues.

Specific complications were encountered with the widespread application of posterior instrumentation in scoliosis. Decompensation is one of the major complications that can be encountered with posterior instrumentation. Decompensation may occur in primary thoracic curves where lumbar curves also have structural abnormalities. In these curves, distraction or derotation maneuvers at the lower level may cause the trunk to move away from the midline. Decompensation disturbs the walking balance. Revision in the early postoperative period is mandatory in this situation. In order to avoid this complication, structural changes in upper levels of curve and vertebras should be determined carefully. Another important complication is the crankshaft phenomenon. Posterior fusion surgeries performed before the growth peak of the spine may cause this complication. The growth of the posterior column is halted with posterior surgery but vertebral bodies continue to grow, therefore causing a spinning of vertebra along the vertical axis. Curve magnitude is stationary in the frontal plane while horizontal and sagittal plane deformities tend to increase. To avoid this complication, it is important to delay posterior surgery until skeletal maturity. If surgery must be performed in a child before this age, anterior surgery is advised to avoid the crankshaft complication (23).

Application of pedicular screws in the thoracic vertebra is another important phase in scoliosis surgery. Although the first introduction of thoracic pedicular screws dates back many years (24), its popularization and widespread

Figure 1: A) A 14-year-old female patient has a thoracic curve. Side-bending radiographs show that the upper thoracic and lumbar curves were compensatory. B) Postoperative radiograph of the patient after selective thoracic instrumentation.
use is quite recent (25). Vertebral rotational deformity is better controlled with thoracic pedicular screws. Segmental instrumentation also transforms the corrective forces to each vertebra therefore to a wider area. This helps reduce implant failure. Rigid and severe curves can be treated without requiring anterior release with segmental thoracic instrumentation. Successful long-term results with segmental screw fixation are reported as this is a very rigid construction (26). The most important aspect of segmental transpedicular screw instrumentation is that it may help lower the rate of postoperative decompensation problems. Distractive-compressive forces in each segment can be used to obtain trunk balance. In a study by the authors not yet published, segmental instrumentation was compared with a screw-hook non-segmental hybrid instrumentation group. It was found that in the segmental instrumentation group the correction in frontal and horizontal plane was better but the physiological kyphosis in sagittal plane was less. Figure 2A and B shows an example of a thoracic pedicular screw application in adolescent idiopathic scoliosis.

The major drawbacks of thoracic transpedicular screw application are a long learning curve and neurological complication risks (27). Potential neurological risks with thoracic screws are devastating. Many surgeons use it cautiously as potentially irreversible spinal cord injury may occur. Although the rate of misplacement of thoracic pedicle screw is reported to be between 3% and 40%, the clinical neurological complication rate is quite low (25,27). It can be concluded that every misplaced screw does not necessarily cause neurologic injury. Pleural injury is another potential complication of thoracic pedicular screws.

Anterior correction systems in scoliosis were developed in parallel to posterior correction systems. The Dwyer anterior cable and screw system was one of the first anterior correction systems with successful results (28). Zielke ventral derotation system was then introduced (29). Many different anterior systems were introduced after reports of successful results with anterior correction systems in scoliosis surgery (30). Lumbar curves are more successfully corrected with anterior instrumentation. In the lumbar area, curves can be corrected with less instrumented segments (31). Horizontal plane deformity is corrected more easily. Besides these advantages, anterior correction surgery has disadvantages such as a long learning curve, proximity to vital organs, risk of major vascular injury, and difficulty of intraoperative evaluation of trunk balance. In our clinical practice, anterior surgical correction of scoliosis is usually used in short segment lumbar curves and in younger age group patients.

Solid bony fusion is still the main objective of the surgical treatment. Metallic implants cannot carry the body weight in long term and fatigue failure can be seen. For this reason, decortication and bone grafting is always advised (1,2,11,19,22). If the fusion fails to occur, pseudoarthrosis may develop. Pseudoarthrosis can result in implant failure and correction loss of the deformity.
Allografts may be used for grafting; however, because of the rapid healing capacity and osteoinductive effects, autografts should be the first choice.

Recently, anterior thoracoscopic or limited posterior fusions with minimal invasive methods are reported. But these techniques are mostly described for younger age group patients rather than adolescents for idiopathic scoliosis.

CONCLUSION

Adolescent idiopathic scoliosis is a popular and interesting subject for spinal surgeons. Even though its etiology is not clear to date despite many studies, strong evidence still indicates that it is a genetically based disorder. Because the etiology is obscure, treatment guidance differs among surgeons. Observation or brace treatment is usually only recommended for curves less than 45 degrees Cobb angle, whereas surgical treatment is an accepted method of treatment for curves with higher degrees.

Surgical treatment can be grouped as; 1- Correction with posterior instrumentation, 2- Correction with anterior instrumentation, 3- Minimal invasive non-fusion techniques, 4- Combination of these procedures. There is no consensus on which method to use for which group of patients. There has been progress in posterior spinal instrumentation techniques in recent years in parallel to developments in implant technologies.

REFERENCES


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