General Approach to Spinal Deformities

Spinal Deformitelere Genel Yaklaşım

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ABSTRACT

Malalignment of the spine can be defined as a spinal deformity. Spinal deformities may be secondary to a variety of causes including congenital anomalies, neuromuscular disorders, skeletal dysplasies, and some other developmental disorders. Pediatric spine deformities may be accompanied by neural and systemic organ pathologies. Therefore the diagnosis, treatment and follow-up strategies may change. Patient age and type of deformity is of importance. Besides standards for the diagnosis and treatment of spine deformities, many classification systems have also been defined for standardization.

Currently spine deformity is diagnosed using scoliosis graphs, CT and MRI. Scoliosis is corrected and instrumented under neuromonitorization. In this study, the general approach to the spine deformities is summarized.

KEYWORDS: Deformity, Scoliosis, Spinal deformity

ÖZ

Omurganın çeşitli eğim ve diziliminin bozukluğuna spinal deformite adı verilir. Spinal deformiteler; konjenital anomali, nöromüsküler bozukluklar, iskelet displazileri ve gelişim bozuklukları gibi bir çok faktöre bağlı gelişebilir. Pediatrik spinal deformitelere nöral patolojiler ve sistemik organ patolojileri eşlik edebilir. Bu nedenle tanı, takip ve tedavi yaklaşımları oldukça farklıdır. Bu süreçte hastanın yaşı ve deformitenin tipi önem arzetmektedir. Spinal deformitelerde tanı, tedavi ve takipte temel standartların yanı sıra, bu süreci yönetmek için birçok sınıflama sistemi geliştirilmiştir.

Günümüzde deformitenin tanısı skolyoz grafisi için aksiyel, koronal ve sagittal düzlemde BT ve MRG'den yararlanılır. Tedavide nöromonitorizasyon eşliğinde korreksiyon ve enstrümantasyon yapılır. Bu çalışmada, omurga deformitelerine genel yaklaşım özetlenmektedir.

ANAHTAR SÖZCÜKLER: Deformite, Skolyoz, Spinal deformite

The concept of spinal deformity represents a pathology going back to the antique periods and drawn on the objects that have remained from that period. The human anatomy impaired in relation with deformities has been perceived and evaluated differently in each period of the human history and each society. While these patients were treated with conservative methods including traction and braces, such methods have been replaced by surgical treatments in contemporary times.

The most important structures in the human anatomy that provide for a balanced posture include the spine and the muscles, ligaments and discs that support it. The ribs in the thoracic region, the sacroiliac joint in the lumbosacral region and the pelvis are the important structures of this system. This entire structure provides for the transmission of the load coming from the weights of the head and the entire body to the legs in a balanced fashion through the pelvis. The spine has to maintain this biomechanical balance to as to protect the spinal cord it contains.

All these structures will ensure the stability of the spine in passive and active conditions. The spine of the newborn includes a curvature only in the sagittal plane with convexity. The spine acquires the sagittal balance with cervical lordosis, lumbar lordosis and thoracic kyphosis with the growth of the child and starting to walk. The line drawn from the uppermost point of the spine passes from the anterior side of the thoracic spine and crosses the L5/S1 joint when a normal healthy individual is in the standing position. Likewise, the spine extends from the cervical to the sacral regions in the coronal plane also. Any breach of the physiological borders of this anatomic alignment in all the three planes of the space, that is, in the frontal, sagittal or transverse planes is called *spinal deformity*. These deformities can be congenital or can be idiopathic or acquired.

Kyphosis and spondylolisthesis are seen in the sagittal plane; scoliosis is seen in the frontal plane; and adolescent idiopathic scoliosis (AIS) and spondylolysis are seen in the transverse plane.

Etiology of spinal deformities can be related to many factors. They can develop in relation with many factors with unknown etiologies including congenital diseases, degenerative diseases, trauma, infections, tumors, neuromuscular diseases or AIS (Table I).

Congenital spinal deformities are seen as a compartment of some systemic pathologies with spinal dysraphism taking

first place. The incidence is approximately 0.5 per 1000 liver births, and 1% of these cases are sporadic (8,54,56,57). Spinal deformity cases accompany intraspinal pathologies with a rate of 5-35% (5,33,34). Spinal deformities can develop in relation with genetic defects particularly in congenital cases, or they can be the result of some disorders that occur within the intrauterine period. Effects of genetic factors on idiopathic cases are controversial.

CLASSIFICATION

Classification of spinal deformities has four basic objectives. The systematic classification of the diseases has the objective of defining the results of treatment and natural course, and providing guidelines for their correlation with the health status or the severity of deformity and for the decisions regarding treatment. Many studies have been published in the last century on the classification of spinal deformities. The first study on this subject includes the classification of Schulthess based on the pattern of scoliosis in 1905 (47). Ponseti et al carried out a more comprehensive study related to the pattern of the scoliosis in 1950 (41).

It is possible to evaluate spinal deformities as congenital spinal deformities and idiopathic spinal deformities. Congenital spinal deformities are classified according to the etiology. Because of the lack of any known etiology for adolescent spinal deformities, various classifications have been made according to clinical and radiological signs. Degenerative spinal deformities seen in the advanced age groups must also be mentioned apart from these two groups.

Congenital spinal deformities: Congenital spinal deformities generally present at very young ages. These are seen as a result of the formation defects of the vertebras, segmentation defects, or formation and segmentation defects both.

1. ***Formation defects:*** These are deformities that develop in relation with deficiencies of the embryological materials required for the development of a normal vertebra. They have a wide spectrum ranging between simple occult spina bifida to multiple hemivertebrae. Size, localization and type of the defect can be completely occult, or the defect can be a very complex deformity with very serious deformities and neurologic defects.
2. ***Segmentation defects:*** The most frequent type is the unsegmented bar, which is a segmentation defect that involves one vertebra unilaterally or that extends to more than one segment and involves different areas. The unsegmented bars, which are most frequently seen in the thoracic region, cause clinical symptoms based on the growth potential of this region.

Idiopathic spinal deformities: Deformities in this group are those mostly seen in the adolescent period. Many subtypes can be mentioned within this group. The most frequently seen types are listed below.

1. Infantile scoliosis
2. Juvenile scoliosis
3. Adolescent scoliosis
4. Adult scoliosis

Spinal deformities in the pediatric age group can develop in relation with congenital abnormalities, neuromuscular disorders, neurofibromatosis, connective tissue disorders or skeletal dysplasia. Idiopathic scoliosis is the most common form, and it is diagnosed after eliminating the generalized syndromes, and congenital or inflammatory causes.

Idiopathic scoliosis is a pathology that can have a familial trait and shows bimodal distribution.

Table I: Classification of Spinal Deformities Based on Etiology

Idiopathic	Neuromuscular
Early onset	Neuropathic diseases
Late onset	Upper motor neuron disease
Adult	Spinocerebellar degeneration
Congenital	Cerebral palsy
	Lower motor neuron disease
Vertebra abnormality	Poliomyelitis
Formation abnormality	Myopathic
Hemivertebra	Congenital hypotonia
Abnormal segmentation	Duchenne's muscular dystrophia
Unilateral bar	**Developmental Syndromes**
Rib fusion	Skeletal system dysostosis (such as Neurofibromatosis)
Spinal dysraphism	Skeletal system dysplasia (like osteogenesis imperfecta)
Tight spinal cord syndrome	**Tumoral**
Chiari malformation	Osteoblastoma
Syringomyelia	Osteid osteoma
Tethered spinal cord syndrome	Intraspinal-intramedullary tumors
Meningocele-meningomyelocele	Extramedullary tumors

Adolescent scoliosis and adult scoliosis differ from each other as regards the clinical signs, radiologic results, therapeutical approaches and prognosis. Therefore, several classifications of AIS have been developed.

Classification of Adolescent Idiopathic Scoliosis

King et al. created a classification in 1983 aiming at the treatment of adolescent thoracic deformity (20). The classification developed by Lenke in 2001 targets adolescent idiopathic scoliosis primarily together with King's classification (26).

In the times that spinal instrumentation had not developed adequately yet, the surgical approach to patients with AIS was limited. Therefore, classifications related to scoliosis cases did not develop adequately. Surgeons have started to perform correction operations on these cases also thanks to the development of spinal instrumentation and surgical conditions within the last 25 years. Consequently, a need emerged for detailed classification of these pathologies. In addition to the classifications of King and Lenke, the Schwab system (25) and Scoliosis Research Society (SRS) classifications related to scoliosis have also been created recently (32).

King Classification:

This is a classification system developed to determine the thoracic fusion levels in AIS. King has advocated that lumbar and sacral pathologies could be corrected more easily if the fusion segment in the thoracic region is selected accurately, and aimed at determining the shortest and the most accurate thoracic fusion segment (Table II). This classification does not include the thoracolumbar, lumbar double major and triple major scoliosis. Evaluation of the coronal system and neglecting the sagittal plane at the same time and limited number of working observers are the issues that have been criticized (9,25,26).

Lenke Classification:

Lenke et all developed the Lenke classification together with SRS (26). In the designing phase of this classification system, inclusion of all the scoliotic segments in the coronal and sagittal planes was aimed at. It includes six major groups and two additional groups based on changes in the thoracic and lumbar lumbar regions. Covering all the scoliotic segments in AIS, allowing evaluation on two planes, suggesting the fusion segment and indicating the segments that fusion should be avoided are aimed at (Table III).

Schwab Classification:

This is the classification system developed by Schwab and colleagues with a clinical study they carried out on 947 adults with spinal deformities (48). This classification radiologically evaluates the frontal Cobb angle, apex of the deformity, lumbar lordosis and intervertebral subluxation. This classification system has been created based on three criteria (Table IV).

Table II: Classification of King and Moe

Scoliosis type	Feature
Type I	Lumbar scoliosis ≥ Thoracic scoliosis Thoracic flexibility > Lumbar flexibility
Type II	Lumbar flexibility > Thoracic flexibility Thoracic scoliosis > Lumbar scoliosis
Type III	Thoracic scoliosis, Lumbar scoliosis does not exceed the midline Lumbar flexibility > Thoracic flexibility
Type IV	Wide thoracic scoliosis L4 participates in the scoliosis, L5 balanced
Type V	Double thoracic scoliosis T1 participates in the concavity of the scoliosis

SRS Classification:

The importance of all these scoliosis classifications includes the standardization of the communication between health-care professionals and making the diagnostic and treatment approaches easier. While the Lenke classification is currently the most frequently used AIS classification, SRS classification takes first place in adult scoliosis cases with the richness of the content, the Schwab classification is preferred because of the clinical relevance, and the Aebi classification is preferred because of the simplicity in use (32) (Table V).

PHYSICAL EXAMINATION

Since spinal deformity is an expected condition in patients with congenital spinal cord pathologies, diagnosis is generally possible with clinical follow-up. In the idiopathic spinal deformities however, the diagnosis is generally delayed. History and physical examination in a patient presenting with spinal deformity will be very helpful in differentiating the secondary causes of the spinal deformity. Family history, menstruation status, presence of pain, neurological changes and any intestinal or bladder dysfunctions must be questioned. Neurologic findings and severity of the pain will give an idea about the severity of the deformity. The Tanner stages and neurological examination must be carried out completely in the physical examination of the cases with scoliosis.

The following conditions must be evaluated in sequence when handling a case with spinal deformity:

1. Age: The risk of neural injury is high in the first decade of life. The neural structures must therefore be shown with MRI in this age group.
2. Gender: Although idiopathic scoliosis does not discriminate gender, the possibility of progression in girls is six times greater as compared to boys.
3. Gait: The gait of the patient must be observed in the examination room. The surgeon must observe the ataxic gait, painful gait or gait related to neurologic damage and the balance of the gait.

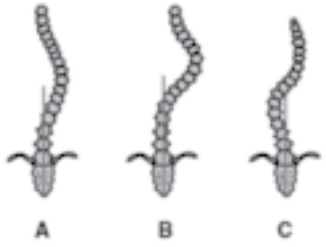
Table III: Classification of Lenke

Scoliosis Type				
Type	**Thoracic Proximal**	**Mainly Thoracic**	**Thoracolumbar/Lumbar**	**Scoliosis type**
1	Nonstructural	Structural (major)	Nonstructural	Mainly thoracic
2	Structural	Structural (major)	Nonstructural	Double thoracic
3	Nonstructural	Structural (major)	Structural	Double major
4	Structural	Structural (major)	Structural	Triple major
5	Nonstructural	Nonstructural	Structural (major)	Thoracolumbar /Lumbar
6	Nonstructural	Structural	Structural (major)	Thoracolumbar /Lumbar Mainly Thoracic

Structural Criteria (Minor scoliosis)
Proximal thoracic: lateral bending Cobb>25°
T2-T5 kyphosis >+20°
Main Thoracic: lateral bending Cobb >25°
T10-L2 kyphosis >20°
Thoracolumbar: lateral bending Cobb>25°
T10-L2 kyphosis >20°

Major: The biggest Cobb angle is always structural
Minor: All the scoliosis other than structural
Apical localization

Scoliosis	Apex
Thoracic	T2-T11-12 disc
Thoracolumbar	T12-L1
Lumbar	L1-2 disc and L4

Variables				
Lumbar variables	**SSVH – Lumbar-apex relationship**		**Thoracic Sagittal Profile: T5-T12**	
A	SSVH between the pedicles		- (hypo)	< 10°
B	SSVH touches the apical body		N (normal)	10-40°
C	SSVH is entirely in the medial		+ (Hiper)	>40°

***CSVL:** Central Sacral Vertical Line, **Evaluation:** Scoliosis type – Lumbar variable – Thoracic sagittal profile, **Example:** 2B+*

Table IV: Schwab Adult Spinal Deformity Classification

Classification	Radiologic Criteria
Scoliosis type	
I	Only thoracic scoliosis
II	Major upper thoracic, apex T4-T8
III	Major alt thoracic, apex T9-T10
IV	Major thoracolumbar, apex T11-L1
V	Major lumbar scoliosis, apex L2-L4
Lumbar lordosis changes	
A	Advanced lumbar lordosis (>40 degrees)
B	Medium lordosis (0-40 degrees)
C	No lordotic appearance (Cobb >0 degree)
Subluxation changes	
0	No intervertebral subluxation at any level
+	Maximum subluxation between 1 and 6 mm
++	Subluxation exceeding 7 mm

4. Pain: Pain in cases with idiopathic scoliosis does not differ from other children in the same age group. Appearance of pain that did not exist before or an increase in the severity of pain must suggest a neural injury.

The physical examination starts in the standing position and from the backside. Spinal balance is evaluated with two methods.

1. A plummet line-passing tangent to the inion or the vertebra prominens is used to determine distance between the line and the congenital cleft. If this distance between this line and the congenital cleft exceeds 2 cm, idiopathic scoliosis or a neural disorder must be thought of.
2. The distance between the line drawn from the thoracic area with the maximum width and the congenital cleft will be measured. The measured value shows the decompensation of the body.

The symmetry between the shoulder heights and symmetry of the body are evaluated with inspection. The spinous processes will be palpated from cervical to sacral areas and the grade of scoliosis and rotation will be evaluated. In addition, it will be determined whether or not that there are any missing spinous processes.

Vertical/sideways evaluation of the patient: Although scoliosis ids known as the pathology of the coronal plane, it is a pathology that develops in the three-dimensional space. Loss of thoracic kyphosis and lumbar lordosis related to rotation in the lateral plane can be seen. Evaluation of the patient in the sagittal plane is important in the following senses:

Table V: SRS Spinal Deformity Classification

Type of the primary scoliosis	
Single thoracic	
Double thoracic	
Double major	
Triple major	
Thoracolumbar	
Lumbar "de novo"/ idiopathic	
Primer sagittal plan deformity	
Adult spinal deformity changes:	
Proximal thorax (T2-T5): ≥ +20°	
Mid-thoracic (T5-T12): ≥+50°	
Thoracolumbar (T10-L2): ≥+20°	
Lumbar (T12-S1): ≥-40°	
Lumbar degenerative changes	
Decrease in the disc height and facet impairment in L1-S1	
Lystesis: ≥3 mm, between L1 and L5	
Angulation ≥10 degrees between L5 and S1	
General balance changes	
Sagittal plane; C7 – ≥5 cm shift in the anterior or posterior of the sacral promontorium line	
Coronal plane; C7 – ≥3 cm shift from the mid sacral line	
Regional definitions according to SRS	
Thoracic : From the apex of T2, T11-T12 disc	
Thoracolumbar T12-L1	
Lumbar: From the apex of L1, L1-L2 disc, L4	
Criteria related to the characteristics of the major scoliosis	
Thoracic scoliosis:	1. Scoliosis ≥40° 2. Over the thoracic scoliosis, T1 rib or the clavicular angle ≥10°
Thoracolumbar and lumbar scoliosis:	1. Scoliosis ≥30° 2. Lateral part of the apical vertebral body is on the central sacral line
Primary sagittal plane deformity: No major coronal scoliosis	

1. In contrast with idiopathic scoliosis, thoracic kyphosis is seen more in patients with neurologic defects.
2. Impairment of the sagittal balance is an important cause of the appearance of pain. The purpose of surgery is to ensure correction in the coronal plane as well as providing the balance that is closest to the physiological structure.
3. Sagittal imbalances can also be the result of hip and leg problems apart from the vertebras. The symmetry of the hip in the coronal plane and leg lengths must therefore be evaluated in cases with impaired sagittal balance.

Adams test: The forward bending test is a rapid and effective method of examination to make a rough scoliosis diagnosis. For this test, the patient joins his/her two hands and brings his/her back to a position parallel to the floor. The examiner inspects the hump that appears in the back from the side and the back of the patient. The angle of this hump respective to the plane of the floor will be measured with a scoliometer. This curvature known as the "Rib Hump" must be evaluated radiologically if it exceeds 10 degrees. The thoracic hump is on the right in more than 90% of the pathologies other than the congenital scoliosis cases. The kyphotic rib angle is directly proportional with the scoliosis grade.

Adams test is used to evaluate the following parameters.

1. Truncal rotation: Scoliometer placed on the spinous processes is used to determine this parameter. The value is generally over 7 in cases with scoliosis.
2. In contrast with the idiopathic cases, this test can be painful in scoliosis cases related to different etiologies.
3. Sagittal contour: thoracic kyphosis significantly increases in cases with Scheuermann disease or osteochondrosis.

A detailed sensory examination must be carried out in the patients. The neurologic impairments particularly seen in pathologies such as Chiari malformation, syringomyelia, tethered spinal cord syndrome and tight spinal cord syndrome accompanied by scoliosis must be considered, and the patients must be evaluated in this context. Pathologies including abnormal hair in the midline, low-neck hairline and abnormal structuring of neck, blemishing of the skin, subcutaneous lipomas or neurofibromas must be searched for in the inspection.

Course of Scoliosis

The most important factor that determines the progression in scoliosis and other spinal deformities is bone maturation. Another factor in scoliosis cases together with maturation is the grade of the scoliosis. Bone maturation is evaluated according to Risser and Tanner grading. Skeletal maturation is calculated based on the apophysieal bone fusion in the Risser grading. Fusion of the iliac bones starts from the anterolateral and extends throughout the posteromedial iliac bone. This fusion line is graded between 0 and 5 and maturation is thus evaluated (Figure 1). The relation between age and progression of the scoliosis in scoliosis cases and the relation between the Risser grading and possibility of progression of the scoliosis are given in tables 6 and 7 (Tables VI and VII) (8,27,28,51,57).

Weinstein and Lonstein performed the most comprehensive study in the literature on the natural course of the scoliosis. In this study, unless the scoliotic angle did not reach 80 degrees

Figure 1: Risser grading system for the skeletal maturation.

Table VI: Possibility of Progression in AIS Based on Age and Scoliotic Grade

Scoliotic angle	10-12 years	13-15 years	16 years
<19°	%25	%10	%0
20-29°	%60	%40	%10
30-59°	%90	%70	%30
>60°	%100	%90	%70

Table VII: Possibility of Progression in AIS Based on Risser Grade and Scoliotic Grade

Scoliotic angle	Risser 0-1	Risser 2-4
5-19°	%22	%2
20-29°	%68	%23

in cases with AIS, respiratory problems related to scoliosis did not develop (27,28,51). The back and low back pain in cases with mild or medium scoliosis does not differ from the normal population in the same age group. Again, the average life span of these cases is the same with their peers. The average life span is shortened in cases with advanced scoliosis in relation with pulmonary and cardiac problems (27,51).

The natural course of the congenital spinal deformities is rather different from that of the natural course of AIS cases. The spinal deformity progresses more rapidly in these cases, and the neural symptoms are more progressive. In this group, the unilateral segmentation defects have a more rapid and progressive course. Unsegmented bar together with the convex hemivertebra is the most serious picture (34). The pathology in this group that progresses the least is the scoliotic cases with block vertebra. Congenital spinal deformities develop within the 6th week of pregnancy. Many problems including renal, cardiac and dermatologic problems are added to the congenital spinal deformities in this period. All these disorders make the clinic of the progressive spinal deformity more difficult, and also make the surgical conditions more difficult (43,45,46). In such cases that the natural course is not favorable, early treatment with a multidisciplinary approach is a must.

Radiologic Examination

A rough diagnosis can be made with plain x-ray in the standing position in a case with spinal deformity. However, understanding the details of this pathology requires examinations including level of the bone pathology, involvement of the neural structures and dynamic x-rays to show the flexibility of the deformity.

The anteroposterior and lateral scoliosis x-rays in the standing position that will include the entire spinal axis, and the lateral bending x-rays to see the flexibility must be obtained in these patients. Together with the computerized tomograms, three-dimensional tomograms as the standard imaging modality in our times with the purpose of obtaining detailed images of bone pathologies are helpful in the evaluation of the bony structure and fusion segments. They is also helpful in determining the surgical treatment mode and the levels. BT myelography can provide important information about the pathologies within the spinal canal as well as the bony structure.

An indispensible diagnostic tool, particularly in congenital deformities, is MR. Congenital cases can involve significant neural disorders together with the bone pathologies. Furthermore, MRI will be needed for the evaluation of the other organ pathologies. Obtaining MRI in cases with AIS in addition to the plain x-rays and CT to eliminate other pathologies will be the accurate approach, while the scoliosis x-rays can suffice for the long-term follow-ups of these cases. However, it must be kept in mind that MRI can be required for neural impairments that develop suddenly or rapidly (13,38).

Genitourinary system pathologies can accompany spinal deformities, particularly in cases with congenital deformities. Evaluation of the urinary system with ultrasonography or pyelography can be required in this case.

The spinal system operates as a whole with the hip. Therefore, patients must be evaluated together with pelvic x-rays; while MRI study of the pelvis can be required as the case may be.

Radiologic evaluation in cases with spinal deformities:

The scoliotic grade is evaluated in scoliosis cases with AP scoliosis x-rays and measurements made in the coronal plane. Making some radiological measurements in scoliosis cases in the preoperative and postoperative periods will be helpful in determining the most suitable surgical modality and the evaluation of postoperative results. These measurements include the Cobb angles of proximal thoracic, main thoracic, lower thoracic and lumbar regions, the translation of the apical vertebra, coronal balance, T1 inclination angle, the inclination angle of the lowermost vertebra that instrumentation has been applied to and the Risser grade (22,37,47). T2-5, T5-T12, T2-T12, T10-L2, T12-S1 and sagittal balance Cobb angles and the Cobb angles in the coronal plane are measured with preoperative and postoperative lateral x-rays in the standing position (Figures 2, 3 and 4).

Although these radiologic measurements are used for all spinal deformities, they are particularly used for cases under follow-up for idiopathic scoliosis. The results obtained are applied to classification systems. The Lenke classification is the most frequently used evaluation mode that involves some of these radiologic parameters (26,48).

Sagittal balance, which is an important factor in spinal surgery, is related to the balance of the lumbar vertebras, sacrum, pelvis and femoral head. The balance between these factors can be evaluated using the spinopelvic angle.

The spinopelvic parameter is measured as the angle between the line vertical to the midpoint of the sacral endplate and the line between this point and the midpoint of the femoral head.

TREATMENT

Patients with spinal deformities must be evaluated as regards the psychological disorders related to their disease, their expectations from the treatment and their socio-cultural status together with the clinical and radiological evaluations. Being isolated from the society, avoiding many social activities and an introvert state of mind can be seen particularly in children and adolescents with serious deformities. Cosmetic reasons alone can therefore be a surgical indication even in the absence of significant neurologic damage or pain.

Conservative or surgical treatment is used in spinal deformities according to the condition.

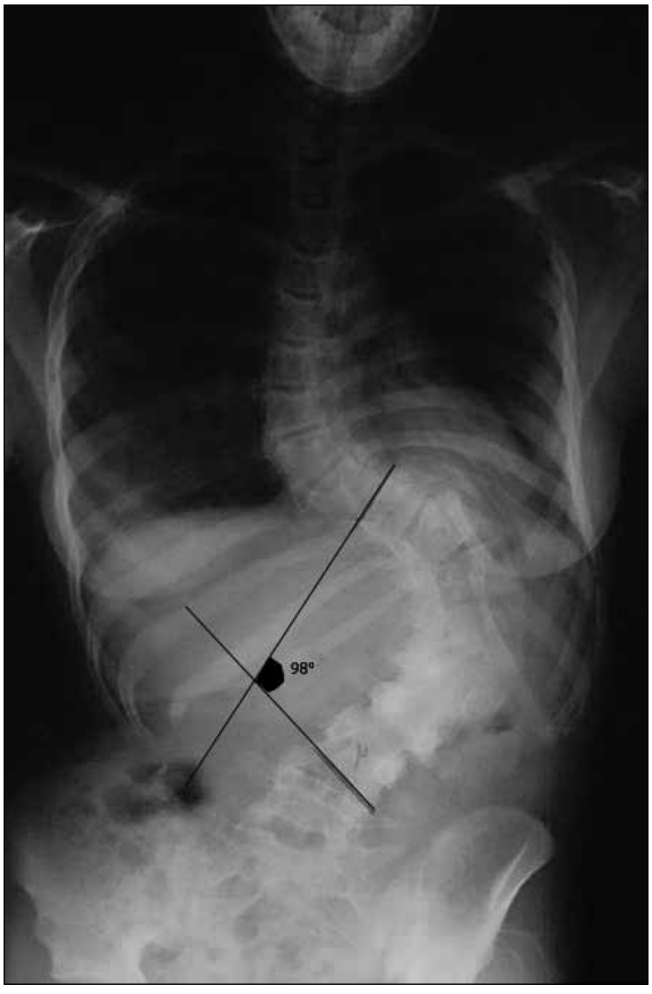


Figure 2: Evaluation of the Cobb angle in the coronal plane.

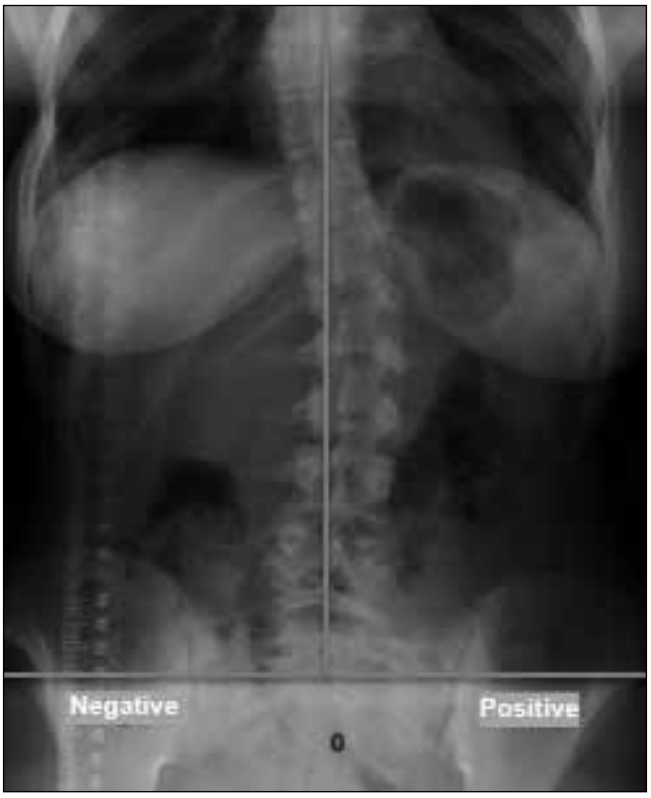


Figure 3: Central sacral vertical line (SSVH).

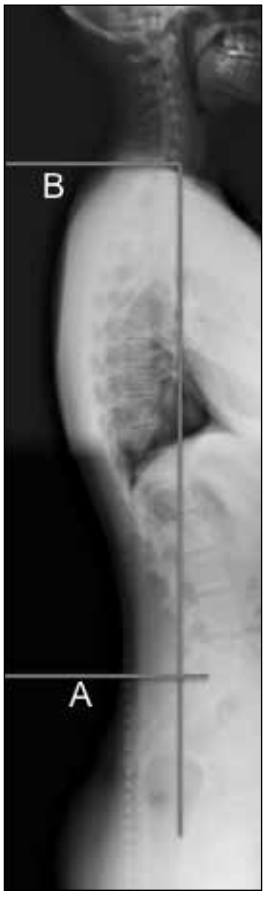


Figure 4: Sagittal balance: The distance between the vertical line drawn from the C7 vertebral body to the L5 pedicle. (Sagittal balance: B=A: Neutral balance, B<A: Negative balance, B>A: positive balance)

1. Conservative Treatment: Several treatment options including physical therapy, chiropractic treatment, bioenergy and electrical stimulation have been reported among conservative treatment options. Braces that are recognized and for which effectiveness has been shown are included in these conservative treatment options nowadays.

Flexibility of the pathology, the age of the patient, localization of the pathology and whether or not the neural structures are under risk all play important roles when determining the treatment modality. Conservative treatment is rarely used in congenital spinal deformities, while it is used more often in idiopathic spinal deformities. While it is difficult to treat sharp and short congenital angular deformities with braces, there is a higher possibility that long and flexible scoliosis cases may benefit from a brace (29-31,37).

There are different opinions about the effectiveness of braces. While it has been reported in some studies that braces have no effect on the progression of the deformity, Lonstein and Winter reported in their study on 1020 patients treated with the Milwaukee brace that the brace reduced the natural course significantly (28,31,56). It has been reported in similar studies that progression was stopped with brace use by 21 to 74% (31,36).

In case of presence of an underlying neurologic deficit or significant kyphosis in cases with congenital deformities, use of a brace can be contra-indicated. Furthermore, brace use in younger ages can impair thoracic development.

Selection of the correct brace according to the localization of the pathology is important. Cervicothoracolumbar braces must be preferred for lesions at T7 and higher levels, while thoracolumbar orthoses must be preferred for deformities in the lumbar and thoracic regions. One of the most important issues is wearing the brace correctly for at least 20 hours a day. Use of bthe race only at nights for 6 months will suffice after meeting these criteria.

2. Surgical Treatment: The basis of the surgical treatment of scoliosis consists of reduction and fusion. Fusion application in scoliosis surgery has been known for a long time. Hibbs published his series of 59 patients with scoliosis that he treated with fusion using autogenic bones with a posterior approach in 1924 (17).

Several modifications of spinal fusion were described by Hibbs, Albee and deQuervain (17). Different options including bovine bone graft, autogenic bone graft and rib grafts have been tried for spinal fusion (7,11,12,19). Different rates of satisfaction were obtained in different series in later periods. While only posterior procedures were defined in the early periods, the anterior procedure was reported first time by William von Lackum and colleagues together with these developments (24).

In the second half of the twentieth century, the internal instrumentation system developed by Dr. Harrington was used effectively for long years in the surgical treatment of

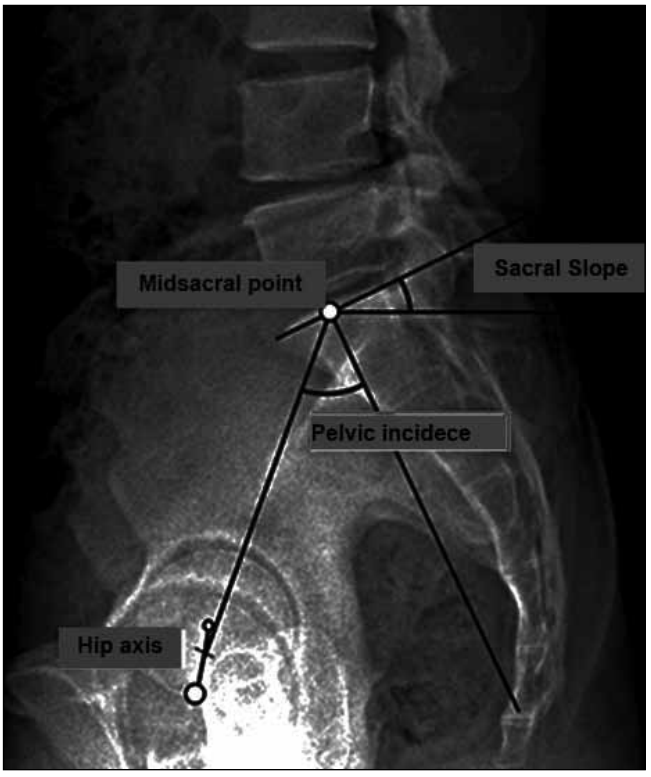


Figure 5: Spinopelvic parameters.

spinal deformities (15,16). Later, Harrington used his system he had used on a poliomyelitis patient for the first time on other cases with other deformities. Harrington did not perform fusion in his initial procedures and encountered some problems related to instrumental failures; in later stages, he added fusion to instrumentation and obtained more successful results (15,16).

Routine use of pedicle screws in thoracic and lumbar vertebras and application of osteotomy methods like Smith-Peterson have resulted in important improvements in spinal deformity surgery. Although the basic principles are the same as of today, the following procedures are used for congenital and idiopathic scoliosis.

A. Surgical Approach in Congenital Spinal Deformities

There are no standards for the treatment of congenital spinal deformities. Many factors including the form of the pathology that causes the deformity, bone maturity of the patient and status of the neurological injury determine the surgical treatment to be used. Intra-channel pathologies or neural abnormalities are generally added to the deformity in congenital scoliosis. Directly intervening on the deformity in such cases can increase the neural damage, as well as causing neural damages that were not present before (2).

Since the spinal canal is normal in idiopathic deformities, the treatment modality and timing in such patients are determined by the deformity level, patient's age and cosmetic expectations. However, the ideal treatment in congenital

spinal deformities includes early surgical fusion before the progression of the deformity or correction in cases with severe deformities.

The surgical options include the following:

1- Posterior fusion, 2- Anterior fusion, 3- Combined antero-posterior fusion, 4- Hemivertebra excision, and 5- Spinal osteotomy and fusion.

1. Posterior spinal fusion has been the golden standard in the surgery of congenital and idiopathic scoliosis and kyphosis. Anterior discectomy and fusion were recommended as a part of the spinal deformity for cases with thoracic lordosis (1,6,10). Spontaneous recovery has been seen after posterior fusion in cases with slight congenital kyphosis if younger than 5 years of age. However, performing posterior fusion alone in cases with kyphosis exceeding 50 degrees causes increased deformity and development of pseudoarthrosis (52-56).

Roaf described the anterior and posterior convex hemiepiphysiodesis technique in 1955 (44).

Spinal instrumentation in cases with congenital spinal deformities involve significant risks for reasons including a narrow diameter of the spinal canal, narrow pedicular structures, and possibility of the existing additional pathologies within the spinal canal. The head must be radiologically centered when determining the upper and lower ends of the instrumentation, and the planning must be made so that a straight line will be obtained in the sagittal and frontal planes. In addition, the lateral bending x-rays and traction x-rays can also be helpful when making the decision (53,55).

2. Anterior fusion: Anterior fusion application is one of the options used in spinal deformity cases. It is used in adult patients and pediatric cases where correction with posterior approach is difficult. Discectomy and corpectomy can be performed with anterior or anterolateral approaches on the vertebral bodies that include the pathologic segment. The anterior approach can provide better correction in cases with advanced kyphosis, while it also provides for a safe working setting for the protection of the spinal cord. Although they are not as common as the posterior fusion techniques in the scoliosis surgery, anterior fusion techniques are also used. In this procedure that is applied in the retroperitoneal approach, in thoracotomy, and the thoracoabdominal approach, interbody fusion is performed at the discectomy or corpectomy sites, and is reduced together with the anterior body screws. The biggest advantage of this procedure, which is preferred for Lenke Types IA and IB, as compared to the posterior fusion techniques is that it provides for the involvement of fewer levels in the fusion segment by 1.2 to 1.5 on average (21,23,42,50). However, it has been reported that kyphosis is more common in the long term in patients where anterior fusion alone has been used, and the resistance against axial rotational movements is less (21,23).

The anterior approach must be avoided in cases with high thoracic scoliosis, pulmonary insufficiencies, or in cases that cannot tolerate large volumes of bleeding (3).

3. Combined anterior-posterior fusion: This procedure can be selected in cases where anterior or posterior fusion alone will not suffice or with the purpose of including fewer segments in the fusion. These procedures can be performed within the same surgical session or in separate sessions based on the general medical status of the patient and duration of the procedure. Discectomy and corpectomy with the posterior approach followed by anterior fusion is the most preferred fusion technique nowadays. This way, both the fusion is widened, and the complications that can occur in relation with a separate procedure are avoided.

4. Hemivertebra resection: This procedure can be performed with a posterior approach alone, or can be performed with a combination of anterior and posterior procedures (4,18,35). The type and location of the hemivertebra and the choice of the surgeon will determine the mode of the surgery. This procedure can provide correction of 25-30° in general. The eggshell osteotomy or the more popular wedge osteotomy is used for excision of the hemivertebra. Unilateral instrumentation following the osteotomy can be performed in several ways. It can be performed with laminar hooks, tension straps and, as the most frequent application, with pedicle screws (2,49).

5. Spinal osteotomy applications: This method, which is used in complex spinal deformities, is based on the resection of one or more vertebra with an anterior approach in the first place. It is a complex procedure involving the resection of the vertebral body till the dura is exposed and resection of the pedicles (14). This procedure must always be performed by monitoring the neural functions and one must be prepared for risks including intra-operative vascular injuries or bleeding (4).

B. Surgical Approach in Idiopathic Spinal Deformities

Idiopathic scoliosis cases are the most frequent ones among the idiopathic spinal deformities. In these patients, the patient and parents must be informed in detail before making the decision for surgery. The decision for surgery will depend on factors including the progression risk, maturity of the skeleton, type and size of the scoliosis, cosmetic appearance and whether or not conservative treatment has been successful.

Intraoperative neuro-monitoring must be used as a standard application in the surgical correction stage. The combined use of the motor and somatosensorial potentials decreases the risks significantly (39,40).

Like in congenital spinal deformities, surgical modalities for idiopathic spinal deformities also include the posterior fusion, anterior fusion or combined fusion techniques. The surgical procedures to be applied will vary according to the type and location of the deformity and habits of the surgeon.

CONCLUSION

Spinal deformity can be the pathology of a single vertebra, or can develop with pathologies of multiple vertebras, ribs or the pelvis. The spine must be evaluated in the coronal, sagittal and axial planes.

Spinal deformity can develop as a result of many diseases or can appear as an idiopathic condition. Congenital spinal deformities are accompanied by multiple organ pathologies.

The treatment modality must be determined by taking into account many factors including the patient's age, neurologic status, etiology and location of the deformity, cosmetic expectations and the possibility of progression of the deformity.

In the physical examination, alignment of the vertebras and position of the pelvis must be noted in addition to the neurologic examination in standing and lateral bending positions so that the entire body will be seen. Adams test and scoliometric measurements are guiding as screening tests, particularly in young patients.

Patients must be evaluated using classification systems that are widely used including the Lenke or SRS. The spinal cord must be evaluated in detail in patients that deformity procedures will be performed on. It must be kept in mind that deformity type can determine the mode of surgery.

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