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Classification System in Adolescent Idiopathic Scoliosis

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ABSTRACT
Scoliosis is defined as the lateral spinal curvature with a 10° Cobb angle or above. Idiopathic scoliosis accounts for nearly 80% of the structural coronal deformities. According to the age groups, it is classified as infantile (the ages between 0-3), juvenile (ages between 4-9), adolescence (the age of 10 – until maturity). King classification and Lenke classification are the mostly widely used classifications in idiopathic scoliosis classification systems. Although the classification system presented by Peking Union Medical College (PUMC) is simple and easy to understand, Lenke system is considered more advantageous for practical use. Lenke classification is the most widely used and accepted classification system.

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INTRODUCTION

Scoliosis is three dimensional curvature deformity greater than 10° degrees accompanied by lateral deviation and rotation of the spine. In other words, it refers to left and right bending of the vertebral bones and their rotating around their axis [1-4]. In general terms, it is described as lateral bending of the spine on frontal plane [5-7].

Scoliosis is a complex curvature causing deformity not only in coronal plane but also in all three planes as a result of spine's rotating around its on axis [3]. In other words, in scoliosis deformity is not only restricted to frontal plane, and it can result in three-dimensional deformity including sagittal and axial planes. Intervertebral extension, which causes lateral bending on the frontal plane, rotation on axial plane and lordosis on sagittal plane is observed [2, 8, 9]. It is a pathology that creates deformation in the body and that can cause cardiopulmonary complications as well in case of its progression. At later stages, it can result in severe clinic disorders like recurrent pulmonary infections, hypoxia, increased pulmonary resistance and heart failure resulting from pulmonary hypertension. It also causes emotional disorders and cosmetic deformities [7-9].

Adolescent idiopathic scoliosis (AIS) is the most frequently seen type of scoliosis and it is reported that it is seen among children between the age group of 10-16 with a rate of 2-4% [2, 10, 11].

The diagnosis of idiopathic scoliosis can be made by identifying the neurological causes and other symptoms (for example neurofibromatosis skin blemishes) through a good physical examination and eliminating the congenital abnormalities through a radiological examination [1, 8, 9, 12]. Idiopathic scoliosis can emerge at any age during adolescence. It peaks at three time frames in terms of its onset. The first year of life, the period between 5-6 and 11 years and the period until skeleton development is finalized are the time frames that scoliosis is mostly observed. In this respect, idiopathic scoliosis is separated into three groups according to the age when deformity appears [1, 8, 12].

1. Infantile idiopathic scoliosis: It refers to the deformities experienced below the age of 3. It is more widely seen among boys than girls and generally it is in the form of thoracal curvatures. Compensatory curvatures are not present.
2. Juvenile idiopathic scoliosis: It refers to the deformities experienced between the ages of 3 and 10. Their incidence is the same among boys and girls. Curvature is predominantly thoracal and its progressive feature is striking.

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3. Adolescent idiopathic scoliosis: It refers to the deformities that emerge from the beginning of 10 years until the completion of skeletal development. It is more widely seen among girls compared to boys. Generally, right thoracic and left lumbar curvatures are seen. Adolescent idiopathic scoliosis is the most frequently seen one among these three groups [1, 8, 9, 12].

Idiopathic scoliosis accounts for nearly 80% of the structural coronal deformities [13]. In fact, idiopathic scoliosis diagnosis is the diagnosis excluding the current causes. Idiopathic scoliosis can emerge at any period during growth period [3]. No precise reason for adolescent idiopathic scoliosis has been found [4]. The reasons for 75-80% of scoliosis cases are not known (idiopathic). It emerges in a normal healthy child in the course of time without being noticed and progresses with the skeletal development. Early diagnosis and treatment of scoliosis are of great importance for preventing the potential deformities and eliminating the factors that contribute to the progress of the disease and for the patients to make use of the treatment at the optimum level as well [7].

In the recent years, it is believed that brainstem and/or posterior colon errors that cause proprioception and vibration sensation defects and developmental abnormalities in melatonin-calmodulin system might have a role in the etiology. Additionally, it is also claimed that AIS is a multi-gene dominant disease with variable penetration (Acaroğlu, 2002).

Incidence:

While the incidence of the curvatures with 10 degrees or above varies between 1-3%, the incidence falls to 0.15-0.3% in the curvatures with 30 degrees or above that require treatment. While the female/male rate is 1.4/1 in the curvatures with 10 degree or above, this rate rises to 5/1 in the curvatures with a degree greater than 30 [3].

Clinical Findings:

In AIS, "rib hump", which grows as the curvatures get bigger in the patients due to transverse and sagittal plane deformities, occurs. The first finding that is noticed or looked for in the scanning tests is hump [4]. Besides, in the adolescents with scoliosis, the complaints associated with deformities like curvature in the back, high shoulder, body asymmetries, one hip's being higher than the other are seen [3, 12, 14]. Apparent neurological loses can be easily identified with scoliosis and all AIS patients should be meticulously examined in terms of occult neurological findings. In particular, clonus, hyperreflexia, abdominal skin reflex asymmetries are the findings that definitely require additional examinations. The curvatures that are not similar to typical adolescent idiopathic scoliosis curvatures clinically (for example left thoracic curvatures) should be evaluated with additional examinations [15, 16].

It is thought that the curvature should be 80 degrees or above in order for the emergence of a scoliosis associated restriction in respiratory functions [4, 15].

Normally, the apex of the thoracic curvature in AIS is on the right side. The first menarch, pubic and axillary hair development are inquired in order to determine maturity. Pubic hair development and breast development are seen just before the onset of the rapid maturation in girls. Axillary hair development indicates the slowing down of the development in both sexes. Besides, menarch indicates that the development pace slows down. In boys, pubic hair development takes place before the rapid development period. Axillary hair development manifests that the development pace slows down in both sexes [1, 3].

Localized excessive hair development in the back, fossette appearance, haemangioma, tense spinal cord or diastematomyelia are present. Facial asymmetry points to scoliosis associated with torticollis. In girls, the breast on the convex side is generally smaller and upper and the breast in the concave side is smaller and lower [1, 3, 8, 17, 18].

It is necessary to eliminate the neurological reasons that can lead to deformity in order to make idiopathic scoliosis diagnosis. Neurological examination starts with reflexes. It is required to examine the abdominal reflexes. If the reflexes are present on one side and not present on the other, further examination is required. This finding is not found in normal patients with scoliosis. Reflex absence can be seen in all quadrants. Patellar and achilles tendon reflexes should be symmetrical. Muscle strength examination and four extremities range of motion examination should be certainly performed. The extremities should be examined with regard to abnormal posture and sensation [1, 3].

Radiolocal Examination:

The radiographic examination of the spine begin with anteroposterior and lateral radiographs recorded on the film cassettes, 90 × 35 cm (36 × 14 inch) in size, from a distance of 2 meters of when patient stands. With the use of long-film cassette, all patterns can be seen on a single film. In anteroposterior radiograph, the curvature pattern, type of scoliosis, the spine and the body's balance, skeletal maturity and lower limb length differences can be assessed. With lateral radiographs, thoracic lordosis in the sagittal contour of thoracic and lumbar spine can be detected and spondylolysis and spondylolisthesis can be imaged [1, 8, 12].

Magnetic Resonance Imaging is a superior method for imaging the spinal canal anomalies clearly. It has no place in the routine evaluation of the typical idiopathic scoliosis patients [1].

While spinal congenital anomalies can be detected with computed tomography clearly, computed tomography is not a routine examination in the idiopathic scoliosis diagnosis. If there is the probability of pseudoarthrosis presence, it is a beneficial method for determining the bone fusion (especially three dimensional reconstruction). Besides, the location of the pedicle screw and the spinal rotation can be determined [1, 8, 12].

Classification on Adolescence Idiopathic Scoliosis:

King-Moe classification, the most commonly known method today, was made in 1983 in consideration of thoracic deformities [19]. Lenke published a more comprehensive version of this classification in 2001 by making up for some shortcomings of this classification [13]. Later in 2005, PUMC (Peking Union Medical College) classification which is easier to use and understandable in practice in comparison with Lenke classification was made [20-22]. Surgical treatment of the previously untreatable advanced age deformities has become possible by means of prolongation of life span, developments in the field of medicine, orthopedic surgery and biomedicine [20].

King Classification:

King-Moe made the classification of idiopathic scoliosis chronologically for the first time [19]. Thoracic region has been indicated with the purpose of determining fusion levels in adolescence idiopathic surgery treatment [19]. King *et al*. classified scoliosis under five subgroups according to the scoliosis occurrence place. They used structural and compensatory (secondary) curvature terms. It also defined flexion index as the difference between improvement rate in lumber curvature and improvement rate in thoracic curvature in lateral bending direct graphs. King classification argued that selective fusion will be sufficient by considering lumber curvatures as compensatory initially and applied selective thoracic fusion on 405 patients with thoracic scoliosis in their own series with Harrington rod system. Richards *et al*. found that spinal imbalance emerges following the selective thoracic fusion operation in patients with lumber curvature of 40 degrees or more [3].

He described the line between the iliac wings as "sacral middle line", the perpendicular drawn over sacrum, and defined the curvature types accordingly. "Flexibility rate in the curvature" concept, which is calculated with the maximum lateral bending made against the curvature in the thoracic and lumber regions has been proposed. Curvature improvement rate in thoracic region is subtracted from the improvement rate in lumber region, and the flexibility rate in the curvature is calculated. These types are determined considering patient's age, curvature degree, curvature types, vertebral rotations, flexibility index and stabile vertebra and treatment recommendations are made according to each type. King *et al*. (1983) made these classifications by using the anteroposterior and lateral bending graphs.

There are three disadvantages of King's classification:

1. It is not able to describe thoracolumbar, lumbar, double major or tipped major curvatures
2. It does not take the sagittal plane deformities into account
3. When the same radiographs are evaluated by a variety of surgeons, the rate of the majority of the surgeons to decide upon the same group is low [13, 19, 20].

Lenke Classification (2 dimensional classification):

Lenke classification has been developed with the aim of determining the fusion levels by evaluating the coronal and sagittal plane deformities [13, 20, 23, 24]. In the evaluations made taking this classification into account, majority of the doctors make decisions accordingly. There are three components of this classification; [20] a) six curvature types, b) lumber spine marker, c) thorocal spine marker.

Type of the curvature: Firstly, the location of the curvature is determined as proximal thoracic, thoracic, thoracolumbar or lumber. Later, the deformity with the highest Cobb angle is defined as major curvature and the others are called as minor curvatures. The curvatures with no flexibility are called structural curvature [20].

Lumber spinal marker:

It is necessary to take lumber region curvature into account in surgical treatment. Lumber region deformity disturbs spine balance and increases the proximal curvatures. Lumber spine array put forward by the lumber markers gives idea about the new array that can be acquired postoperatively. With regard to King classification, the main determinant of the marker, 64% same results were obtained and it was underlined that Lenke classification is more valid [25]. In Lenke classification, thoracal marker is more comprehensive in sagittal plane compared to King classification. Patients can be classified under 42 different groups according to this classification. Lenke system is criticized for being complex and difficult to use, and for not dealing with the deformity three-dimensionally [20, 21].

Thoracal spinal marker:

In the radiographs taken when the patient stands, normally, there is a +30 degree (between +10 and +40) physiological kyphosis between upper side of the 5th thoracal vertebra and lower side of the 12th thoracal vertebra. Accordingly, the evaluation performed under +10 degrees are negative (–), the ones between +10 and +40 are N (normal) and the ones greater than +40 degrees are accepted as positive (+) [20].

Structural curvature is considered as the biggest curvature and the other curvatures are minor curvatures. Whether the minor curvatures are structural or not is also assessed according to certain criteria. Lenke classification introduced lumber spine determinant and sagittal spine determinant definitions along with 6 types of curvatures (I-VI) (Lenke *et al*., 2001). Main curvature is present in main thoracal in Lenke Type I. The deformities in proximal thoracal (PT) and lumbothoracal (LT/L) are minor but not structural. Double thoracal curvature is present in Lenke Type II curvatures. The curvatures in proximal thoracal (PT) and main thoracal (MT) are structural, the curvature in lumbothoracal is not structural. In Lenke Type III, in main thorocal, there is structural deformity in thoracolumbar. Triple curvatures are Lenke Type IV. In Lenke Type V, the main curvature is at thoracolumbar (TL) junction. The curvatures in proximal thoracic (PT) and main thoracic (MT) are not structural. In Lenke Type VI, the curvature in main thoracic (MT) and thoracolumbar/lumber region are structural. TL/L curvature is bigger than MT curvature. The restrictions of Lenke Classification are: It is not clear what are the upper and lower limits of the fusion are and how much of the structural curvature should be incorporated into the fusion. Classification does not take shoulder imbalance, patient maturity, body balance into consideration. Besides, compared with the King classification, Lenke Classification is beneficial as the common language when the surgeons explain the curvature [3, 13].

Peking Union Medical College (PUMC) Classification:

This classification system that recommends surgical approach and fusion level was published in 2005. Single, double and triple curvatures are separated into three main groups and classified under 13 subgroups according to apex location, curvature flexibility and curvature width [23]. In this classification, efficiency rate is 85%. It can evaluate the deformity three-dimensionally and it is easily understandable [20, 21].

Surgical Limits, Implantation and Fusion Levels:

Moe, [26] claimed that non-structural segments should not be incorporated into the fusion field by recommending fusion from upper neutral vertebra to lower neutral vertebra. What is mentioned in the classification is SMVC. The spine at the very tip of the curvature is centered and is called as stable vertebra. Curvature apex is vertebra or disc, which is at the longest distance from stable vertebra on horizontal plane laterally. Three classifications, namely A, B and C are made with lumber marker. A: SMVC centers stable vertebra and if there is no different lumber curvature, curvature has a thoracic apex. B: SMVC fits into the vertebra in lumber curvature apex even if it is tangential. Also in this case, curvature has an apex in the thorax. C: SMVC is inside the vertebra in the lumber curvature and it does not overlap with vertebra even tangentially. In this case, there is an apex in thoracal-thoracolumbar or lumbar region [20].

It was asked to evaluate the same radiographs by different surgeons by using Lenke and King-Moe classifications. According to King [19] stable vertebra is the lower vertebra that is intersected by middle sacral line in thoracal curvature. In type 1 curvatures, the instrumentation should be finalized in stable vertebra and thorocal and lumbar curvatures should not be incorporated into the fusion together. Lenke *et al*. [13, 23, 24] reported four criteria in order to finalize instrumentation at a higher level with the purpose of protecting the mobile segments.

1. Rotation should not be present in the vertebra just above stable vertebra or maximum stage I rotation should be present. There should be a slope under 30 degrees.
2. Stable vertebra slope should be less than 20 degrees.
3. Apical disc should not be located above the L1-L2 disc.
4. L3-L4 disc should have an expansion towards curvature convexity [13, 23, 24].

In King II curvatures, King *et al*. [19] recommended selective thoracic fusion. If neutral vertebra and stable vertebra are different, the instrumentation should be finalized in stable vertebra.

Selective thoracic fusions performed by using instrumentation systems (CD, TSRH, Isola) that are able to do derotation and distraction maneuver mostly resulted in spine imbalance [19]. King type II curvatures were separated into two subgroups as A and B with the purpose of getting rid of this imbalance and some criteria are reported [19].

1. The fact that lumbar curvature is below 35 degrees
2. The fact that there is 70% improvement in bending graphs
3. The fact that lumbar apex touches central sacral line
4. The fact that Lumbosacral fraction curvature is below 12 degrees

King type III curvatures are treatment limited thoracic fusion and instrumentation. Instrumentation should extend unstable vertebra in anteroposterior plane and extend on kyphosis deformity apex distal in sagittal stable

plane. In King type IV curvatures, it is recommended to finalize instrumentation in stable vertebra. King type V curvatures are double structural thoracal curvatures, and posterior instrumentation should be performed on both thoracal curvatures [19, 20].

The cases in which instrumentation should reach T2 level are given below: [20, 27].

1. T1 is inclined to upper curvature and the shoulder is elevated in convex part in upper curvature.
2. The fact that the upper curvature is above 30 degrees and has limited flexibility.
3. The fact that transition vertebra between the curvatures is at T6 or at lower levels.

According to Lenke classification, if the minor curvature is not structural, selective thoracal fusion is recommended.

According to Lenke *et al*., structural curvature criteria are as follows:

- The fact that Cobb angle is above 25 degrees in lateral bending radiographs
- Presence of hyperkyphosis in proximal thoracal (T2-T5) or thoracolumbar region (T10-L2) kyphosis > +20°) [13, 20, 23, 24].

Conclusion:

Scoliosis is defined as the lateral spinal bending with Cobb angle which is 10° or above. Each patient with idiopathic scoliosis should be evaluated with regard to his/her age, curvature degree and the circumstances in which he/she lives. The main objective in scoliosis treatment is to stop curvature until maturation is completed. After maturation is completed, it aims to correct the patient's curvature as possible by preventing the complications. The surgery that will be performed should fulfill the cosmetic expectations of the patient to the extent possible. While trying to achieve body balance, shoulder balance and in particular, breast balance for female patients should be ensured. King classification and Lenke classifications are the most widely used classification systems in idiopathic scoliosis classification systems. The classification system put forward by Peking Union Medical College (PUMC) is simple and easily understandable; however, Lenke system is considered more advantageous compared to it. Lenke classification system is the most frequently used and most widely accepted classification system today.

Contribution Of Authors:

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