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Classification of scoliosis
Clasificarea scoliozelor

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Abstract

The classification of scoliosis is particularly important in the medical management of scoliosis and the maintenance of spinal mobility for as long as possible is important.

In 1983, Howard King classified adolescent idiopathic scoliosis into five distinct types, with specific recommendations for each. A new classification was presented by Lawrence Lenke in 2001, including for the first time sagittal plane changes. Although the Lenke classification is much more complete than that presented by King, it is far from being perfect. It does not include the rotational component involved in the development of scoliosis. New technologies allowing for the three-dimensional reconstruction of the spine can be used for a real 3D classification of scoliosis and for the approach of new therapeutic concepts.

Congenital scoliosis, which occurs during the first six weeks of intrauterine life, can be associated with cardiac or renal malformations. Vertebral malformations may result from the partial fusion of the vertebral bodies. Congenital kyphosis can also develop in this period.

Neuromuscular scoliosis is associated with cerebral palsy, muscular dystrophy, spina bifida.

Idiopathic scoliosis, in which no cause can be identified, is divided depending on the patient's age.

The various conditions that can initially manifest as scoliosis should be taken into consideration: lower limb length differences, bone tumors, infections, antalgic scoliosis. Also, a number of systemic diseases can be associated with scoliosis: Marfan syndrome, Klippel-Feil syndrome, Down syndrome, osteogenesis imperfecta, neurofibromatosis, Ehlers-Danlos syndrome.

Key words: scoliosis, classification, functional scoliosis, structural scoliosis

Rezumat

Clasificarea scoliozelor este deosebit de importantă în managementul medical al scoliozelor, fiind importantă menţinerea mobilităţii coloanei cât mai mult timp posibil.

În 1983 Howard King clasifică scolioza idiopatică a adolescentului în cinci tipuri distincte, cu recomandări specifice fiecăruia. O nouă clasificare a fost prezentată de Lawrence Lenke în 2001, fiind incluse pentru prima dată şi modificările în plan sagital. Deşi clasificarea Lenke este mult mai completă decât cea prezentată de King, este departe de a fi una perfectă. Clasificarea nu cuprinde componenta rotaţională implicată în apariţia scoliozei. Noile tehnologii care permit reconstrucţia tridimensională a coloanei pot servi pentru o clasificare 3D reală a scoliozei şi pentru abordarea unor noi concepte terapeutice.

Scolioza congenitală, ce apare în primele şase săptămâni de viaţă intrauterină poate fi asociată cu malformaţii cardiace sau renale. Malformaţiile vertebrale pot rezulta din fuziunea parţială a corpilor vertebrali. De asemenea în această perioadă se poate dezvolta cifoza congenitală.

Scolioza neuromusculară este asociată cu paralizia cerebrală, distrofia musculară, spina bifida.

Scolioza idiopatică, în care nu poate fi identificată o cauză, se clasifică în funcţie de vârsta pacienţilor.

Trebuie luate în considerare diversele situaţii ce se pot manifesta iniţial ca şi o scolioza: diferenţele de lungime a membrelor inferioare, tumorile osoase, infecţii, scoliozele antalgice. De asemenea, o serie de boli sistemice pot fi asociate cu scolioza: sindromul Marfan, sindromul Klippel-Feil, sindromul Down, osteogeneza imperfectă, neurofibromatoza, sindromul Ehlers-Danlos.

Cuvinte cheie: scolioza, clasificare, scolioze funcţionale, scolioze structurale.

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Introduction

The spine or the axial skeleton represents the central segment of the human locomotor system, a segment that has gained a particular importance with the acquisition of verticality. The spine must support the body in space, resist gravitational forces and all strains from the exterior environment to which it is permanently subjected, and protect the spinal canal content, the spinal cord with its nerve roots. On the other hand, the vertebral column must be sufficiently mobile to allow flexion, extension, rotation and inclination movements of the head and trunk, as well as head motion in space.

The spine must protect nerve tissue, without limiting its own mobility, which is possible due to a complex multisegmental osteoligamentous and muscular structure and to a complicated physiology, which represents an adaptation necessary to the acquisition of the vertical position.

There are many causes that may affect the balance of the spine, preventing the optimal achievement of its functions. Frontal and sagittal plane imbalances occurring in childhood will predominantly worsen in the period of the pubertal growth spurt, until bone maturation. However, there is also the possibility of a slower aggravation throughout adulthood, if these imbalances exceed a certain threshold. Spinal deformities occurring in the adolescent and the adult may cause functional and structural disoders, as well as more or less severe neurological deficits.

Galen defines for the first time scoliosis as being a frontal plane deviation of the spine. Normally, there is no physiological frontal curvature, but the majority of the authors accept a small degree of spinal asymmetry of about 10º. Thus, because of the absence of physiological curvatures in frontal plane, any frontal plane deviation of the spine of more than 10º is considered to be pathological (Antonescu, 2010).

Scoliosis is a deformity of the vertebral column in the three planes, frontal, sagittal and transversal, without the loss of osteoligamentous continuity, which develops over a segment or over the entire length of the spine (Herring & Saunders, 2002).

Classification of scoliosis

A first differentiation should be made between functional scoliosis (scoliotic posture/non-structural scoliosis) and structural scoliosis.

Non-structural or functional scoliosis is transient and can be corrected passively, representing a disturbance of spinal balance in orthostatism, without anatomical changes of the vertebrae or intervertebral discs.

The most frequent causes of functional scoliosis are: lower limb length differences, unilateral paravertebral muscle contracture, torticolis, upper limb asymmetry (Fisher, 2011; Ovadia, 2013).

Stagnara classifies this type of scoliosis into three main categories: *posture defects*, *reducible scoliotic curvatures*, and *compensatory curvatures* (de Mauroy, 2011).

a) Postural defects are scoliotic postures without an obvious cause that occur during childhood; they can be intermittent or permanent, are not accompanied by vertebral rotation, do not evolve into structural scoliosis and disappear during the pubertal growth spurt.

b) Reducible scoliotic curvatures are usually antalgic postures caused by vertebral or juxtavertebral disorders (Bess et al., 2013).

c) Compensatory curvatures develop due to defects located at a distance from the vertebral column, and they can be easily identified through a careful clinical examination: lower limb length differences, inadequate hip postures (stiffness during adduction or abduction of the coxofemoral joint), irreducible muscle retraction.

The objective examination of the locomotor system is particularly important to avoid the misdiagnosis of spinal deviations that could be the onset symptoms of orthopedic or neurological disorders as scoliotic postures and, on the other hand, to avoid overestimating symptomatology and making a diagnosis of structural scoliosis, which might entail the initiation of useless, expensive and long duration orthopedic and/or surgical treatments (Waller et al., 2013).

Structural scoliosis develops in all three spatial planes, due to a lateral inclination, curving and rotation movement of the vertebrae, which maintain their osteoligamentous continuity (Wang, 2012).

The Scoliosis Research Society classifies structural scoliosis as follows:

a) Idiopathic scoliosis represents the most frequent form of structural scoliosis.

Depending on the age at which it develops, idiopathic scoliosis can be divided into:

- infantile scoliosis, between 1-3 years of age, which can be resolutive or progressive;
- juvenile scoliosis, between 4 years of age and the onset of puberty;
- adolescent scoliosis, which develops between the onset of puberty and bone maturation.

Some authors consider that the classification into these three categories is not justified, as the 3 onset ages reflect the different growth rates in childhood and adolescence. The growth rate is higher during early childhood and adolescence and is much lower in the juvenile period. Thus, juvenile scoliosis should not be considered as a separate category (Qiu et al., 2008).

The presence of an important thoracic deformity before the age of 5 years increases the risk of altered pulmonary function and secondarily, cardiac function (cor pulmonale); this is why Dickson opines that idiopathic scoliosis should be divided into two subgroups: early onset scoliosis, between 0 and 5 years, and late onset scoliosis, over 5 years of age. Shufflebarger considers for therapeutic reasons that idiopathic scoliosis should be divided into two categories, early onset scoliosis and late onset scoliosis, but he establishes the delimiting age at 10 years (Wise et al., 2000).

In these children and adolescents, no neurological or muscular disorder is present, and radiographs do not detect congenital or other disease-induced vertebral changes.

b) Neuromuscular scoliosis can be neuropathic or myopathic.

Neuropathic scoliosis can occur through central motor neuron lesions (cerebral palsy, spinocerebellar degenerescence, medullary tumors and trauma, syringomyelia), or through peripheral motor neuron lesions (poliomyelitis, trauma, myelomeningocele).

Myopathic neuromuscular scoliosis occurs in disorders such as: arthrogryposis, Duchenne or Becker muscular dystrophy, congenital hypotonia, dystrophic myotonia etc.

c) Congenital scoliosis is due to formation defects

(cuneiform vertebrae, hemivertebrae), or to segmentation defects (unilateral or bilateral unsegmented bar), or the two can be mixed.

d) Dysmetabolic scoliosis occurs in rickets, osteogenesis imperfecta, juvenile osteoporosis.

e) Scoliosis of infectious cause: spondylodiscitis, Pott's disease

f) Thoracogenic scoliosis: trauma, thoracoplasty, post-burn scars, congenital thoracic deformities.

g) Scoliosis in system diseases: mucopolysaccharidosis, Ehler-Danlos syndrome, Marfan syndrome, von Recklinghausen neurofibromatosis (Al Kaissi et al., 2013).

h) Scoliosis of rare causes: cardiac malformations, osteoid osteoma, genu valgum, concave foot.

i) Tumor scoliosis: brain tumors, spinal tumors, medullary tumors (Schwab et al., 2012).

In approximately 75-80% of the cases, scoliosis is idiopathic, while the rest of 20-25% of the cases are secondary forms.

Anatomo-radiological classification of scoliosis

The Committee of the Scoliosis Research Society defined the types of scoliotic curves depending on the location of the apical vertebra.

A major (primary) curve is a structural curve whose value in degrees is the highest, which is the least reducible curve, with the most important rotation.

Compensatory (secondary) curves are curves that allow the rachis to find its alignment above and below the major curve. They can be non-structural or become structuralized during bone maturation.

An apical vertebra is the most rotated and the most displaced vertebra in relation to the gravity line of the body.

A superior end vertebra is the vertebra at the upper limit of the curve, whose upper end plate has the greatest inclination towards the concavity of the curve.

An inferior end vertebra is the vertebra at the lower limit of the curve, whose lower end plate has the greatest inclination towards the concavity of the curve.

A neutral vertebra is the vertebra at the upper or lower limit of the curve, which is not rotated. It can sometimes be a superior or inferior end vertebra (Newton et al., 2011).

The types of scoliotic curves are (Qiu et al., 2005):

- single high thoracic (cervicothoracic);
- single thoracic;
- single thoracolumbar;
- single lumbar;
- double major thoracic and lumbar;
- double major thoracic;
- double major thoracic and thoracolumbar;
- multiple curves.

The high thoracic curve has its apex at T3 or T4, the superior end vertebra is usually T1 or T2, rarely C7, and the inferior end vertebra is T7. It is usually a left thoracic curve that has a compensatory thoracic or thoracolumbar curve below, which can become structuralized during evolution.

The thoracic curve is one of the most frequent curves and has a marked evolutive potential. The apex is usually situated at T8 or T9, the superior end vertebra is between T4-T6, and the inferior end vertebra is between T11-L2. The most frequent form is T5-T12. 95% of scoliosis cases in adolescents are right thoracic. It is frequently accompanied by a compensatory curve below, which can be quite ample and may generate confusion with double major thoracic and lumbar scoliosis. The right shoulder is elevated, the trunk is deviated to the right and right thoracic gibbosity of variable sizes is present.

The thoracolumbar curve has its apex at T12 or L1, or even at the level of the disc between the vertebrae. The superior end vertebra is between T8-T10, and the inferior end vertebra is usually L3. It can be right or left, with compensatory curves above and below.

The lumbar curve usually has its apex at L2, the end vertebrae between T11-L1 and L4-L5, the majority of the cases being left curves, with compensatory curves above and even below (Schwab et al., 2013).

The double major thoracic and lumbar curve has two curves of similar size and rigidity. The thoracic curve is usually a right curve with the apex in T7 or T8 and the end vertebrae between T4-T6 and T10-T12. The lumbar curve, usually a left curve, has the apex in L2 and extends inferiorly up to L4-L5.

The double major thoracic curve is formed by a high left thoracic curve and a right thoracic curve. The upper curve is short, extending to T5 or T6, while the lower curve extends inferiorly between T11-L2.

The double major thoracic and thoracolumbar curve usually has a right thoracic curve, with the apex at T6 or T7, extending between T4 and T9-T10, and a left thoracolumbar curve, with the apex at the level of the disc between the vertebrae T12 and L1, extending inferiorly to L3.

The presence of multiple curves is usually reduced, aggravation being rare (Potter et al., 2005).

During the course of time, there have been several classifications of scoliosis, the first classification of idiopathic scoliosis being that of King-Moe, which subdivides scoliosis into 5 types depending on the location of the curves (Table I, Fig. 1) (Ovadia, 2013).

Table I

King classification: scoliosis is divided into 5 subgroups according to the main curve and compensatory curve.

Type	Primary curve	Secondary curve	Lateral bending
I	Lumbar, crossing the midline	Thoracic, crossing the midline	Lumbar curve is larger
II	Thoracic, crossing the midline	Lumbar, crossing the midline	Thoracic curve is larger
III	Thoracic	Lumbar, not crossing the midline	–
IV	Long thoracic	Where L5 is centered over the sacrum	–
V	Double thoracic	-	-

(Ovadia, 2013)

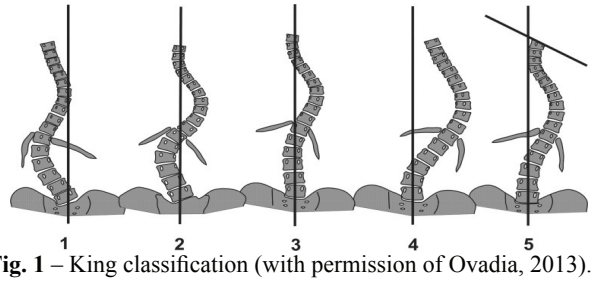

Fig. 1 – King classification (with permission of Ovadia, 2013).

The Lenke classification considers that the structural curve is the major one, and the other two curves are considered as minor, compensatory, the reliability of the classification being 93% compared to only 69% for the King classification (Fig. 2).

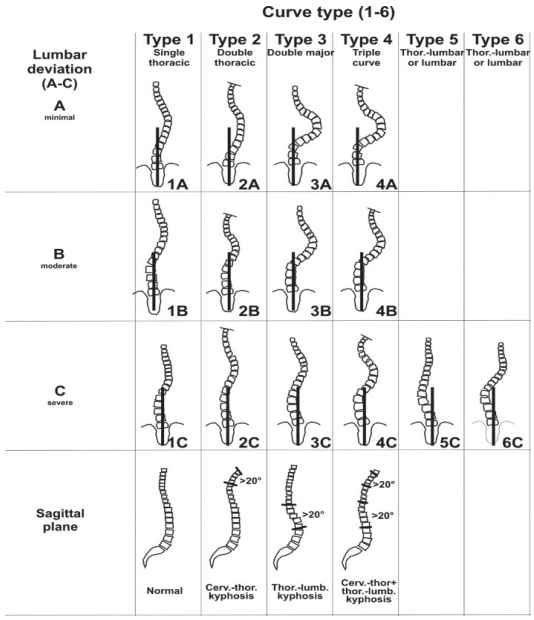

Fig. 2 – Lenke classification (with permission of Ovadia, 2013).

Lenke et al. (2001) estimate the reliability of the classification between 84-90%; also, Ogon et al. (2002) consider the Lenke classification to be more reliable than the King classification. The Lenke classification provides important information about the choice of the type of surgery; scoliosis cases classified as types 1 and 5 can be treated by anterior as well as posterior approach, while for types 2, 3, 4 and 6, only the posterior approach is chosen. Although compared to other classifications it is much more comprehensive and reliable, the Lenke classification is far from being perfect. In approximately 15% of the cases, the surgical treatment chosen does not match the treatment initially proposed by the therapeutic algorithm (Yaman et al., 2014; Niemeyer et al., 2006).

The stereoradiographic measurements of the spinal curves use for analysis the Cobb angle, the apical vertebra, the axial rotation of the apical vertebra and the orientation of the apical vertebra in relation to the sagittal plane.

The new technologies allowing for a three-dimensional reconstruction of the spine can be used for a real 3D classification of scoliosis as a basis for the development of new therapeutic concepts and procedures (Ovadia, 2013).

For establishing an optimal therapeutic approach, the natural history of the scoliotic curve throughout the growth period and at adult age is important. This history refers to the progression of the curve, the frequency of vertebral pain, the possible alteration of pulmonary function, mortality, psychosocial effects, and the influence of pregnancy and delivery on the scoliotic curve.

There are a number of factors correlated with the risk of aggravation of the curve, some related to the patient's growth potential and others related to the particularities of the scoliotic curve: female sex, young onset age of scoliosis, development of scoliosis before the onset of menarche in girls, a low value of the Risser test, a double major curve (the curves with the higher risk of aggravation are represented by the double thoracic curve, the double thoracic and lumbar curve, the single right thoracic curve), a high degree of the curve at the time of diagnosis (Sturm et al., 2010; Weiss et al., 2003).

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