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Update Article

Current concepts on the sagittal balance and classification of spondylolysis and spondylolisthesis☆,☆☆

Marcos Antonio Tebet

Discipline of Orthopaedics and Traumatology, Faculdade de Medicina de Jundiaí, Jundiaí, SP, Brazil

ARTICLE INFO

Article history:
Received 4 April 2013
Accepted 9 April 2013

Keywords:
Spondylolisthesis
Spondylolysis/classification
Postural balance
Radiography panoramic

ABSTRACT

Treatment of spondylolysis and spondylolisthesis remains a challenge for orthopaedic surgeons, neurosurgeons and paediatrics. In spondylolisthesis, it has been clearly demonstrated over the past decade that spino-pelvic morphology is abnormal and that it can be associated to an abnormal sacro-pelvic orientation as well as to a disturbed global sagittal balance of spine. This article presents the SDSG (Spinal Deformity Study Group) classification of lumbosacral spondylolisthesis. The proper treatment of spondylolisthesis is dependent on recognizing the type of slip, sacro-pelvic balance and overall sagittal balance and its natural history. Although a number of clinical radiographic features have been identified as risk factors, their role as primary causative factors or secondary adaptative changes is not clear. The conservative treatment of adult isthmic spondylolisthesis results in good outcome in the majority of cases. Of those patients who fail conservative treatment, success with surgery is quite good, with significant improvement in neurologic function in those patients with deficits, as well as improvement in patients with back pain.

Conceitos atuais sobre equilíbrio sagital e classificação da espondilólise e espondilolistese

Palavras-chave:
Espondilolistese
Espondilólise/classificação
Equilíbrio postural
Radiografia panorâmica

RESUMO

O tratamento da espondilólise e da espondilolistese permanece um desafio para ortopedistas, neurocirurgiões e pediatras. Nas espondilolisteses, tem sido claramente demonstrado na última década que a morfologia sacro-pélvica está anormal e que isso pode estar associado a uma anormal orientação sacro-pélvica e também alterar o equilíbrio sagital global da coluna. Este artigo apresenta a classificação SDSG (Spinal Deformity Study Group) da espondilolistese lombossacral. As propostas de tratamento para a espondiolistese são dependentes do reconhecimento do tipo de deslizamento, equilíbrio sacro-pélvico e balanço sagital e de sua história natural. Apesar de haver diversos achados clínicos e radiográficos que são identificados como fatores de risco de progressão, os fatores primários ou secundários que causam a progressão permanecem obscuros. O tratamento conservador para espondilolistese ístmica do adulto apresenta bons resultados na maioria dos casos.

☆ Please cite this article as: Tebet MA. Conceitos atuais sobre equilíbrio sagital e classificação da espondilólise e espondilolistese. Rev Bras Ortop. 2014;49:3–12.

☆☆ Study conducted at the Discipline of Orthopedics and Traumatology, Faculdade de Medicina de Jundiaí, Jundiaí, SP, Brazil.
E-mail: matebet@uol.com.br

2255-4971 http://dx.doi.org/10.1016/j.rboe.2014.02.003

Naqueles em que há falha do tratamento conservador, o resultado do tratamento cirúrgico também é bom, com melhoria significativa da função neurológica tanto quanto melhoria da dor lombar.

Introduction

The term spondylolisthesis is defined as a translation of one vertebra over another in the anterior or posterior direction. In the adult, this occurs in the lumbar column as a result of a defect in bone architecture, trauma or degenerative process.[1]

The term spondylolisthesis is derived from the Greek *spondylos*, meaning "vertebra", and *olisthesis*, meaning "to slide". The first observation of spondylolisthesis occurred in 1772 by the Belgian obstetrician Herbiniaux[2] during a delivery complicated by a narrowing in the channel because of a slippage of L5 vertebra over the sacrum.

This term was first used in 1854 by Kilian *in* Lonstein et al.[3] Spondylolisthesis is defined as a translation of one vertebral body over the adjacent caudal vertebra in an anterior or, in more serious cases, anterior and caudal direction. Spondylolysis is a defect in the *pars interarticularis*, but without occurrence of slippage.

Spondylolisthesis has been a condition difficult to understand for orthopaedists, neurosurgeons and paediatricians, because of the great variety of existing anatomical and clinical forms. There are few pathological conditions of the column in which there is so much therapeutic controversy.

Considering that the spondylolisthesis is "a slippage of a portion of the column over other adjacent part", we must remember that the column that slid also moved the entire trunk, and this may bring clinical consequence.

The aetiology of this disease is multifactorial and is not yet perfectly clear. The natural history is not well established from the point of view of the knowledge of its real causes, pathogenesis and development.[4]

Spondylolisthesis and spondylolysis are usually well tolerated by patients, but in some cases the severity of the symptoms and a condition unresponsive to conventional medical treatment have caused the indication for surgical treatment.[5]

Epidemiology and aetiology

The incidence of spondylolysis in the general population is about 6%, with a male: female ratio of 2:1.[6]

The incidence of spondylolisthesis in children under 6 years is 2.6%, while in adults it is 5.4%.[6]

The degenerative spondylolisthesis rarely affects individuals below the age of 40 years, and is four to five times more common in women than in men. In a study by Love et al.,[7] subjects who had facet orientation >45° in the sagittal plane were 25 times more likely to develop degenerative spondylolisthesis.

There seems to exist a genetic and familial association with spondylolysis and spondylolisthesis, because 26% of patients with isthmic spondylolisthesis had first-degree relatives with the same disease.[8]

The incidence varies according to ethnicity: it is more common in Caucasian than in black people. In a tribe of Eskimos in Alaska the incidence reaches about 50%.[9]

The exact aetiology of most cases remains obscure.

The dysplastic lesions of the *pars interarticularis*, fracture or of the elongament and of spina bifida conceal a broad distal spinal canal. Dysplasia in both facets (lower lumbar and upper sacral) is a common finding in spondylolisthesis, especially in those with high grade.

The superior sacral facet together with the lower lumbar facet forms a bone hook which prevents translation. Dysplasia can occur in either or both facets. Thus, the hook effect is lost.[6]

The presence of spondylolysis/spondylolisthesis is rare in non-ambulatory patients, which attaches importance to the orthostatism role and of repeated microtraumas in the development of spondylolysis.

Biomechanical studies have demonstrated an increase in stress in the *pars interarticularis* with the column in extension and increase of shear forces through the same area, with persistence of lordosis.[7]

Activities that increase lordosis and maintain the column in extension, such as olympic gymnastics, diving, weightlifting, volleyball, football and pathologies such as kyphosis, increase the incidence of fracture of the *pars* and of spondylolysis and spondylolisthesis.[10]

Sagittal balance in spondylolisthesis

The spondylolistheses are divided into high (slippage >50%) and low (slippage <50%) grade.

The classifications used for spondylolisthesis are not useful for surgical treatment indications and, as noted in the last decade, the sagittal balance is the key factor for surgical treatment.[11]

One explanation for the aetiology of developmental spondylolisthesis, which takes into account the sagittal balance, is that, in the presence of spondylolysis and bone dysplasia, the mechanical stress applied to the lumbosacral junction is increased because of the altered sacro-pelvic morphology, which leads to an abnormal secondary spino-pelvic equilibrium. Because of bone remodelling by growth plates (Heuter-Volkman law), a secondary deformity of the body of L5, sacrum and pelvis also alters the biomechanical forces in the lumbosacral column, which contributes to the progression of spondylolisthesis, in a process similar to what occurs in Blount disease.

The pelvic incidence (PI) is a specific and constant parameter for each individual, measured in the lumbosacral radiograph on the profile incidence, and defined as the angle between the line connecting the midpoint of upper plateau of S1 and the centre of femoral rotation and the line

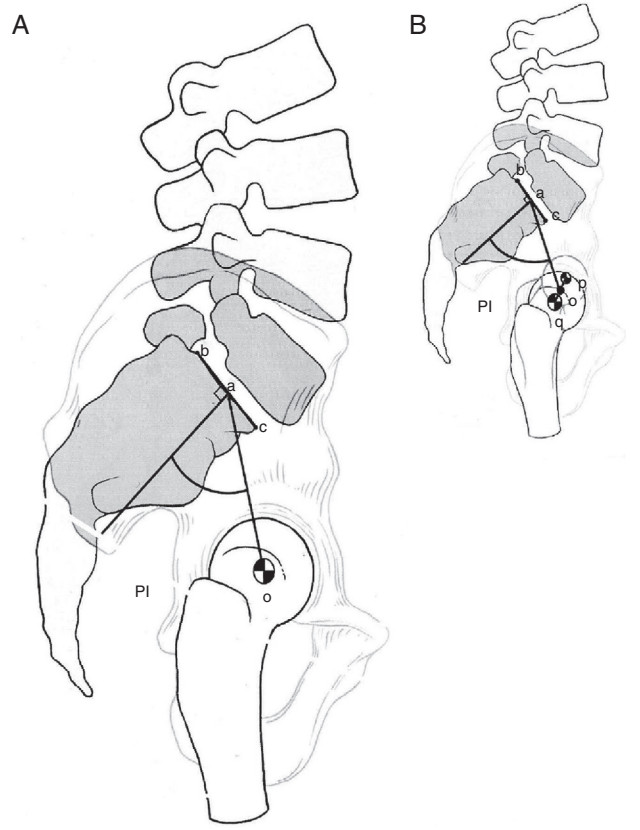

Fig. 1 – (A) Pelvic Incidence (PI) is defined as the angle formed by the intersection of a line drawn from the centre of the femoral head towards the midpoint of the sacral endplate (o–a) and a line perpendicular to the centre of the sacral endplate (a). The sacral endplate is defined by a segment (b–c) formed between the posterior horn of the sacrum and the anterior top of the S1 sacral promontory. (B) When the femoral heads are not perfectly overlapped, the centre of each one of them is marked and a line drawn between two points (q–p) will connect the centre of the two heads. The line (o–a) will be drawn from the centre of the line (q–p), i.e., point (o), to the centre of the sacral endplate.

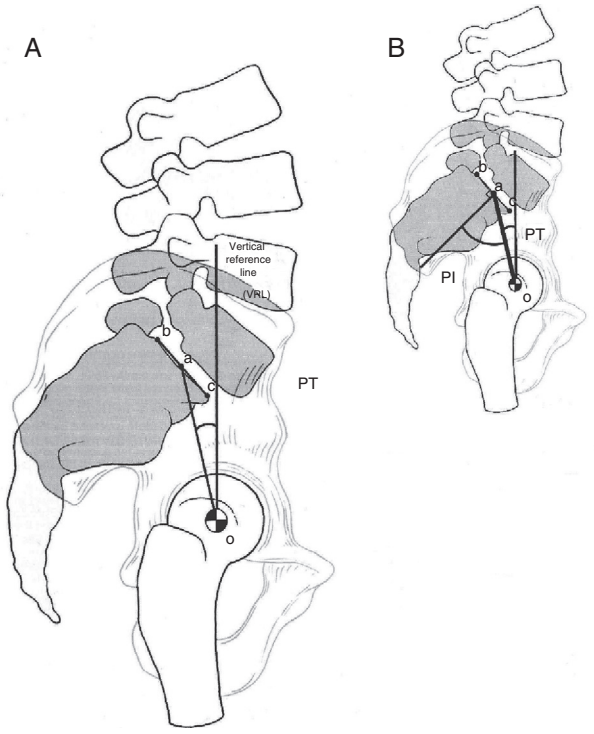

Fig. 2 – (A) Pelvic tilt (PT) is defined by the intersection of a vertical reference line, which originates from the femoral head centre (o) and the midpoint of the sacral endplate (a). (B) PT can be influenced by PI, since they share the line (o–a) and the terminal sacral plate is a common reference line for both.

perpendicular to the upper plateau of S1. PI increases slightly and consistently in adulthood.[12] The value of PI is higher in spondylolisthesis, increasing linearly, according to the severity of slippage[12] (Fig. 1).

The pelvic tilt (PT) and the sacral slope (SS) measure the sacro-pelvic orientation in the sagittal plane, being evidenced in the lumbosacral lateral view. SS is defined as the angle between the upper horizontal plateau and S1, while PT is the angle between the line connecting the midpoint of the upper plateau of S1 and the centre of femoral rotation with a vertical line (Figs. 2A–B and 3B).

PT has a value (+) when the line (o–a) is located posterior to VRL value and (–) when the line (o–a) is anterior to VRL.

We must understand that PI is a measure of a static structure. PT and SS, on the other hand, are dependent positions, because they depend on the angular position of the sacrum/pelvis in relation to the femoral head, which changes in the orthostatic and sitting positions. PT/SS ratio is also affected by the bending and lumbosacral-pelvic extension.

PI is the sum of SS and PT (Fig. 3B); then, IP is a strong determinant of the spatial orientation of the pelvis in the osthostatism, i.e. the higher the PI, the greater will be the PT or SS, or both. The normal values of PI, SS and PT in children are 49.1°, 41.4° and 7.7°, respectively.[13] In adults the normal values are 51.8°, 39.7° and 12.1°.[12]

The values in spondylolisthesis[12] are shown in Table 1.

In the study by Roussouly et al.,[14] patients with high PI and SS result in increased shear force incident on the lumbosacral junction, which creates more stress on the *pars interarticularis* of L5. But in those patients with low PI and a minor SS, there may be an impact among the posterior elements between L5 and those of L4 and S1 during extension, thereby causing an effect of "nutcracker" in *pars interarticularis* of the 5th lumbar vertebra.

Table 1 – Values of spondylolisthesis in accordance with the degree of slippage.

	Grade I	Grade II	Grade III	Grade IV	Grade V
PI	57.7°	66°	78.8°	82.3°	79.4°
SS	43.9°	49.8°	51.2°	48.5°	45.9°
PT	13.8°	16.2°	27.6°	33.9°	33.5°

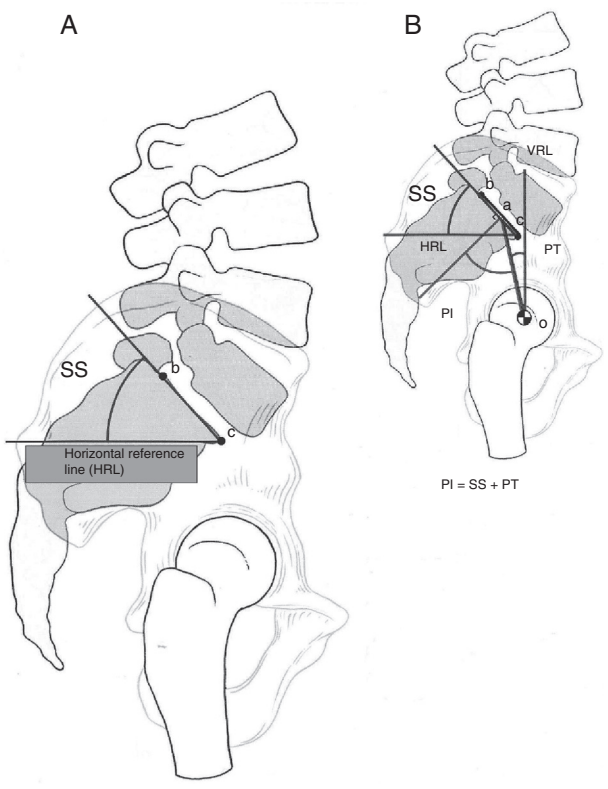

Fig. 3 – (A) Sacral tilt (SS) is defined as the intersection of the horizontal reference line (HRL) and the sacral endplate (b–c). (B) The sacral slope (SS) is related to PI and PT because it shares a reference line (b–c) in common along the sacral endplate.

The sacral projection (distance from the sacrum to a plumb line from C7) is another biomechanical determinant. Typically, the plumb line (PL) passes through S1 (Fig. 4).

Because of these morphological changes, the sagittal balance can only be achieved by hyperlordosis. Greater vertical tilt of the sacrum will be required to maintain sagittal balance, when this is not possible only with hyperlordosis. This verticalization of the sacrum is accompanied by contracture of the hamstrings, which circumvent caudally the ischial muscles, and the anterior pelvis cephalad.[14]

With these data, there are three possible biomechanical outcomes: first, the forces generated by an increase in lumbar lordosis have, as consequence, the development and progression of spondylolisthesis; and second, the biomechanical changes generate changes in posture and gait that are compensatory mechanisms to maintain sagittal balance; and finally the biomechanical changes mould the adjacent vertebrae.

Evidence of the presence of abnormal sagittal spino-pelvic alignment in spondylolisthesis

Although the correlation between pelvic incidence (PI) and spondylolisthesis is evident, there are no published data in the literature that may confirm the cause/effect relationship between these two. However, as the pelvic incidence (PI) is a morphological parameter that describes the shape of the pelvis, an increased PI is associated to an increase in lumbar lordosis, which predisposes to mechanical changes of the lumbar column and of the lumbosacral junction and increases the risk of spondylolisthesis occurrence.[15]

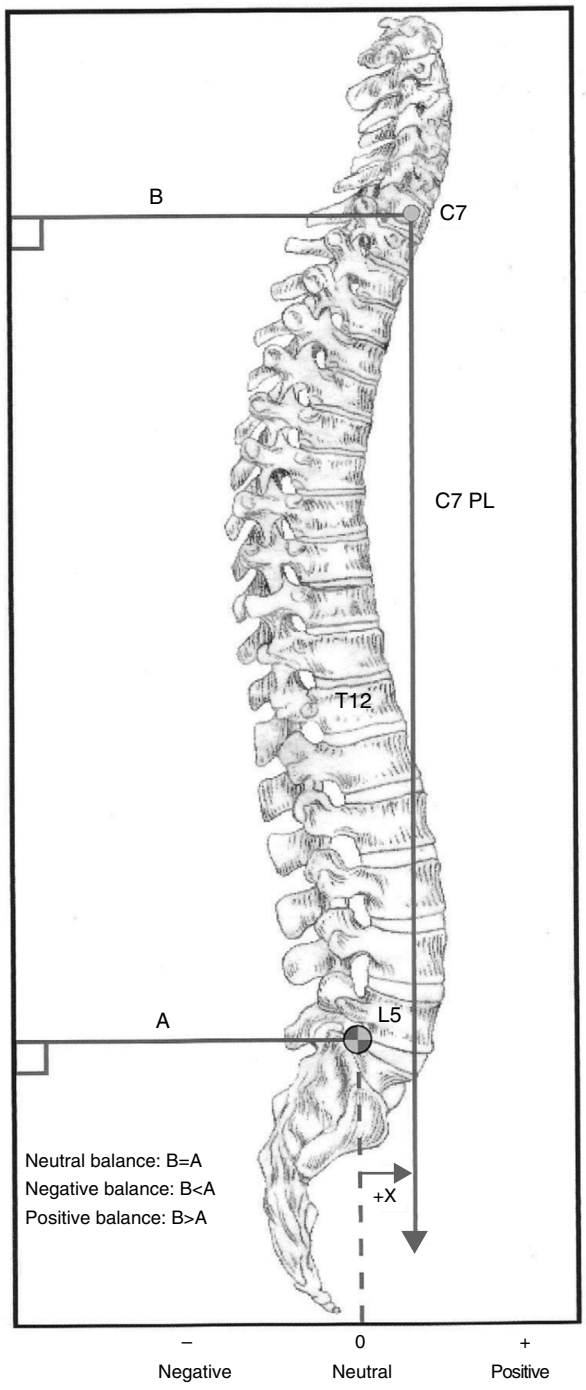

Fig. 4 – Sagittal Balance: PL = plumb line. The A line is drawn from the superior-posterior border of S1 perpendicular to the vertical edge of the radiograph. Its length is measured in millimetres. The B line is drawn from the centre of C7 perpendicular to the vertical edge of the radiograph. Its length is measured in millimetres.

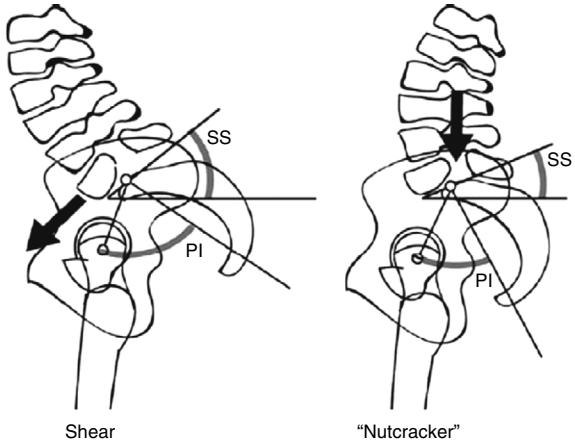

Fig. 5 – The posture in shear and in "nutcracker", published by Roussouly et al.[14] for low-grade spondylolistheses.

However, not all patients with spondylolisthesis at L5-S1 present with PI above the normal. Roussouly et al.[14] observed, in a study with 82 subjects with low-grade spondylolisthesis, the presence of two distinct subgroups with respect to form and sacro-pelvic balance, which can be affected by different pathogenic mechanisms. According to these authors, patients with high PI and sacral slope (SS) show an increase in the shear forces incident at the lumbosacral junction, which causes further tension on the *pars articularis* of L5: the shear type (Fig. 5). On the other hand, those patients with low PI and SS may present clamping of the posterior elements of L5 between L4 and S1 during extension, which eventually causes an effect in "nutcracker" on the *pars articularis* of L5.

For cases of high-grade spondylolisthesis, Hresko et al.[16] identified two subgroups of sacro-pelvic alignment: with balanced or unbalanced pelvic posture (Fig. 6). The "balanced" group includes patients who in the orthostatic position show high SS and low pelvic tilt (PT). Patients in the group "unbalanced" include those who in the orthostatic position have retroverted pelvis and verticalized sacrum, which corresponds to a low SS and high PT. It has been shown that patients with high degree of vertebral slippage have a mean PI >60°.

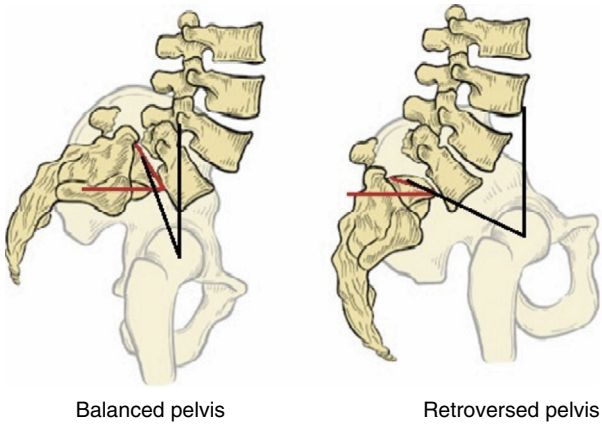

Fig. 6 – Balanced and retroversed pelvic posture published by Hresko et al.[16] for high-grade spondylolistheses.

Table 2 – Classification of Wiltse, Newman and Macnab.

Type I – dysplastic congenital abnormalities of the posterior elements
Type II – isthmic: defect in the pars interarticularis. Three types: Lithic – fatigue fracture of the *pars* Elongation of the *pars* Acute fracture of the *pars*
Type III – Degenerative: degeneration of the disc and facets, which creates instability and mobility on segment
Type IV – Traumatic: acute fracture of the pedicles, facets or blades (except pars)
Type V – Pathologic: because of neoplastic or metabolic processes

This contrasts with those with low-grade spondylolisthesis, in whom PI values are low, normal or high.

Furthermore, it was observed that the sagittal balance, i.e. the measurement of the plumb line from C7, was significantly increased (>3 cm) in those with retroverted posture (unbalanced); this suggests that the positive sagittal imbalance may be associated with this type of spino-pelvic alignment. Mac-Thiong et al.[17] showed in a comparative study between a group of 131 patients with spondylolisthesis and a control group of 120 patients, that the normal sagittal balance of the trunk was maintained in patients with low-grade spondylolisthesis, while the sagittal balance was changed in patients with high-grade spondylolisthesis. Again, the spino-pelvic balance was altered in the group of high-grade spondylolisthesis associated with sacral-pelvic imbalance.

Classification

The spondylolisthesis has been described by Wiltse et al.[18] classification (Table 2), based on etiological and topographical criteria, with five types. It is difficult to predict its progression and response to treatment. The recognition that surgical decompression may lead to instability of the column made necessary a sixth type: iatrogenic spondylolisthesis.

Another system used is the one proposed by Meyerding et al.[19] in 1932 (Fig. 7), in which the degree of slippage is calculated by the ratio between the anterosuperior diameter of the sacrum and the distance of previous slippage of vertebra L5. Thus, it can be considered: grade I – 25% or less, grade II – between 25% and 50%, grade III – between 50% and 75%, and grade IV – greater than 75%. The degree V, as spondyloptosis, does not belong to the original description.

The scale of Meyerding only describes the degree of tangential slippage, though in high-grade dysplasias there is kyphosis, in addition to the tangential translation. The more used grading system for high-grade slippages is that proposed by Newman and modified by DeWald et al.,[20] in which the dome and the anterior surface of the sacrum are divided into ten parts (Fig. 8). The measure is taken based on the position of the posterior-inferior corner of the body of the fifth vertebra in relation to the dome of the sacrum (first measure) and the second measure is given by the position of the anterior-inferior corner of the body of the vertebra L5 in relation to the anterior surface of S1.

Marchetti et al. and Bartolozzi et al.[21] developed a classification system that distinguishes spondylolisthesis acquired

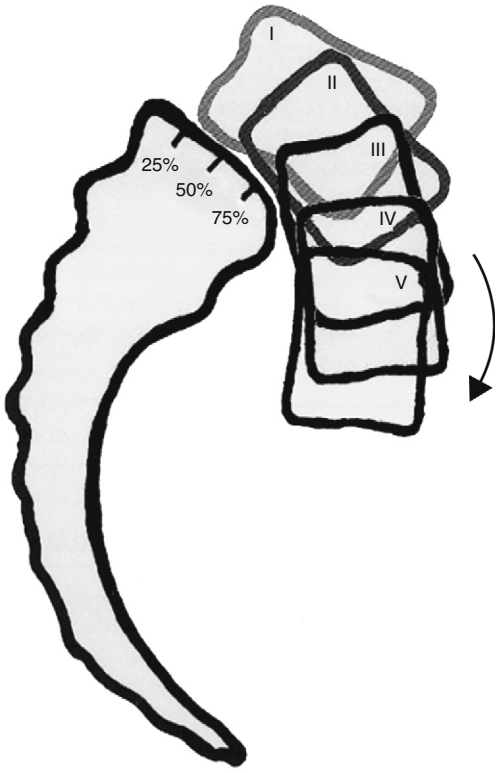

Fig. 7 – Meyerding classification.

versus developmental type and also divides the developmental spondylolisthesis in dysplastic of low and high grade.

None of these classification systems were designed with the goal of assisting in surgical planning of spondylolistheses. Thus, the guidelines and outcome studies and clinical follow-up are mostly based on the degree of slippage.[21,22] Furthermore, these classifications[20,21] do not take into account the sacro-pelvic sagittal balance, although more recent studies suggest the importance of this balance in the assessment, progression and treatment of spondylolisthesis.[23,24] This may be the explanation for the large amount of published studies on surgical techniques.

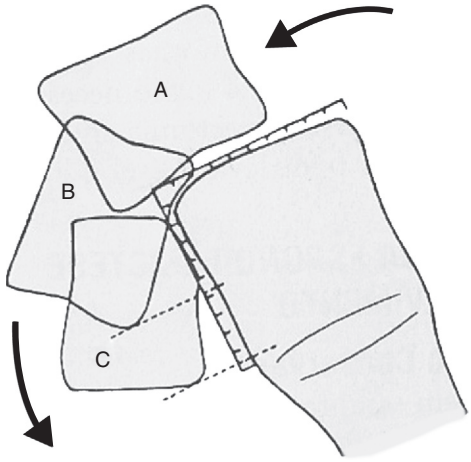

Fig. 8 – Newman graduation system, modified by DeWald.[20]

Table 3 – SDSG classification based in spino-pelvic posture.

Spondylolisthesis
Low grade < 50%
Type 1: PI < 45° ("nutcracker")
Type 2: PI = 45–60°
Type 3: PI > 60°
High grade > 50%
Type 4: Balanced pelvis
Retroversed pelvis
Type 5: Balanced column
Type 6: Unbalanced column

Recently, Mac-Thiong et al. and Labelle et al.[25] proposed a new classification system for spondylolisthesis, with the goal of assisting in the evaluation and treatment of lumbosacral spondylolisthesis. This classification clarifies the concepts of dysplasia of low and high grade presented by Marchetti et al. and Bartolozzi et al.[21] and incorporates the latest knowledge of the morphology and the sacral-pelvic sagittal balance. Eight types of spondylolisthesis are described as follows: (1) degree of slippage (low and high grade), (2) degree of dysplasia (low and high grade) and (3) sagittal sacro-pelvic balance. The classification is organized into groups and subgroups in ascending degrees of seriousness, in order to develop a progressive algorithm of surgical complexity proportional to the increase in the severity of spondylolisthesis.

Classification proposed by the study group of spinal deformities (Spinal Deformity Study Group [SDSG])

The SDSG submitted a classification for spondylolisthesis between L5 and S1 that has been simplified and refined. This classification is based on three characteristics that can be evaluated in lateral view (sagittal) radiograph of the column and pelvis: (1) degree of slippage (low or high), (2) pelvic incidence (low, normal or high) and (3) spino-pelvic balance (balanced or unbalanced). Thus, six subtypes can be identified (Table 3).[23–25] To apply the classification, in the first place the degree of slippage is measured on a lateral radiograph of the column. So it can be determined whether the slippage is low-grade (0, 1 and 2: <50% slippage) or high grade (3, 4 or spondyloptosis: >50% slippage). Then, the sagittal balance is measured to determine the sacro-pelvic and spino-pelvic alignment. The measures of PI, SS, PT and of the plumb line of C7 are used. For low-grade spondylolistheses, three types of sacro-pelvic balance can be found: type 1, "nutcracker", a subgroup with low PI (<45°); Type 2, a subgroup with normal PI (between 45° and 60°); and type 3, a shear type, a subgroup with high PI (>60°). For those cases with high-grade spondylolisthesis, three types are also found. Each case must first be classified as if presenting a balanced or unbalanced sacro-pelvic, using values of PI and SS.[16] The spino-pelvic balance is determined with the use of the plumb line of C7. If this line falls on or behind the femoral head, the column will be balanced; if it falls in front of the femoral head, the column will be unbalanced.

The three types of high-grade spondylolisthesis are: type 4 (balanced pelvis), type 5 (pelvis retroverted with balanced

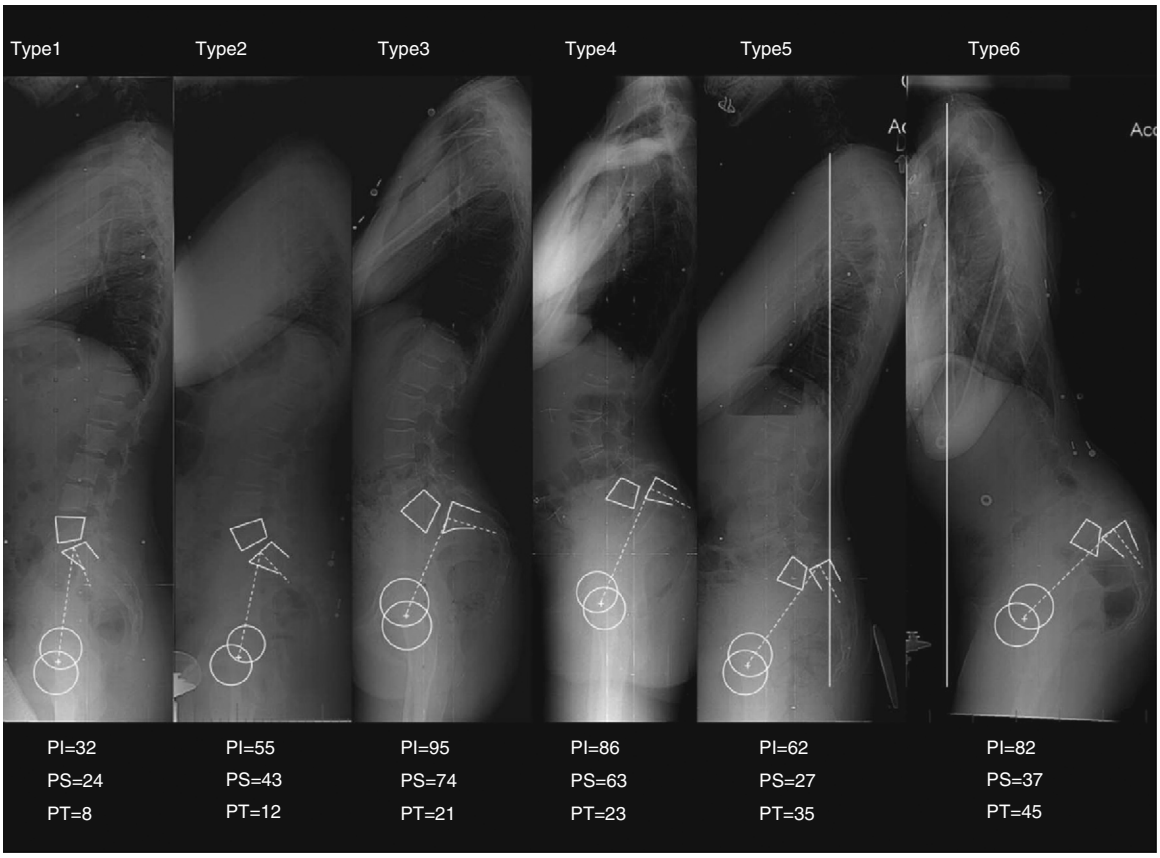

Fig. 9 – Classification of the Spinal Deformity Study Group. PI = pelvic incidence, SS = sacral slope, PT = pelvic tilt.

column) and type 6 (retroverted pelvis with unbalanced column). Fig. 9 shows six clinical examples of these positions.

Progression factors

According to Boxal et al.,[26] the best parameter to predict progression is a great slippage angle (>55°); this angle is formed by the intersection of a line drawn parallel to the inferior face of L5 and a perpendicular to the posterior face of the body of S1. The authors also report that a progression may occur, even after a solid posterior arthrodesis.

Patients with low PI and low SS ("nutcracker" mechanism) have a low risk of progression. Dysplasia and slippage of high grade (>50%) were also reported as a factor for progression of spondylolisthesis.[27]

Other factors in favour of progression to isthmic spondylolistheses are female gender, slippage >50% and children before the growth spurt.[24]

It was observed that patients with spondylolisthesis caused by dysplasia have a higher chance of progression versus those with spondylolitic spondylolisthesis.[28]

Clinical manifestations

The symptoms can be divided into symptoms in children and adults.

In children, the spondylolisthesis is usually asymptomatic. Exaggerated lumbar lordosis may be the first warning sign and a shortening of hamstrings occurs. With the verticalization of the sacrum, the buttocks become heart-shaped, because of the bony prominence. With the progression, the patient develops a typical posture, because of the hamstring shortening, verticalization of the sacrum and increased lordosis, known as Phalen-Dickson signal (bending of the knees and hips). In symptomatic cases, the mechanical low back pain is the most common complaint.[3] The severity of pain may or may not be related to the degree of slippage. Radiculopathy is less common, but is observed with the progressive translation, when instability is present. Radiculopathy of L5 occurs more often than radiculopathy of S1. S1 root compression occurs in high degrees of slippage because of the root stretching stress above the edge of the sacrum. The pain increases with the extension of the column and improves with rest.[29]

In adults the lumbar pain with or without irradiation to the lower limbs is common; this is typically a mechanical pain that worsens with extension. The pain must be differentiated from discogenic pain, which worsens with flexion and in the sitting position. Neurogenic claudication is also a common symptom, defined as a pain in the lower extremities, numbness or weakness associated with ambulation or with the seated position.[30] Pain is the predominant symptom, present in 94% of patients, followed by paresthesia (63%) and weakness (43%).[31] Neurogenic claudication must be differentiated from vascular claudication, as shown in Tables 3 and 4.

Table 4 – Differential diagnosis between neurogenic claudication and vascular claudication.

Evaluation	Vascular	Neurogenic
Walking distance	Fixed	Variable
Factors of worsening	Orthostatism	Sitting/flexion of column
Factors of worsening	Walking	Walking/standing
Climb slopes	Worsening	Improvement
Ergometric cycle	Positive (painful)	Negative (painless)
Pulses	Absent	Present
Skin	Glossy/phaner loss	Normal
Weakness	Rare	Common
Low back pain	Occasional	Common
Lumbar mobility	Normal	Limited
Muscular atrophy	Unusual	Occasional
Pain characteristics	Cramps/distal to proximal	Paresthesia/proximal to distal

Diagnosis

The diagnosis is established on radiographs of the lumbar column in frontal and profile incidences with the patient in the orthostatic position. Other views used are located profile and right and left oblique incidences.

In radiographs in oblique incidence, the "Scottish dog" can be seen, where the "collar" represents lysis in the *pars*.[26]

Computed tomography has little value in the diagnosis; this technique can demonstrate sclerosis and the defect in the *pars*.

MRI is the exam of choice to view the disc at the level of the deformity. This imaging technique is used in cases of radiculopathy and to visualize bone oedema and defects in the *pars articularis*. More advanced image examinations, such as computed tomography by single photon emission (SPECT),[32] are more sensitive and provide more details. Anderson et al.[33] reported that 20% of patients with negative results on a standard bone scan with suspected acute spondylolysis showed a lesion of the *pars* when assessed with SPECT.

Treatment of spondylolisthesis

The spondylolisthesis can be of low grade (slippage <50%) or of high grade (slippage >50%) and both types can be treated conservatively. However, the high-degree spondylolistheses respond more poorly to conservative treatment when compared with those conditions of low degree.[31] The conservative treatment is best suited for displacements smaller than 30–50% in the growing child and for some displacements larger than 50% in young adults. For symptomatic patients, excellent clinical response has been obtained with restriction of physical activity and the use of ortheses (TLSO) in order to avoid repetitive movements of hyperextension of the lumbar column.[13]

For patients with chronic low back pain, Panjabi et al.[34] demonstrated that the strengthening of specific muscle groups improves the patient's response to pain; so, these authors started to recommend the strengthening of the transverse abdominal, internal oblique and multifidus muscles. Besides the strengthening of these specific muscle groups, the strengthening of the hip flexors and the stretching of hamstrings also improve the patient response to low back pain.[13]

According to DeWald,[20] the goal in the surgical treatment of spondylolisthesis is the fusion of the smallest possible number of mobile segments of the column, which restores the sagittal vertical axis, with the sacrum and lumbar column in as normal as possible a position, and the fusion of the non-competent disc spaces. This type of treatment is indicated in asymptomatic children with greater than 50% slippage, for asymptomatic patients with skeletal maturity and greater than 75% slippage, for symptomatic patients who do not respond to conservative treatment, progression of deformity and neurological deficit.[30]

In symptomatic adult patients with low-grade degenerative spondylolisthesis, posterolateral arthrodesis (PLA) in situ has better clinical outcomes when compared to supervised exercise programmes.[35,36] However, PLA has been unable to maintain intraoperative correction of the slippage angle, due to the progressive degeneration of the anterior disc space.[35] Suk et al.[37] and La Rosa et al.[38] conducted a comparative study between PLA and 360° arthrodesis (PLA + PLIF) and found that many postoperative radiological parameters, such as fusion rate, reduction of the slippage angle and maintenance of the correction of the deformity, were superior in patients with arthrodesis 360°. However, clinically in none of these studies PLA or PLIF was statistically superior. [39]

A decompression is indicated in cases of radiculopathy. Usually the L5 root is involved at the foraminal level and compressed by the proximal portion of the *pars* as the slippage is enhanced by fibrocartilaginous tissue in the defective *pars*. In cases of radiculopathy or other neurological deficits, such as cauda equina, decompression is indicated. The Gill procedure is the basis for decompression by removing the loose blade.[39] The decompression of the nerve root can be done only in adult patients with radiculopathy and low grade spondylolisthesis through the procedure of Gill et al.[40] However, this procedure is contraindicated in paediatric patients, in whom it should always be accompanied by an arthrodesis.

The reduction of high grade spondylolisthesis has been indicated, since this procedure is able to improve the aesthetic appearance, correct the lumbar angles, improve the pelvic index and the sagittal balance and even recover the kyphosis that occurs in the lower lumbar region.[40] In most cases, this reduction is not made in adult patients with spondylolisthesis. This is due not only to the degree of slippage, but also to the anatomic position of the roots, which are more cephalad; and to the presence of a bend formed in the dural sac, which is

relatively more elongated. Because of these anatomical findings, the reduction manoeuvre can apply tension to the roots, with the risk of neurological injury.[41]

Final considerations

The isthmic spondylolisthesis is an acquired disease that becomes symptomatic in young adults, because of the premature degenerative process of the intervertebral disc and facet joints, as well as the mechanical imbalances that lead to changes in the sagittal balance of the column. The progression of slippage is more rare in adults than in children.

The radiographic examination of these patients should include the panoramic radiograph of the column and the visualization of the femoral heads, to allow an angular evaluation of the lumbosacral junction and of the sagittal balance.

Conservative treatment with physical rehabilitation and analgesics has generally shown good results.

The surgical treatment with nerve root decompression and arthrodesis is indicated in cases where the conservative treatment has failed or there is a progressive neurological deficit. The result of surgical treatment has been good in terms of relieving the chronic low back and radicular pain.

The classification system proposed by SDSG is practical and easy to apply and should be used and more studied in our country. The purpose of this classification emphasizes that patients with spondylolisthesis L5/S1 form a heterogeneous group with several postural adjustments and that this should be considered by physicians when indicating any type of treatment. While we cannot employ an algorithm that establishes a specific treatment for each subtype, it is suggested that in patients with type 4 of spino-pelvic alignment, forced attempts at reduction may not be necessary. Obtaining the sagittal alignment with arthrodesis and surgical instrumentation is enough. For those patients with type 5, we should preferably try to reduce and realign, but in very difficult cases, instrumentation and arthrodesis after postural reduction may be sufficient for obtaining the proper sagittal alignment, since that the alignment of the column is maintained. The reduction and alignment are mandatory in type 6 patients, in whom the sagittal alignment is seriously impaired.

The circumferential fusion (360°) with surgical instrumentation has shown a lower rate of non-union, but this cannot be correlated with results superior to those of the posterolateral arthrodesis.

Conflicts of interest

The author declares no conflicts of interest.

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