Pathogenesis, diagnosis and management of spondylolysis and mild spondylolisthesis in athletic children and adolescents

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Introduction

During his talk at the 2001 French Society of Orthopedic Surgery & Traumatology (SOFCOT) conference on lumbosacral spondylolysis (SL) and spondylolisthesis (SPL) in children and adolescents, Jouve [1] reviewed the historic, anatomic and pathogenic bases of this complex pathology. In 2015, during another conference on the same topic, a literature review of recent developments on the link between this pathology and global spinal sagittal alignment were presented, and the significant and still-present controversies relating to the treatment of SPL, especially in its severe forms, were highlighted [2]. However, the topic of SL was only briefly touched upon. As such, in this chapter, the controversial topic of the hypothetical post-traumatic type of SPL will be discussed, a type that differs from that of severe progressive SPL which is often dysplastic, even though other forms of SPL may be secondary to an initial SL and which are deemed “spondylolytic spondylolisthesis”.

Definition

Spondylolysis is a defect of the pars interarticularis of the vertebral arch. This can present as either a uni- or bilateral defect, either simultaneously or developing over time. This may also be associated with an SPL. Spondylolisthesis signifies translation (olisthesis) of one vertebral segment (spondylo) over the one directly beneath it. This translation may be either anterior (anterolisthesis) or posterior (retrolisthesis). In children and adolescents, translation is mostly anterior.

The pars lesion is most frequently found at the level of L5 (71-95%), less frequently at the level of L4 (5-23%), and exceptionally at other levels [3-5].

Incidence and Pathogenesis

Similar to SPL, SL is an acquired condition. The most frequently used classification for the categorization of SPL based on the severity of anterior translation of the vertebra is that of Meyerding.

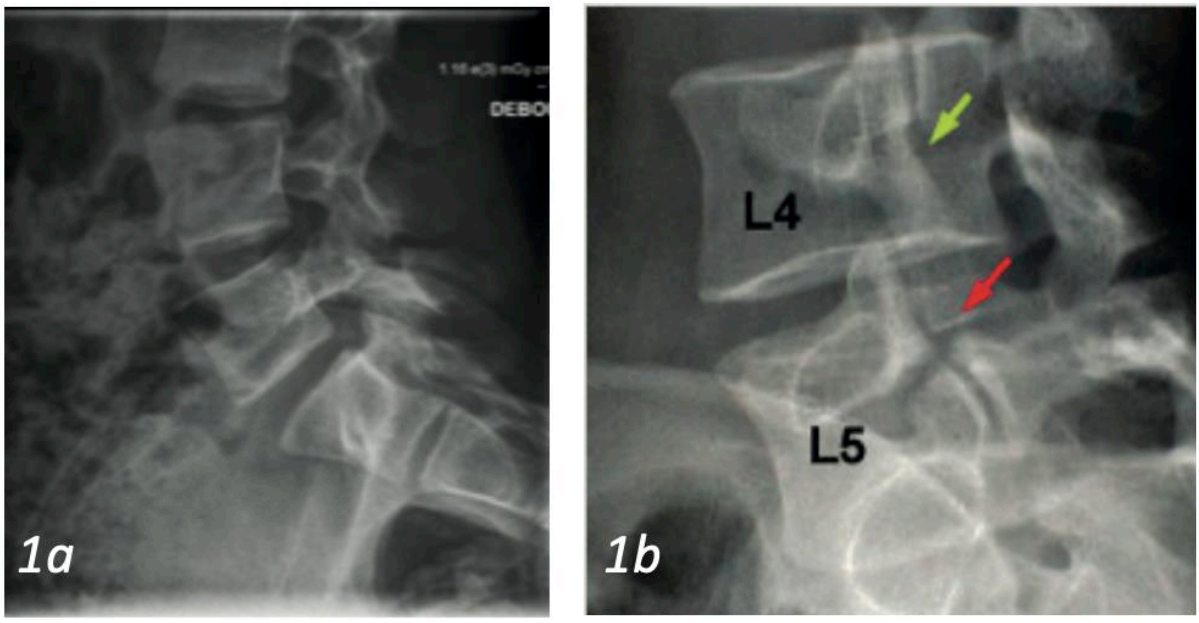
During childhood and adolescence, vertebral bone mass is generally low [6] and the posterior arches continue maturing until 20-25 years of age [7,8]. The increased elasticity of the intervertebral discs during adolescence compounds the stresses placed upon the neural arch, and specifically the pars interarticularis. Consequently, the principal etiologies of this pathology are often believed to be the traumatic and micro-traumatic events that arise secondary to repetitive compressive, torsional, and rotational constraints during certain types of sports in which these violent and cyclical movements are required [9,10]. As a result, even though the global prevalence of SL in athletes seems similar to that of the general population, certain types of sports, such as wrestling (30-35%) and Olympic-style weightlifting (23-30%), may lead to a significantly higher prevalence of SL. In fact, SL is fourfold more frequent in gymnasts compared to the rest of the female population [11].

Clinical presentation

Athletic children with SL are usually asymptomatic, with incidental discoveries on radiographic images being undoubtedly the most frequent presentation. When SL is symptomatic, the patient usually presents with band-like or unilateral low-back-pain, which may or may not be associated with unilateral, bilateral, or alternating radicular pain. This pain is particularly reproduced by hyperextending the lumbar spine. Resumption of sports in spite of the pain might lead to a clinical scenario associating paravertebral muscle spasms, a flattening of lumbar lordosis, functional scoliosis, hamstring tightness, and rarely L5 radiculopathy. In such cases, imaging studies must be obtained in order to confirm the diagnosis and eliminate differential diagnoses.

Medical imaging

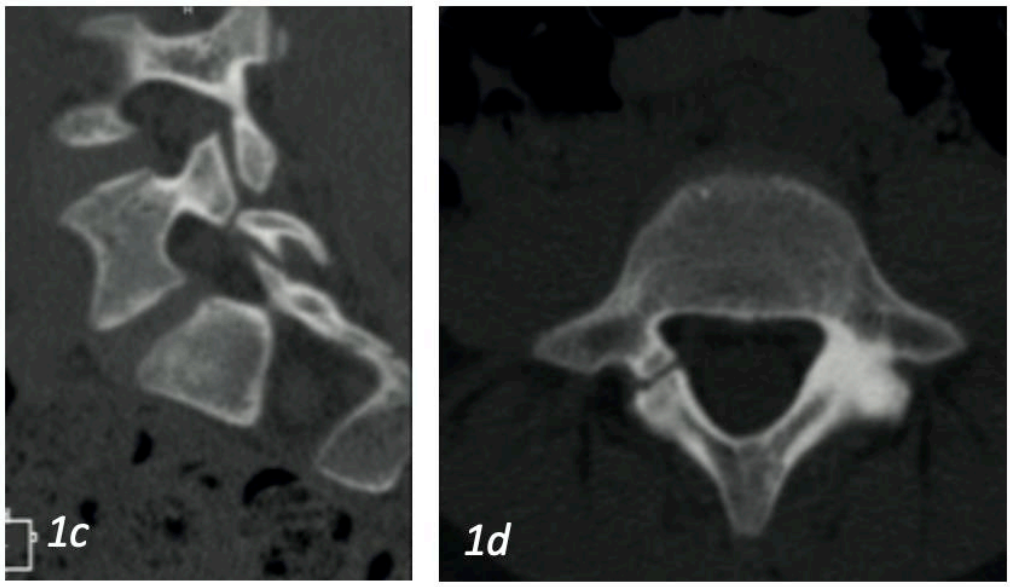
The diagnosis of SL can be made on conventional coronal and lateral radiographs of the lumbar spine, which may be completed with oblique views, ideal for the visualization of pars interarticularis defects.



Unilateral L5S1 spondylolysis barely visible on the lateral view (1a), more easily recognizable on the oblique view (1b).

Teleradiographic images of the spine on coronal and sagittal views, realized preferentially with the EOS® system in order to decrease radiation exposure, would complete the global morphological analysis of the spine, especially in the sagittal plane.

Conventional radiographs, and more commonly CT-scans can reveal the unilateral nature of SL, or contralateral sclerosis may sometimes also be identified, which is thought to be secondary to excessive mechanical load on the contralateral isthmus.



CT-scans confirming the unilateral character of the isthmic lysis (1c) with contralateral sclerosis (1d)

Conventional radiographs may appear normal initially. However, the best algorithmic approach for diagnostic imaging has yet to be established. Single-photon emission computed tomography (SPECT) is an imaging modality with high sensitivity but low specificity for the diagnosis of SL. CT-scans might serve useful as a complementary imaging modality for the visualization of bony anatomy, sclerosis, and bony healing, but with the inconvenience of high radiation exposure. MRI can be a useful diagnostic and follow-up tool with many advantages compared to conventional imaging modalities, but more data is required in order to assess its potential advantages compared to other techniques.

Therefore, there is actually no consensus regarding the choice of complementary imaging, especially between MRI and CT-scans [12]. West et al. [13] conducted a study with the aim of determining the precision of MRI and CT-scans in young athletes who had previously been diagnosed with SL through the use of SPECT. This cross-sectional study on 22 young athletes (14.7 ± 1.5 years old) where both an MRI and a CT-scan were obtained on the same day, showed the superiority of CT-scans for the diagnosis of SL. Their results showed 13 true positive (TP) and 9 false negative (FN) results for the MRI, compared to 17 TP and 5 FN results for the CT-scan. The sensitivity and FN rates of the MRI were 59.1% (95% Confidence Interval [95% CI] = 36.7% - 78.5%) and 40.9% (95% CI = 21.5% - 63.3%), respectively. The sensitivity and FN rates of the CT-scans were 77.3% (95% CI = 53.2% - 91.3%) and 22.7% (95% IC = 0.09% - 45.8%), respectively.

Treatment

Initial management usually consists of conservative treatment for a period of several months and is generally effective by itself. Surgical management is usually only indicated after failure of conservative treatment.

1. Conservative treatment and the possibility of isthmic consolidation

Conservative management is the initial treatment modality to be attempted and is generally sufficient. However, debate still exists within the framework of conservative treatment on whether a simple cessation of physical activity would suffice, or the use of a brace would be indicated, with even the choice of type of brace being controversial. Nevertheless, the effectiveness of conservative treatment and the non-requirement of immobilization was highlighted by a meta-analysis conducted by Klein et al. [14]. The primary goal of their study was to identify and summarize the evidence found in the literature on the effectiveness of conservative treatment in SL, including subjects with grade 1 SPL. The minimum follow-up period was that of one year. The results of the included studies were presented following two criteria: clinical outcome or radiographic evidence of consolidation of SL. Fifteen observational studies measuring the clinical outcomes were included, which showed weighted and pooled success rates of 83.9% in 665 patients. Subgroup analysis comparing the clinical outcomes of patients treated with or without immobilization did not show significant differences. Ten studies assessing radiographic healing of SL showed a pooled success rate of 28% (n=847). Subgroup analysis showed that unilateral defects healed with a pooled and weighted rate of 71% (n=92), which was significantly higher than bilateral defects with healing rates of 18.1% (n=446, $p<0.001$). A supplementary subgroup analysis showed that acute

defects healed at a rate of 68.1% (n=236), which was a significantly higher rate than chronic defects with healing rates of 28.3% (n=224, p<0.001). This meta-analysis of observational studies suggested that clinical results may not correlate well with radiographic evidence of pars defect consolidation . Acute lesions seemed to be more amenable to healing after conservative treatment, as were unilateral defects when compared to bilateral SL.

These conclusions should still be contemplated. It should also be noted that symptomatic patients may be treated more effectively, and sometimes even more quickly, if cessation of physical activity is associated with immobilization with a lumbar support or a short lumbar brace, such as the delordosing spondylogenic Boston brace [15].

The idea of a persistent pars defect, even after clinical improvement, remains widespread. Nonetheless, bony healing and consolidation of the isthmic lysis are possible even without surgery. As such, Sakai et al. [16] recently showed that, depending on the acute or chronic nature of the lesion (analysis by coupling CT-scans and MRI), as well as its uni- or bilateral character, significant and rapid healing may be achieved. For most patients, with the exception of those presenting with chronic isthmic lysis, conservative treatment comprised of rest and the wear of a thoraco-lumbo-sacral orthosis (TLSO).

2. Failure of conservative treatment: choosing from the types of surgery

Isthmic reconstruction may be indicated in patients with SL without concomitant SPL or with only mild translation (grade 1, rarely grade 2). These generally include patients without predictors of severe disease, such as lumbosacral kyphosis. No neurological deficits are usually found, and surgery may be justified after conservative treatment has been attempted for a period of at least twelve months (cessation of physical activity, physiotherapy, lumbar support) without evidence of complete or even partial symptomatic improvement. The absence of anomalies at the level of the intervertebral discs confirmed by MRI is required during pre-operative planning. Otherwise, arthrodesis may be indicated. Isthmic reconstruction is more frequently attempted in patients who are at the end of their growth. This surgical approach preserves the mobility of the spine. The most frequent complication is non-union. An adapted construct is required in order to achieve isthmic healing in compression without bulky osteosynthesis, especially at the level of the subjacent articular mass.

Numerous isthmic reconstruction techniques have been described. Of note, the cerclage wire around the transverse and spinous processes technique of Nicol, temporary butterfly plate of Louis, and Buck's technique of direct fixation of the isthmic lysis. To this end, Bodman et al. [17] analyzed the clinical and radiographic results of Buck's modified fixation technique, in patients with symptomatic SL, with grade 1 SPL and normal L4-L5 and L5-S1 intervertebral discs, after failure of conservative treatment. Functional outcomes were quantified through the use of the Oswestry disability index (ODI). Healing of the pars defect was evaluated by conventional radiographs and CT-scanning. The motion of the L4-L5 and L5-S1 segments was measured on dynamic flexion/extension radiographs. In thirty-five patients with a mean follow-up of ten years, the authors reported excellent functional results in 22 patients and good results in 8 patients, with 5 patients in whom treatment had failed. Consolidation of the defect was found in 91.4% of patients. Other techniques may also be considered and may

entail fixation of the pedicles and laminae, such as Morscher's approach. Some authors have observed correction of the olisthesis in patients in whom isthmic reconstruction was undertaken during the early stages of the disease. Hefti et al. [18] and Preyssas [19] noted that, in two and six cases respectively, complete healing of a grade 2 SPL was achieved by the end of growth after isthmic reconstruction was undertaken. Nevertheless, this endpoint does not represent the purpose behind isthmic reconstruction.

Are there any recommendations from sports federations?

No specific recommendations have been put forth on this subject. After interviewing different national sports federations along with their medical staff, certain responses were obtained, such as: In the case of rugby, no specific indications exist for SL or SPL. Temporary contra-indications in relevance to injuries of the spine are transient neurological deficits of 1 to 4 limbs in the absence of exploration (MRI) and specialized opinion, non-operated herniated discs, and lumbar spinal stenosis. Definitive contra-indications are motor deficits due to injury to the spinal cord, confirmed tetra-pyramidal syndrome, three or more episodes of transitory tetra-paresis, severe cervical ligamentous sprains, spinal stenosis without safety margins on MRI, odontoid agenesis or hypoplasia, congenital or surgical fusion of 3 or more levels, intra-medullary edema, a true syrinx, and Arnold-Chiari-type malformations of the cervico-occipital junction with occupation of the cisterna magna.

For the French swimming federation (FFN; swimming, diving, water-polo), the French federation for the education of underwater sports (FFESSM; Scuba diving), the French football (soccer) federation (FFF), and the French judo and jiu-jitsu federations, there are no specific indications. Physicians are thereby required to formulate temporary and absolute contra-indications depending on the patient.

In the case of boxing, the only absolute contra-indications found for spinal pathologies were reserved for herniated discs, without more detail being provided.

In the case of motocross, absolute contra-indications included non-consolidated affections that may jeopardize the stability of the spine. This definition remains ambiguous.

For the remainder of sporting activities, especially volleyball, handball, gymnastics, Olympic-style weightlifting, and athletics, absolute contra-indications are noted as being any severe static and/or dynamic morphological affections, particularly at the level of the thoraco-lumbar spine, running the risk of acute injury or accelerated degeneration. The indications here are also ambiguous.

In summary, there appear to be no clear recommendations by the different sports federations, who would rather leave the decision on the temporary or absolute contra-indications to the physicians. Since sporting federations have not provided recommendations, referring to different scientific societies may be a viable option in the future.

Conclusion

The initial step in athletic children and adolescents presenting with low-back-pain should be to assess the presence or absence of SL. This approach may prove difficult, as pars interarticularis defects are frequently encountered in the general population, including in children. Imaging should therefore be utilized, with no evidence as to the modality of choice. MRI could be prescribed during the diagnostic workup of acute SL, and CT-scans may rather be useful in evaluating healing of the pars defect after conservative treatment. It would appear that bracing may not be necessary but may sometimes be a complementary means of limiting movement in order to further restrict activity in impatient children and parents, but also their coaches. In fact, the treatment of current or future athletes with SL and/or SPL may be difficult. Before deciding on surgery, one must be wary of any pressure by the patient's family or environment toward the rapid return to competition. Such pressures may lead to harm if a decision to operate has been made, and these motivations must necessarily be taken into account. After the failure of a well-conducted conservative treatment for an arbitrarily set period of one year, surgery may be indicated, although this may be only rarely necessary.

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