Conservative management of spondylolysis and spondylolisthesis in children and adolescents

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Introduction

The estimated prevalence of spondylolysis in the general population, which may or may not be associated with spondylolisthesis, is approximately 5%. It is more frequently found in young athletes and up to 20 to 30% in certain high-intensity sports.

Patients are infrequently symptomatic in these patients and the incidental diagnosis on conventional radiographs is rather the norm. It is therefore considered as a compensatory mechanism allowing for the maintenance of a satisfactory sagittal alignment. Nevertheless, the diagnosis of spondylolysis or spondylolisthesis requires frequent follow-ups and certain preventive measures must be adopted in order to avoid deterioration.

In general, 80% of children presenting with isthmic lyses are symptomatic, and over 80% of these children are relieved by medical management alone [1,4,5]. **Conservative management and physiotherapy may ensure the stabilization of the lesion and pain relief.**

The clinical semiology of isthmic lysis is typical and reproduceable and allows to make the diagnosis: It is characterized by lumbosacral pain, on either the right or left side, rarely bilateral initially, which is aggravated on exertion, improved with rest, and which may appear either acutely or progressively over weeks. Upon resumption of physical activity, there is typically recurrence of the pain at increasingly lower levels of exertion.

Two factors are generally present: one predisposing factor (such as a sagittal alignment favoring lumbosacral hyperextension), and repetitive spinal microtrauma during growth.

***Figure 1**: isthmic lysis*

1-Definitions

Spondylolysis: A defect at the level of the interarticular isthmus (pars interarticularis) without displacement of the vertebra. The isthmus may be drawn out, thinned or condensed, brittle, or broken off, but may also consist of fibrous tissue or progress into pseudarthrosis.

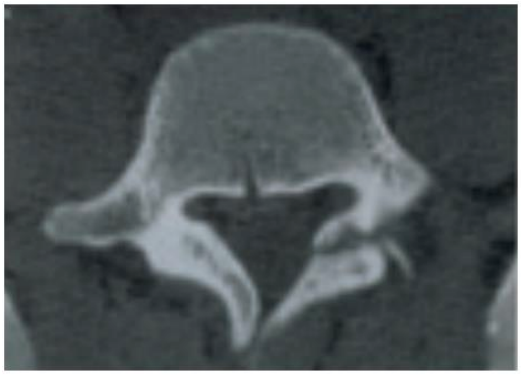

Figure 2: *non-union*

This bony defect is most frequently found at the level of L5. As a result, the sole elements supporting L5 over the sacrum and preventing its translation are the lumbo-sacral intervertebral disk (L5-S1), the paraspinal muscles that are found in a permanently contracted state and are at the origin of pain, the joint capsules, and the ligaments. Spondylolysis may be rarely encountered at L4 or L3.

Spondylolisthesis: A bilateral isthmic defect may be accompanied by slippage of L5 over S1. This translation may be measured in percentage or a grade may be attributed depending on the degree of translation relative to the width of the sacral plate, or according to the Meyerding classification by dividing the sacral base into 4 parts: Grade 1 is slippage within the 1st quartile, grade 2 within the 2nd quartile, until stage 4. When the vertebra is no longer in contact with the sacrum, it is known as spondyloptosis [2].

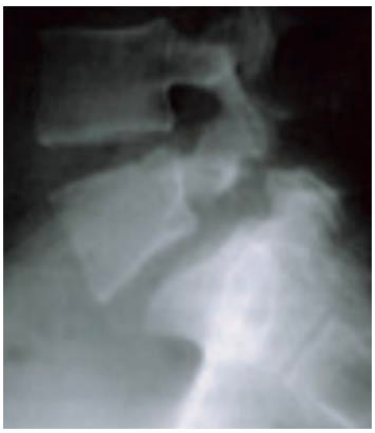

Figure 3*: Stage 1 spondylolisthesis over bilateral isthmic lysis*

2- Clinical diagnosis in the young athlete

- Medical history: The diagnosis may be incidental. In fact, isthmic lysis, which may be bilateral and associated with spondylolisthesis, may take place during growth and non-athletic children may even be pain-free. It is thought to be a compensatory mechanism secondary to fragility of the isthmic region and to the vertical posture which places mechanical strain on this region. As a result, not all patients with spondylolisthesis or spondylolysis are symptomatic. No relationships have been found between severity of the slippage (as visible on radiographs) and functional impact: anatomical and clinical dissociation is one of the characteristics of spondylolisthesis. The diagnosis may also be evoked during painful episodes. Acute low-back-pain is usually secondary to a uni- or bilateral isthmic fracture. Consequently, this fracture is believed to occur as a result of indirect trauma, movements of hyperextension (e.g. gymnastics), or sudden load (e.g. rugby, basketball).

Pain secondary to isthmic lysis or spondylolisthesis has certain characteristics:

- Localized at the lumbo-sacral region and lateralized to one side
- Activated by extension of the spine
- Relieved by rest, especially in the fetal position
- May sometimes irradiate to the gluteal region
- Awakened by physical activity at increasingly earlier phases of a workout usually requiring the child to stop the activity
- After a prolonged period of cessation (at least 15 days), pain reappears after resumption of physical exercise

The assessment of sagittal alignment is primordial and may be done with a plumb line allowing for the assessment of the sagittal curves.

Upon palpation of the L5 spinous process, pain may be elicited. Pelvic retroversion can often be found with reactionary distal hyperlordosis and lumbosacral kyphosis. Plumb line assessment may highlight any anterior sagittal imbalance.

Dynamic examination is also important, where the patient is asked to perform flexion and extension of the spine: back pain and stiffness are usually evident especially during painful episodes. Harmony of the curves must be noted: in flexion, the disappearance of the lordosis or its maintenance, in extension the capacity to realize extension of the thoraco-lumbar region or the existence of a break in the lumbo-sacral region (figure 5). Extension of the hip and spine are evaluated in the prone position by passively raising the straightened lower limbs: the presence of pain and the flexibility extension must be noted.

Figure 4*: appropriate thoraco-lumbar extension*

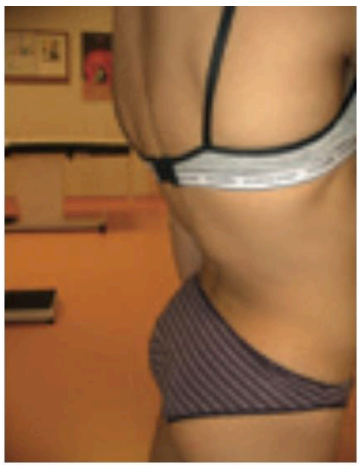

Figure 5*: distal thoracic hyperkyphosis with disruption of the harmonious lumbo-sacral alignment*

Hamstrings tightness may be identified on physical exam and, in case of advanced spondylolisthesis, pelvic retroversion, lumbar hyperlordosis, lumbosacral kyphosis, hip and knee flexion contracture, and tightness of the triceps surae may also be found.

Figure 6*: extension test in prone position*

3- Radiographic diagnosis

Spondylolisthesis may be diagnosed on conventional radiographs. With the use of the EOS® system, radiation doses may be decreased while maintaining excellent image quality. Based on this imgaging modality, the sagittal profile may be classified into one of 4 different types of backs, as per the Roussouly classification [9].

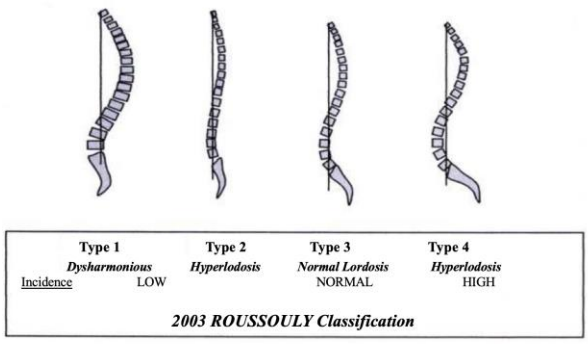

***Figure 7**: Roussouly classification*

However, isthmic lysis without spondylolisthesis may not always be diagnosed on conventional radiographs. In young athletes, early diagnosis is imperative, and MRI or scintigraphy are more frequently resorted to. CT-scans are generally avoided due to the high doses of radiation but may lead to the diagnosis of isthmic lysis in certain patients in whom the diagnosis is uncertain.

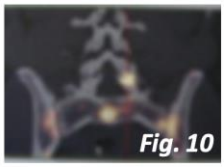

***Figure 11**: intervertebral disc disease above and below the level of spondylolisthesis*

***Figure 10**: isthmic lysis as seen on scintigraphy*

The angle of lumbosacral kyphosis or slip angle is most frequently measured using the Louis method and is defined as the angle between the tangent to the posterior edge of S1 and the superior plateau of L5. If this angle falls below 90°, the sacrum is considered vertical, and if the lumbosacral kyphosis is superior to 100°, the sacrum is considered horizontal [3].

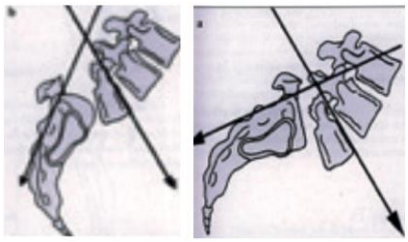

***Figure 8**: vertical sacrum*

***Figure 9**: horizontal sacrum*

While assessing the sagittal alignment, pelvic incidence (as described by Duval-Beaupère) and the position of the sacrum are essential for the interpretation of lumbo-scaral sagittal imbalance [8,10].

4-Risk factors

The configuration of the sagittal curves of the spine plays an important role in spinal pathology. In fact, both high and low pelvic incidence may increase strain on the isthmus by increasing traction or slippage forces anteriorly, or by increasing the shear forces exerted by the L4 articular processes over the L5 isthmus, respectively. Similarly, the abnormal or repetitive shear or compressive forces which are imposed on the spine could have similar consequences: the incidence of spondylolysis increases notably in practitioners of certain types of sports (diving, Olympic-style weightlifting, wrestling, gymnastics, etc.).

Most frequently, the pars defect does not consolidate. This may be simply be an adaptation of the spine to situations where, among others, spinal balance is dictated by the pelvic incidence. During growth, progressive anterior displacement of the vertebra may take place. After skeletal maturity, progressive slippage is rare and may be due to secondary degeneration of the intervertebral disc.

When spondylolysis occurs in the context of low pelvic incidence, secondary dysplasia takes place: the L5 vertebra takes a cuneiform shape and dysplasia of the dome of S1 is observed. When pelvic incidence is higher, dysplasia and displacement are often less significant. Thereby, 3 primary risk factors may be determined:

- Familial: probably genetic, linked to isthmic fragility
- Postural: Global hyperlordosis (Roussouly type 4) or short lumbosacral hyperlordosis (Roussouly type 1)
- Repetitive microtrauma

Two ulterior factors may also be found: On the one hand, anomalies of the lumbosacral junction with partial lumbarization of S1 which could lead to instability of L5 over S1. On the other hand, sacralization of L5 would increase strain at the level of L4, especially if there is highly localized extension at the same level.

A final intervening factor: the growth element. Isthmic lysis with a fragilized vertebral growth plate arising around the time of puberty may rapidly progress if the physeal lesion reaches

the superior endplate of S1. The Example of a high-level gymnast who presented with isthmic lysis in 2007 with progressive erosions of the anterior edge of the S1 endplate is presented in figures 12 to 15.

Figure 12 to 15*: progression of the isthmic lysis between 2004 and 2011*

5- Conservative treatment

It is crucial to underline the fact that the majority of patients respond well to functional or orthopedic treatment and do not require surgical management [1,4,5].

5.1 Rehabilitation

Our experience with gymnasts of the French Pole of St Etienne, a population in whom isthmic lysis and spondylolisthesis are frequently found, allows us to better define the objectives of rehabilitation in these patients.

Said objective is generally to maintain an adapted level of physical activity with little strain on the lumbosacral junction while avoiding hyperextension of the spine.

The basis of rehabilitation relies on the core conditioning of the lumbar region and stretching the hip and thigh muscles. Core conditioning consists of exercises that maintain isometric contraction (i.e. without modifying the length of the muscle fibers) of multiple agonistic and antagonistic muscle groups simultaneously thereby locking many different joints. The patient must remain immobile in a fixed position for a certain amount of time. The muscles reinforced during these exercises are specifically the deep and postural muscles (vertebral and para-vertebral, abdominal, gluteal, hamstrings, etc…).

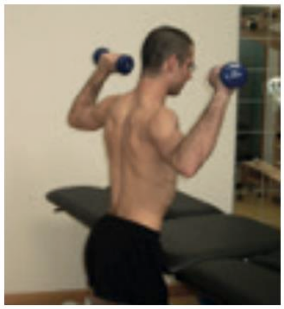

Figure 16*: abdominal muscle conditioning*

Figure 17*: Paravertebral muscle reinforcement*

Stretching exercises should concentrate on hip and thigh muscles, particularly the hamstrings, as well as the anterior chain, psoas, and quadriceps. These exercises can be undertaken with the help of a physiotherapist as muscle energy techniques, or by maintaining certain postures for a certain amount of time, such as the Mézière method for global stretching of the posterior chain.

Obtaining a harmonious relationship between the sagittal curves is imperative. As a result, rehabilitation must take into account the child's type of back:
In patients with a global hyperlordosis with a type 4 back (Roussouly's classification), the objective is to reduce both lordosis and kyphosis through core strengthening, pelvic retroversion, active spinal elongation , and global postural rehabilitation. The Mézière techniques involving certain postures which stretch the posterior chain are particularly useful.

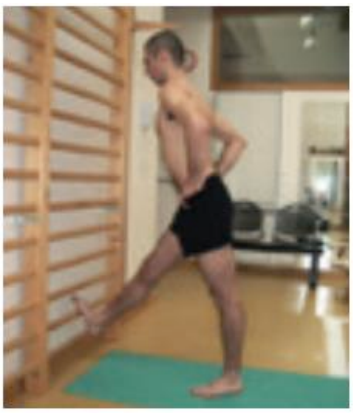

Figure 18*: stretching of the posterior chain and reinforcement of paravertebral muscles*

In situations where the lumbar spine is hyperlordotic over a short segment with underlying thoracolumbar kyphosis and a flat back (Roussouly type 1), the objective is to harmonize the lordosis in order to further extend it proximally into the thoracolumbar region and to lock the lumbosacral junction. Reinforcement of the paravertebral muscles in the thoracolumbar region is thus indicated. In high-level young athletes, rehabilitation must take place in collaboration with the trainer. **Modification of body movement during physical activity is indispensable** along with the active locking the lumbosacral region. Eccentric reinforcement of the abdominals in order to better control lumbar extension has been developed specifically for gymnasts along with an increase in flexibility of the shoulders in order to decrease strain on the lumbosacral region during the bridge maneuver.

Figure 19*: Stretching of the thoracolumbar region*

Figure 20*: Gain in extension of the thoracolumbar spine while protecting the lumbosacral region*

Figure 21*: Gain in shoulder extension*

Figure 22*: isokinetic exercises*

Isokinetic exercises may be justified for high-level athletes while privileging eccentric reinforcement (especially abdominals for their role of limiting lumbar hyperextension).

5-2 Orthopedic management

Patients who have recently been diagnosed with symptomatic spondylolysis, with or without associated spondylolisthesis, benefit from orthopedic treatment.

The objectives are to quickly relieve the patient's pain, modify maladapted postures, and finally to ensure continued rehabilitation, which should initially be undergone while wearing a brace.

Three possible orthopedic treatment modalities have been described:

- Initial cast immobilization in order to achieve consolidation of the isthmic lysis. This is generally undertaken for a period of 3 months.
- A brace with unilateral femoral support for the limitation of motion at the lumbosacral region. This brace should be worn for 23 hours a day for a period of 3 months with the objective of obtaining consolidation.
- Generally, consolidation is not achievable and relative immobilization with a bivalve polyethylene brace may suffice. Time of brace wear is reduced to approximately 8 hours a day for a period of 3 months. Weaning must be done progressively, and the brace must be worn for a period of 1 to 2 hours after physical exercise.

Figure 23: *Brace with unilateral femoral support.*

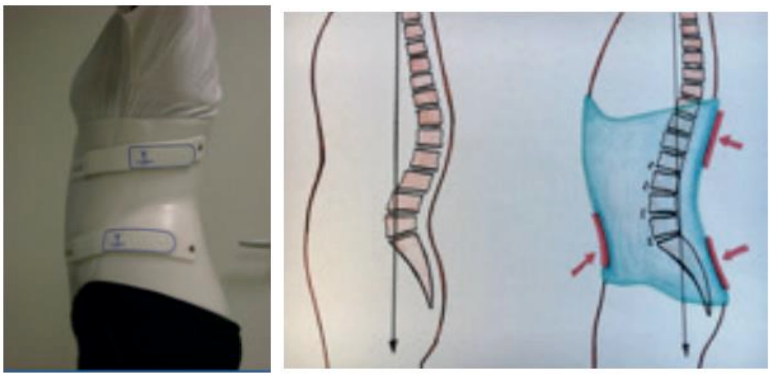

Figure 24 and 25*: bivalve brace with maintenance of a certain degree of lordosis*

No matter the type of brace chosen, the following principles must be observed (figure 25):

- No excessive decrease in lumbar lordosis: The lumbosacral junction must be immobilized in a position that best reproduces the parallel positions of the surfaces of the superior plateau of S1 and inferior endplate of L5. The pelvis should not be retroverted during the application and molding of the cast.
- Placement of pressure points at the sub-umbilical and pelvic levels are indispensable for the repositioning of L5 over the sacrum.
- If the patient presents with a high pelvic incidence (Roussouly type 4), lumbar lordosis must be respected but decreased with abdominal and sacral pressure points. The

latter must not be situated too distally over the sacrum in order to avoid overly retroverting the pelvis.

- If the patient presents with low pelvic incidence (Roussouly type 1), lordosis at the level of the thoracolumbar junction must be extended and slightly reduced at the lumbosacral region with a more proximal placed pressure point with the sacrum. Another pressure point must be placed between the breasts in order to allow for proper thoracolumbar extension.
- Anterior imbalance, which favorizes pelvic retroversion and lumbosacral kyphosis, must be avoided.
- During molding of the cast, the pressure points must to place the patient in an antalgic position. As a result, it is preferable to mold the cast using either plaster of Paris or fiberglass and in the standing position rather than utilizing 3D computer-aided design and manufacturing (CAD/CAM), which does not allow for the proper placement of pressure points in order to obtain an antalgic position.
- Rehabilitation while wearing a brace is indispensable. During the casting phase or while wearing the femoral brace, muscle mass must be maintenance with stretching exercises and static contractions of the paravertebral and abdominal muscles. While wearing the bivalve polyethylene brace, core conditioning is intensified during brace wear with progressive reconditioning to physical activity.
- Carbon braces with anterior windows should be avoided since they do not allow for sub-umbilical support.

Indications:

- In symptomatic patients in whom the acute nature of the lesion is confirmed via scintigraphy or MRI, consolidation of the pars defect may be attempted as long as pelvic biomechanical characteristics remain favorable; a very high pelvic incidence (>70°) would lead to extremely high shearing forces and may lead to non-union.
- If the patient presents with an unstable spine along with daily pain with minimal changes in position, femoral support may be indicated for a period of 1 to 3 months. Relay with a bivalve brace may then be authorized.
- In all other cases, a bivalve brace according to the previously cited principles is indicated.

Clinical and radiographic follow-up at 6-month intervals is indicated. In patients with a recurrence of symptoms, the bracing period is prolonged until complete relief of pain is achieved. The brace may sometimes even be required for a period of 6 months to 2 years.

CONCLUSION

Conservative management of isthmic lysis and spondylolisthesis in children and adolescents is the standard treatment modality. It comprises of rehabilitative and orthopedic management and is indicated in either symptomatic patients or those presenting with progressive exacerbation of spondylolisthesis during growth.

The objectives of management are to achieve quick pain relief along with adaptation of inappropriate postures which could have been, in part, the source of the isthmic lysis.

Rehabilitation is initiated while wearing a brace. Generally, physical activity is contra-indicated for a period of 3 months, which may be shortened if the patient is managed at a high-level rehabilitation center with daily therapy sessions. Physical activity is then reinstated while maintaining brace-wear after physical activity. Surveillance during the entire period of growth is essential. Reestablishing an appropriate sagittal alignment and developing lumbosacral locking reflexes during physical exercise maximize the chances of a successful outcome after conservative management.

References

1. Klein G, Mehlman CT, McCarty M. Nonoperative treatment of spondylolysis and grade I spondylolisthesis in children and young adults: a meta-analysis of observational studies. J Pediatr Orthop 2009;29(2):146-56. 2. Meyerding H. Spondylolisthesis. Surg Gynecol Obstet 1932;54:371-7.

3. Jouve J. Spondylolyse et spondylolisthésis lombosacré de l'enfant et de l'adolescent. In: Conférences d'enseignement de la SOFCOT; 2001; Paris: Cahiers d'enseignement de la SOFCOT; 2001. p. 171-192. 4. Hu SS, Tribus CB, Diab M, Ghanayem AJ. Spondylolisthesis and spondylolysis. J Bone Joint Surg Am 2008;90(3):656-71.

5. Logroscino G, Mazza O, Aulisa G, Pitta L, Pola E, Aulisa L. Spondylolysis and spondylolisthesis in the pediatric and adolescent population. Childs Nerv Syst 2001;17(11):644-55.

6. Hammerberg KW. New concepts on the pathogenesis and classification of spondylolisthesis. Spine (Phila Pa 1976) 2005;30(6 Suppl):S4-11.

7. Labelle H, Roussouly P, Berthonnaud E, Dimnet J, O'Brien M. The importance of spino-pelvic balance in L5-s1 developmental spondylolisthesis: a review of pertinent radiologic measurements. Spine (Phila Pa 1976) 2005;30(6 Suppl):S27-34.

8. Labelle H, Roussouly P, Berthonnaud E, Transfeldt E, O'Brien M, Chopin D, et al. Spondylolisthesis, pelvic incidence, and spinopelvic balance: a correlation study. Spine (Phila Pa 1976) 2004;29(18):2049-54.

9. Roussouly P, Gollogly S, Berthonnaud E, Labelle H, Weidenbaum M. Sagittal alignment of the spine and pelvis in the presence of L5-s1 isthmic lysis and low-grade spondylolisthesis. Spine (Phila Pa 1976) 2006;31(21):2484-90.

10. Legaye J, Duval-Beaupere G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 1998;7(2):99-103.

11. Fu KM, Smith JS, Polly DW, Jr., Perra JH, Sansur CA, Berven SH, et al. Morbidity and mortality in the surgical treatment of six hundred five pediatric patients with isthmic or dysplastic spondylolisthesis. Spine (Phila Pa 1976);36(4):308-12.

12. Cheung EV, Herman MJ, Cavalier R, Pizzutillo PD. Spondylolysis and spondylolisthesis in children and adolescents: II. Surgical management. J Am Acad Orthop Surg 2006;14(8):488-98.

13. Gill GG, Manning JG, White HL. Surgical treatment of spondylolisthesis without spine fusion; excision of the loose lamina with decompression of the nerve roots. J Bone Joint Surg Am 1955;37-A(3):493-520. 14. Agabegi SS, Fischgrund JS. Contemporary management of isthmic spondylolisthesis: pediatric and adult. Spine J;10(6):530-43.

15. Lenke LG, Bridwell KH. Evaluation and surgical treatment of high-grade isthmic dysplastic spondylolisthesis. Instr Course Lect 2003;52:525-32. 16. Transfeldt EE, Mehbod AA. Evidence-

based medicine analysis of isthmic spondylolisthesis treatment including reduction versus fusion in situ for high-grade slips. Spine (Phila Pa 1976) 2007;32(19 Suppl):S126-9.
17. Hresko MT, Hirschfeld R, Buerk AA, Zurakowski D. The effect of reduction and instrumentation of spondylolisthesis on spinopelvic sagittal alignment. J Pediatr Orthop 2009;29(2):157-62.