24 Spondylolysis and Isthmic Spondylolisthesis

Sumeet Garg and Mark Erickson

24.1 Introduction

Back pain in the pediatric population is common, and increases during adolescence. The incidence of back pain has been reported as high as 50 % by the age of 15 years [1, 2]. While in most cases the pain is due to muscular pain or inflexibility, the most common structural cause of back pain in adolescents is spondylolysis with or without spondylolisthesis, the signs and symptoms of which are exaggerated upon lumbar spine hyperextension and rotation. A thorough history and physical exam is imperative when assessing for this condition in children with back pain.

Spondylolysis is a stress fracture of the pars interarticularis, usually at the L5 level. Five percent of the population has radiographic evidence of spondylolysis. The condition is believed to occur due to repetitive hyperextension of the lumbar spine and has increased prevalence in dancers, gymnasts, and football linemen. Prognosis is excellent with nonoperative treatment, and surgical management is rarely recommended.

Spondylolisthesis is a forward slippage of one vertebra on its adjacent vertebra. It occurs commonly in the degenerated lumbar spine. In children and adolescents, however, spondylolisthesis generally occurs due to displacement at the site of stress fracture of the pars interarticularis or due to dysplastic development of the L5/S1 posterior articulation. Surgery is not usually required to treat low-grade spondylolisthesis, but is almost universally required for the management of high-grade spondylolisthesis. Surgical management of high-grade spondylolisthesis is among the most debated and contentious topic of discussion among spine surgeons.

24.2 Case Example Spondylolisthesis

An 11-year-old female presented with a six-month history of back pain, stiffness, and worsening gait. She has been progressively walking on her toes. She has difficulty standing straight with her knees extended. She has lower back pain, but no numbness or paresthesias in her legs. She does have radicular pain in the anterior and lateral lower left leg. She denies bowel and bladder incontinence. She is an otherwise healthy female. Her neurologic exam demonstrated no focal deficits with 5/5 strength throughout the lower extremities and a normal sensory examination of the lower extremities. She has significant hamstring tightness, with popliteal angles of 60° on the left and 30° on the right. She has absent deep tendon reflex at the left Achilles tendon only. No neurologic symptoms with straight leg raise test bilaterally. Radiographs were taken (Fig. 24.1), demonstrating a grade 3 spondylolisthesis with dysplastic

S. Garg (✉) • M. Erickson
Department of Orthopaedic Surgery,
University of Colorado School of Medicine,
Children's Hospital Colorado,
13123 E. 16th Avenue, B060, Aurora, CO 80045, USA
e-mail: sumeet.garg@childrenscolorado.org;
mark. erickson@childrenscolorado.org

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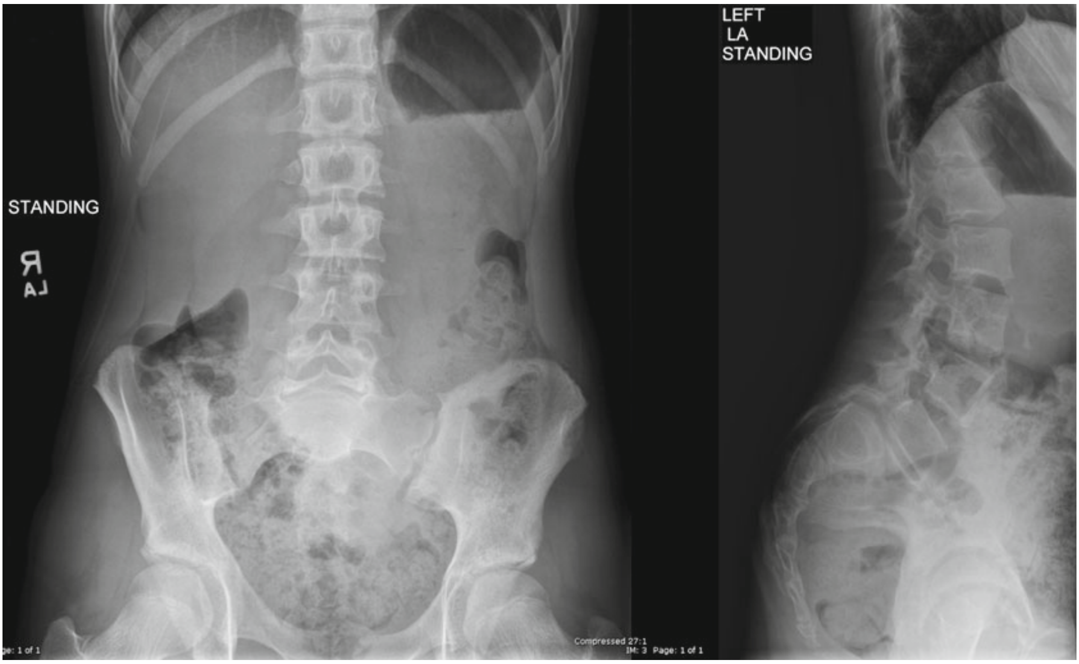

Fig. 24.1 AP and lateral lumbar spine radiographs demonstrating a grade 3 dysplastic spondylolisthesis. Note the elongated pars interarticularis of L5 without isthmic defect

features. She has been undergoing physical therapy for 6 months without any significant improvement of her symptoms.

24.3 Case Example: Spondylolysis Without Spondylolisthesis

A 12-year-old competitive gymnast presents with a 1–2-year history of vague back pain. Her pain has been increasing in frequency over the past 6 months and is now causing difficulty with completing her competitions and practice sessions. She describes the pain as dull, aching, and constant. The symptoms are at their worst in the hours after practice and competition. There are no radicular symptoms and the pain is fairly well localized to the lower lumbar region. She has normal bowel and bladder habits. Her examination is remarkable for a normal gait and neurological examination. However, her pain is readily reproduced with extension efforts in her lumbar spine (Fig. 24.2). Radiographs were obtained of her lumbar spine and are read as normal. She has had no previous treatment.

24.4 Pathology

In 90 % of patients with spondylolysis, a unilateral or bilateral defect of the pars interarticularis is observed at the L5–S1 junction [3]. Though the etiology is still unclear, spondylolysis is most likely due to the mechanical factors associated with the upright position, as there have been no reports in infants or non-ambulators, and it is rarely diagnosed before age 5; furthermore, the prevalence rate increases from 4 % at age 6 years to 6 % by age 18 years [4]. Spondylolysis is a consequence of mechanical factors such as repetitive microtrauma (stress fractures) and/or acute trauma.

The pars interarticularis is the weakest part of the posterior elements of the vertebra and is responsible for resisting shear stresses and therefore preventing anterior displacement of the vertebra (Fig. 24.3). During lumbar hyperextension, the load on the posterior bony arch in the normal spine increases dramatically across the lumbar vertebrae, with most of the force concentrating at L5. Therefore, spondylolysis is

Fig. 24.2 Provocative maneuvers, such as controlled lumbar extension, can be useful in eliciting tenderness/pain that mimics the patients' complaints. Such physical examination techniques help to elevate the clinicians' suspicion toward a diagnosis of spondylolysis

Fig. 24.4 Activities requiring extremely repetitive lumbar spine hyperextension, such as gymnastics, put athletes at risk for the development of spondylolysis

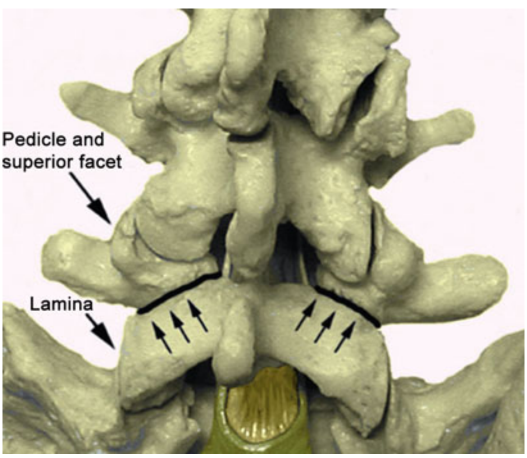

Fig. 24.3 Saw bones image depicting the anatomic location of spondylolysis, the pars interarticularis

particularly prominent among individuals participating in sports that involve repetitive hyperextension of the trunk, such as gymnastics, weight lifting, tennis, volleyball, baseball, cheerleading, swimming/diving, football, and soccer (Fig. 24.4) [5, 6]. Once a defect is created, these repetitive increased shear forces prevent healing, causing the center of gravity to move forward which further increases shear force at the lumbosacral junction. These forces are also increased as the sacrum becomes more vertical. Progression of deformity may result in secondary spondylolisthesis.

Spondylolisthesis occurs due to a variety of underlying pathology. The commonly used Wiltse classification separates spondylolisthesis into five types (Table 24.1) [7]. The isthmic and dysplastic types at the L5/S1 level are the most commonly seen in pediatrics. Isthmic type is an extension of a spondylolytic defect, whereas dysplastic type is a result of pathologic development

Table 24.1 Wiltse classification

Type 1: dysplastic
Type 2: isthmic
Type 3: degenerative
Type 4: posttraumatic
Type 5: pathologic

of the L5/S1 articulation. Dysplastic spondylolisthesis occurs either due to an elongated pars interarticularis at L5 and/or deficient facet formation at the L5/S1 level. These two anatomic features predispose to development of spondylolisthesis. Isthmic defects frequently occur in patients with preexisting dysplastic spondylolisthesis.

Another etiology-based classification was developed by Marchetti and Bartolozzi and groups isthmic and dysplastic together as developmental spondylolisthesis (type I) with subgroups being low and high grade with proposed prognostic implications on slip progression, neurologic symptoms, and surgical treatment. The second type in their classification was acquired spondylolisthesis (type II) encompassing degenerative, posttraumatic, and pathologic [8]. This chapter focuses on the management of isthmic and dysplastic (developmental) spondylolisthesis in the pediatric population.

Severity of spondylolisthesis is often described using the Meyerding classification. Each 25 % forward slippage of L5 on S1 advances the grade 1 level. Grade 5 occurs when there is 100 % displacement of L5 on S1 and the superior end plate of L5 is inferior to the sacral promontory. This condition is also known as spondyloptosis. In clinical practice, spondylolisthesis is classified as low grade (Meyerding 1 and 2) and high grade (Meyerding 3–5). Progression of deformity and need for surgery is infrequent in low-grade spondylolisthesis, especially the isthmic type. In contrast, surgery is almost always needed to relieve symptoms in high-grade spondylolisthesis [9].

Several anatomic and radiographic features have been used to describe spondylolisthesis and help evaluate risk of progression and assist with treatment decisions. These include the *Meyerding grade*, *slip angle*, and *pelvic incidence*. High-grade spondylolisthesis (Meyerding 3–5) have high rates of progression whereas low grades (Meyerding 1–2) have very low risks of progression. Slip angle is the angle between the superior end plate of L5 and the superior sacral end plate. Higher angles are more likely to have symptoms and progression. Pelvic incidence represents the combination of sacral slope and pelvic inclination and is uniform regardless of body position [10]. High pelvic incidence has been suggested to lead to increased risk of spondylolisthesis, but has not been shown to be prognostic for progression of spondylolisthesis [11]. As a fundamental descriptor of the lumbopelvic anatomy, it continues to be studied as a measure to assist with prognostic and treatment decisions.

Patients with dysplastic spondylolisthesis have a worse prognosis than those with isthmic spondylolisthesis. The dysplastic L5/S1 articulation allows for forward slippage without fracture of the pars interarticularis. The presence of intact posterior elements can lead to compression of the dural sac as L5 slips forward. Consequently, patients with dysplastic spondylolisthesis tend to be more symptomatic and present earlier than those with strictly isthmic spondylolisthesis. Neurologic symptoms are more common than in isthmic spondylolisthesis. Making the distinction between isthmic and dysplastic spondylolisthesis is critical since low-grade isthmic spondylolisthesis has a very low risk of progression versus near certain progression in dysplastic spondylolisthesis. Treatment will be more aggressive surgically in dysplastic spondylolisthesis and will be discussed in more detail in the treatment section.

24.5 History

Obtaining a thorough history is imperative when assessing a child or adolescent with back pain. Patients between the ages of 10 and 15 years old that participate in hyperextension sports are at high risk of spondylolysis. Common presentation includes dull aching pain that is localized in the lower back and exacerbated by activity. Patients may occasionally experience radicular-type pain. The nature of the pain, onset, character, location, and duration must all be taken into account. Pain associated with spondylolysis is often exacerbated with activities involving hyperextension of the lumbar spine. Gait changes may also be observed. Family history must also be taken into account, as there exists an inherited predisposition [4].

24.6 Physical Examination

Patients commonly present during late childhood or early adolescence with symptoms of localized midline low lumbar back pain and tenderness that is exacerbated by physical activity, prolonged standing, and/or lumbar hyperextension. In many cases, however, the patients are poorly able to localize their symptoms.

Effects on posture, gait, and transitional movements (spinal rhythm), as well as alignment and deformity issues, may also be observed. Sagittal and coronal alignment should be assessed, along with spinal mobility. Pain radiating to the buttock and posterior thighs upon walking or standing is a common finding. Hamstring tightness has also been noted in a majority (80 %) of patients [12].

Standard neurological exams are commonly normal among spondylolysis patients. Therefore, neurological assessment should also include sitting, standing, toe walking, heel walking, jumping, hopping, testing reflexes, and provocative maneuvers such as hyperextension of the lumbar spine.

24.7 Differential Diagnosis

Common differential diagnoses include muscle strain and overuse. Less commonly encountered are disc herniation, Scheuermann's disease, discitis, and apophyseal ring fracture. Tumors, JRA, ankylosing spondylitis, and intra-abdominal and intrathoracic causes may also be seen but are rare [1, 3, 12].

24.8 Diagnostic Imaging

24.8.1 X-Rays

Spondylolysis can be diagnosed by obtaining anteroposterior, lateral, and oblique radiographs of the lumbar spine. Bilateral pars defects can be identified on the lateral view, which should be obtained with the patient standing in order to identify any associated spondylolisthesis. The oblique view is optimal for identifying unilateral pars defects and offers a unique view of the pars often referred to as the "Scottie dog" (Fig. 24.5). A spondylolytic defect may appear as the collar or broken neck of the Scottie dog.

During the early phases, the spondylolytic defect may be easy to miss on plain radiographs and/or the pars may appear normal. If suspicious based on clinical findings, further investigation is warranted.

24.8.2 Bone Scan

A bone scan or SPECT scan is helpful in diagnosing spondylolysis in patients with normal x-rays (Fig. 24.6). Increased metabolic activity on the scan ("hot spots") are areas of increased osteoblastic activity indicating a stress reaction or subacute injury which may precede a fracture, while decreased metabolic activity ("cold spots") signify areas of nonunion [13].

24.8.3 CT Scan

A CT scan may offer superior visualization of the area in question. However, slices must be small (1.0–1.5 mm) or the lesion may be overlooked. In instances where a SPECT scan denotes an area of abnormal metabolic activity, a CT scan can then be targeted to this specific anatomic region. (Fig. 24.7)

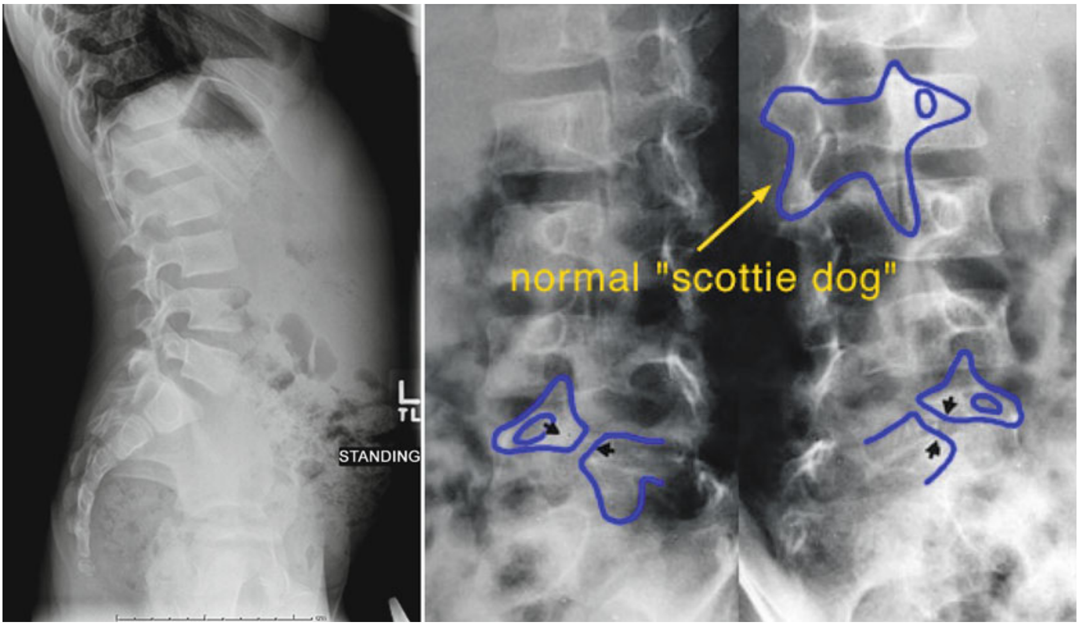

Fig. 24.5 Occasionally, bilateral spondylolyses can be visualized on lateral projection x-rays as seen in this figure. However, more commonly they are best seen on oblique views. Note that the “neck” of the “Scottie dog” is representative anatomically of the pars interarticularis

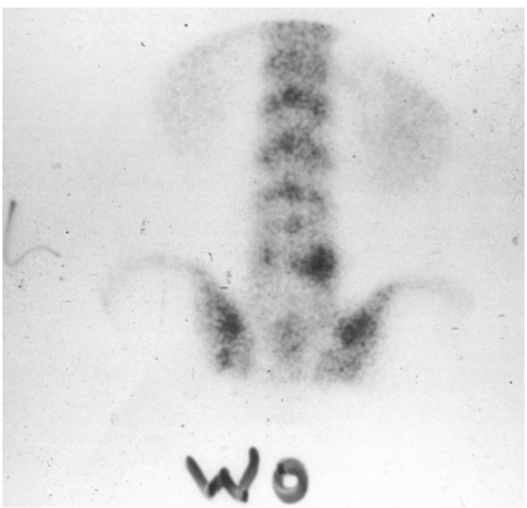

Fig. 24.6 This SPECT scan denotes a focal increase in metabolic activity unilaterally at the L5 region

Fig. 24.7 Fine cut CT scans are necessary in order to discern the spondylolytic defect, as seen in this image

24.8.4 MRI

An MRI scan can also be a useful diagnostic tool. If radicular symptoms are present, an MRI scan is indicated. MRI provides the opportunity to assess for associated degenerative disc disease and disc herniation. Viewing the pedicle, disc space, and parasagittal views at the level of the pars allows for assessment of the lesion as well as the surrounding soft tissue structures [14, 15].

24.9 Treatment: Spondylolysis

24.9.1 Nonoperative

Treatment for spondylolysis is largely nonoperative, unless prolonged conservative measures are unsuccessful. Management should largely focus on core strengthening, activity modification, and immobilization [16].

Core fitness programs often include physical therapy and Pilates or yoga-type activities. Focus should be placed on avoiding lumbar extension activities while strengthening core muscles and increasing the flexibility of the hamstrings.

Exercises should be complemented with activity modification. Patient recommendations should include avoiding high-risk hyperextension activities and sports until after pain resolves. Subsequently, patients may return gradually to normal activity. Patients who stop sports until pain resolution have been shown to have better outcomes [17]. Return to the same high-risk hyperextension activities, however, can lead to repetitive cycles of recurring back pain.

Immobilization, such as casting or bracing, may be used to reduce the shear stresses acting on the pars of the affected vertebrae. Bracing should include the application of a thoracolumbar spinal orthosis for 3–6 months. Bracing and casting have proved effective in successfully healing the majority of unilateral or bilateral spondylolytic defects if diagnosed early [3, 14, 18]. Close follow-up is imperative and patients whose pain does not resolve must be reevaluated.

24.9.2 Operative

Only after failure of prolonged attempts at nonoperative management should surgery be con-sidered for spondylolysis. In cases where it is unclear as to whether or not the spondylolysis is the source of the patient's pain, a localized in-jection into the pars interarticularis may prove beneficial.

The options available for surgical management are repair of the spondylolytic defect (pars repair) and single level fusion (Fig. 24.8). Indications for a single level fusion include failed attempts at pars repair, bilateral spondylolysis associated with mild spondylolisthesis, and bilateral L5 spondylolysis [12]. In some individuals, the pars interarticularis at L5 can be quite small and atrophic. The high likelihood of failure of pars repair in these patients makes L5–S1 fusion a more attractive option.

The optimal utility for pars repair would be a patient with mid-lumbar spondylolysis, no spondylolisthesis, no disc disease, and a positive local injection conforming pain relief. The principles surrounding a successful attempt at pars repair involve creating a biologic environment suitable to bone healing and achieving biomechanical stability. First, resecting fibrous tissue from the spondylolytic defect site and subsequently adding bone graft material establish the biologic environment. Stability can be achieved by a variety of implant choices including wires, intralaminar screws, and pedicle screws with wires and/or hooks.

24.9.3 Postoperative Management

Immobilization after surgery is not necessary and has not been shown to improve healing rates. Postoperative management consists of a 3–4-day hospital course, immediate ambulation, and expected return to full activities by 3–4 months.

24.9.4 Outcomes

With careful patient selection, including attention to detail in the nonoperative course of management, overall excellent results can be expected from operative management of spondylolysis. The vast majority of patients experience excellent relief of their pain and return to normal activities. Unfortunately, the biology surrounding spondylolytic defects is not always conducive to healing. Failed attempts at pars repair can typically be salvaged with a single level fusion with excellent outcomes being the standard.

24.9.5 Complications

Failure of healing in pars repair and pseudarthrosis after single level attempts at fusion are accepted risks in this population. The current literature is sparse relative to actual healing and

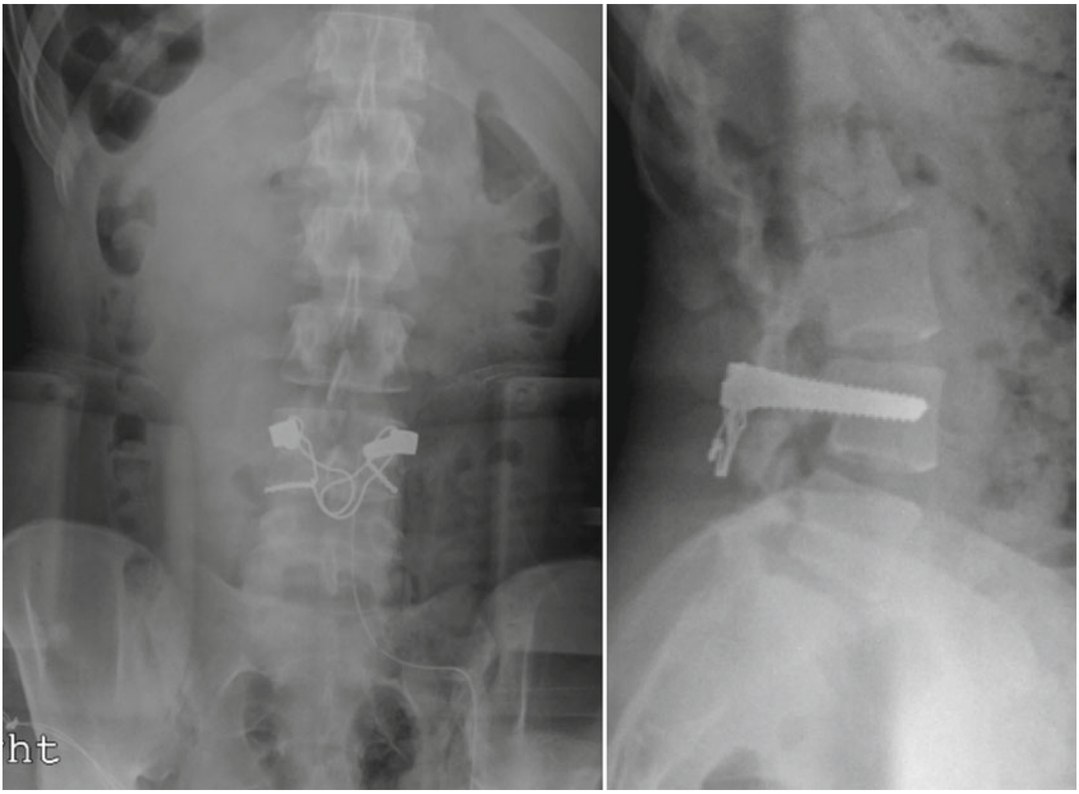

Fig. 24.8 AP and lateral radiographs demonstrating postoperative changes after surgical pars repair at L4. A bilateral pedicle screw/compression wiring technique was utilized to create stability and compression across the pars defect

fusion rates with high-quality data lacking. In general, rates of healing/fusion are reported to be in excess of 90 %. The risk of iatrogenic neurologic injury in this group of patients is low. Other complications that occur are consistent with all spine surgery such as infection, dural tear, implant prominence, implant failure, and medical complications.

24.10 Treatment: Spondylolisthesis

24.10.1 Nonoperative

Asymptomatic patients with low-grade isthmic spondylolisthesis do not require any routine treatment or follow-up. Progression is rare, and if it occurs, almost universally will cause symptoms and prompt return to the clinic for evaluation. Families should still be counseled to follow up for new back pain or neurologic symptoms. No activity restrictions are recommended. Bracing is not efficacious. Long-term studies have shown only rare cases of progression of pure isthmic spondylolisthesis. Symptomatic patients with low-grade isthmic spondylolisthesis benefit from a physical therapy program emphasizing spinal flexibility, core strengthening, aerobic conditioning, and hamstring stretching. Home program with daily exercises is recommended for best results. Advanced imaging with MRI is not indicated unless the nonoperative program fails to relieve symptoms. Long-term follow-up studies have demonstrated resolution of symptoms in more than 80 % of patients with symptomatic low-grade isthmic spondylolisthesis without surgery [16, 19, 20].

Patients with dysplastic low-grade spondylolisthesis should be followed up annually, regardless of symptoms, to monitor for progression. Symptomatic patients will benefit from a nonoperative therapy program. Surgery should be strongly considered for any patients with dysplastic spondylolisthesis showing progression regardless of symptoms. Once demonstrated, progression universally continues and will nearly always become symptomatic. Treatment prior to the deformity becoming high grade simplifies treatment decisions and carries less risk than surgical management of high-grade spondylolisthesis.

24.10.2 Operative

Operative treatment is indicated for patients with symptomatic low-grade isthmic spondylolisthesis that fails to respond to nonoperative management and for patients with dysplastic spondylolisthesis that is progressive. Presence of neurologic symptoms in particular is a generally accepted indication for surgical treatment. High-grade spondylolisthesis of any type also usually requires surgical treatment since symptoms are invariably present and nonoperative treatment is ineffective. For low-grade spondylolisthesis, uninstrumented posterolateral fusion from the transverse processes of L5 to the sacral ala is the gold standard. Surgical treatment of high-grade spondylolisthesis is more controversial. Treatment options proposed range from uninstrumented posterolateral fusion to full reduction of L5 on the sacrum via anterior and posterior approach. The decision whether to not reduce, partially reduce, or fully reduce the spondylolisthesis deformity is a topic of great contention among spine specialists.

24.10.3 Uninstrumented In Situ Fusion

Posterolateral fusion, in situ, without instrumentation is the preferred treatment for symptomatic low-grade spondylolisthesis without neurologic symptoms. This is done via a paramedian muscle splitting approach as originally described by Wiltse et al. [21]. This approach splits the paraspinal muscles and allows for direct exposure of the transverse process of L5 and sacral ala. Iliac crest autograft is placed between these structures, and often a flap of the superior sacral ala can be lifted off with an osteotome to bridge the gap to the transverse process of L5 and provide a base for the autograft. Immobilization after surgery is not necessary and has not been shown to improve fusion rates.

Results of uninstrumented in situ fusion for low-grade spondylolisthesis without neurologic symptoms are excellent [22, 23]. In general fusion, rates between 80 and 90 % are reported with generally excellent relief of symptoms. Some argue for this type of treatment even in patients *with* neurologic symptoms. Reports have demonstrated relief of radicular symptoms, hamstring tightness, and improvement of altered gait after in situ fusion. Persistent neurologic symptoms after arthrodesis can be addressed by second-stage decompression. Other complications include pseudarthrosis and consequent progression of spondylolisthesis. This occurs in 10–20 % of patients, even in some who have radiographically solid fusion [22]. Surprisingly, despite a high rate of pseudarthrosis, often symptom relief at long-term follow-up is equivalent despite quality of the fusion mass after in situ uninstrumented fusion [24]. Although no dural exposure or reduction is attempted, cauda equina dysfunction has still been reported after in situ uninstrumented fusion and is best addressed by immediate decompression [25].

The presence of motor defects or bowel or bladder dysfunction, however, should compel surgeons to neurologic decompression as part of the surgical treatment. Traditionally, a Gill laminectomy is done with complete removal of the posterior elements of L5. In isthmic cases, or dysplastic cases with isthmic defect, there is retained superior articular facet of L5 that also must be removed. The decompression should allow for full relief of the L5 and S1 nerve roots along with the dural sac. Frequently, in high-grade spondylolisthesis, sacral dome osteotomy is also required to relieve tension on the dural sac. Return of pulsations of the dural sac generally heralds appropriate decompression. Although in situ posterolateral fusion can also be utilized following thorough neurologic decompression, instrumentation is usually placed because of the instability created by the bony resection.

24.10.4 Instrumented Fusion (Includes Reduction Discussion, Transsacral Implants, Fibular Graft)

Addition of instrumentation to fusion for lumbar spondylolisthesis has been established to improve fusion rates in adult degenerative spondylolisthesis. If reduction of the deformity in isthmic or dysplastic spondylolisthesis is to be attempted, then instrumentation is mandatory. The decision to reduce, and how much to reduce, a spondylolisthesis deformity in children and adolescents is controversial. Proponents believe correction of the deformity, especially the slip angle, will improve long-term functional outcomes by correction of the abnormal sagittal plane caused by the spondylolisthesis [26]. Furthermore, they believe fusion rates are higher with instrumented versus uninstrumented in situ fusion. High-quality data is lacking for both of these assumptions. Those against reduction point to the lack of evidence supporting reduction along with presence of data showing increased rates of neurologic deficits following attempts at reduction.

Increasingly, the push from experts in the field has been to a middle ground in high-grade spondylolisthesis with decompression of the neural elements, partial reduction with a primary goal of slip angle improvement as a way to restore sagittal plane alignment without the neurologic risks of a full reduction [27]. If reduction is to be attempted, decompression of the dural sac and visualization of the nerve roots are mandatory to avoid iatrogenic compression with reduction. Posterior sacral dome osteotomy is often needed to decompress the dural sac. Strong segmental pedicle screw fixation of the vertebrae and sacrum is important to achieve and hold reduction. Fixation of L5–S1 can be either via segmental screws or screws directed supero-posterior from the S1 pedicle into the L5 vertebral body [28]. High-grade spondylolisthesis usually benefits from additional fixation to L4 and into the pelvis via iliac bolts or S2 alar iliac screws. Reduction is done by patient positioning with the hips extended on the table preoperatively and by distraction and posterior reduction of L5 (and L4 if instrumented). Extended tab (reduction) pedicle screws are useful in L4 and L5 when attempting reduction to allow for posterior force on these levels during attempted reduction.

In high-grade cases, including spondyloptosis, spinal fixation can also be supplemented with a fibular auto- or allograft from the sacrum into the body of L5 between the S1 and L5 screws. This can be done regardless of whether reduction is being attempted. This technique was popularized by Bohlman and affords excellent fusion rates in high-grade spondylolisthesis with relief of symptoms [29–31]. Bohlman did not have any neurologic deficits postoperatively in his published series, but other authors have described neurologic deficit postoperatively with this technique [31]. Use of an ACL reamer through the sacrum and L5 is a helpful technique for bony tunnel preparation for the fibular allograft. The graft can be placed either from the posterior approach as described by Bohlman or anteriorly as described by Sasso et al. [32]. If reduction is attempted, anterior support in the L5–S1 disc is beneficial for supporting the corrected sagittal plane and for improving fusion rates. This can be done either via anterior interbody fusion or posterior or transforaminal lumbar interbody fusion based on the surgeon's preference.

Results of instrumented fusion with reduction have been published recently demonstrating high fusion rates, improved clinical status, and low rates of neurologic injury [27, 33–36]. No direct trials comparing uninstrumented and instrumented fusion with reduction have been done to compare the two techniques. Pseudarthrosis is a complication of instrumented fusion with reduction; however, the rates seem to be less than with uninstrumented fusion in the small series reported. The most feared complication, neurologic deficit, which occurs in up to 25 % of cases, however, is most often transient with a permanent deficit incidence less than 5 % [37, 38]. A recent large review of the SRS morbidity and mortality database for pediatric spondylolisthesis surgery reported a 5 % rate of neurologic injury, of which 94 % of patients had improvement (half of who had full resolution) [37]. Other complications that occur less frequently are similar to those for all spine surgery such as infection, dural tear, implant prominence, implant failure, and miscellaneous postoperative medical complications.

24.10.5 L5 Corpectomy and Fusion

Gaines has described a comprehensive surgical treatment of high-grade spondylolisthesis and spondyloptosis that involves complete vertebrectomy of L5 [39]. The body of L5 is removed initially via an anterior approach, followed by posterior decompression, instrumentation of L4 and the sacrum, and reduction of L4 onto the sacrum with posterolateral fusion. There is a high rate of neurologic injury described, with 23 of 30 patients having transient motor and/or sensory L5 injury, of which two have permanent motor deficit. Other surgeons have not published results of this surgical treatment. The neurologic complication rate described by Gaines is higher than other described reduction techniques preserving L5 from a posterior-only approach. Although some centers continue to offer this treatment for high-grade spondylolisthesis, most utilize some form of instrumented posterior fusion with or without reduction.

24.10.6 Postoperative Management

After surgery, it is recommended to initially keep the hips and knees flexed with pillows under the knees. This reduces neural tension. The pillows are slowly removed over the postoperative course as the patient tolerates. Mobilization is encouraged as soon as postoperative day #1. Neuropathic pain is common, in particular when there has been dural retraction as part of the surgical procedure. Medications such as gabapentin and tricyclic antidepressants can be useful in the management of acute neuropathic pain postoperatively. These can usually be weaned off within 1–2 months following surgery.

In the past, patients with uninstrumented fusion in situ were often immobilized in a pantaloon cast after surgery. Currently, most surgeons do not use any immobilization following surgical treatment of spondylolisthesis regardless of use of instrumentation. Activity restrictions postoperatively should include limitation of bending at the waist for a minimum of 6 months. Patients can generally resume light activities such as swimming, running, and bicycling after 1–2 months when the soft tissue is healed. Contact sports are discouraged until at least 6 months, ideally until radiographic evidence of arthrodesis is appreciated.

24.10.7 Case Example: Spondylolisthesis Outcome

The presence of dysplastic features and high-grade spondylolisthesis prompted the recommendation for surgical treatment. The patient underwent posterior spinal fusion with instrumentation from L5 to S1 with transforaminal lumbar interbody fusion at L5–S1. This was done through a left-sided hemilaminectomy which allowed for decompression of the dural sac and in particular the left L5 and S1 nerve roots. There was no attempt at reduction, only postural correction of the slip angle to neutral via positioning with hips extended and knees flexed on the operating table. She had relief of her radicular symptoms immediately, and her gait improved steadily after surgery. By 6 months after surgery, she had complete relief of her back and leg pain and restoration of normal gait. Radiographs demonstrated stable fixation (Fig. 24.9).

24.10.8 Case Example: Spondylolysis Without Spondylolisthesis Outcome

SPECT scan imaging revealed a focal area of increased uptake unilaterally at the right L5 pars interarticularis. Subsequently, she stopped her gymnastics activities. Physical therapy focused on achieving and maintaining core fitness, while eliminating lumbar spine hyperextension, was introduced successfully. Over the ensuing 4 months, she experienced complete resolution

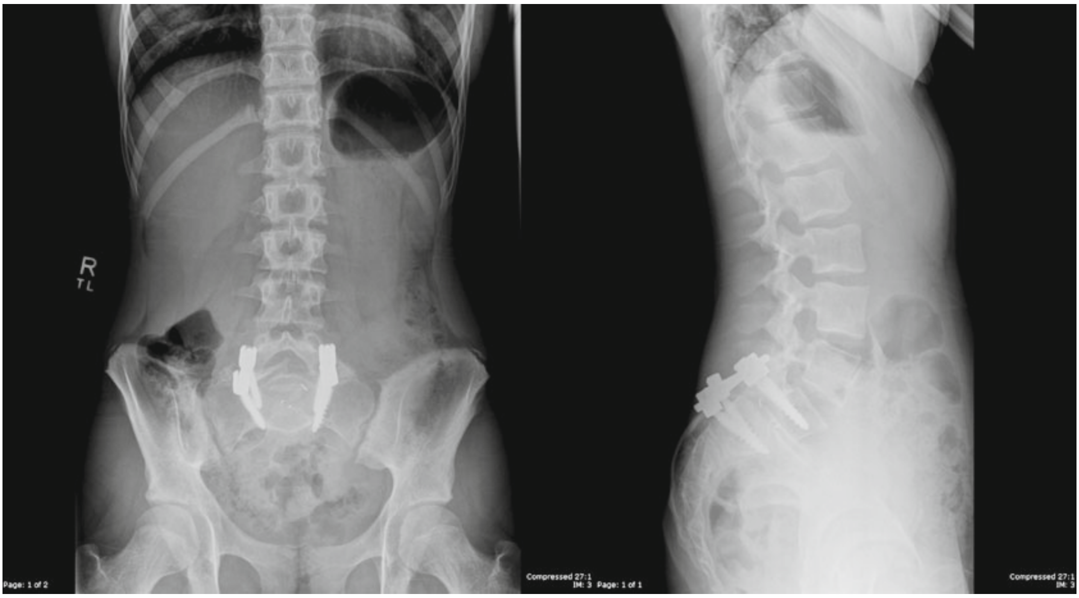

Fig. 24.9 AP and lateral lumbar spine radiographs demonstrating postsurgical changes of L5–S1 posterior fusion with TLIF at L5–S1. Radiographic markers identify cage in the L5–S1 interspace

of her back pain. Her gymnastics activity was gradually reintroduced over an additional 2 months without recurrence of her symptoms.

Questions

1. Which types of spondylolisthesis are most common in the pediatric population?
   (a) Pathologic and isthmic
   (b) Pathologic and degenerative
   (c) Isthmic and dysplastic
   (d) Isthmic and posttraumatic
   Preferred response (c): Isthmic and dysplastic are the most common types of spondylolisthesis in the pediatric population and can occur in tandem. Degenerative spondylolisthesis is common in the adult population, most frequently at L4–L5. Pathologic spondylolisthesis is rare in all ages.
2. Patients with high pelvic incidence have:
   (a) Increased prevalence of spondylolisthesis
   (b) Increased rates of progression of deformity
   (c) Low fusion rates following surgery
   (d) Elevated sacral slope
   Preferred response (a): While some argue that increased pelvic incidence results in increased rates of progression, only an increased prevalence of spondylolisthesis has been demonstrated in population studies. No relationship to fusion rates following surgery has been established. Pelvic incidence is the summation of sacral slope and pelvic tilt.
3. A patient with spondylolysis is most likely to have long-term problems including?
   (a) Progressive spondylolisthesis
   (b) Incontinence
   (c) Chronic back pain
   (d) No long-term spinal problems
   Preferred answer (d): Spondylolysis generally is a self-limiting problem that responds to improving back strength and flexibility. Progression to spondylolisthesis is infrequent, and incontinence has not been described. Chronic back pain can occur with spondylolysis, but is not the most likely outcome.
4. Surgical intervention is most likely to be required in which clinical scenario?
   (a) 16-year-old gymnast with symptomatic spondylolysis
   (b) 8-year-old with dysplastic spondylolisthesis, Meyerding grade 2
   (c) 18-year-old with isthmic spondylolisthesis, Meyerding grade 1

(d) 12-year-old with isthmic spondylolisthesis, Meyerding grade 2

Preferred answer (b): A young child with dysplastic spondylolisthesis has a high risk of progression of deformity and development of neurologic symptoms. Any progression should prompt consideration of surgical treatment with spinal fusion. Patients with low-grade isthmic spondylolisthesis have an extremely low rate of progression and should be treated symptomatically with strengthening and flexibility.

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