The first written description of spondylolisthesis is attributed to Herbiniaux, a Belgian obstetrician; in 1782, he described an osseous prominence anterior to the sacrum that caused narrowing of the birth canal. This obstruction was due to anterior subluxation of L-5 onto S-1. The term spondylolisthesis was coined approximately one century later, in 1854, by Kilian. He proposed that various forces caused subluxation of the lumbosacral facets; this in turn was believed to cause gradual VB subluxation. Soon thereafter, anatomical studies conducted by Robert and Lambi revealed that, typically, a neural arch defect preceded the subluxation. This defect, at the pars interarticularis, was termed spondylolysis. In 1888, Neugebauer demonstrated that both lysis and elongation of the pars interarticularis could lead to spondylolisthesis. A new dimension was added when Junghanns detailed a series of patients with spondylolisthesis in whom pars defect or elongation was absent.\textsuperscript{11,16}

As knowledge of the origin of spondylolisthesis was gained, attempts were made to classify its various types; the classification proposed by Wiltse, Newman, and Mac-Nab is universally accepted today as providing the means for discussing spondylolisthesis. In this system, spondylolisthesis is subdivided into five subtypes: isthmic, degenerative, dysplastic, traumatic, and pathological types. The different types refer to the various underlying abnormalities that give rise to subluxation of one vertebra over another. In this paper, we will specifically consider isthmic spondylolisthesis.

**Key Words** • spondylolisthesis • isthmic • pars interarticularis

**Isthmic spondylolisthesis**

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Isthmic spondylolisthesis, which is demonstrated in 4 to 8\% of the general population, is one of the most common types of spondylolisthesis. The three subtypes of this condition all manifest some variation of a pars interarticularis defect as a result of recurrent injury to that structure. A multifactorial origin is postulated for this disease; mechanical, hereditary, and hormonal factors are believed to play a role. Presenting signs and symptoms may include those referable to neurological compromise or those related to the spinal deformity. The majority of patients with spondylolysis and spondylolisthesis respond to conservative, nonoperative treatment. Pain, neurological compromise, and cosmetic defects unresponsive to traditional therapies may require surgical intervention. Surgical options include any combination of the following: neural decompression, bone fusion, instrument-assisted fusion, and reduction. In this paper, the natural history and treatment options are presented, and the supporting literature is reviewed.

**REVIEW OF ISTHMIC SPONDYLOLISTHESIS**

**Anatomical Features**

The pars interarticularis, or isthmus as it is commonly known, is the portion of the neural arch that connects the lamina with the pedicle, facet joints, and transverse process. As such, this is a key component in segmental integrity. A spondylolisthetic defect in the pars interarticularis may lead to a VB subluxation; this is known as isthmic spondylolisthesis.\textsuperscript{13}

Three subtypes of the isthmic spondylolisthesis are recognized. Subtype A refers to the classic lytic lesion of the pars indicative of a stress fracture. Subtype B indicates an elongated but intact isthmus; this is thought to represent a healed fracture. Subtype C refers to an acute fracture of the pars interarticularis and is the rarest of the subtypes.

The authors of cadaveric and mechanical studies have shown that because of its shape and location, the pars interarticularis is subjected to the greatest force of any structure in the lumbar spine; regrettably, these same authors have suggested that the pars interarticularis is the weakest part of the neural arch.\textsuperscript{10,13,14,29,31}

A lytic defect of the pars interarticularis at any given level allows for separation of that VB from its inferior facet, thus allowing the vertebra to slip forward. Over time, this deformity may remain stable or progress. In addition, the anterior subluxation of the spine places stress upon the adjacent disc, leading to progressive disc degeneration.

The most common site of isthmic spondylolisthesis is at the L5–S1 level because of an L-5 pars defect. It has been estimated that this pars abnormality is at L-5 in 90\% of cases, L-4 in 5\%, and other areas in the remaining cases.\textsuperscript{29}
**Origin of Isthmic Spondylolisthesis**

Isthmic spondylolisthesis has a multifactorial origin; mechanical, hereditary, and hormonal factors are all believed to play a role. Both gravitational and postural forces, acting upon the upright spine, place stress on the pars interarticularis, making it susceptible to injury. It has been shown that fatigue fractures develop in response to cyclic flexion-extension, axial, and rotational loading. In the setting of predisposing factors, repetitive trauma can lead to microfractures of the pars. At times, these fractures heal; at other times, a fibrous union, consisting of fibrocartilaginous tissue is formed. Typically, this fibrous union is weaker than bone; it responds to further stress across the pars by lengthening.7,10,27,29,31

Although the genetic basis of isthmic spondylolisthesis is unknown, one possibility can be inferred from the high incidence of the disease in near relatives of those with isthmic spondylolisthesis. Whereas the incidence of spondylolysis is 4 to 8% in the general population, the reported incidence in near relatives is approximately 25 to 30%.18,27,29,30

Progression of the vertebral slippage has been noted during adolescence; whether this implicates hormonal influences or growth potential as factors in the development of spondylolisthesis is uncertain.8,27,29,30

Taking these factors into account, it appears that a congenital predisposition to spondylolysis, in the setting of repeated injury to the pars, is responsible for the development of isthmic spondylolisthesis.

**Epidemiological Features**

Identified only in humans, spondylolisthesis has never been recognized in any other species. In humans, the earliest report of a pars defect was in a 3.5-month-old infant; typically, spondylolisthesis is not observed in newborns. It is believed that the development of spondylolisthesis is related to man’s ability to maintain an erect posture and the development of lumbar lordosis, the latter being unique to humans.24,31

Of the different types of spondylolisthesis, the isthmic variety, as well as the dysplastic and degenerative types, is the most common. The incidence of spondylolisthesis in the general adult population is 4 to 8%, varying depending on the race, age, and sex of the population sample.

As expected, the incidence of spondylolysis is higher than that of spondylolisthesis; roughly 50% of pars defects give rise to VB subluxation. Reported incidence of spondylolysis ranges from 4.4 to 5.8%; that of isthmic spondylolisthesis ranges from 2.6 to 4.4%. There are two peaks in the temporal presentation of isthmic spondylolisthesis—one occurring between the ages of 5 and 7 years and a second occurring in the teenage years.1,8,10,28,29

With regard to sex, isthmic spondylolisthesis occurs twice as often in males as females. Females, however, are fourfold more likely to suffer progression of the slippage. In general, the higher-grade slippages (> Meyerding Grade I) have the highest risk of progressive deformity.

Additionally, congenital anomalies, such as spina bifida occulta, that cause the absence of or hypoplastic posterior elements, can increase the stress transmitted to the pars, leading to its injury and subsequent deformity. This situation is not trivial; in anywhere from 24 to 70% of isthmic spondylolisthesis cases, associated spina bifida occulta may be present.10,18,25,27

In one prospective radiographic study of 500 patients, the authors found a pars defect in 4.4% of 6-year-old children and in 6% of adults. The L-5 vertebra was the most common level to be defective; 90% of abnormalities were discovered at this site. Of the 27 L-5 pars defects, 21 were bilateral; the majority of these patients harboring these defects developed spondylolisthesis. The authors also reported that in 30% of patients with a pars defect, a spina bifida occulta was present at the same level.8

It is well accepted that in young athletes, specifically gymnasts and weight lifters, the mean incidence of pars defects is higher. It has been postulated that repetitive forces of flexion, hyperextension, and rotation required in such athletic activities results in the significant number of pars stress fractures.14

**Presenting Signs and Symptoms**

Although isthmic spondylolisthesis is known to have its onset in childhood, most of those affected do not seek medical attention until later in life. In those adolescents and adults who seek medical evaluation, pain is the typical presenting symptom, usually musculoskeletal in nature. In approximately half of the cases, there is a history of a precipitating event.11,16,28 The musculoskeletal pain is a deep ache localized to the lumbar area, occasionally radiating into the buttocks or posterior thighs. Typically weight bearing and lifting exacerbate the pain, whereas rest and recumbency relieve it. This pain is often attributed to vertebral instability or pseudarthrosis at the level of the spondylolisthesis. In other situations, the lumbar pain may be discogenic in origin, secondary to adjacent-disc degeneration.

Radicular pain is typically caused by irritation, compression, or tension of the L-5 nerve root. Both uni- and bilateral symptoms may be seen. In spondylolysis, the L-5 nerve root may be compressed by fibrocartilaginous scar tissue appearing in the area of the pars defect. Rarely, the intervertebral foramen can be compromised by a degenerated, herniated disc or by the subluxation.

In higher-grade subluxations, there can be traction of the cauda equina over the sacrum, leading to signs and symptoms of cauda equina compromise. In this setting, S-1-related symptoms, as well as perineal numbness and sphincter disturbances, may manifest.

In younger patients with higher-grade subluxations, deformity may precipitate medical evaluation. On physical examination, this can be appreciated as a palpable stepoff. In isthmic spondylolisthesis in which the defect affects L-5, the L-5 neural arch of remains stationary with respect to the sacrum, whereas the L-4 neural arch slides anteriorly with the L-5 VB. As such, the abnormality is palpated at the L4–5 junction.

In mild cases of spondylolisthesis (Meyerding Grade I), the L5–S1 subluxation occurs without any disruption of the normal relationship of the VBs; the subluxation is merely a uniplanar translation. In cases in which the subluxation is 50% or greater, the translation of L-5 on S-1 is also accompanied by an angular displacement, essentially creating a lumbosacral kyphosis. To maintain global sag-
Isthmic spondylolisthesis

ittal balance, the patient compensates by two maneuvers: hyperextension of the lumbar spine and rotation of the pelvis such that the sacrum is vertical; flexion of the knees and hips also assists in maintaining balance.

High-grade spondylolisthesis is also associated with hamstring tightness, which is best described as a muscle spasm of the posterior thighs associated with a fixed flexion of the hip joints and knees. Because electromyographic and neurological abnormalities are absent, most physicians do not believe that there is a neurological basis for the hamstring tightness; rather, the tight hamstring syndrome once again represents the patient’s attempt to maintain sagittal balance.\(^2,3\)

**Imaging Characteristics**

Radiographic assessment of spondylolisthesis begins with standard plain radiographs that include lateral, anteroposterior, and oblique views. Thirty-degree oblique cranial tilt x-ray films may be more sensitive than traditional oblique x-ray films for demonstrating spondylolisthesis; the abnormality is classically described as a fracture of “the Scottie dog’s neck” (Fig. 1). Although not routinely obtained, dynamic radiographs such as the hyperextension and -flexion views can highlight occult mobility, if present.

Modern CT scanning, with its ability to provide multiplanar reformatting, has largely replaced tomography for delineation of osseous anatomy. Additional studies, such as MR imaging and myelography are of benefit in defining the neural elements; these studies provide information regarding the need for decompression and/or fusion (Fig. 2). Bone scanning may be helpful in determining the age of a lysis, with acute lesions demonstrating increased contrast uptake on examination.

Several methods exist for radiographically characterizing the degree of spondylolisthesis. The most common is the Meyerding classification in which the degree of subluxation is described as the percentage of translation of the upper VB over the lower one. The categories include

![Fig. 1. Oblique radiograph revealing outlined normal pars (Scottie dog’s neck) at upper level and lysis of pars at lower level.](image1)

Grade I (0–25% subluxation), Grade II (25–50% subluxation), Grade III (50–75% subluxation), and Grade IV (75% subluxation).\(^6,17\) Complete or 100% spondylolisthesis is termed spondyloptosis (Fig. 3).

Whereas the Meyerding classification only takes into account translational subluxation, other measurements take into account the angular displacement that can occur in spondylolisthesis. The “slip angle” or sagittal rotation measures the degree of lumbosacral kyphosis. This is calculated by measuring the angle formed by the intersection of two lines: 1) a tangent to a line drawn along the posterior aspect of the sacrum; and 2) a line parallel to the inferior endplate of L-5. In the normal situation, the angle formed by the intersection of these two lines measures zero. The “tilt” or sacral inclination refers to the vertical position of the sacrum, which is measured by drawing a line perpendicular to the floor and measuring the angle formed by the intersection of this line with a second one drawn parallel to the posterior aspect of the sacrum. Usually this angle should be greater than 30°; as the sacrum obtains a more vertical position, this angle becomes progressively smaller.\(^3,11,16,29\)

![Fig. 2. Axial CT scan (left) and MR image (right) revealing spondylolysis, visualized as an incomplete neural arch.](image2)

![Fig. 3. Schematic drawing illustrating representative grades in the Meyerding classification system.](image3)
**Management Strategies**

**Nonoperative.** Most patients who present with spondylolisthesis are asymptomatic; however, in the pediatric and adolescent population, spondylolisthesis is the predominant cause of low-back pain and sciatica. Nevertheless, nonoperative treatment is successful in the majority of cases, with surgical intervention being reserved for those in whom symptoms are refractory to these measures. Conservative measures include nonsteroidal medications, selective nerve/pars injections, brace therapy, restriction of athletic activities, and bed rest. Typically, these restrictions may be relaxed as symptoms improve. Regardless of whether the pars defect heals, most patients experience resolution of symptoms over time.

In one study, 82 adolescents with symptomatic spondylolysis or spondylolisthesis were treated nonoperatively. In a follow-up period of 1 to 14.3 years, only 25 patients required surgical treatment for pain. Of those with Meyerding Grade I or II subluxation, resolution of pain occurred in approximately 70% after conservative therapies.22

**Operative.** It is the minority of patients who, after nonoperative treatment fails, require surgical intervention. In general, children with spondylolysis and spondylolisthesis respond well to conservative measures; however, this is the population that presents with either high-grade subluxation or progression of dislocation requiring intervention. Typically, the surgery-related results tend to be better in this group compared with those in the adult population.

In evaluating a patient with isthmic spondylolisthesis, the course of the disease in the absence of surgical treatment, the potential for progression, and the results of operative treatment must all be considered. Widely accepted criteria for surgical intervention include: 1) persistence of pain or neurological symptoms despite an adequate course of nonoperative treatment,4,12,18 2) progression of slippage greater than 30%;4,14 3) presentation with greater than Grade II subluxation;4,14 and 4) cosmetic deformity secondary to postural and gait difficulties.11

Once it is established that conservative treatment has failed, the next step is to determine a surgical plan. Operative interventions include any of the following: decompression, in situ fusion, instrument-assisted fusion, and reduction surgery.

**Decompression.** In adults in whom only radicular symptoms are present, neural decompressive surgery can be performed. As described in 1955, this removal of loose posterior elements and cartilaginous tissue is known as the "Gill procedure."9 Its drawback is the potential for increasing the subluxation postoperatively. In one study, however, the reported 23% incidence of postoperative subluxation did not preclude a good clinical outcome.20

In children, decompressive surgery is rarely indicated; in situ stabilization has been shown to be effective in resolving neural symptoms; resection of posterior elements carries an unacceptable risk of inducing vertebral column instability.

**Bone Fusion.** In patients with axial low-back pain or progressive spondylolisthesis, noninstrumented fusion of the lumbar spine may be useful. Although bone fusion can be performed using a number of different methods (anterior interbody, posterior interbody, transforaminal intervertebral, or intertransverse), it is the latter (intertransverse or transversesacralalar) that makes the most sense mechanically. In the adult patient with concomitant neural symptoms, the posterior approach also allows for neural decompression. In the pediatric patient, radicular symptoms are rarely due to a cartilaginous compression and are, rather, secondary to the mechanical movement of the unstable element. Typically, immobilization of the involved segment leads to resolution of the neural symptoms.9,12

Reported results for in situ (intertransverse) fusion indicate that relief of pain can be achieved in both adolescent and adult patients. Pizzutillo, et al.,23 have reported on 40 adolescent patients who underwent posterolateral fusion; resolution of neurological and pain-related symptoms occurred in all.23 In only two of these patients did progression of subluxation occur postoperatively. In a later series, eight adult patients with isthmic spondylolisthesis were treated in a similar manner; in a follow-up period of 2 to 14 years, excellent relief of both radiculopathy and low-back pain was demonstrated in all patients. In addition, all eight patients returned to their previous occupations.21

**Instrument-Assisted Fusion.** Spinal instrumentation is typically used to improve arthrodesis rates, to repair a pars defect directly, or to reduce the dislocation in high-grade spondylolisthesis. Specifically, pedicle screw fixation devices have been shown to be mechanically superior to other stabilization systems in the lumbar spine. Compared
with other devices, they allow for the selective segmental application of force to the spinal cord without the need for extension to adjacent levels (Fig. 4).

In the pediatric population, spinal instrumentation is placed for either direct repair of the pars defect or for reduction of the high-grade subluxation. For Meyerding Grade I lesion, direct repair can be performed by passing a wire around the transverse and spinous processes of the affected level or by placing a screw through the lamina and pars defect into the pedicle. Bone grafting of the defect is performed in conjunction with the repair.

The benefit of the direct repair procedure is that it preserves motion of the involved motion segment, decreasing stress placed on adjacent levels. This procedure, however, should only be performed in the setting of the low-grade subluxation (Grade I or lower). Surgeons who advocate performing reduction surgery in patients with high-grade subluxations reduction list correction of deformity and spinal realignment as a means to achieve higher fusion rates and reduce progression of the dislocation. In this setting, anterior interbody fusion can be used both to release the spine and obtain maximum surface for fusion. With significant relief of pain and neurological symptoms reported after conducting intertransverse fusions, however, it is difficult to appreciate the benefit of reduction surgery. Risks are considerable, with postreduction neural deficits approaching 20%.

CONCLUSIONS

Spondylolisthesis is best treated by understanding the underlying origins of the deformity. In those patients with isthmic spondylolisthesis, nonoperative treatment is successful in the majority of cases. In those with symptoms refractory to conservative therapies, surgical intervention can be successful in alleviating symptoms (Figs. 5 and 6). Careful correlation of the clinical picture with neuroimaging data will allow for an accurate understanding of the structural issues and will help in the surgery-related decision-making process.

References

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Fig. 5. Case 2. Imaging studies obtained in an adult patient who presented with axial low-back pain and neurogenic claudication. Upper Left and Right: Radiographic and MR imaging studies revealing a Grade I L5–S1 spondylolisthesis and lumbar stenosis. Lower Left, Center, and Right: Axial CT scans demonstrating the presence of the L-5 pars lysis and multilevel central stenosis.

Fig. 6. Case 2. Postoperative radiographs. Despite conservative treatment, symptoms failed to abate. The patient underwent an L3–S1 instrument assisted posterolateral fusion with multilevel laminectomy.

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