Isthmic Spondylolisthesis in the Adult

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Abstract

Isthmic spondylolisthesis is a common condition and is frequently identified in the adult patient with low back pain. Although the natural history of this condition is not well defined, it is a common indication for nonoperative and operative treatment. The authors outline a systematic approach to the evaluation of the adult patient with isthmic spondylolisthesis. If radiologic studies are required, magnetic resonance imaging has improved the visualization of nerve-root compression in the neural foramen and is now widely used. Nonoperative treatment is the preferred approach in most symptomatic patients and is successful in as many as 60%. If nonoperative treatment fails, surgery may be recommended. Arthrodesis continues to be the mainstay of surgical treatment. Nerve-root decompression can be used in selected patients with radiculopathy. Although the Food and Drug Administration still considers the use of pedicle-screw instrumentation investigational or experimental, it has gained wide acceptance as an adjunct to fusion in the adult. It is important to note, however, that such use has not yet been proved safe and effective. Reduction of the spondylolisthetic segment has increased in acceptance for a small subset of patients with defined indications but carries a significant risk of complications.

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Spondylolisthesis refers to the forward displacement of one vertebra on another. The condition is most commonly seen at the lumbosacral junction. Spondylolysis, a defect in the pars interarticularis, is present in about 5% to 6% of the adult population. Isthmic spondylolisthesis occurs in the presence of spondylolysis and is the most common type of spondylolisthesis in both children and adults. The condition is seen more frequently at L5-S1, followed by L4-L5 and L3-L4. Hereditary predisposition to the development of a fatigue, or stress, fracture of the pars is currently the most widely accepted theory explaining the development of an isthmic defect.[1]

Any physician who routinely treats patients with low back pain will frequently need to define the causal relationship of the patient's symptoms to spondylolisthesis and prescribe a treatment regimen. Although isthmic spondylolisthesis is a developmental condition that usually begins during childhood,[2] most patients do not seek evaluation and treatment until adulthood. Much has been written about the management of isthmic spondylolisthesis in children and adolescents, but until recently there has been little about this condition in adults. This review focuses on management concepts applicable in adult patients with isthmic spondylolisthesis.

Epidemiology and Natural History

In a prospective study of 500 children, Fredrickson et al[2] found the incidence of spondylolysis to be 4.4%, which increased to 6% by young adulthood. They found that 75% of the defects were radiographically evident by 6 years of age and that 74% of the patients with spondylolysis also demonstrated spondylolisthesis. An increased incidence of spondylolysis and spondylolisthesis is well documented among participants in sports involving repetitive or forceful lumbar extension, particularly gymnastics and American football.

Radiographically evident pars defects generally develop before skeletal maturity, but symptoms severe enough to cause the patient to seek treatment usually begin in adulthood. In our practice, isthmic spondylolisthesis has been the most common type of slip treated surgically through the sixth decade of life. Adolescents represent fewer than 10% of cases requiring surgery. Other published surgical studies reflect a similar age distribution, with adults representing between 52% and 90% of patients.[3] However, the

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age distribution in any group of patients reflects, in large part, the referral pattern to the reporting surgeon. Saraste[4] conducted a longitudinal study and documented that the onset of symptoms tends to occur after childhood, with a mean age at presentation of 20 years.

The clinical and radiographic natural history of adults with isthmic spondylolisthesis has recently received considerable attention. Radiographic slip progression in the adult has long been considered unusual and clinically insignificant.[1,5] The percentage of slippage, the slip angle (the angle between the inferior end plate of L5 and a line perpendicular to the posterior cortex of the body of the sacrum), the lumbar index (the ratio of the posterior height to the anterior height of the body of L5), and the amount of disk degeneration have all been suggested as parameters that relate to the risk of progression. In the adult, however, none of these has been proved clearly predictive, nor has the degree of progression been correlated with the onset or presence of pain.[4]

It has been suggested that low back pain is more prevalent among patients with isthmic spondylolisthesis than in the general populace. Saraste et al[6] found symptoms to be more common in a group of 255 persons with lumbar spondylolysis or spondylolisthesis than in a control group. They found that radiographic evidence of disk degeneration and a slip of greater than 10 mm correlated positively with symptoms, as did a low lumbar index, increased lumbar lordosis, and a defect at L4.

Although low back pain is relatively common and may be an indication for surgery, many patients have good long-term back function without surgery. Frennered et al[7] found that 30% of young patients with symptomatic low-grade slips required surgery. However, 83% of their patients treated nonoperatively had results rated excellent or good at 7-year follow-up. Furthermore, in a review of the data on 32 adults with grade III or IV spondylolisthesis, Harris and Weinstein[5] found that 10 of 11 who were treated nonoperatively were able to remain active and required only minor modifications in activity. Moreover, there were no instances of disabling pain, neurologic deficit, or bowel or bladder incontinence.

Much as the relationship between spondylolisthesis and low back pain is debated, the source of pain in patients with symptomatic spondylolisthesis continues to be studied. Some authors have suggested that spondylolisthesis produces segmental instability or abnormal motion under physiologic loads, which results in acute pain.[8] Disk degeneration at the level of the spondylolisthesis has also been implicated on the basis of biochemical and radiographic findings. Saraste et al[6] have reported an increased prevalence of disk degeneration in spondylolisthesis and an association between disk-space narrowing and the presence of low back pain.

Another possible source of pain is narrowing of the intervertebral foramen with associated nerve-root compression. The pathoanatomy of this nerve-root compression has been the subject of several reports. Most recent studies, including intraoperative and cadaveric observations, have located the pathologic source within the neuroforamen, resulting in compression of the exiting nerve root. Several abnormalities, alone or in combination, can contribute to root compression in a given patient. These include a fibrocartilaginous frond originating from the pars defect, bulging or herniation of the disk within the foramen, a traction spur arising from the annular attachment to the inferior end plate of the cephalad vertebra, and a fibrous or osseous beak extending inferiorly from the caudal aspect of the stump of the pars. Extraforaminal sources of impingement include the corporotransverse ligament and the alotransverse, or sickle, ligament.[9,10] Morphologic abnormality of the foramen is routinely present, but root symptoms usually do not begin until disk narrowing accentuates the anatomic abnormality of the nerve-root tunnel. This foraminal stenosis occurs in as many as 75% of patients and may be, but is not always, associated with leg pain or radicular symptoms.[3]

Evaluation

Evaluation of the adult with isthmic spondylolisthesis and back pain includes a detailed history and physical examination followed, when necessary, by radiographic and neuroradiographic evaluation. A cause of pain other than the spondylolisthesis must be considered. Treatment, particularly surgical, based on the assumption that the patient's pain is caused by the slip should be undertaken only when other potential sources of pain have been excluded with a reasonable degree of certainty.

History and Physical Examination

The relative importance of back pain and leg pain as presenting complaints and the prevalence of objective neurologic deficits vary widely in reported series. Lower-extremity pain and paresthesias have been reported to be contributing indications for surgery in as many as 56% to 100% of patients and are more common in those with higher grades of spondylolisthesis.[3,11] While subjective complaints of leg pain are common, documented neurologic deficit or

radiculopathy is seen less frequently (16% to 27% of cases). Subjective decrease in light-touch sensation over the dorsum of the foot and mild weakness of the extensor hallucis longus are the most common neurologic abnormalities, correlating with L5 root irritation as seen with L5-S1 spondylolisthesis. Straight leg raising is usually normal. Loss of bowel and bladder function does not routinely appear as an indication for surgery in any of the large series reviewed. Electromyographic testing does not usually provide meaningful information not otherwise gleaned from the physical examination.

Radiologic Evaluation

Radiologic imaging of the patient with symptomatic isthmic spondylolisthesis begins with plain radiography and proceeds, as indicated, to dynamic testing, scintigraphy, or neuroradiographic evaluation. Plain radiography routinely consists of anteroposterior and lateral views, preferably taken in the standing position (Fig. 1). Additional views include oblique projections to highlight the pars and the 30-degree caudal-tilt anteroposterior view. Although the oblique view may help to define a pars defect or to localize a unilateral defect, plain lateral radiographs demonstrate more than 80% of lesions and are more likely than the oblique view to show defects at L5.

Scintigraphy, including single photon emission computed tomography, and particularly axial computed tomography (CT) have demonstrated superiority in the diagnosis of occult spondylolysis, with high rates of specificity and sensitivity, although scintigraphically active lesions are rare in adults.[12] We use dynamic radiography to assess the amount of motion present at the involved level. Compression-traction radiography has recently been described and appears to offer greater sensitivity than previous dynamic methods of assessment.[8]

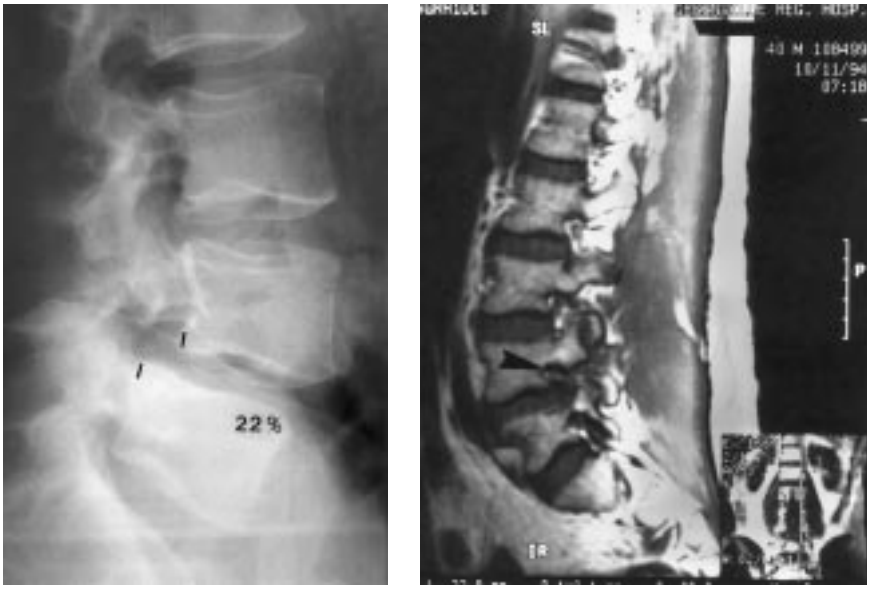
Fig. 1 Plain lateral radiograph demonstrates grade I isthmic spondylolisthesis at L5-S1 in a 39-year-old man. The pars defect at L5, disk-space narrowing, osteophytes, and a vacuum-disk phenomenon are seen in this patient with chronic backache and a 1-year history of worsening radicular pain bilaterally.

Neuroradiographic evaluation of the adult with spondylolisthesis can include myelography, CT, and magnetic resonance (MR) imaging. Myelography has long been used and can demonstrate not only the conus medullaris but also thecal-sac compression in high-grade deformity. However, myelography may not adequately define lateral causes of nerve-root compression that occur peripheral to the area of obliteration of the root sleeves (e.g., neuroforaminal stenosis and far-lateral entrapment). For this purpose, CT, including multiplanar reconstruction, and MR imaging are now considered more optimal imaging techniques. The potential advantages of MR imaging include the ability to accurately define the intervertebral foramen and the nerve root in the foramen, to identify possible conus abnormalities, to assess the hydration status of the disks throughout the lumbar spine, as well as possible disk herniation above the slip, and to identify occult defects in the pars.[13,14] In our practice, MR imaging is the modality of choice in the preoperative assessment of the adult patient with isthmic spondylolisthesis (Fig. 2).

Principles of Treatment

Despite a wide array of surgical options available, nonoperative care continues to be the mainstay and initial focus of treatment for the adult with isthmic spondylolisthesis. A back maintenance program including activity modification, generalized aerobic conditioning, muscle-strengthening exercises, smoking cessation, and antilordotic bracing is used, but there is little scientific documentation of efficacy. Sinaki et al[15] compared the results between flexion and extension back-strengthening exercises in a group of nonoperatively treated patients. They found that both short-term results and 3-year outcomes were significantly better in those patients who followed a flexion-exercise program in addition to attention to proper posture and lifting techniques and the use of heat for relief of symptoms. This group had an overall recovery rate of 62%.

Although most patients with mild to moderate symptoms respond favorably to nonoperative treatment, some will ultimately require surgical intervention. Accepted indications for surgery include persistent and intolerable back or leg pain. Progressive deformity is unusual in the adult, and worsening motor deficit, including foot-drop and bowel or bladder dysfunction, is extremely rare in most series. It should be noted that a decreased success rate



A B

Fig. 2 Plain lateral radiograph **(A)** and sagittal MR image **(B)** of a 39-year-old man with significant bilateral leg pain due to grade I isthmic spondylolisthesis at L4-L5. On the MR image, marked foraminal stenosis (arrowhead) is seen, as well as flattening of the nerve root and loss of perineural fat.

has been reported in patients with an ongoing Workers' Compensation claim.[3,8,11] Therefore, we believe that an added degree of prudence is merited when indicating surgery in this setting. Surgical options include arthrodesis, cauda equina and nerve-root decompression, and reduction of the spondylolisthesis. To select the appropriate procedure, the surgeon must prioritize the pathologic components (deformity, instability, nerve-root compression) that are present in a given patient. This can be an inexact process.

Arthrodesis

For patients who have persistent complaints of lower back pain, with or without radiculopathy, and who have not responded satisfactorily to nonoperative management, arthrodesis may be indicated. When outcome success is determined according to radiographic evidence of fusion, recent reports have noted solid arthrodesis in more than 90% of cases.[3,11,16,17] Fusion may be affected by several variables, including smoking, degree of slippage, type of fusion selected (posterior, posterolateral, posterior interbody, anterior interbody, or a combination thereof), number of levels fused, and the use of supplemental instrumentation or postoperative bracing.

In a retrospective review of the data on 65 adults who underwent posterolateral fusion for isthmic spondylolisthesis, Kim et al[11] found a significantly higher success rate when combined anterior-posterior fusion was performed and when cast immobilization, rather than bracing, was used postoperatively. No other variable, including a previous failed fusion, slip severity, or the use of posterior instrumentation, significantly improved the rate of fusion as determined radiographically.

The functional outcome of lumbar arthrodesis is likewise influenced by age, disability compensation status, litigation, and patient expectations, among other variables. Hanley and Levy[3] reported significantly better clinical results in noncompensation cases, women, patients with back pain only, and nonsmokers. The pseudarthrosis rate in their patients was 12%, which correlated positively with clinical failure. As a group, patients with spondylolisthesis tend to fare better than patients who undergo arthrodesis for other reasons.[17]

Surgical Approach

In 1955, Gill et al described resection of the loose posterior arch of L5 as surgical treatment for isthmic spondylolisthesis. The Gill procedure, performed without concomitant arthrodesis, remained popular for many years but has fallen into disfavor because the rates of persistent pain and slip progression were unacceptably high, even in adult patients. As a result, isolated decompression has been reappraised, and arthrodesis is now the mainstay of operative treatment.

We routinely perform fusion in all patients with spondylolisthesis who undergo decompression, even those undergoing simple diskectomy alone. Posterolateral fusion is the procedure most commonly described in the literature and is our preference because of the simplicity of technique and the biomechanical advantage gained by placing the bone graft within the lateral gutters. Because this location is closer to the weight-bearing axis of the spine, better compressive loading and earlier incorporation of the fusion mass theoretically result; rates of successful arthrodesis in excess of 90% have been reported.[18,19]

For patients with a slip of less than 50% and a normal or near-normal adjacent disk, single-level fusion is used. If the spondylolisthesis is greater than 50%, or if there is significant disk degeneration just above the level of the slip, extension of the fusion to the next level is undertaken. If the significance of plain-radiographic or MR imaging findings suggesting abnormality of the adjacent disk is in question, pain-provocation diskography is thought by some to be a useful study.

When instrumentation is not used, postoperative bracing, utilizing a thigh cuff for fusions that extend to the sacrum, is employed for 3 to 4 months. Formal back rehabilitation is then begun, and work hardening is routinely offered to physical laborers. Full return to strenuous work and recreational activity is usually not possible before 6 months.

Internal Fixation

A variety of internal fixation techniques have been developed as adjuncts to spinal fusion. Pedicle-screw instrumentaion is still viewed as investigational or experimental by the Food and Drug Administration and is not currently approved for routine use in spondylolisthesis. Although its use has not yet been proved safe and effective, its development is perhaps the most significant—albeit the most controversial—recent advance in spondylolisthesis surgery. Biomechanical evidence has been shown for the superiority of transpedicular fixation in stabilizing spondylolisthesis,[20] and many published reports have suggested that this technique enhances stability, resulting in a higher rate of arthrodesis and improved functional outcome. West et al[17] recently reported the results of posterolateral fusion and instrumentation with the Steffee VSP system (Acromed, Cleveland). Their success rate was greater than 90% in patients who underwent first-time surgery. They concluded that the use of this pedicle-screw system, although associated with a significant complication rate, offered substantial advantages over fusion performed without instrumentation.

Interest in the use of pedicle-screw instrumentation has far outpaced the production of scientific evidence to document its cost-effectiveness. Nonetheless, a handful of prospective comparisons have suggested that transpedicular fixation significantly enhances fusion rates and clinical outcomes.[16,21] In one series, Zdeblick[21] identified solid fusion in 97% of patients (many with spondylolisthesis) in whom a rigid pedicle-screw–rod fixation system had been used for posterolateral fusion. This rate was significantly higher than that for patients in whom a semirigid pedicle-screw–plate system or no internal fixation system had been used.

Not all authors have come to these conclusions, however. In a prospective, randomized study of adults with spondylolisthesis, McGuire and Amundson[22] found no significant improvement in the fusion rate with the addition of internal fixation. Furthermore, several authors have documented a significant learning curve and complication rate with the use of these systems.[23] Thus, despite wide utilization, particularly in higher grades of spondylolisthesis, in revision surgery, and in conjunction with extensive decompression, the risk-benefit ratio remains in question. In adults, we favor the routine use of pedicle-screw instrumentation in patients with a slip greater than 25% who are undergoing decompression, in all patients with slips greater than 50%, in patients undergoing revision surgery, and in patients with radiographically documented instability before surgery. The role of instrumentation in the patient with a grade I spondylolisthesis without documented instability has not been established (Fig. 3).

Interbody fusion has long been utilized in the surgical treatment of spondylolisthesis. Both anterior and posterior lumbar interbody fusion have been applied, most often as a salvage procedure after failure of posterior or posterolateral arthrodesis. These procedures are advocated by some because they can restore intervertebral height, thereby increasing the sagittal-plane diameter of the neuroforamen and decompressing the exiting nerve root. Both procedures also place bone graft in the disk space, centered along the weight-bearing axis, in optimal position to resist compressive loading. Reported fusion rates for these procedures range from 73% to 100%.[16,24,25]

Anterior interbody fusion requires the use of an anterior transperitoneal or retroperitoneal approach to the spine. Extensive diskectomy is followed by placement of weight-bearing iliac, fibular, or femoral grafts. The potential complications of this approach include graft dislodgment, ileus, vascular injury, and injury to the sympathetic plexus, which may cause retrograde ejaculation.

In posterior interbody fusion, appropriately contoured, full-thickness, weight-bearing grafts are inserted into the disk space. Reported complications of this procedure include graft migration, epidural fibrosis, and nerve-root injury.

Smith and Bohlman[25] treated patients with severe spondylolisthesis with the use of a modification of posterior lumbar interbody fusion. After posterior decompression, twin fibular dowel grafts are inserted through the sacrum and disk space and into the vertebral body of L5. This one-stage decompression and

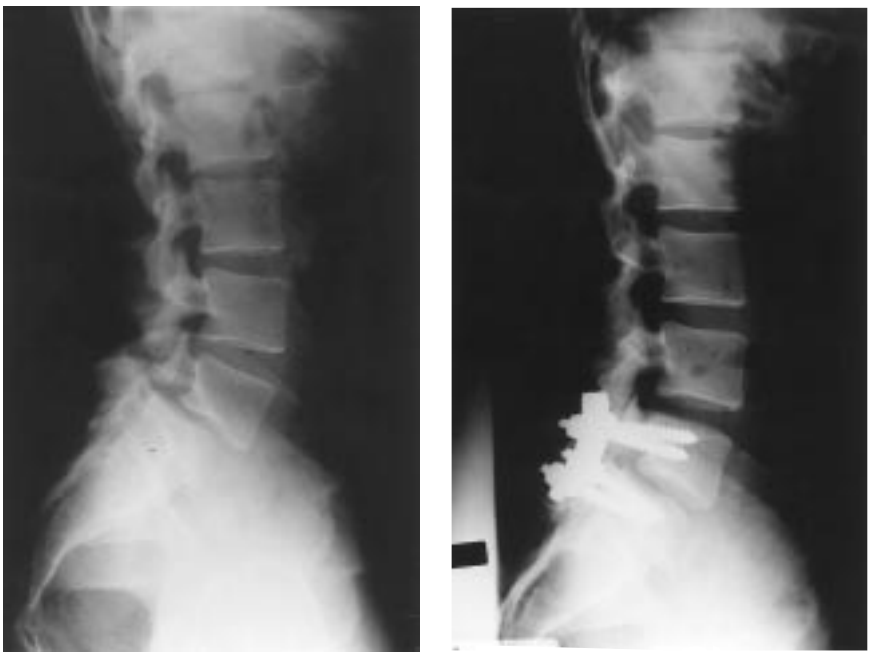


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Fig. 3 Plain lateral radiograph **(A)** of a 24-year-old man with a 2-year history of low back pain and a 1-year history of worsening leg pain and paresthesias. Low-grade isthmic spondylolisthesis is seen at L5-S1. **B,** The patient underwent resection of the loose arch at L5, with bilateral foraminotomies and decompression of the L5 nerve roots and posterolateral fusion with pedicle-screw instrumentation at L5-S1.

interbody fusion is supplemented with standard posterolateral fusion. Use of this procedure resulted in solid arthrodesis for all 11 patients so treated.

Decompression

Neuroforaminal narrowing with associated nerve-root compression and leg pain is common in adults with isthmic spondylolisthesis. The technique for decompression is in evolution. While the Gill procedure (excision of the loose posterior arch) was long considered to constitute adequate decompression, recent reports advocate a more aggressive approach to lateral nerve-root release.[9,10] Failure of the Gill procedure to address abnormalities in the neuroforamina is now widely accepted, and formal foraminotomy is considered necessary to adequately decompress the affected root. Limited decompression, consisting of generous foraminotomy, with resection of interposed fibrocartilaginous material from the pars defect while retaining the lamina, has recently been advocated. The theoretical advantages of this approach include a broader surface area for incorporation of fusion mass, osseous protection of the thecal sac, and enhanced stability.[26]

The need for decompression in isthmic spondylolisthesis is still debated. In eight adult patients with severe sciatica and concomitant high-grade slips, Peek et al[19] obtained a 100% fusion rate and excellent relief of sciatica after in situ fusion without decompression. The authors were unable to explain why the radiculopathy resolved, but speculated that gradual compression of the nerve roots rendered them more tolerant of injury and that solid arthrodesis eliminated the irritating influence of micromotion by the extraforaminal ligaments.

Others, however, have advocated routine decompression for adults with significant radicular pain or nerve-root dysfunction. Kaneda et al[26] recently reported on 53 patients treated with posterolateral fusion with instrumentation, with or without decompression. They performed decompression only when clear evidence of nerve-root compression was present, categorizing patients as having either nerve-root irritation (pain, numbness, or sensory loss without associated motor involvement) or nerve-root compression (radiculopathy and/or motor loss). Patients with root compression underwent limited decompression and fusion, while those with root irritation underwent instrumented fusion only. Similarly excellent results were reported in both groups. Johnson et al[18] also defined the indication for formal decompression as the presence of an objective neurologic deficit and stated that patients with leg pain, but without objective deficit, benefit from fusion without decompression.

Despite these reports, it has been our experience that adults with significant leg pain, even in the absence of a neurologic deficit, benefit from foraminal decompression. We prefer resection of the loose arch and wide foraminotomy.

Reduction

For some patients with high-grade spondylolisthesis, reduction of the slippage may be indicated. Reports of this procedure involve mostly

children and adolescents; however, according to its proponents, reduction is a viable technique in young adults as well. Various indications have been reported, but most authors have included high-grade slips with significant lumbosacral kyphosis (increased slip angle) resulting in an unacceptable deformity and/or a mechanically unfavorable position of L4 relative to the sacrum.[6,9,11] Potential benefits include improved cosmesis, facilitation of nerve-root decompression, and a more favorable biomechanical environment for arthrodesis.[27-29] Surgical reduction of high-grade slips, as well as lesser deformities, continues to attract interest despite the acceptable long-term results seen after fusion in situ for severe spondylolisthesis.

Reduction of spondylolisthesis can be performed via a posterior, an anterior, or a combined approach. All authors describe a demanding surgical technique with a significant rate of complications,[27-30] including loss of reduction and failure of fusion in as many as 33% of cases. The most worrisome complication is neurologic deficit, most commonly L5 root injury, which is manifested clinically as foot-drop. Permanent deficits of this type have occurred in all reported series, affecting up to 20% of patients. Thorough root decompression, slow reduction of the slippage, and intraoperative neurologic monitoring have been suggested to lessen the risk of neurologic injury.[27,30]

Many reduction techniques have been described, but we believe that the use of pedicle-screw instrumentation best facilitates partial or complete reduction of a high-grade slip.[29] Despite the stabilization these devices afford, failure of fixation has been reported, prompting some authors to recommend interbody fusion at the time of reduction and fixation.[29,30] Bradford and Boachie-Adjei[27] caution that complete translational reduction may be impractical and unsafe and is not necessary for an acceptable functional result. They stress the importance of reducing the slip angle. By rotating L4 back over the sacrum to compress the grafts, the lumbosacral kyphosis can be diminished. This achieves the goals of providing cosmetic benefit and optimizing the biomechanical environment of the bone grafts.

Reduction of high-grade spondylolisthesis with use of a combined anterior-posterior approach has been most often described.[27] Edwards[31] recently reported on the use of a pedicle-screw instrumentation system for the gradual reduction of severe slips, in which an isolated posterior approach was utilized. This method combines simultaneous and gradual distraction, posterior translation of the upper lumbar spine, and flexion of the sacrum to reduce all aspects of the spondylolisthesis deformity. At long-term follow-up of 25 patients treated with this technique, he found that the mean slip correction was 91%, and the mean slip angle had been reduced from 33 degrees to 4 degrees, despite early ambulation. Edwards described complications similar to those cited by other authors but concluded that single-stage reduction with use of this technique held promise as an alternative to radical release, bone resection, traction, or long recumbency. He also noted the occurrence of neurologic injury and advocated intraoperative neurologic monitoring.

Another technique for the reduction of high-grade spondylolisthesis and spondyloptosis (greater than 100% slip) involves staged resection of the L5 vertebral body, pedicles, and posterior elements, with reduction of L4 on the sacrum. This technique avoids the need for distraction to reduce the spondylolisthetic segment. Although the technique does not restore spinal height, it does achieve the goals of reduction while reducing the risks of potential complications.[28]

While the indications for, and the techniques of, reduction are undergoing definition, recent series indicate a clear trend toward less aggressive techniques with better results. However, although diminished, the rate of neurologic complications is still formidable and must be weighed against the purported benefits of reduction. We reserve reduction for those patients with high-grade slippage and severe lumbosacral kyphosis that results in an objectionable cosmetic appearance or a biomechanical environment in which failure to achieve fusion is likely. According to these criteria, all grade I or II slips and the large majority of grade III and even grade IV slips should be treated with fusion in situ.

Summary

Isthmic spondylolisthesis or spondylolysis is present in 5% to 6% of the adult population, with uncertain clinical implications. Persistence of unacceptable back and leg pain after nonoperative treatment is the most common indication for surgery. Arthrodesis is commonly employed, with reported success rates, based on radiographic and clinical indices, greater than 90%. Although adjunctive internal fixation is gaining widespread acceptance, its benefits have not yet been proved. For some patients with high-grade spondylolisthesis, reduction of the deformity is favored. Better understanding of the potential pitfalls of this procedure and the availability of newer instrumentation systems are combining to make this a safer and more successful undertaking.

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