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Operative Management of Adult High-Grade Lumbosacral Spondylolisthesis

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High-grade lumbosacral spondylolisthesis refers to the translation of more than 50% of one vertebral body relative to the adjacent vertebral body below (Meyerding grades 3–5) [1,2] and most often affects the alignment of the L5 and S1 vertebral bodies. The treatment of high-grade lumbosacral spondylolisthesis is different from that of low-grade slips, and operative management poses a significant challenge [3]. Although there are a variety of causes and different classification systems for spondylolisthesis, this review focuses on anatomic risk factors for the development of high-grade slips, indications for and types of surgical intervention, and complications associated with operative management of high-grade spondylolisthesis.

Role of spinopelvic anatomy in the development of high-grade spondylolisthesis

Several authors have attempted to quantify the relation between the lumbosacral spine and pelvis by means of various geometric parameters, including sacral slope (SS) and pelvic tilt (PT), which are position-dependent parameters, and, subsequently, to define an association between these parameters and the development of abnormal lumbosacral alignment and spondylolisthesis [4–11]. The pelvic incidence (PI), defined as the algebraic sum of the SS and PT (SS + PT), is a constant anatomic parameter and is perhaps the most comprehensive measure of the morphology of the pelvis and its orientation in the sagittal plane; it is therefore a strong determinant of sagittal spinopelvic balance [4,7,8,12]. Lumbar lordosis (LL) has been directly correlated to SS and PI and represents an adaptation of the spine to balance the trunk in the standing position, increasing as the SS and PI increase [4,7,8,13]. In a recent study, Labelle and colleagues [7] analyzed the PI, SS, PT, and LL of control subjects and compared these measures with those of subjects with various grades of spondylolisthesis. The authors found that these measurements were significantly greater than normal in subjects with spondylolisthesis compared with controls and that the values increased with the severity of the spondylolisthesis. They concluded that PI (and thus pelvic anatomy) influences the development of spondylolisthesis and that an increased PI may be a risk factor for the development and progression of developmental spondylolisthesis [7].

Surgical considerations

Although numerous reports have documented the efficacy of surgical treatment of high-grade spondylolisthesis, the role, timing, and type of operative intervention remain controversial, with the operations themselves technically demanding [1,3,14–21]. Specifically, the role of decompression and reduction of slippage, necessity of instrumentation, and operative technique remain topics of much debate. Moreover, postoperative complications associated with the surgical treatment of high-grade spondylolisthesis can be significant [22].

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Indications for surgical intervention

Unlike in the pediatric or adolescent populations, in which progression of spondylolisthesis often occurs, adults with high-grade spondylolisthesis are typically in a stable position after skeletal maturity [23–26], and the severity of the deformity itself is not necessarily an indication for operative intervention in the adult, especially if sagittal balance is maintained. Nevertheless, progression of the vertebral slippage can occur in adults and is one indication for surgical treatment; however, the most common indication is usually pain with or without neurologic symptoms [14,16,23–25,27,28]. A variety of surgical techniques for the treatment of high-grade spondylolisthesis have been described, including posterior in situ fusion [23,26,28–30], posterior fixation with or without interbody fusion [1,3,15,31], transvertebral screws [14,16,32,33], L5 vertebrectomy (Gaines procedure) [20,34], combined anterior-posterior procedures [18,35], and others. The role and necessity of neural element decompression and reduction of the spinal deformity remain important and controversial aspects of any surgical procedure.

Role of decompression and deformity reduction

Although the cause of neurologic injury during operative treatment for high-grade slips remains unclear and may be attributable to direct nerve root injury during surgery or excessive nerve root tension during reduction, wide nerve root decompression has traditionally been used by most authors, regardless of the choice of surgical technique [3,14,25,36]. Preoperative evidence of nerve root compression is usually an indication for laminectomy, although laminectomy alone without fusion or instrumentation for high-grade slips can lead to progression of the deformity and is not recommended [24,25,29,37]. Neural element decompression in high-grade spondylolisthesis has also been accomplished by means of sacral dome resection [14,16,25,36], which has also been found to aid in reduction of the spinal deformity and in the placement of interbody grafts [16,38,39]. Still others have reported the successful treatment of high-grade spondylolisthesis with in situ and instrumented fusion without decompression, even when neurologic symptoms are present [1,29,30,37]. Sailhan and colleagues [1] reported a 2.3% rate of persistent motor deficits after posterior instrumented reduction and fusion of high-grade spondylolisthesis without decompression. These authors hypothesize that neurologic complications after reduction of high-grade slips are the result of excessive nerve root tension, because most patients in their series had normal findings on initial postoperative neurologic examinations. Indeed, in an anatomic study, Petraco and colleagues [40] found that most tension on the L5 nerve root was produced by the final 50% reduction of the deformity. Sailhan and colleagues [1] therefore recommend slow progressive postoperative mobilization after no greater than 50% reduction without decompression to allow the nerve roots to adjust to their new position.

As previously mentioned, most adults with high-grade spondylolisthesis have reached a stable position. Given that postoperative neurologic deficits are thought to be attributable, in part, to excessive nerve root tension after deformity reduction, the role of reduction in high-grade slips remains controversial, particularly for adult patients [24]. The incidence of postoperative neurologic deficits after reduction ranges from 10% to 75%, and although most are temporary, permanent neurologic deficits and cauda equina syndrome have been reported [27,38,40–42]. In an anatomic study of stretch on the L5 nerve during spondylolisthesis reduction, Petraco and colleagues [40] found that only 29% of strain on the L5 nerve root occurs during the first 50% of reduction, whereas 71% of L5 nerve strain occurs during the second half of complete reduction. In a recent series of 27 patients with high-grade (Meyerding grades 3–5) spondylolisthesis who underwent complete reduction and instrumented fusion, Ruf and colleagues [15] reported a 22% incidence of L5 root symptoms after surgery (all but 1 patient had complete resolution). In general, reduction should be attempted when there is evidence of marked sagittal imbalance or instability or evidence of clinically evident deformity [38,41,43,44]. To minimize neurologic complications, only partial reduction is necessary, especially if this is being attempted without decompression [1,24]. Benefits of reduction include improved sagittal balance and cosmetic results, improved fusion rates (because there is less tension on the fusion mass), and increased patient satisfaction [1,16,24,43]. When reduction is attempted, supplemental anterior interbody support or grafting has been shown to result in improved rates of arthrodesis by several authors [38,39,43,45].

Operative techniques

Posterior techniques

Posterior in situ fusion from L4 to S1 has traditionally been the procedure of choice for the treatment of high-grade spondylolisthesis [23–26,30,37]; however, pseudoarthrosis has been found to occur in up to 45% of cases [23,25,45], and bending of the fusion mass with subsequent deformity progression has also been observed, despite successful fusion [24,25,46]. The addition of posterior instrumentation to the fusion procedure has been used in an attempt to increase postoperative stability, improve rates of arthrodesis, and assist in reduction of deformity and is, in general, the procedure of choice for high-grade spondylolisthesis [2,25,39]. Pedicle screw-rod fixation remains the most common instrumentation; however, inserting transpedicular screws into the listhesed L5 pedicles can be challenging in higher grade cases. Consequently, transvertebral screws, in which transsacral S1 pedicle screws are extended across the sacral promontory into the slipped L5 vertebral body, have been used successfully in these cases and not only provide support for the L5 body anterior to the sacrum but achieve tricortical bony purchase through the sacrum and L5 body [14,16,24,32]. Fibular dowels and various cage implants have also been inserted through the sacrum into the L5 body through a posterior approach with good results (Fig. 1) [14,16,17,47,48]. In general, the use of interbody support is recommended for high-grade spondylolisthesis to aid in deformity correction and improve rates of fusion [14].

Anterior vertebrectomy (Gaines procedure)

The Gaines procedure (L5 vertebral resection) remains a surgical option for the treatment of spondyloptosis [20,21,34,48]. In this procedure, the L5 vertebral body is resected and the vertebral body of L4 is placed directly superior to the S1 body and secured with pedicle screw-rod instrumentation [34]. In Gaines' recent review of 30 cases of fixed spondyloptosis treated with L5 vertebrectomy over 25 years [20], two patients required revision surgery for screw fracture; two had permanent neurologic deficits; all improved in terms of back and leg pain; and there were no instances of bowel, bladder, or sexual neurologic deficit (1 case of retrograde ejaculation). Although improvement in lumbopelvic alignment and posture was noted in all patients, improvement in overall sagittal balance (C7 plumb line) was not as consistent [20].

Although anterior approaches may be used in the placement of interbody structural support grafts, these approaches risk injury to important neurovascular structures [14,21,34] and high-grade slips make anterior approaches to the disc

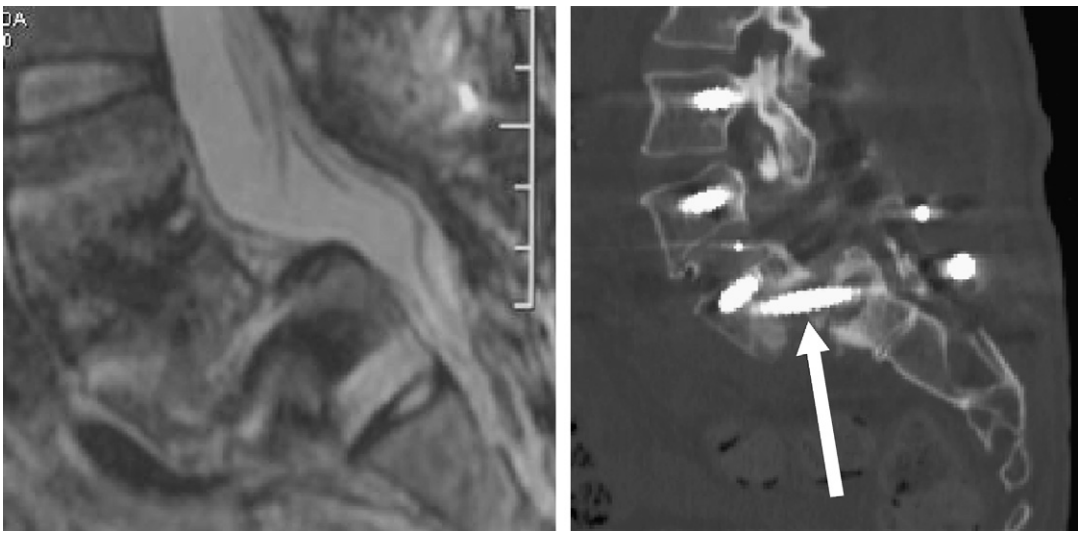

Fig. 1. (*Left*) Sagittal T2-weighted MRI view of a 43-year-old woman with severe back pain and grade 4 L5-S1 spondylolisthesis who had undergone a prior failed fusion procedure. (*Right*) Sagittal CT reconstruction after placement of a transvertebral screw across the sacral promontory into the listhesed L5 vertebral body (*arrow*).

space challenging, often requiring an osteotomy of the anterior-inferior corner of the L5 body to expose the L5-S1 disc space [24,49].

Complications after surgical treatment

The main complications associated with the surgical management of adult high-grade spondylolisthesis include neurologic deficits (permanent or temporary), pseudoarthrosis, instrumentation failure, and accelerated adjacent segment degeneration [22]. Although the addition of instrumentation and anterior interbody structural grafts has improved fusion rates, adjacent segment degeneration has been reported to occur in as many as 35% of cases [22,50] and requires extension of instrumentation, often including iliac fixation. The use of neuromonitoring during surgery for high-grade spondylolisthesis may reduce the incidence of postoperative neurologic deficits, and its use has become more prevalent, especially when reduction maneuvers are attempted [14,17,51]. Somatosensory-evoked and motor-evoked potentials should be used [14].

Summary

The operative management of high-grade adult lumbosacral spondylolisthesis remains extremely challenging, and the role and type of surgical intervention can be controversial. Pelvic anatomy plays an important role in determining sagittal spinopelvic balance, and therefore influences the development of high-grade spondylolisthesis. Although the role of reduction remains controversial, operative intervention should be considered for symptomatic patients presenting with severe pain, neurologic deficits, or progressive deformity. Posterior instrumented fixation and fusion with attempted partial deformity reduction and interbody structural support have been found to provide satisfactory rates of fusion and a good clinical outcome. Transvertebral screws or grafts, sacral dome resection, and L5 vertebrectomy are important alternatives in cases of severe spondylolisthesis and spondyloptosis. Regardless of the choice of surgical technique, significant complications can be associated with the surgical treatment of high-grade spondylolisthesis.

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