Fusion Problems in L5-S1 Surgeries

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ABSTRACT

AIM: Over the past decade, spinal arthrodesis with or without instrumentation has become a common technique in the surgical treatment of symptomatic degenerative disease of the lumbar spine. Interbody fusion at L5–S1 may be achieved anteriorly (anterior lumbar interbody fusion [ALIF]), posteriorly (posterior lumbar interbody fusion [PLIF]), or via the neural foramen (transforaminal lumbar interbody fusion [TLIF]). These techniques have specific advantages and pitfalls, making none of them the ideal approach for lumbosacral fusion. The more recently described transsacral axial lumbar interbody fusion (AxiaLIF) addresses some of the concerns of the previous fusion techniques. Early evidence suggests that the technique may be performed safely to achieve L5–S1 fusion for degenerative disc disease, spondylolisthesis, and at the distal end of long posterior fusion constructs.

MATERIAL AND METHODS: A literature search using PubMed was performed to identify articles published on L5-S1 fusion. Articles reviewed included L5-S1 interbody fusion methods and clinical fusion results.

CONCLUSIONS: Interbody fusion can be performed through an anterior, posterior, transforaminal, transsacral, or lateral approach. The choice of surgical method depends on the pathology, the patient's history of previous surgery, and the surgeon's training and preferences. Factors considered when determining the approach to the interbody space are previous surgeries, size of the implant to be placed, and the potential injury to neural and vascular structures, as well as to the musculature.

This review article discusses the L5-S1 fusion problems in different surgical techniques and their advantages and disadvantages to each other.

KEY WORDS: ALIF, AxiaLIF, lumbosacral fusion, lumbar spine, interbody fusion, screw fixation, TLIF

INTRODUCTION

Low-back pain is a highly prevalent and disabling condition associated with significant health care resource utilization and costs in the US (27,54,67,75). By the age of 50 years, 85% of the population in US will experience an episode of debilitating lumbar back pain with 1- and 10-year recurrence rates of 45% and 80%, respectively (2,17). Furthermore, an estimated 3% of patients with back pain will require surgical intervention (1,18,20,68). Symptomatic back and leg pain in elderly patients (age > 65 years) can cause loss of function and an associated inability to perform basic activities of daily living (5,11,12,78). Hence, a growing number of studies have recommended the treatment of low-back and radicular pain in this population. Increasingly, elderly patients demand medical care, including surgery to improve their life quality.

Degenerative disc disease of the lower lumbar spine is common. Over the past decade, spinal arthrodesis with or without instrumentation has become a common technique in the surgical treatment of symptomatic degenerative disease of the lumbar spine. Many forms of spinal fusion have been described for the alleviation of lumbosacral pain and other symptoms of instability, and for many years these procedures were done exclusively using open

anterior or posterior approaches. Interbody fusion at L5–S1 is indicated for specific pathology including degenerative disc disease (26), instability (71), neural foraminal stenosis (13) and protection of S-1 screws at the end of long fusion constructs to the sacrum (6,21,76). As far as we know, the operative treatment has evolved along 2 pathways: fusion and arthroplasty. Pedicle screw systems engage all three columns of the spine and can resist motion in all planes. Several studies suggest that pedicle screw fixation is a safe and effective treatment for many spinal disorders (24,79). Interbody fusion at L5–S1 may be achieved anteriorly (anterior lumbar interbody fusion [ALIF]), posteriorly (posterior lumbar interbody fusion [PLIF]), or via the neural foramen (transforaminal lumbar interbody fusion [TLIF]). These techniques have specific advantages and pitfalls, making none of them the ideal approach for lumbosacral fusion. The more recently described transsacral axial lumbar interbody fusion (AxiaLIF) addresses some of the concerns of the previous fusion techniques. Early evidence suggests that the technique may be performed safely to achieve L5–S1 fusion for degenerative disc disease, spondylolisthesis, and at the distal end of long posterior fusion constructs.

Compared with less invasive approaches, however, open approaches have the potential to cause more muscular, neural, vascular, and visceral injury. To decrease the risks of open surgical techniques for spinal fusion, a push has been made toward minimally invasive approaches. Generally, anterior and posterior approaches are chosen for direct exposure of the lumbosacral spine. These kinds of open approaches are often poorly tolerated by patients because they require muscular and ligamentous dissection, neural retraction, and annular disruption, sometimes with mobilization of vascular and visceral structures. In addition to these potential problems, vascular injury, sympathetic dysfunction, bowel injury, and neurological deficit often also complicate the perioperative and surgical course (55, 57).

Bone fusion is important and may be achieved using one or more of three surgical strategies: in situ, onlay, or interbody fusion. In situ fusions are used when native bone is allowed to come in contact with other native bone that was previously prevented from doing so because of intervening soft tissue.

Combinations of Anterior column support (ACS) and posterior stabilization procedures can make the construct stronger. In addition, several screw augmentation techniques exist. It is important to fully understand all available surgical options when selecting the most appropriate plan for a given patient.

This review article discusses the L5-S1 fusion problems in different surgical techniques and their advantages and disadvantages to each other.

Surgical Options (Table 1)

ACS and posterior stabilization procedures are surgical options for lumbosacral fusion (LCS). ACS can be performed using an anterior or posterior approach. Anterior approach procedures include ALIF, ALIF + plate, and ALIF cage with screws. Posterior approach procedures include PLIF, TLIF, axial lumbar interbody fusion (AxiaLIF), and pedicle screw (PS) fixation.

Translaminar facet screws, sacral sublaminar wires/hooks, S1 PS [bicortical (anterior cortex or S1 end plate), tricortical (promontory), transdiscal], S2 PS, alar screws, Jackson intrasacral rod technique, iliosacral screws, Galveston technique, iliac screws, and S2 alar iliac screws are used for posterior stabilization procedures. In addition, S1 PS and iliac screws can be combined. ALIF + plate and S1 PS + iliac screws are other options for combinations of ACS and posterior stabilization procedure (34).

ALIF Procedure

The ALIF procedure is known to stabilize the anterior spinal column provide additional indirect decompression for the neural foramen, and maintain normal lordotic curvature of the lumbar spine (32,40,42,74). It has been increasingly acknowledged that the maintenance of normal lordosis of the lumbar spine is important to prevent increased loading in adjacent segments, and thus avoid adjacent segment disease (3,15,28,49,69). The ALIF method may also be preferable in elderly patients, because posterior fusion surgery yields a relatively high perioperative complication rate (8,11,12,19,53). Recently, some researchers (40,42) have reported good results in short- and long-term follow-up after using ALIF and percutaneous pedicle screw fixation (PSF), instead of ALIF and instrumented posterolateral fusion (PLF), for patients with isthmic spondylolisthesis. These investigators have contended that ALIF with percutaneous PSF was an efficacious alternative for low-grade isthmic spondylolisthesis. Access to the complete disc space allows greater distraction, and thus the ability to correct deformity as well as the ability to place larger interbody devices, increasing the likelihood of arthrodesis (35). Manipulation and subsequent scarring of nervous structures are avoided, and in certain situations the canal and neural foramina can

Table 1: Surgical Options for Lumbosacral Fusion

Anterior Column Support Procedures	Posterior Stabilization Procedures
Anterior approach	Translaminar facet screws
ALIF	Sacral sublaminar wires and hooks
ALIF+plate	S1 pedicle screws
ALIF cage with screws	Bicortical (anterior cortex or S1 and plate)
Posterior approach	Tricortical (promontory)
PLIF	Transdiscal
TLIF	S2 pedicle screws
AxiaLIF	Alar screws
Transdiscal S1 pedicle screws	Jackson intrasacral rod technique Iliosacral screws Galveston technique Iliac screws S2 alar iliac screws Screw augmentation procedures

Combinations of posterior stabilization procedures are an option, such as S1 pedicle screws and iliac screws. Furthermore, combinations of ACS and posterior stabilization procedures are other options, such as ALIF+plate, S1 pedicle screws, and iliac screws. As such, a multitude of surgical options exist for lumbosacral fusion.

***ALIF:** anterior lumbar interbody fusion, **PLIF:** posterior lumbar interbody fusion, **TLIF:** transforaminal lumbar interbody fusion, **AxiaLIF:** axial lumbar interbody fusion.*

be indirectly decompressed. In addition, other stabilizing elements such as the dorsal bone, soft tissue, and associated tension bands are kept intact.

Pseudarthrosis, or nonunion, is a complication of any fusion technique, whether it be an anterior or posterior method. In a systematic review by Jacobs et al. (37), the authors found a fusion rate ranging between 47% and 90% for ALIF, with most cited fusion rates approaching 90%. Several studies have identified factors that may decrease the incidence of pseudarthrosis, including graft/cage preparation and usage, the use of biologics, and the addition of supplemental instrumentation.

Thalgott et al. (64) performed a study in which 50 patients undergoing ALIF were randomized to receive either frozen or freeze-dried femoral ring allograft. Six of 7 patients who experienced pseudarthrosis received the freeze-dried allograft, suggesting a benefit for frozen allograft products as opposed to freeze dried, although a mechanism for this difference was not proposed. Madan et al. (46) compared 27 patients who received noninstrumented ALIF (that is, graft only) with 29 patients who received instrumented ALIF (that is, graft and cage). The authors found a significant difference in fusion rates between the 2 groups of 83.3% and 100%, respectively, arguing for the use of instrumentation in ALIF procedures.

Whereas a number of studies have shown greater fusion rates in ALIF when supplemented posteriorly, the guidelines set forth in 2005 by Resnick et al. (59) do not advocate a circumferential fusion in the setting of 1- or 2-level disc disease, citing much higher rates of complications when an additional posterior approach is used.

However, one disadvantage of the ALIF procedure is the necessity of anterior longitudinal ligament (ALL) resection. Ploumis et al. (56) reported that average segmental motion increased by 69, 24, and 142 % in axial rotation, lateral bending, and flexion extension, respectively, after ALL resection. The ALL provides significant structural support to the motion segment, especially in extension. In this situation, sacral plates or ALIF cages with screws can replace the role of the ALL and supply more rigid LSJ stability. Beaubien et al. (7) reported that sacral plates added significant ALIF stability, despite being not as rigid as pedicle or translaminar screws.

AxiaLIF Procedure

The concept for AxiaLIF (TranS1, Inc., Wilmington,

NC) was to gain access to the interbody space at L5-S1 through a minimally invasive approach without disturbing the anterior or posterior longitudinal ligaments, leaving the disc annulus intact. The approach reduces the potential for vascular injury associated with traditional anterior interbody fusion and avoids potential neural injury associated with posterior interbody fusion (73). This technique has certain potential advantages including a muscle-sparing approach and complete preservation of the annulus fibrosus (47,60). The minimally vascular presacral corridor allows for safe implant placement with little risk for vascular injury (47). However, the trajectory must be very precise as the implant is navigated posterior to the rectum, and rectal injury has been reported in conjunction with this technique (9,44). Biomechanical and preliminary clinical data suggest good short-term outcomes for axial lumbar interbody fusion for degenerative disc disease, spondylolisthesis and as anterior support caudal to long fusion constructs (16,22,41).

Erkan and colleagues have tested 2-level fusion (L4–S1) using the axial rod technique. Six human cadaveric L4–S1 motion segments were tested in axial torsion, lateral bending, and flexion-extension following intact, standalone AxiaLIF (2-level rod), and AxiaLIF with posterior fixation and either facet screw or pedicle screw placement. At the L5–S1 level in axial torsion and lateral bending, none of the surgical treatments showed statistically significant differences. However, in flexion-extension, the stand-alone AxiaLIF had significantly greater range of motion than the posterior fixation techniques, suggesting that AxiaLIF should be performed in conjunction with posterior fixation to achieve greater stability for a successful arthrodesis (22).

Aryan and colleagues (6) reviewed data obtained in 35 patients with back pain due to lumbar degenerative disc disease, degenerative scoliosis, or isthmic spondylolisthesis treated with AxiaLIF and recombinant human bone morphogenetic protein. Twenty-three patients underwent supplemental posterior pedicle screw fixation. In 32 patients (91%), there was clinical and radiographic evidence of L5–S1 interbody fusion at a mean follow-up of 17.5 months. Tobler and Ferrara (65) prospectively followed up 26 patients with degenerative disc disease who underwent AxiaLIF with posterior pedicle screw fixation for 2 years. The fusion was at 1 level (L5–S1) in 17 patients and at 2 levels (L4–S1) in 9 patients. Interbody fusion was achieved at 1 year in 22 patients and 2 years in 23 patients. One patient with a pseudarthrosis underwent successful revision posterolateral fusion. In a larger retrospective study, Tobler and colleagues (66) evaluated 156 patients who underwent an L5–S1 interbody fusion in which an AxiaLIF rod was used. There were significant improvements in pain and mean Oswestry Disability Index scores at the 2-year follow-up. Radiographic evidence of interbody fusion was observed in 94% of the patients (145 of 155). Gerszten and colleagues reported on 26 patients with Grade 1 or Grade 2 symptomatic L5–S1 isthmic spondylolisthesis who underwent L5–S1 AxiaLIF and posterior pedicle screw fixation. Approximately half the patients showed a reduction of at least one grade. Axial pain improved after AxiaLIF with a 66% reduction from baseline. The fusion rate at 2 years was 100% with outcome in 81% of patients deemed excellent or good according to Odom criteria (25).

With the AxiaLif cage construct, significant segmental stiffness is immediately afforded by distraction across the disc space. As the ligaments and annulus are completely intact, this provides the strongest possible ligamentotaxis, thereby affording the best interbody fusion construct stiffness. AxiaLif transsacral cage provide excellent resistance to shear, translation, flexion, and extension that is far superior to that of traditional interbody constructs (30).

PLIF Procedure

Lumbar interbody fusion with supplemental posterior pedicle screw fixation ("circumferential" fusion), based on biomechanical evaluation, stabilizes all 3 columns of the spine and has been used routinely for the operative treatment of painful spinal disorders. Posterior lumbar interbody fusion is a popular lumbar arthrodesis. Posterolateral graft and fixation is easily added to the PLIF, further enhancing spinal stability and the induction of fusion (63,72). Unfortunately, the PLIF procedure is usually limited to use at levels below L-3, because of the risk of damage to the conus medullaris and to the cauda equina that may result from bilateral root retraction here (48,50). In the PLIF procedure, a portion of the PLL is cut to position the interbody space devices. The PLIF procedure, requires a bilateral laminotomy as well as partial, and at times, complete facetectomies, to place an adequate interbody spacer device.

Posterior lumbar interbody fusion and fixation results in excellent fusion rates. Optimal results can only be expected, however, if the basic principles of osteosynthesis, as reiterated by Lin, are respected. Even though exposure is limited when performing this modification of the PLIF, disc removal and endplate preparation must be thorough and meticulous. It is only by way of this thorough preparation, followed by the complete packing of the disc space with bone graft, that optimal fusion rates can be expected (43).

TLIF Procedure

Transforaminal lumbar interbody fusion is a surgical technique that has proven to be successful in improving symptoms associated with spondylolisthesis and DDD of the lumbar spine (51). The technical advantages of the TLIF include avoidance of thecal sac and/or nerve root retraction injury, safe performance below L-3, and a decrease in epidural bleeding and scarring (33,36,50,62,72,77).

The TLIF procedure requires a complete unilateral facetectomy, and spares the contralateral lamina, facets, and pars interarticularis. Harms and Jeszenszky (31) originally recommended that the cage be placed in the middle or posterior third of the intervertebral space. Groth et al. (29) and Cheng et al. (14), however, postulated in their biomechanical studies that placing the cage further anteriorly would better share the load and thus enhance stability. Lowe et al. (45) also recommended that the cage be placed just anterior to the pedicle so as to avoid endplate failure or subsidence. Other authors reported that stability was not affected by cage positioning inside the disc space in the TLIF (4,23). Transforaminal lumbar interbody fusion has been compared with other fusion techniques in a number of biomechanical studies (4,39,52,56), but these papers have not included the effects on the adjacent segments with regard to fusion techniques, however.

The TLIF procedure offers many of the same advantages as PLIF, such as the ability simultaneously to decompress the neural elements, correct abnormalities in alignment and sagittal balance, and achieve circumferential arthrodesis through a single dorsal approach. Both TLIF and PLIF yield high arthrodesis rates secondary to a large fusion surface area, ample blood supply to the interbody space, and the ability to place the interbody graft in compression. However, the more lateral to medial approach offered by TLIF has several potential advantages over PLIF. Because access is obtained via a transforaminal approach with TLIF, little if any neural retraction is required to enter the disc space. In contrast, PLIF almost always requires neural manipulation and retraction, and neurological injury is one of the most commonly reported complications of that procedure (58).

Pedicle Screw Fixation

Pedicle screw systems engage all three columns of the spine and can resist motion in all planes. Several studies suggest that pedicle screw fixation is a safe and effective treatment for many spinal disorders (24,79). Theoretically, the role of the posterior fixation system is to increase the interbody fusion rate. The fixation system should be maintained until fusion occurs. However, if fusion does not occur within the proper time, the incidence of hardware failure may increase in elderly patients, who have relatively lower bone density. Consequently, this may cause a deleterious cycle of further delaying or hindering interbody fusion. Lee et al. (42) reported that the fusion rate for their 73 patients (both L4-L5 and L5-S1 levels) was 97.3%, and that the rate of "excellent" or "good" clinical outcomes was 94.5%, with a mean follow-up period of 16 months.

CONCLUSION

Various kinds of surgical techniques and implants have been developed for lumbar spinal fusion. Interbody fusion can be performed through an anterior, posterior, transforaminal, trans-sacral, or lateral approach. The choice of surgical method depends on the pathology, the patient's history of previous surgery, and the surgeon's training and preferences. Factors considered when determining the approach to the interbody space are previous surgeries, size of the implant to be placed, and the potential injury to neural and vascular structures, as well as to the musculature.

Spinal fusion is performed to treat a variety of lumbar spinal conditions, which frequently occur at the L5-S1 level. Lumbosacral fusion has lots of options both for anterior column support (ACS) and posterior stabilization procedures. Combination of posterior stabilization procedures is an option. Furthermore, combinations of ACS and posterior stabilization procedures are other options.

The ALIF has the advantages of direct access for reconstruction of the anterior spinal column and indirect decompression of the vertebral foramen. It has the disadvantages, however, of requiring the assistance of a vascular or general surgeon to provide exposure and entailing the risks of deep vein thrombosis and vascular injury. A 6% risk of retrograde ejaculation has also been found to occur (10, 38, 50). In the absence of severe osteoporosis or severe systemic disease, ALIF with instrumented PLF could be the first recommended treatment option for L5– S1 isthmic spondylolisthesis and foraminal stenosis, even in elderly patients. Meanwhile, ALIF with percutaneous PSF may be an alternative treatment for elderly patients for whom lengthy operative periods accompanied with more bleeding may be too risky.

The AxiaLIF surgical technique is sufficiently different from other fusion techniques and requires strong knowledge of sacral anatomy. The clinical outcomes have generally been good with a greater than 91% fusion rate (6,44,66). In comparing the AxiaLIF results with a study involving minimally invasive transforaminal interbody fusion (TLIF),

open TLIF, and combined anterior/ posterior fusion, the perioperative data in the AxiaLIF studies were favorable and the reoperation rate was similar to that in the anterior/ posterior fusion group but higher than that in either of the TLIF groups (72).

PLIF provides a higher immediate stability than the TLIF, especially for the lateral bending motion. The implant position in the disc space, however, is not an important factor for the immediate stability of a single-level TLIF.

Interbody fusion techniques have been developed to preserve the load-bearing capacity of the spine, restore sagittal plane alignment and facilitate compressive loading onto bone, all of which enhance the potential for fusion (48,50,63).

However, it is important to know all aspects of the options and decision-making of surgical options for LSF needs to be tailored for each patient, considering factors such as osteoporosis and biomechanical stress.

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