

The Selection of L5 Versus S1 in Long Fusions for Adult Idiopathic Scoliosis

Ganesh Swamy, MD, FRCSC^{a,*}, Sigurd H. Berven, MD^b,
David S. Bradford, MD^b

^a*Department of Orthopaedic Surgery, University of Calgary, Room C1240, 12th Floor, Foothills Hospital,
1403 29th Street NW, Calgary, Alberta T2N 2T9, Canada*

^b*Department of Orthopedic Surgery, University of California, San Francisco, San Francisco, CA, USA*

The treatment of adult spinal deformity is evolving in response to gathering information on an evidence-based approach to care. As we begin to categorize the important descriptors of curves to identify the determinants of outcome in surgical management, we can determine surgical strategies that are effective [1,2]. The decision-making process in adult deformity is complex because of the many combinations of degenerative changes, stenosis, and deformity. The ongoing debate on the caudal extent of long thoracolumbar fusions and whether the fusion should stop at L5 or cross the lumbosacral junction is an important example of a controversy in operative approaches to adult deformity.

The decision to select L5 or S1 as the caudal extent of the fusion occurs mainly in thoracolumbar or lumbar curves, representing most cases in adult deformity [1]. For this article, a long thoracolumbar deformity includes cases in which the structural thoracic spine is included in the fusion cephalad and the deformity extends to the lower lumbar spine. Characteristically, the end vertebra in this situation is L4, with a compensatory lumbosacral hemicurve, or fractional curve, below. Often, there are anatomic variables that dictate S1 as the caudal level for arthrodesis, including stenosis or previous decompression at L5-S1 (Box 1). Terminating a fusion at L5 when the L5-S1 segment is “healthy” is useful to maintain lumbar motion and avoid the higher risks and complications associated with fusion across the

lumbosacral junction. This exposes the patient to the risk of subjacent disc degeneration at L5-S1, late lumbosacral pain, loss of sagittal balance, and possible revision surgery, however. The purpose of this article is to review the factors that may determine whether to end a long thoracolumbar fusion at L5 or S1 and to provide an evidence-based approach to making this choice.

Function of the lumbosacral disc

The L5-S1 disc is unique when compared with the remaining lumbar vertebrae in terms of its anatomy and function. It is usually the largest disc in the lumbar spine, and along with the L4-L5 disc, it contributes most of the flexion-extension range of motion of the lumbar spine [3,4]. In contrast, because of the almost sagittal orientation of the facets at L5-S1, there is little axial rotation or lateral bending [3]. By virtue of the stabilizing influence of the iliolumbar ligament, the lumbosacral disc has been suggested to be less susceptible to strain and degenerative changes [5,6]. Despite the important function of the L5-S1 disc, we have a limited understanding of the long-term effects of fusion of this motion segment. Although some link changes in gait and ability to perform perineal care to fusion across L5 and S1, there is no objective evidence to support the claims [7,8]. The benefit of improved pain from the lumbosacral junction and preserved trunk balance may outweigh the compromise of motion at L5-S1.

The effects of a long fusion on the biomechanics of the L5-S1 disc are not well quantified in

* Corresponding author.

E-mail address: gswamy@ucalgary.ca (G. Swamy).

Box 1. Absolute indications for fusion to S1

- Previous or planned decompression at L5-S1
- Spondylolisthesis L5-S1
- Oblique take-off L5-S1
- Advanced degenerative disc disease at L5-S1
- Severe lumbosacral pain
- Major coronal or sagittal plane deformity

a straight spine or in a scoliotic or kyphotic spine. We can hypothesize that the force experienced under a long construct is greater than the normal loads experienced in the native low lumbar spine, which can be estimated to be at least between one and four times body weight [9–11]. In addition, biomechanical studies show the increased stress seen adjacent to fusions [12,13]. Although an L5-S1 disc may be healthy and stable in a clinical scenario, it is subject to abnormally large forces in vivo beneath long constructs.

Absolute indications for fusion to S1

Certain clinical scenarios are accepted as indications for fusion to the sacrum based on the presence of pathologic findings at L5-S1 (see Box 1) [14,15]. A history of previous decompression or discectomy at L5-S1 or a planned decompression at L5-S1 is an indication to extend a fusion to the sacrum, because advanced degenerative changes exist at that level. Examination of plain lumbar radiographs is useful to identify pathologic findings at the L5-S1 level, including spondylolisthesis or advanced degenerative changes. Involvement of the L5-S1 disc in the coronal or sagittal plane deformity (oblique take-off) with failure of L5 to correct to within 10° of neutral is an indication to fuse to the sacrum. Pain from the lumbosacral junction, which may be identified on discography or by physical examination, may also be an indication to include L5-S1 in the fusion for deformity [16].

Healthy L5-S1 motion segment

The debate on distal fusion level pertains mainly to the clinical scenario in which the

deformity and stenosis do not involve L5-S1 and the surgeon believes that a long fusion to L5 can achieve the goals of the surgery, namely, achieving coronal and sagittal plane balance. There is no strict definition of a healthy segment, however. Edwards and colleagues [17,18] modified the radiographic scale of Weiner and colleagues [19] for disc degeneration; the variables include disc height, status of the end plates, spondylolisthesis, and presence of the intradiscal vacuum phenomenon. In these studies, a healthy segment was defined as a score of 0 or 1 on the modified Weiner scale, with possible scores of 0 through 3. Danielsson and colleagues [20] validated this scale for interobserver variability in lumbar scoliotic curves. Ghiselli and colleagues [21] defined a similar radiographic scale based on disc height, end-plate sclerosis, and osteophytes. Although important in concept, the use of radiographic classification scores is hampered by error, arising mainly from variability in the quality of radiographs. Radiographs of the lumbosacral junction can often be obscured and end plates difficult to discern; this problem is only magnified in the post-operative spine, wherein instrumentation is present. The ability to quantify radiographic changes is hindered by the axial rotation and lateral tilt present in the lumbosacral hemicurve as well as by the distortion and magnification errors present in all lumbar radiographs [22,23]. To visualize the L5-S1 disc adequately, Ferguson view radiographs and spot lateral views are required. Because of the inherent error, radiographic grading scales are useful to identify discs at extremes of the spectrum of disc degeneration but are less able to detect discs with moderate degenerative changes. The use of MRI to evaluate disc degeneration has not been validated in this setting [24,25]. Although disc desiccation provides some evidence of degeneration, there is a poor correlation between degeneration and pain or dysfunction. Modic changes in the vertebral bodies are associated with disc degeneration [26], with some authors suggesting a link between such changes and symptomatic back pain [27–29]. This association is poorly explained and circumstantial [30], however, and the presence of Modic changes alone should not be used as a criterion for fusing the disc. Similarly, although CT scans can be used to evaluate facet arthritis with a classification scheme, the prognostic significance of this finding is unclear. Moreover, patients undergoing adult scoliosis surgery to L5 are likely to have degenerative changes by virtue of age alone [31], further

confusing our ability to define a healthy disc. Clearly, symptomatic degenerated discs likely should not be preserved under long constructs. For lesser degrees of degeneration, long-term clinical results should guide our decision making. With this in mind, the authors sequentially examine the clinical issues surrounding the selection of L5 and S1 as the caudal fusion level, followed by a discussion of the clinical results.

Fusion to L5

Proponents of ending long fusions at L5 cite three main reasons: (1) maintenance of lumbosacral motion, (2) decreased operative morbidity, and (3) decreased complication rate (Box 2). As discussed previously, the functional significance of retaining a single level of motion below a long fusion is unclear. Thus, the main known advantages relate to operative morbidity and complication rate.

Fusion to L5 is tempered by concerns about the loss of sagittal balance in the medium and long term from loss of fixation and L5-S1 degeneration, respectively. In the medium term, fusion to L5 relies on the purchase of the L5 pedicle screws to maintain correction. The L5 pedicles are large and cancellous and are subject to large cantilever forces underneath long fusions [32,33]. In addition, many adult patients with scoliosis are osteoporotic [34], further compromising fixation. Kwon and colleagues [35] described a series of 13 patients with heterogeneous spinal disorders developing distal junctional kyphosis from L5 screw

pullout or pedicle fractures; revision in most of their cases required a pedicle-subtraction osteotomy. Gonya and Kebaish [36] have presented a similar series of patients fused to L5, finding 5 of 31 patients having distal implant failure, with a further 8 patients having radiographic loosening. Forces on these screws are greater in patients with higher degrees of preoperative sagittal and coronal plane imbalance, and patients may benefit from extension of the fusion.

Long-term progressive L5-S1 motion segment degeneration can lead to pain and loss of sagittal balance. The L5-S1 disc is more lordotic than the remainder of the lumbar spine, with loss of anterior disc height potentially leading to positive sagittal balance. Edwards and colleagues [17,18] have reported a high rate of radiographic L5-S1 degeneration (61% at 3–5 years of follow-up), although most patients remained asymptomatic. They identified the risk factors for subsequent advanced degeneration as preoperative sagittal plane imbalance, younger age, and even mild radiographic degenerative changes before surgery [17]. Swamy and colleagues [37] presented a similar series of patients with a 30% surgical revision rate arising from subsequent L5-S1 degeneration, resulting in pain or loss of spinal balance at a mean follow-up of almost 8 years. Thus, the incidence of subsequent degeneration at L5-S1 is high and may lead to pain or progressive sagittal plane imbalance [17]. Many cases remain largely asymptomatic over time, however (Fig. 1).

If symptomatic subjacent disc degeneration occurs, the treatment of choice is revision surgery to the sacrum. Revision operations to extend scoliosis fusions to the sacrum are complex, involving the usual difficulties fusing across the lumbosacral disc, often difficult implant removal, correction of any acquired deformities, and re-instrumentation. Historically, this procedure has been complicated mainly by pseudarthrosis. Although the rate of pseudarthrosis has decreased steadily with improved lumbosacral fixation techniques, this remains an important limitation [38]. Islam and colleagues [39] reviewed a series of 41 patients with previous scoliosis fusions undergoing a revision fusion to the sacrum. The distal level of fusion in this cohort was mainly L4, but a significant number of patients had fusions to L5. Eighteen of 41 patients required osteotomies to achieve a balanced spine, and an overall 73% complication rate was noted. Twenty-eight of 41 patients required a second revision operation after their initial revision fusion to address the

Box 2. Advantages and disadvantages to long fusions to L5

Advantages

- Save motion at L5-S1
- Avoid risk of pseudarthrosis at L5-S1
- Avoid possible anterior surgery at L5-S1
- Lower medical complication rate

Disadvantages

- Potential for subsequent degeneration at L5-S1
 - Loss of sagittal plane correction
 - Pain
- Poor purchase in L5 pedicle, leading to implant loosening

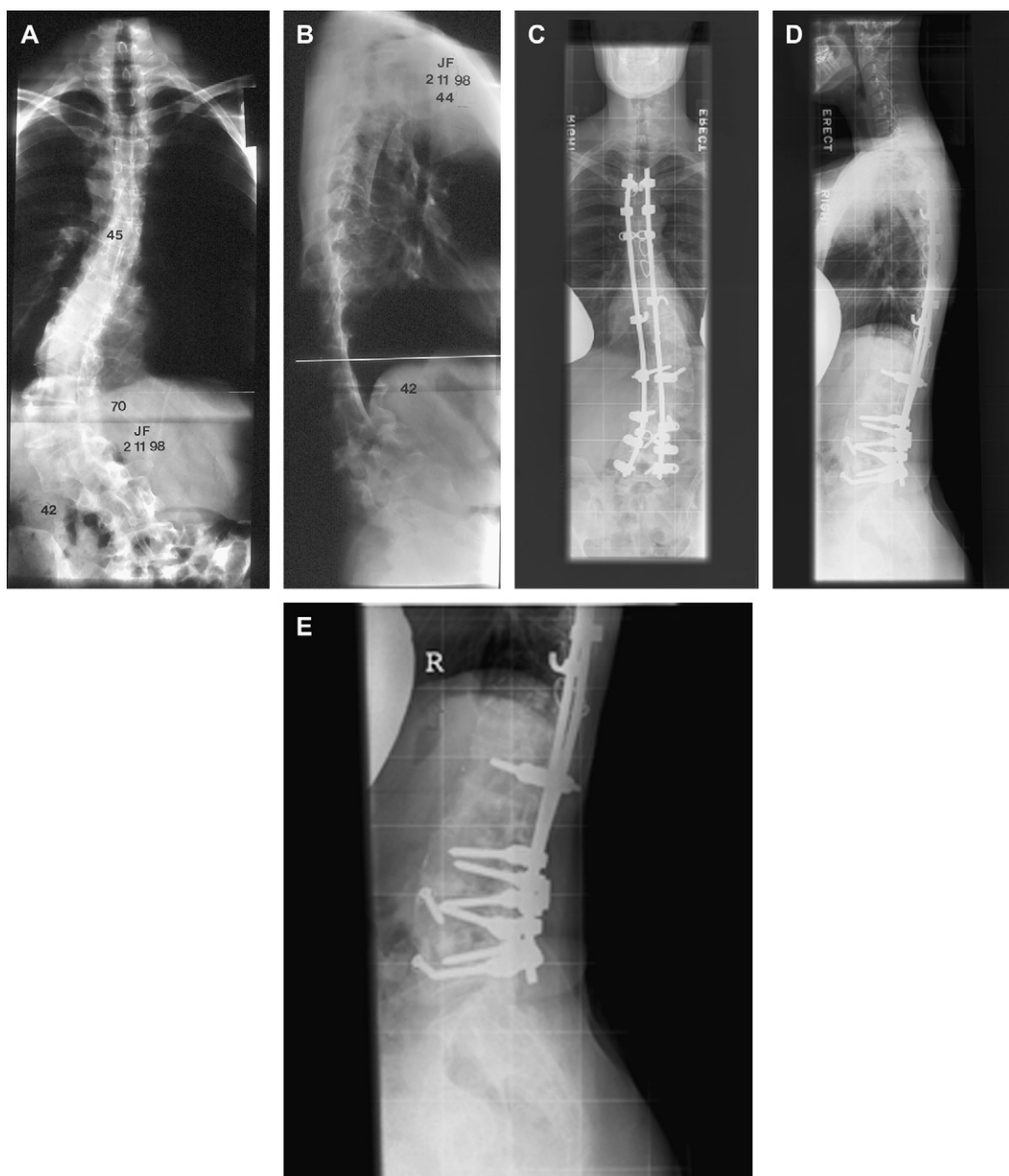


Fig. 1. This 45-year-old woman presented with increasing pain and deformity 8 years ago. (A, B) Thoracolumbar fusion was proposed, and the L5-S1 segment was deemed “healthy.” (C) Uncomplicated T4-L5 fusion was performed, with good functional improvement. At 8 years of follow-up, the patient is functioning well and is free of low-back pain. Note that the L5-S1 disc height is maintained (E), with no change in overall sagittal balance (D).

complications encountered, including pseudarthrosis repair, debridement for infections, and revision of instrumentation. Almost 40% of patients undergoing revision operations developed pseudarthrosis, mainly at the lumbosacral junction. Not all patients in this cohort had structural graft

anteriorly at L5-S1 and additional iliac fixation, however; it is likely, using modern instrumentation with iliac fixation, that the pseudarthrosis rate would be lower. Thus, salvage operations to fuse to the sacrum are much more complex than a simple one-level extension of fusion.

Fusion to S1

When a healthy L5-S1 disc is seen, primary fusion to the sacrum is advocated mainly for the avoidance of junctional degeneration seen with fusions to L5 and their consequences. In this scenario, the surgeon accepts the higher complication rate of crossing the lumbosacral junction, including more medical complications and pseudarthroses [18].

Fusion to the sacrum demands increased exposure, blood loss, and operative time (Box 3) [18,32]. The use of iliac fixation is recommended to reduce stress on the S1 screws, demanding additional exposure. In addition, anterior interbody support is recommended at L5-S1 to protect against the significant pseudarthrosis rate [40–42]. In general, this is performed by means of a formal anterior paramedian approach, necessitating a second operation, whereas when fusion ends at L5, the need for a second operation is usually obviated [18]. The complication rate for adult scoliosis is an important consideration, especially in older patients with comorbidities, and has been estimated to be between 34% and 86% [42–44]. Decreasing operative morbidity with modifications of surgical strategies is important in adult deformity surgery. Edwards and colleagues [18] found a 33% rate of medical complications in their group of patients fused to the sacrum, as compared with 0% in the L5 group. The decision to fuse across the lumbosacral junction must be individualized according to the risk profile of each patient.

Box 3. Advantages and disadvantages to long fusions to S1

Advantages

- Avoid potential subsequent degeneration at L5-S1
- Maintain sagittal plane correction, particularly in case of major preoperative sagittal plane imbalance

Disadvantages

- Loss of L5-S1 motion
 - Possible gait abnormality
 - Possible difficulty with perineal care
- High complication rate
 - Medical complications
 - Pseudarthrosis
- Potential sacroiliac (SI) joint arthrosis

Several articles have recently characterized the persistently elevated rate of pseudarthrosis at L5-S1 during index operations, ranging from 10% to 42% [18,40,42,45]. Revision of these pseudarthroses is also technically challenging, requiring potential use of osteotomies to achieve balance. In another article in this issue, Dr. Polly describes the difficulties of achieving fusion at L5-S1 and reviews the technical requirements to instrument successfully across the lumbosacral junction.

Outcomes

Despite the various published debates and position statements on the merits of fusing to L5 or S1 [32,46–48], there is a paucity of data to support a given position. Data from three centers have contributed to our knowledge, and the authors proceed to review them. Because of the number of factors involved in decision making and the lack of a clear benefit to L5 or S1, no definite recommendations have been made thus far in the literature.

Edwards and colleagues [17,18] published two separate studies, first as a retrospective review of 34 patients with long fusions to L5 with a minimum 2-year follow-up and mean follow-up of 5.6 years [17]. In this study, 61% of patients were found to have radiographic evidence of advanced degenerative changes at final follow-up [19]. Patients who developed degenerative changes at L5-S1 were found to be at risk for development of positive sagittal imbalance. Four of 19 patients with degenerative changes underwent revision, with 2 more considering surgery. Risk factors for subsequent degeneration were preoperative major sagittal plane deformity, younger age, and the presence of even minor degenerative changes at L5-S1. In addition, 6 patients had loss of fixation of their L5 screws, although only 2 of these required revision surgery. A statistically significant improvement in Scoliosis Research Society-24 (SRS-24) outcomes was seen in patients without preexisting degeneration as compared with those with some L5-S1 degeneration.

Edwards and colleagues [18] then published a matched cohort analysis of patients with adult scoliosis fused to L5 or S1 at the index procedure, all having minimal preoperative degeneration on plain radiographs. Patients were matched for age, smoking status, sagittal plane balance, number of levels fused, and status of the L5-S1 disc before surgery, yielding 27 patients in the L5 group and 12 patients in the S1 group. A higher

complication rate, immediately after surgery and on a delayed basis, was seen in the S1 group. The L5 cohort was found to have inferior correction of sagittal balance, because L5-S1 disc lordosis decreased from 19° to 10°. At final follow-up, 67% of the L5 cohort had advanced degenerative changes at L5-S1, with 4 of 19 patients undergoing revisions. Interestingly, both cohorts had equivalent outcomes on SRS-24 questionnaires, including the pain and function subsets.

Brown and colleagues [49] reviewed 16 patients with long fusions to L5, with a mean follow-up period of 32 months (minimum of 8 months). Six of 16 patients (38%) developed degeneration at L5-S1, with 3 requiring revision surgery. Five of these patients presented with sagittal plane imbalance associated with degeneration of the L5-S1 disc, and 2 of these patients underwent revision surgery.

Swamy and colleagues [37] presented a series of 20 patients who underwent long fusions to L5 with a minimum follow-up of 4 years and a mean follow-up of almost 8 years. Two separate groups were defined based on need for revision surgery (6 patients requiring revision). No risk factors were identified for developing subjacent degenerative changes. Revision surgery was found to be large in magnitude, with no difference found between groups with respect to average blood loss and operative time. A Kaplan-Meier survivorship curve was constructed, showing a 70% chance of not needing a revision at 10 years. If one considers that 4 additional patients are considering revision surgery, however, a 50% survivorship is seen at 10 years. SRS, Oswestry Disability Index (ODI), and Short Form-36 (SF-36) outcomes were similar between the patients who required revision surgery and those who did not require further surgery at final follow-up. The patient satisfaction subset of the SRS instrument showed no significant differences between the two groups.

Future investigations

The decision to fuse a long thoracolumbar deformity to L5 or S1 remains controversial, with benefits and risks associated with both choices. The patient and surgeon are faced with a difficult choice of a larger more complicated procedure to S1 or a simpler procedure to L5, which may be followed by significant degenerative changes. No study has demonstrated a clear difference in

postoperative function between patients fused to L5 or S1. The functional significance of fusing the L5-S1 level needs to be measured with reference to specific activities, including gait, perineal care, and activity level. Such specific outcomes may lend insight into the cost of extending a fusion to the pelvis. In the absence of a demonstrable functional compromise in adults fused to S1, primary fusion to the sacrum in medically stable patients may minimize long-term complications and the need for revision surgery. Perioperative complications, including infection, blood loss, and operative time, are significant costs of extending the fusion to the sacrum, however.

Pseudarthrosis is an important cost and consideration in extending fusion to the sacrum. Kim and colleagues [45] demonstrated that patients with pseudarthrosis have inferior scores in all domains of the SRS instrument. The use of recombinant proteins may have a significant impact on pseudarthrosis rates in deformity surgery and may change the balance of evidence between fusing to L5 or S1 (see the article by Chang and colleagues in this issue).

Finally, all evidence to date is retrospective with small numbers. A prospective study or patient registry with a detailed radiographic description, validated outcome measures, and larger numbers of patients is likely to be more useful in differentiating between terminating long fusions at L5 or S1 and in providing an evidence-based approach to care.

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