Selection of instrumentation and fusion levels for scoliosis: where to start and where to stop

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Object. Although there are several papers in the literature regarding selection of fusion levels in the adolescent patient, fewer articles pertain to this in the adult patient. The author reviewed his experience and the literature and reports on the choice of fusion levels in the adolescent and adult patient.

Methods. After a review of available data, the author determined that the proximal and distal extent of the fusion should be based on defining curves as either major or minor in the adolescent patient. It is often possible to exclude minor curves from the fusion. Relative Cobb measurement, apical deviation from the plumb line, and apical rotation are the most useful means of distinguishing a major from a minor curve. Otherwise, the proximal and distal extent of a fusion should be performed in such a way that the proximal and distal vertebrae are both neutral and stable (bisectioned by the center sacral line) postoperatively. Additional segments may need to be included in the adult patient in whom extensive degenerative changes and subluxations are present. The decision of whether to terminate a long fusion at L-5 or the sacrum in an adult degenerative lumbar curve is complex and many factors have to be considered.

Conclusions. Guidelines exist for fusion levels in both adolescent and adult patients. Not all curves require fusion. There are many coronal and sagittal considerations that have to be analyzed when making the final decision.

KEY WORDS • spinal fusion • scoliosis • instrumentation • subluxation

Abbreviations used in this paper: ODI = Oswestry Disability Index; SRS = Scoliosis Research Society.
In the case illustrated in Fig. 1 the follow-up period was 9 years. Instrumentation was placed from T-4 to T-12. It was not necessary to include the lumbar curve. Note the patient’s postoperative flexibility in Fig. 1C.

**Double Major Scoliosis: Termination at L-3 or L-4**

When is it possible to stop the fusion at L-3 rather than L-4 in a double major curve? If the thoracic and lumbar curves are absolutely equal in terms of Cobb angles, apical deviation, and rotation, then both curves should be included in the fusion mass. Whether it is possible to terminate the fusion at L-3 rather than L-4 depends on the following factors: 1) the distance between the apex of the curve and L-3; 2) the distance between L-3 and the center sacral line; 3) the extent of tilt at L3–4; 4) how neutral L-3 is; and 5) the possibility of applying pedicle screws to the convexity throughout. Greater deformity correction can be achieved using pedicle screws.

If global and regional balance can be achieved, then the fusion may be terminated at L-3. Global balance means that the coronal plumb line from C-7 bisects the sacrum and that the shoulders are relatively level postoperatively. Regional balance indicates, in this circumstance, that L-3 should be parallel to the sacrum, of neutral rotation, and...
bisected by the center sacral line. If the end result is that L-3 is tilted, off to the left of the center sacral line, and rotated, then stopping the fusion at L-3 is likely not the proper choice.

A successful outcome after extending the fusion mass to L-3 is illustrated in Fig. 2. The thoracic and lumbar curves were 68°. An isthmic spondylolisthesis was also present at L5–S1. The lumbar curve was quite flexible, and pedicle screws could be placed on the convexity. Because L-3 was relatively neutral and fairly far from the apex of the curve, the fusion could be terminated at L-3. The follow-up period in this patient was 6.5 years.

Fusion in the Adult

General Comments

In the surgical management of the adult spine, the possibility of degenerative changes makes decision making more difficult. In most cases, we do not want to terminate a fusion next to a severely degenerated segment, especially if there is fixed tilt or subluxation (coronal or sagittal at the adjacent segment.

Selective Thoracic Fusion

At times, it is possible to perform a selective thoracic fusion (Fig. 3). The thoracic curve illustrated in Fig. 3 is one of 73° and the lumbar curve is one of 48°. There is, however, very little in the way of clinical deformity, apical deviation, and lumbar curve rotation. The Cobb angles are rather misleading. All segments from T-12 to the sacrum are degenerated. The patient had complained of lumbar back pain, but her principal complaint involved progression of her thoracic deformity and thoracic pain.

A selective thoracic fusion was performed to the stable vertebra, that is, L-1. Fusion, placement of instrumentation, and thoracoplasty were performed. The translational deformity improved by instrumentation-assisted fusion, and the axial deformity was corrected by the thoracoplasty. The patient’s postoperative SRS score was extremely high. A high SRS score and a low ODI score are both good and comparable. A high SRS score indicates better function, reduced pain, and a high level of satisfaction, whereas a high ODI score indicates significant disability, significant pain, and low function.

Double Major Scoliosis: Termination at L-4

Occasionally, a double major curve pattern and little to no L4–5 disc degeneration will be present in the adult patient. If it is possible to effect a result in which L-4 is parallel to the sacrum, neutral, and bisected by the center sacral line, then it is possible to terminate the fusion at L-4 and avoid accelerated L4–5 and L5–S1 disc degeneration, however, this is somewhat unpredictable. If there is fixed tilt or subluxation at L4–5, then this level cannot be used as the termination point of the fusion (Fig. 4). Figure 4 provides studies and charts related to the treatment of a 35-year-old woman. The thoracic curve exhibits a greater Cobb angle than the lumbar curve, but the apical deviation of the two curves is relatively comparable. Thus, both curves were instrumented. During a 10-year follow-up period, there was no evidence of subsequent L4–5 or L5–S1 degeneration. The patient’s SRS and ODI scores reflected good surgery-related outcome.

Lumbar Scoliosis: Termination at L-5 or the Sacrum

The more common presentation in the adult patient with lumbar scoliosis is that of an L3–4 rotatory subluxation, L4–5 fixed tilt subluxation, and a variable amount of L5–S1 disc degeneration (Fig. 5A and B). In cases such as
that represented by the images in Fig. 5, it is controversial whether to stop the fusion at L-5 or the sacrum.\(^3\) Most surgeons agree that the fusion should be extended to the sacrum if one of the following is present: 1) L5–S1 spondylolisthesis; 2) previous L5–S1 laminectomy; 3) any form of L5–S1 stenosis, be it central, lateral recess, or foraminal; 4) an oblique takeoff at L5–S1; and 5) severe L5–S1 disc degeneration (but not necessarily if there is L5–S1 disc calcification).

Extending a long fusion to the sacrum is extremely difficult. For a successful solid fusion to form, the following factors are necessary: 1) segmental fixation without jumps or gaps from the middle lumbar spine to the sacrum; 2) four-point fixation of the sacrum and pelvis to protect the S-1 screws; 3) bicortical S-1 screws; 4) load-sharing ability with anterior-column support/anterior fusion in the distal lumbar spine, if not the entire lumbar spine; and 5) neutral or negative sagittal balance. If a plumb line is dropped from C-7 on a long cassette lateral x-ray film, it should fall either through the lumbosacral disc (neutral balance) or behind it (negative sagittal balance).

Our group published its experience with stopping at L-5 in cases in which there was a mild amount of L5–S1 degeneration.\(^4\) We performed thoracic to L-5 fusion in 34 consecutive adult patients; subsequent L5–S1 disc degeneration developed in 66% after long fusion to L-5. Not all of these cases required revision extension to the sacrum, but several did. We also observed cases in which the L5–S1 disc was normal, as verified by discography. In such a case, we have extended the fusion to L-5 and not included L5–S1. In one particular instance, an initially normal L5–S1 disc (based on discography) progressed within 3 years to such a degenerated condition that L5–S1 spondylolisthesis was present.

Our group also published experience with sacropelvic fixation.\(^9\) We found that insertion of bilateral iliac screws combined with bilateral S-1 screws provided excellent distal fixation for lumbosacral fusions in cases of both high-grade spondylolisthesis and long fusions to the sacrum.\(^2\) More recently, Tsuchiya (unpublished data) analyzed most of these patients who underwent follow up of 5 years. There were no cases of sacral screw failure involving either sacral screw fracture or loosening/pullout. There have been cases of late fracture of the iliac screw(s)

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**Fig. 3.** Studies acquired in a 52-year-old woman with a 73˚ thoracic curve and a 48˚ lumbar curve. A: Standing posteroanterior and lateral radiographs. B: Standing posteroanterior and lateral radiographs obtained 10 years after surgery. C: Photographs showing improvement in the translational correction due to the instrumentation. D: Photographs showing the improvement in the axial plane due to the thoracoplasty. E: Graph demonstrating postoperative SRS scores converted to 100-point scale.
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and halo around the iliac screw(s), which is to be expected. There have been cases of rod breakage at L5–S1, signifying pseudarthrosis (incidence of 5%). In these cases, L5–S1 fusion has been achieved by posterior revision and regrafting at L5–S1. Of the cases that we reviewed after a minimum 5-year follow-up period (as many as 10 years postoperatively), we observed no substantial problem with sacroiliac joint arthritis.

Decision making regarding the proximal level requires identification of the stable, neutral, and horizontal vertebrae in the coronal and sagittal planes as well as determination of shoulder height and apical deviation of the curves. These issues are addressed in the case featured in Fig. 5 in which a 57-year-old woman presented with L3–4 rotatory subluxation, fixed tilt at L4–5, and substantial L5–S1 disc degeneration. We chose to perform the fusion to the sacrum. Proximally we chose to fuse to the vertebra that was stable (intersected by the center sacral line) and relatively neutral in the coronal plane. The sagittal plane must also be assessed to avoid stopping at a segment that is close to the apex of thoracic kyphosis. In cases involving a lumbar curve, we typically terminate the fusion proximally at T-10 or T-11. If there is a substantial kyphosis at the thoracolumbar junction or in the lower thoracic spine, then we often extend the fusion to a higher spinal level well above the apex of the thoracic sagittal curve. In some circumstances, even in the absence of substantial coronal deformity in the thoracic spine, we extend the fusion to T-3, T-4, or T-5 to get above kyphosis. The problem with this is that achieving a solid fusion of additional segments becomes more difficult.

**Lumbar Scoliosis: de Novo Degenerative**

Thus far the discussion has centered on idiopathic scoliosis and idiopathic scoliosis with superimposed degenerative changes in the adult. In cases involving degenerative/de novo scoliosis, the decision-making process may
be somewhat different, especially distally. It seems that in a high percentage of patients with de novo scoliosis, some component of L5–S1 disc degeneration is present, but the disc is frequently calcified and almost autofused. In this case it may be acceptable to stop at L-5 rather than extending to the sacrum (Fig. 6). This is illustrated in the case of a 60-year-old woman with degenerative scoliosis. Severe stenosis at L3–4 and L4–5 was demonstrated and accounted for her principal complaint. Subluxations were present at every lumbar level (Fig. 6). In such a case, it is not logical to perform only decompression without fusion and instrumentation. There are two problems with just decompression alone. 1) To an extent, realignment of the spine is necessary for adequate decompression. 2) Decompression without fusion and instrumentation carries a very high likelihood of the subluxations progressing and leading to eventual worsening of the symptoms and disease. Although the disc is degenerated at L5–S1, it is possible to perform a shorter-length fusion, L-1 to L-5. In this circumstance, L-1 is neutral, stable, and parallel to the sacrum. At L3–4 and L4–5 an anterior operation can be performed to create a ligamentotaxis effect to reduce the subluxations at those two levels and facilitate decompression (posterior direct decompression at those two levels was also performed in the case depicted in Fig. 6). Because there was no coronal or sagittal deformity above L-1, we did not extend the fusion any higher. Only time will tell whether these decisions were correct.

At other times with de novo scoliosis, the observed deformity is purely radiographic and not clinical. The usual reason for undertaking surgery is the presence of spinal stenosis, and decisions must be made concerning what levels to fuse and fit with instrumentation based on which levels have substantial stenosis (Fig. 7). Note in the standing radiographs in Fig. 7 that some radiographic subluxation and scoliosis are present at L2–3, L3–4, and L4–5. This...
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was purely a radiographic curve with asymmetry to the discs but no true apical deviation and no substantial rotation manifesting clinically. The patient’s problem is a combination of central, lateral recess and foraminal stenosis at L4–5 where an asymmetrical disc collapsed and degenerative spondylolisthesis developed. There is no stenosis at the other two segments. Therein, it was our decision to perform only L4–5 fixation and fusion. In a way this breaks some rules because superior and inferior ends of the fusion mass are not entirely parallel to the sacrum and the fusion terminates next to segments affected with minor degrees of subluxation. Certainly some surgeons would have chosen to fuse and place instrumentation at all three segments; however, we chose the less extensive surgery because the radiographic deformity at the other two segments was relatively mild. In such cases, we counsel the patient that it is quite possible that breakdown- and stenosis-related problems will occur in the future at the other two segments. Of course, if we had placed instrumentation from L-2 to L-5 it is also possible that transitional breakdown at L1–2 would develop. To some extent, the greater the length covered by the fusion and instrumentation, the more likely the occurrence of adjacent-segment breakdown. This case illustrates that rules related to fusion in the adult spine are not entirely clear cut.

Conclusions

In deciding where to start and stop a fusion, it is helpful to identify the anticipated neutral, stable, and horizontal vertebrae. It is also useful to assess the health of the discs above and below the anticipated fusion site and the antici-
ipated end vertebra relative to the sagittal plane. In the adult patient with lumbar degenerative scoliosis, the point of distal termination is usually L-5 or S-1. The proximal termination point may vary considerably according to the circumstances and presentation.

References


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Fig. 7. Studies acquired in a 53-year-old woman with subluxation and scoliosis at L2–3, L3–4, and L4–5, but minimal apical deviation and rotation. A: Standing posteroanterior and lateral radiographs. B: Preoperative axial magnetic resonance image obtained at L4–5 demonstrating central and lateral recess stenosis. C: Parasagittal slices acquired through the right and left L-4 foramina. Note the right L-4 foramen is patent and the left L-4 foramen is stenotic. D: Standing posteroanterior and lateral radiographs obtained 7 months after surgery. E: Cone down of standing posteroanterior and lateral radiographs acquired 7 months postoperatively. F: Postoperative computerized tomography scan demonstrating the fusion. G: Preoperative and postoperative ODI scores.