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L5–S1 Segment Survivorship and Clinical Outcome Analysis After L4–L5 Isolated Fusion

Gary Ghiselli, MD, Jeffrey C. Wang, MD, Wellington K. Hsu, MD, and Edgar G. Dawson, MD

Study Design. A retrospective investigation of the L5–S1 motion segment after an isolated L4–L5 posterior lumbar fusion

Objective. To determine the survivorship of the L5–S1 segment in patients undergoing L4–L5 fusion and to identify the correlation between radiographic degeneration and clinical outcome at this level.

Summary of Background Data. There is current controversy regarding future degeneration of the L5–S1 segment following single-segment fusion at L4–L5. There are no long-term studies that look at L5–S1 after L4–L5 fusion to assess the rate of degeneration at this adjacent segment and the functional clinical outcome of the patient.

Methods. Thirty-two consecutive patients (average age 56.4 years, range 27–77 years) having isolated L4–L5 posterior spinal fusion for instability or stenosis by a single surgeon were included in this study. There were 25 females and 7 males with an average follow-up of 7.3 years (range 2.3–12.4 years). A survivorship analysis was performed to determine the degeneration at the adjacent L5–S1 segment. Radiographs were analyzed for arthritic degeneration at that level. At the time of the L4–L5 index procedure, the L5–S1 disc spaces were graded on a 4-point scale for degeneration. Questionnaires were submitted by mail, and telephone interviews were conducted by one of the authors to determine the current level of patient function.

Results. Of the total 32 patients assessed, 31 (97%) had no evidence of symptomatic degeneration at L5–S1 requiring additional decompression or fusion. One patient had clinical symptoms that required a foraminotomy and laminotomy at L5–S1, but none of the patients required any further fusion. Although there was a trend of progression of the arthritic grade at L5–S1 from preoperative to postoperative examination, there was no correlation between preoperative arthritic grade *versus* further degeneration. The discs showed progression of degeneration from an average score of 2.28 before surgery to a score of 2.49 after surgery at the last follow-up.

Conclusion. There appears to be no need to routinely include the L5–S1 segment when performing a posterior lumbar fusion for patients with instability or stenosis at L4–L5 if no symptoms are attributed to the lumbosacral level. At an average of 7.3 years, there was neither increased symptomatic disc degeneration nor symptoms necessitating the need for an L5–S1 fusion. [Key words: lumbar spine fusion, adjacent segment, degenerative changes, long-term follow-up] **Spine 2003;28:1275–1280**

Spinal fusion is a common procedure performed in the lumbar spine for a variety of pathologic conditions.[1] The incidence of lower lumbar fusions has continued to rise because of the emergence of newer surgical techniques and better imaging methods that allow more accurate recognition of the pathology of the spine. The levels involved in the fusion are typically unstable or have symptomatic degeneration. The ultimate goal of the arthrodesis is to provide symptomatic relief and to restore or maintain stability. Of particular interest is the information regarding the long-term outcome of lumbar fusions with specific attention focused on the adjacent segments and their subsequent degeneration.

Adjacent segment degeneration in the lower lumbar and lumbosacral spine has been examined extensively through biomechanical and clinical studies. Cadaveric evidence of increased proximal segment motion and increased intervertebral stress at adjacent motion segments has been well described.[1–3] Clinically, retrospective scoliosis studies on lumbar fusions as well as longitudinal adult lumbar fusion studies have suggested that lower lumbar fusions predispose patients to problems in the adjacent motion segments.[4–22] With the exception of a few studies, all of the biomechanical and clinical studies address cranial segment degeneration.[16,17,23] Miyakoshi *et al* investigated lumbosacral degeneration after isolated L4–L5 posterior lumbar interbody fusion and found no correlation between the changes in L5–S1 disc height and clinical outcome.[23] Although this study specifically addressed the L5–S1 segment, it did not address the incidence of adjacent segment disease caudal to a fusion segment and the survivorship of the lumbosacral junction.

A difficult decision-making situation arises when performing an L4–L5 lumbar fusion when concomitant radiographic pathology exists at L5–S1. The preoperative radiographic degeneration of L5–S1 will often influence the inclusion of this adjacent level in the fusion. Determining the survivorship and the rate of degeneration according to the present condition of the adjacent L5–S1 segment may provide evidence for a proper surgical decision. The purpose of this study was as follows: 1) to determine the survivorship and rate of degeneration of the L5–S1 segment in the lumbar spine following L4–L5 fusion; 2) to assess the clinical outcome both radiograph-

From the Department of Orthopaedic Surgery, UCLA School of Medicine, Los Angeles, California.
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Address correspondence and reprint requests to Jeffrey C. Wang, MD, Department of Orthopaedic Surgery, UCLA School of Medicine, Box 956902, Los Angeles, CA 90095-6902, USA; E-mail: Jwang@mednet.ucla.edu

Table 1. Criteria for the Assessment of Clinical Outcome[21]

Outcome	Pain	Medication	Activity	Work Status
Excellent	None except for occasional back pain	None	Normal	Normal
Good	Markedly improved, occasional pain	Episodic use of non-narcotic pain medication	Minimal functional limitations	Return to work although not at the same job activity
Fair	Some improvement	Daily use of non-narcotic pain medication	Restricted	Limited
Poor	No change in symptoms or a worsening of the patient's condition	Oral use of narcotics	Incapacitated	Disabled

Patients were rated based on the lowest score for one category.

ically and symptomatically; and 3) to examine the demographic and surgical factors associated with radiographic degeneration and measured functional outcomes.

■ Materials and Methods

A retrospective medical records review was performed at a single institution to identify potential patients who had a single-level posterior lumbar fusion performed only at L4–L5 between April 1983 and August 1994. Isolated posterior L4–L5 lumbar fusions were only performed on those patients who had pathology that was identified specifically at that level. No patient had a history of previous lower lumbar surgery at L4–L5 or L5–S1. The hospital records and office charts were reviewed and analyzed by an independent observer to determine demographics, symptoms, preoperative and postoperative diagnosis, surgical instrumentation, surgical technique, and patient function at each follow-up visit. All information was entered into a computer database for analysis.

Patients were also contacted by telephone or mail and were questioned by an independent observer regarding their functional outcome based on a standardized questionnaire. This questionnaire was based on a modified Whitecloud's function scale (Table 1).[21] They were given a grade of excellent, good, fair, or poor based on the lowest rated category. The most recent follow-up date was defined as the date of the interview if they were contacted either by mail or telephone or the last clinic visit with detailed documentation of patient function.

Radiographs from the preoperative visit as well as the last postoperative visit were reviewed. Raters were blinded as to the patient name and the date of the radiograph. Standardized biplanar anteroposterior, lateral, flexion, and extension radiographs of the lumbosacral spine were reviewed for each patient. The lateral films with neutral and flexion–extension views were measured for anteroposterior translation and intervertebral disc height at both segments from L4 through S1. Objective intervertebral disc heights were measured using accepted methods.[24,25] Instability was defined based on the accepted standards for instability: >4 mm of translation or >10° of angular motion between adjacent endplates on lateral flexion–extension radiographs when compared with the adjacent proximal and distal levels.[26] These measurements were performed independently by three of the authors.

The degenerative grade of each lumbar disc level was rated at the time of initial surgery and again at the same levels at the time of the last radiographic follow-up visit. The amount of degeneration was based on a modified Arthritis Grading Scale (Table 2). These values were recorded and analyzed as described next.

To provide an objective analysis of the subjective radiographic readings, kappa values were calculated for the three independent evaluators. Kaplan-Meier survivorship analysis was performed to assess the degeneration of the adjacent lumbosacral segment. Survivorship was defined as lack of any surgical procedure at L5–S1 subsequent to the initial L4–L5 fusion. Correlation analysis using a Spearman rank test was used to determine the independent variable contribution to the measured functional outcome. Independent variables included age at index procedure, sex, preoperative diagnosis, time from initial surgery until the last follow-up, and preexisting degeneration at L5–S1.

■ Results

Demographics

Hospital charts were reviewed and resulted in the identification of 32 patients who met the study inclusion criteria. All of these patients had a preoperative hospital visit including a full physical examination, documentation of function, and radiographs. All patients were observed clinically until they had evidence of a solid fusion mass radiographically and for at least 2 years from the time of index surgery; 22 of these 32 patients (69%) were reached by telephone or mail and completed the follow-up questionnaires. The remaining 10 patients (31%) had functional outcomes assessed based on a chart review and last follow-up visit.

Of the 32 patients, 7 were men and 25 were women. Ages ranged from 27 to 77 years (median 56 years). Length of follow-up ranged from 2.3 to 12.4 years. The

Table 2. Arthritic Grade for Intervertebral Disc Degeneration

	UCLA Grading Scale for Intervertebral Space Degeneration		
	Disc Space Narrowing	Osteophytes	End Plate Sclerosis
I	−	−	−
II	+	−	−
III	+/−	+/−	−
IV	+/−	+/−	+

Grade is based upon the most severe radiographic finding evident on plain radiographs. These categories are mutually exclusive when used for grading. Patients were rated based on the worst category satisfied.
+ = present; − = absence; +/− = either present or absent.

Table 3. Patient Demographics Including Age, Gender, Diagnosis, Time to Follow-up, and Modified Whitecloud Criteria of Function at Last Follow-up[21]

Patient No.	Age at Time of Surgery (yrs)	Gender	Diagnosis	Follow-up Time (yrs)	Whitecloud at Last Follow-up
1	71	F	1	11.3	Fair
2	71	M	1	6.6	Fair
3	65	F	1	6.7	Excellent
4	50	F	1	6.9	Good
5	59	M	1	2.3	Good
6	32	M	1	8.3	Good
7	28	F	1	7.4	Poor
8	64	F	1	7.0	Fair
9	66	F	1	7.2	Good
10	43	F	1	6.3	Fair
11	54	F	1	6.7	Good
12	63	F	1	7.0	Good
13	41	F	1	4.9	Poor
14	69	F	1	6.3	Excellent
15	56	M	1	7.7	Excellent
16	26	F	1	3.9	Fair
17	41	F	1	3.3	Fair
18	77	F	1	2.7	Fair
19	59	F	1	10.2	Fair
20	74	F	1	8.9	Good
21	59	M	1	6.0	Good
22	69	F	1	6.1	Good
23	62	F	1	7.3	Poor
24	68	F	1	7.8	Excellent
25	59	F	2	7.6	Excellent
26	68	F	2	10.9	Poor
27	39	M	2	6.0	Excellent
28	51	F	2	8.3	Fair
29	50	M	2	11.1	Good
30	61	F	2	7.9	Poor
31	45	M	2	12.4	Good
32	67	F	3	9.5	Poor

Diagnosis: 1 = instability; 2 = spinal stenosis; 3 = posttraumatic lumbar fracture stenosis.

mean follow-up was 7.3 years. The most common indication for fusion was degenerative spondylolisthesis, accounting for 75% of our preoperative diagnoses. Other indications for surgery in our study included spinal stenosis and post-traumatic fracture stenosis (Table 3). No patients were fused for chronic discogenic back pain alone. All patients had an isolated fusion performed at L4–L5. Instrumented fusions with pedicle screw constructs were performed in 14 of 32 patients. Of those 14 patients, 2 of 14 patients had unilateral instrumented fusions and 12 of 14 had bilateral pedicle screw constructs. All patients had an intertransverse process fusion with autogenous iliac crest bone graft (16 of 32), autogenous local bone graft (14 of 32), and/or allograft supplementation (8 of 32). All patients went on to radiographic fusion as determined by flexion–extension radiographs.

Radiographic Analysis

The intervertebral disc height measurements were analyzed and found to be an inaccurate measurement of disc degeneration. Subjectively, disc degeneration at the lumbosacral level was evaluated based on the aforementioned arthritic grading scale and was found to be an average of 2.28 (range 1–4) before surgery and 2.49 (range 1–4) after surgery. These final scores are an average of the three physicians' scores rather than a consensus reading. The overall kappa coefficient for the preoperative radiographs was 0.548 and for postoperative radiographs was 0.573. This relates to a moderate agreement between raters.

Clinical Outcomes

Using Whitecloud's criteria for outcome, 5 patients had an excellent outcome, 11 had a good outcome, 9 had a fair outcome, and 6 had a poor outcome.[21] Analysis of the clinical outcome defined by Whitecloud's measure was performed to determine any correlation with the following variables: age at index procedure, sex, preoperative diagnosis, time from initial surgery until the last follow-up, use of instrumentation, and pre-existing degeneration at L5–S1. Using a Spearman rank correlation, there was a strong association between poor outcome and female sex: Spearman's rho (r) = 0.40, $P = 0.021$. There was statistically insignificant correlation with diagnosis (r = 0.15, $P = 0.42$) or instrumentation (r = 0.28, $P = 0.125$), age (r = 0.09, $P = 0.77$), time to follow-up (r = −0.14, $P = 0.45$), or preoperative arthritic grade of L5–S1 (r = −0.12, $P = 0.19$).

Of the patients analyzed, only one patient developed subsequent symptoms at L5–S1 that required subsequent surgery. This patient had a previous lumbar fracture that

required delayed decompression and fusion at L4–L5. This patient developed degeneration at L5–S1 7.9 years after the initial fusion that required a posterior decompression but did not require fusion.

Kaplan-Meier survivorship analysis predicted that there is a 90% (± 9.4%) 10-year survivorship of L5–S1 after a L4–L5 segmental fusion. The failure rate was predicted to be 0.0044 failure per year of follow-up (95% confidence interval 0.006, 0.0301).

■ Discussion

The continued degeneration of motion segments adjacent to lumbar fusions is a potential concern of both patients and surgeons when performing lumbar spinal fusions. Adjacent segment disease does remain a problem and accounts for a significant portion of revision spine surgery. Although the development of adjacent segment degeneration can be considered part of normal aging and the degenerative process, this phenomenon appears to be at least partly influenced by the altered stresses that arise as a consequence of lumbar fusion.[2,3,5,27–29]

There are multiple clinical studies that describe accelerated degeneration of lumbar segments adjacent to a previous fusion.[4–23,30] These studies detail disc space narrowing and spondylolisthesis in the adjacent segments after lumbar or, more commonly, lumbosacral fusion. The stated postoperative changes in degeneration at the adjacent segments compared with preoperative degeneration increased in a range from 5% to 43%.[5,11,16] However, the increase in repeat lumbar surgery performed for this degeneration was much lower with rates ranging from 2% to 15%. All of the studies document, at least to some degree, disc degeneration at the adjacent segment.

There are only a few studies that specifically address degeneration of L5–S1 after a "floating fusion" performed at L4–L5.[16,17,23] Although these studies have a short follow-up interval, they support our hypothesis that preoperative or postoperative radiographic degeneration of the L5–S1 disc does not affect the clinical outcome.

Additionally, there are biomechanical studies that support the increased incidence of degenerative disease adjacent to the fusion.[2,3,19,30–32] Cadaveric studies of lumbosacral fusions showed that there is increased stress seen at the facet joints and at the juxta-free motion segments L3–L4 and L4–L5. Quinell and Stockdale specifically addressed the influence of a single lumbar floating fusion at either L3–L4 or L4–L5 on the remaining lumbar spine.[2] Their conclusions were that the disc above is unaffected in terms of its external dimensions and the discs below underwent a change in their loading characteristics.

There are clearcut advantages for sparing L5–S1 when performing surgery for obvious pathology at L4–L5. Previous studies have shown that there are inferior results of two-level fusions compared with single-level fusions.[11,33,34] These studies detail higher rates of pseudarthrosis at L4–L5, the exact area of our preoperative pathology. There are proponents of fusion of adjacent levels, but firm indications are limited to grade 3 or grade 4 spondylolisthesis.[35]

The main purpose of this study was to look at the L5–S1 segment after an L4–L5 fusion and determine the rate of degeneration. Few studies have previously addressed this specific level after an isolated fusion.[16,17,23] This may be due to the fact that some surgeons will fuse to the sacrum if there is isolated disease with the assumption that there will eventually be increased stress at L5–S1 that will later necessitate fusion. Our survivorship analysis shows that there was a 90% survivorship of the lumbosacral segment 10 years following a L4–L5 fusion. In this follow-up period, only one patient developed significant radicular symptoms attributed to degeneration of L5–S1 that required further surgery. This patient had a laminotomy and decompression but did not have symptoms warranting a lumbosacral fusion.

Overall, the amount of radiographic degeneration did progress at L5–S1, which agrees with previously quoted studies that there is a radiographic progression of the disease but no clinical correlation.[5,11,16] Radiographic measurement of degenerative disc disease proved to be a difficult task. Many studies have looked at traction spurs, osteophytes, and facet arthrosis in an attempt to correlate radiographic findings with clinical symptoms.[20,27,36–38] Others have attempted to objectively measure intervertebral disc height but have found that it is impossible unless one carefully controls the tube-target-film association, uses optimum radiographic techniques that include bony landmarks, and compensates for radiographic magnification.[25,33] Our data also showed a large amount of inconsistency when measuring the intervertebral disc height quantitatively. Therefore, a modified arthritis grading scale was developed to qualitatively grade disc degeneration. This grading scale proved to have a moderate interobserver agreement with some grades of arthritis, but considerably worse with other grades. This grading system provided an advantageous platform from which longitudinal patient data as well as comparison data could be obtained. The disadvantages of this scale were the less than perfect interobserver agreements and the exclusion of MRI or clinical contributions.

There are obvious limitations to this study. As a retrospective study, the patients have to rely on memory for their clinical outcome. This may decrease the validity of reported outcomes. Additionally, there was disparity between the clinical follow-up and the radiographic follow-up. Patients who were asymptomatic and had previous radiographic documentation of fusion did not have any further radiographs. This limited the length of radiographic follow-up to 3.9 years compared with the clinical follow-up of 7.3 years. This study was also limited to a single surgeon at a single institution. Lastly, another limitation of this study is that it is impossible without a randomized controlled trial to determine whether adjacent segment degeneration is due to the natural degeneration of the lumbosacral segment or to the influence of the previously fused adjacent segment.

The demographic makeup of the patient sample was not controlled. All patients who had an isolated L4–L5 fusion were included in this study unless they had previous surgery at the lumbar spine. Therefore, the number of females was 75% of the patient population. This limits the ability to generalize the outcomes of the study, and it would have been advantageous if the composition were more gender equal.

It is difficult to make generalizations with a patient population of varying ages, predominantly female composition, different operative indications, and different follow-up times. However, the data support some important clinical suggestions that can be made with respect to floating lumbar fusions at L4–L5. Our correlation analysis suggests that neither preoperative diagnosis nor instrumentation during fusion influences the clinical outcome. They do suggest, however, that female patients tend to have a poorer outcome after the isolated L4–L5 fusion.

Unless the patient has specific symptoms attributable to L5–S1 or radiographic evidence of deformity, it appears that this level does not need to be routinely included in the fusion segment. The rate of adjacent segment degeneration at this level after a L4–L5 fusion does not appear to be significant for the development of adverse patient functional outcomes. This may be due to the restraining effect of the lumbosacral ligaments and its recessed location within the pelvis. This may also be a reasonable explanation for why the L5–S1 segment degenerates at a rate different than that of the proximal junction interspaces.

None of the patients in this study had L4–L5 fusion for back pain alone. All had the primary diagnosis of stenosis or instability. The results of this study should not be applied to patients with low back pain alone in which L5–S1 may be included as a potential source of symptoms.

Degeneration at the L5–S1 segment after an L4–L5 fusion seems to be only a radiographic finding without any associated clinical symptoms. When considering a posterior L4–L5 fusion for instability or stenosis, surgeons should not include the L5–S1 segment based on radiographic degeneration alone but should carefully evaluate patient symptoms and radiographic instability of the L5–S1 segment before including it in the fusion construct.

■ Key Points

- This is the first study to specifically analyze the lumbosacral junction after isolated adjacent segment fusion.
- This study statistically determines survivorship and rate of degeneration of L5–S1 after L4–L5 fusion for instability or stenosis.
- The lumbosacral segment, regardless of the amount of initial intervertebral disc degeneration, has a very low rate of subsequent degeneration when the adjacent L4–L5 segment is fused.

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Point of View

Paul C. McAfee, MD

Too bad the FDA did away with using retrospective historical controls for comparative benchmarks. I would *beg* the FDA to be able to compare my series of patients undergoing L4–L5 disc replacements with this reported series (25% clinical failure rate; Whitecloud criteria); the definition of success was no additional surgery performed at the adjacent L5–S1 level. No preoperative or postoperative functional outcome measures, visual analog scale, ODI, or SF-36 were performed to quantify the patient's pain level (functional outcomes based on chart review are not acceptable to the FDA); and none of the patients move at L4–L5. If this article represents surgical success, bring back the good old days because total disc replacement looks pretty good.

The article by Ghiselli *et al* is valuable in pointing out that radiographic evidence of disc space narrowing and degenerative changes do not correlate with symptoms.

Clinical Symptoms

Only one patient of 32 was symptomatic enough to require additional surgery, foraminotomy, and laminectomy (3% incidence of symptoms), whereas radiographically, overall, the L5–S1 discs showed progression of degeneration from an average score of 2.28 before surgery to a score of 2.49 (scale 1–4) after surgery at the last follow-up. The best overall review of the subject of adjacent segment degeneration is by Hilibrand and Robbins.[1]

Radiographic Studies

Lehmann *et al*[2] found radiographic evidence of adjacent segment degeneration in 15 of 33 (45%) patients followed for an average of 33 years. Aota *et al*[3] followed 65 patients for an average of 35 months after surgery and found a 24.6% incidence of postfusion instability, usually retrolisthesis. Rahm and Hall[4] followed 49 patients for a mean of 5 years and found adjacent segment degeneration in 35% of patients.

Clinical Studies of Symptomatic Degeneration

In contrast, Etebar and Cahill,[5] who studied 125 patients with a 44.8-month follow-up, calculated an annual incidence of symptomatic adjacent segment disease at 3.9%. Cochran *et al*,[6] studying patients with scoliosis with lumbar distal hook sites, had a 1.2% overall annual incidence of symptomatic adjacent segment disease.

Because of the extreme length of follow-up required to get meaningful data (5–10 years), the topic of symptomatic adjacent segment disease is a difficult area of study. Ghiselli *et al* admitted running into the same shortcoming of most studies without a randomized controlled trial, *i.e.*, it is difficult to distinguish natural degeneration of the L5–S1 disc from deterioration because of the influence of the previously fused L4–L5 level. Ghiselli *et al* presented are a very successful paper, however. They convincingly make the point that, for a Grade 1 degenerative L4–L5 spondylolisthesis, an isolated instrumented L4–L5 fusion is the treatment of choice and that extension of the fusion to include L5–S1 is not usually necessary.

From the Department of Spinal Reconstructive Surgery, St. Joseph's Hospital, Spine and Scoliosis Center, Towson, Maryland.
Address correspondence and reprint requests to Paul C. McAfee, MD, Department of Spinal Reconstructive Surgery, St. Joseph's Hospital, Spine and Scoliosis Center, O'Dea Medical Arts Building, Suite 104, 7505 Osler Drive, Towson, MD 21204, USA; E-mail: Mack8132@aol.com
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