

Does the Number of Levels Fused Affect Spinopelvic Parameters and Clinical Outcomes Following Posterolateral Lumbar Fusion for Low-Grade Spondylolisthesis?

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Abstract

Study Design: Retrospective cohort.

Objectives: To determine how the number of fused intervertebral levels affects radiographic parameters and clinical outcomes in patients undergoing open posterolateral lumbar fusion (PLF) for low-grade degenerative spondylolisthesis.

Methods: This was a retrospective cohort study on patients who underwent open PLF for low-grade spondylolisthesis at a single institution from 2011 to 2018. Patients were divided into groups based on number of levels fused during their procedure (1, 2, or 3 or more). Preoperative and postoperative spinopelvic radiographic parameters, patient-reported outcomes (Visual Analog Scale [VAS]-back, VAS-leg, Oswestry Disability Index [ODI]), and postoperative complications were compared.

Results: Of the 316 patients eligible (203 one-level, 95 two-level, 18 three or more levels), change in initial postoperative to final pelvic incidence-lumbar lordosis was greatest in 2-level fusions ($P = .039$), while 3 or more level fusions had worse final pelvic tilt measures ($P = .021$). In addition, multilevel fusions had worse final VAS-back scores (2-level: $P = .015$; 3 or more levels: $P = .011$), higher rates of dural tears (2-level: $P = .001$), reoperation (2-level: $P = .039$), and discharge to facility (3 or more levels: $P = .047$) when compared with 1-level fusions.

Conclusions: Patients in multilevel fusions experienced less improvement in back pain, had more complications, and were more commonly discharged to a facility compared with single-level PLF patients. These findings are important for operative planning, for setting appropriate preoperative expectations, and for risk stratification in patients undergoing posterior lumbar fusion for low-grade spondylolisthesis.

Keywords

posterolateral fusion, low-grade spondylolisthesis, single-level, multi-level, back pain, postoperative complications

Introduction

It is estimated that roughly 39 million individuals worldwide suffer from degenerative spondylolisthesis (DS), and direct posterior decompression with a posterolateral lumbar fusion (PLF) is commonly performed for this condition.¹ In patients with multilevel disease, some surgeons opt for multilevel fusion given the adjacent segment instability generated by laminectomy, though others will aim to conservatively fuse minimal segments despite multilevel decompression.^{2,3} The

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comparative clinical outcomes of single-level versus multilevel lumbar fusion for multilevel stenosis have been reported in the literature, including within a Spine Patient Outcomes Research Trial (SPORT) cohort, and demonstrate a lack of utility of extending lumbar fusion for DS to additional stenotic levels.³ However, in the setting of multilevel DS, the comparative clinical outcomes for single-level versus multilevel fusion is less clear. Additionally, there has been increased attention paid to optimizing spinopelvic parameters during spinal fusion; however, little information in the literature exists on the relative effects of single-level or multilevel lumbar fusion on commonly discussed parameters. Therefore, the purpose of this study was to determine how number of fused intervertebral segments in PLF affects radiographic and clinical outcomes in patients with symptomatic low-grade DS.

Methods

After institutional review board approval, a retrospective cohort study was conducted at a single academic institution using consecutive patients from 2011 to 2018 who underwent elective primary instrumented posterolateral lumbar spinal fusion for symptomatic low-grade spondylolisthesis (Grade I or II). Specifically, all patients underwent surgery to address lumbar radiculopathy and/or neurogenic claudication after failure of conservative treatment. Multilevel fusion was pursued in the setting of concomitant adjacent-level degenerative disease, when there were concerns that neighboring pathology would rapidly progress to instability if left untreated. Patients were excluded if they had less than 6 months of clinical or radiographic follow-up, they were under 18 years of age at the time of surgery, or if they had a surgery for fracture, tumor, or infection. In addition, patients with prior lumbar surgeries, fusions involving the thoracic spine, high-grade spondylolisthesis, concomitant deformity, and use of interbody were excluded. Eligible patients were then divided into 3 groups based on the number of intervertebral levels fused intraoperatively: 1, 2, or 3 or more levels.

Age, sex, body mass index, diabetes mellitus, smoking status, psychiatric condition (depression, substance abuse, bipolar disorder, or anxiety), and American Society of Anesthesiologists class were collected as demographic information. Other baseline characteristics such as preoperative opioid use and duration of preoperative pain symptoms was also noted.

The radiographic parameters pelvic incidence (PI), lumbar lordosis (LL), and pelvic tilt (PT) were measured preoperatively, at the first postoperative visit, and at the most recent follow-up using standing neutral lateral plain radiographs of the lumbar spine, using a previously validated system of measurement by Presciutti et al.⁴

The patient-reported outcomes Visual Analog Score (VAS)-back pain, VAS-leg pain, and Oswestry Disability Index (ODI) were collected at preoperative and final postoperative visits. The rates of intraoperative dural tear, postoperative complications (aspiration, urinary tract infection, acute renal failure, epidural hematoma, altered mental status,

deep vein thrombosis/pulmonary embolism, stroke, myocardial infarction, pneumonia, pleural effusion, urinary incontinence, neurological deficit, or hardware complications), post-discharge destination, reoperation, pseudarthrosis, as well as postoperative length of stay were recorded.

Analysis was conducted using Stata version 13.1 (StataCorp LP, College Station, TX). Baseline patient and operative characteristics were compared using χ^2 and analysis of variance (ANOVA) tests for categorical and continuous data, respectively. Binary outcome variables were compared between groups with multivariate logistic regression, and continuous outcome variables were compared using multivariate linear regression, with 1-level fusions used as the reference group. Multivariate analyses controlled for differences in baseline patient and operative characteristics. The threshold for statistical significance was set at $P < .05$.

Results

A total of 316 patients met the inclusion criteria of which 203 (64.24%) underwent a single-level fusion, 95 (30.06%) had a 2-level fusion, and 18 (5.70%) had a 3 or more level fusion. Patients who underwent fusion at 3 or more levels had longer duration of preoperative pain symptoms ($P = .006$), though no additional differences in demographic characteristics were found (Table 1).

Radiographically, patients who underwent 3 or more level fusions had significantly lower preoperative LL ($P = .015$) and a larger PT ($P = .031$) in comparison to single-level fusions. Immediately postoperatively, patients with 3 or more level fusions had significantly greater PT ($P = .021$) in comparison to single-level fusions. Last, change in PI-LL difference was greater for 2-level fusions than single-level fusions ($P = .039$). There were no additional significant differences in the remaining spinopelvic parameters (Table 2).

After controlling for differences in baseline characteristics, 2-level and 3 or more level ($P = .011$) fusions had significantly worse final VAS-back scores when compared with single-level fusions ($P = .015$ and $P = .011$, respectively). Furthermore, 3-level patients experienced a smaller improvement in VAS-back scores ($P = .003$) and reported worse final ODI scores than single-level fusions ($P = .024$). All other patient-reported outcomes (PROs) were comparable between all 3 groups (Table 3).

Last, regarding complications, patients with 2-level fusions experienced significantly greater rates of intraoperative dural tears ($P = .001$), development of early adjacent segment degeneration (ASD; $P = .025$), and reoperation ($P = .039$) than single-level fusions. Furthermore, patients with 3 or more levels fused had much higher rates of discharge to facility ($P = .047$; Table 4).

Discussion

Posterolateral lumbar fusion is a successful surgical technique used in the treatment of DS; however, the relationship between

Table 1. Baseline Patient/Operative Characteristics^a.

	One Level		Two Levels		Three or More Levels		All Patients		P
	N/Mean	%/(SD)	N/Mean	%/(SD)	N/Mean	%/(SD)	N/Mean	%/(SD)	
Overall	203	64.24%	95	30.06%	18	5.70%	316	100%	
Demographics									
Age	64.78	(10.57)	64.87	(8.77)	69.22	(8.59)	65.06	(9.98)	.190
Body mass index	31.43	(6.29)	31.96	(6.64)	29.09	(5.52)	31.47	(6.37)	.249
Pain duration (months)	40.78	(63.40)	31.38	(36.51)	86.88	(139.69)	40.44	(64.20)	.006
Female sex	130	64.04	65	68.42	13	72.22	208	65.82	.638
Diabetes mellitus	23	11.33	11	11.58	1	5.56	35	11.08	.743
Current smoker	23	11.5	9	9.68	2	11.11	34	10.93	.897
History of psychiatric condition	23	11.5	13	13.98	4	22.22	40	12.86	.398
Preoperative opiate use	47	23.5	18	19.35	8	44.44	73	23.47	.071
ASA \geq 3	100	49.26	37	38.95	7	38.89	144	45.57	.210
Spondylolisthesis									
Grade 1	166	81.77	75	78.95	15	83.33	256	81.01	.818
Grade 2	13	6.4	9	9.47	1	5.56	23	7.28	.610
Duration of Follow-up (months)	18.43	(12.05)	26.10	(21.96)	22.50	(19.44)	21.27	(16.76)	.061

Abbreviations: SD, standard deviation; ASA, American Society of Anesthesiologists.

^aBolded text indicates statistically significant values at $P < .05$.

additional fused levels, spinopelvic parameters, and clinical outcomes remains unexplored. The present study compared spinopelvic parameters and PROs from 316 patients undergoing 1, 2, or 3 or more level fusions. Collectively, patients undergoing multilevel fusion had significantly lower measures of LL, greater measures of PT and PI-LL mismatch, accompanied by worse PROs and increased rates of perioperative complications. This provides evidence of inherent complications of multilevel fusion in low-grade DS and may guide preoperative discussions on the risks and benefits of these procedures in patients with multilevel pathology.

In the present literature there are remarkably few studies examining outcomes of multilevel arthrodesis in the setting of low-grade DS with adjacent degenerative disc disease or spondylolisthesis. This, in part, is largely due to a lack of validated evidence regarding the indications for extending fusions in this setting, making study difficult due to a heterogeneous cohort. Despite this, there is ample literature promoting the use of multilevel PLF in other conditions, primarily in the setting of multilevel degenerative disc disease.^{5,6} Nonetheless, concerns about adverse outcomes associated with increasing fusion levels remain. In a recent study by Crawford et al, patients were more likely to experience resolution of their symptoms with shorter fusions in lumbar DS.⁷ Similarly, in Franklin et al, longer fusions were more likely to predict worse work disability outcomes in lumbar arthrodesis.⁸ Conversely, in their prospective study, Lettice et al found number of fusion levels led to significant improvements in physical function and bodily pain when compared with shorter fusions.⁹ Collectively, when considering the findings of the present study, these results suggest that there continues to be disagreement on the precise risks and benefits of extended fusions and that a deeper exploration of the associated outcomes in treating various multilevel pathologies is warranted.

After controlling for baseline characteristics, differences in spinopelvic radiographic parameters were observed between 1, 2, and 3 or more level fusions. Specifically, the lower preoperative LL, and larger preoperative and postoperative PT observed in patients with 3 or more level lumbar fusions compared with those with 1-level fusions likely reflects the use of spinopelvic compensatory mechanisms in patients with multilevel DS pathology. Loss of lordosis is a known consequence of DS, causing sagittal imbalance and compensatory retroversion of the pelvis (ie, increased pelvic tilt), extension of the hips, and flexion of the knees. This outcome is to be expected, as multilevel pathology more likely presents with worse radiographic disease. Though speculative, this finding may affect the decision-making process surgeons use when opting for multilevel fusion in the management of DS. Evidence of diffuse disease on radiographs may influence the clinician to perform longer fusions to correct spinopelvic parameters, while addressing subsequent instability. However, further evaluation of radiographic spinopelvic imbalance is required to better determine the nature of these findings. Specifically, understanding whether these findings are structural (secondary to DS or other degenerative change) or positional (due to patient's comfort level and symptoms) can aid in preoperative planning when choosing levels to fuse.

Of particular concern is multilevel fusions had a greater increase in postoperative to final measures of PI-LL mismatch when compared with single-level fusions. PI-LL mismatch is a validated metric that is traditionally used to help evaluate and manage surgical correction of adult spinal deformity. In general, the difference in PI and LL should be $\leq 10^\circ$, as values greater than this have been associated with increased risk for ASD, worse sagittal plane alignment, worse health-related quality-of-life scores, and other adverse outcomes.¹⁰⁻¹² However, in the setting of DS, PI-LL mismatch is understudied, and

Table 2. Radiographic Measurements: Single-Level Degenerative Spondylolisthesis as Reference.^a

	One Level, Mean (SD)	Two Levels, Mean (SD)	Three or More Levels, Mean (SD)	Two Levels (vs One) Multivariate Linear Regression		Three or More Levels (vs One) Multivariate Linear Regression	
				Beta	P	Beta	P
Preoperative							
Lumbar lordosis	-47.37 (15.04)	-46.75 (16.39)	-37.32 (17.08)	1.86	.474	12.77	.015
Pelvic tilt	24.50 (13.08)	27.19 (13.47)	32.76 (15.90)	3.23	.202	11.88	.031
Pelvic incidence	54.44 (14.99)	55.03 (16.95)	46.28 (21.74)	-0.63	.834	-11.83	.073
PI-LL difference	6.60 (12.56)	8.97 (17.77)	2.12 (23.00)	2.26	.434	-7.34	.237
Postoperative							
Lumbar lordosis	-43.76 (17.88)	-45.04 (14.37)	-34.95 (11.87)	-0.51	.842	10.31	.064
Pelvic tilt	27.39 (13.92)	26.78 (11.66)	37.18 (15.81)	-1.04	.667	11.61	.021
Pelvic incidence	55.33 (14.47)	57.47 (13.54)	53.08 (18.21)	0.43	.866	-5.05	.331
PI-LL difference	11.87 (19.40)	11.57 (16.90)	17.45 (20.69)	-0.51	.881	3.83	.581
Final							
Lumbar lordosis	-46.60 (21.02)	-43.97 (20.07)	-36.08 (16.60)	3.90	.231	12.64	.074
Pelvic tilt	24.93 (13.93)	29.49 (13.96)	30.57 (17.37)	4.43	.087	8.32	.234
Pelvic incidence	53.60 (18.79)	57.71 (16.36)	59.06 (13.48)	3.89	.229	9.52	.275
PI-LL difference	7.47 (21.86)	11.63 (21.64)	15.19 (14.88)	4.79	.222	9.11	.388
Change preoperative to postoperative							
Lumbar lordosis	2.82 (14.67)	3.18 (9.10)	1.06 (7.93)	0.46	.840	-3.57	.445
Pelvic tilt	1.04 (6.56)	1.30 (7.59)	5.14 (5.21)	0.15	.912	3.38	.239
Pelvic incidence	0.22 (6.89)	1.15 (8.60)	5.45 (4.85)	1.41	.346	5.24	.090
PI-LL difference	2.24 (8.92)	4.22 (10.77)	9.82 (7.53)	2.80	.162	7.02	.090
Change postoperative to final							
Lumbar lordosis	0.92 (15.82)	4.49 (17.94)	0.63 (9.42)	4.88	.083	-1.77	.763
Pelvic tilt	-1.10 (7.74)	1.58 (9.56)	0.15 (3.90)	2.54	.163	-0.79	.864
Pelvic incidence	-1.43 (15.59)	0.58 (9.10)	3.10 (3.32)	2.58	.358	8.99	.209
PI-LL difference	-2.26 (16.65)	4.32 (14.70)	2.68 (9.92)	6.89	.039	6.05	.469
Change preoperative to final							
Lumbar lordosis	-2.36 (20.90)	0.82 (15.61)	0.29 (5.52)	3.67	.221	4.76	.483
Pelvic tilt	-2.31 (8.15)	0.04 (4.83)	-5.17 (7.35)	2.61	.065	-3.06	.434
Pelvic incidence	-1.48 (13.60)	-0.00 (6.44)	-4.25 (6.35)	2.02	.369	-0.16	.980
PI-LL difference	-2.87 (21.56)	0.64 (14.74)	-6.65 (8.19)	4.65	.221	-2.80	.791
Postoperative length of stay (days)	3.82 (1.77)	3.80 (1.62)	4.72 (2.42)	-0.03	.88	0.878	.83

Abbreviations: SD, standard deviation; PI, pelvic incidence; LL, lumbar lordosis.

^aBolded text indicates statistically significant values at $P < .05$.

its role in management of short fusions is currently under debate. One study, by Hsieh et al, found that PI-LL mismatch and other radiographic parameters were not associated with risk of ASD after a short fusion for single-level DS.¹³ Similarly, Wang et al found that PI-LL mismatch may be more important in 2-level DS pathology. They noted that 2-level DS patients are more likely to have abnormal preoperative spinopelvic measures, and preoperative planning should give consideration for correction of PI-LL mismatch and sagittal imbalance.¹⁴ Future investigation should aim to better understand the implications of residual PI-LL mismatch after short segment lumbar fusion, and determine how this affects further radiographic, clinical, and PROs.

In addition, PROs for 2 and 3 or more level fusions were significantly worse after surgery when compared with single-

level fusions. These differences were observed both in ODI and VAS-back scores despite no significant differences in preoperative PROs. Though changes in PROs were not uniformly significant, and all groups experienced some degree of improvement after surgery, patients with single-level fusions tended to appreciate the greatest improvement in their symptoms. Conversely, Lee et al evaluated patients with degenerative spinal stenosis undergoing 1- and 2-level PLFs and found that these patients experienced significantly greater PRO scores when compared with 3 or more level fusions at 10 years follow-up.⁵ However, they argue that this difference may largely be due to the severity of the disease and extent of surgical procedure, delaying the recovery phase for longer PLFs. This may be the case with patients in this study, as patients with worse preoperative radiographic disease were

Table 3. Patient-Reported Outcomes^a.

	One Level, Mean (SD)	Two Levels, Mean (SD)	Three or More Levels, Mean (SD)	Two Levels (vs One) Multivariate Linear Regression		Three or More Levels (vs One) Multivariate Linear Regression		
				Beta	P	Beta	P	
Preoperative								
VAS back	6.04 (2.66)	6.78 (3.01)	6.49 (4.05)	0.89	.163	-1.13	.416	
VAS leg	5.56 (2.79)	5.55 (3.43)	6.51 (4.36)	-0.16	.837	-0.72	.663	
ODI	39.13 (15.34)	43.52 (15.79)	53.19 (27.42)	4.91	.174	3.81	.629	
Final								
VAS back	2.98 (2.91)	4.56 (3.08)	5.66 (3.15)	0.96	.224	1.54	.311	
VAS leg	3.43 (3.03)	3.92 (3.31)	2.99 (3.08)	0.76	.351	-1.07	.487	
ODI	26.47 (20.17)	33.31 (19.06)	37.96 (22.06)	4.05	.332	11.39	.138	
Change preoperative to final								
VAS back	3.58 (2.88)	2.18 (2.24)	0.14 (2.31)	-0.90	.383	-4.61	.016	
VAS leg	2.86 (3.64)	2.50 (3.80)	4.04 (5.43)	-1.15	.447	-1.12	.670	
ODI	15.58 (16.25)	13.58 (17.71)	3.51 (15.30)	-5.79	.294	-14.89	.134	

Abbreviations: SD, standard deviation; VAS, Visual Analog Scale; ODI, Oswestry Disability Index.

^aBolded text indicates statistically significant values at $P < .05$.

Table 4. Postoperative Complications and Reoperation^a.

	One Level		Two Levels		Three or More Levels		Two Levels (vs One) Multivariate Logistic Regression		Three or More Levels (vs One) Multivariate Logistic Regression	
	#	%	#	%	#	%	OR	P	OR	P
	Dural tear	9	4.43	16	16.84	2	11.11	5.18	.001	1.47
Postoperative complication	28	13.79	5	5.26	5	27.78	0.41	.081	3.21	.060
Discharge to facility	26	12.81	10	10.53	5	27.78	0.67	.376	4.00	.047
Reoperation	8	7.21	11	18.97	1	8.33	2.88	.039	1.00	—
Unspecified fracture	0	0.00	0	0.00	1	8.33	—	—	—	—
Pseudarthrosis	0	0.00	2	2.11	0	0.00	—	—	—	—
Deep soft tissue infection	0	0.00	1	1.05	0	0.00	—	—	—	—
Superficial soft tissue infection	1	0.49	0	0.00	0	0.00	—	—	—	—
Adjacent segment disease	6	2.96	6	6.32	0	0.00	—	—	—	—
Instrumentation complication	0	0.00	1	1.05	0	0.00	—	—	—	—
Recurrence of symptoms	0	0.00	1	1.05	0	0.00	—	—	—	—
Seroma	1	0.49	0	0.00	0	0.00	—	—	—	—
Pseudarthrosis (total)	10	6.9	8	10.81	0	0	1.66	.337	1.00	—

Abbreviation: OR, odds ratio.

^aBolded text indicates statistically significant values at $P < .05$.

selected for longer fusions. However, based on these findings, the potential for worse PROs should be discussed with the patient to better establish preoperative expectations and guide recovery goals.

Though no differences in postoperative complications or fusion rates were seen, longer fusions increased odds of dural tears, reoperation, and rates of discharge to facilities. Though number of fusion levels has been associated with increased rates of reoperation and discharge to facilities, the literature regarding dural tears has been mixed.¹⁵⁻¹⁷ Irrespective, these findings demonstrate an increased rate of potential complications and health care resource utilization in longer PLFs further complicates the risk-benefit profile of multilevel fusion in low-grade DS.

The present study does have several limitations. For instance, as a retrospective study, there was no randomization involved in determining who received a particular surgery; selection bias is a significant concern. This was evidenced by the fact 3 or more level fusions were used preferentially in patients with worse preoperative radiographic indices. However, multivariate analysis was used in an attempt to control for these differences by using baseline demographics as covariates. Similarly, the number of patients undergoing 3 or more level fusions was generally low. This may have led to low statistical power in some of this study's measured outcomes and may have underappreciated the true effect of multilevel fusion in low-grade DS. In addition, preoperative diagnoses likely differed between each group and may have had some

influence on reported outcomes. However, indications for 2- and 3-level lumbar fusions in the setting of 1-level DS without multilevel spinal stenosis differ from surgeon to surgeon. Similarly, although principles of treatment exist, much of the planned procedure decision making is often based on individual patients and the combination of their clinical and radiographic presentation. This makes it difficult to compare patients with similar baseline conditions, though conclusions about the number of levels fused in this cohort may still affect clinical decision making. Furthermore, full-length standing radiographs were not taken and prevents a global assessment of sagittal balance. Such differences can largely affect postoperative clinical outcomes and relevant health-related quality-of-life scores, and may have influenced the results presented here. Last, as with all studies conducted at a single institution, the findings of this study may not necessarily apply to the general population.

Conclusion

In the present study comparing radiographic and clinical outcomes of single-level versus multilevel fusion for DS, multilevel fusions experienced less improvement in back pain, had more complications, and were more commonly discharged to a facility compared with single-level PLF patients. These findings are important for operative planning, for setting appropriate preoperative expectations, and for risk stratification in patients undergoing posterior lumbar fusion for low-grade spondylolisthesis.

Declaration of Conflicting Interests


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