Iatrogenic spondylolisthesis following laminectomy for degenerative lumbar stenosis: systematic review and current concepts

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OBJECT Decompression without fusion for degenerative lumbar stenosis is an effective treatment for both the pain and disability of neurogenic claudication. Iatrogenic instability following decompression may require further intervention to stabilize the spine. The authors review the incidence of postsurgical instability following lumbar decompression, and assess the impact of surgical technique as well as study design on the incidence of instability.

METHODS A comprehensive literature search was performed to identify surgical cohorts of patients with degenerative lumbar stenosis, with and without preexisting spondylolisthesis, who were treated with laminectomy or minimally invasive decompression without fusion. Data on patient characteristics, surgical indications and techniques, clinical and radiographic outcomes, and reoperation rates were collected and analyzed.

RESULTS A systematic review of 24 studies involving 2496 patients was performed, assessing both open laminectomy and minimally invasive bilateral canal enlargement. Postoperative pain and functional outcomes were similar across the various studies, and postoperative radiographic instability was seen in 5.5% of patients. Instability was seen more frequently in patients with preexisting spondylolisthesis (12.6%) and in those treated with open laminectomy (12%). Reoperation for instability was required in 1.8% of all patients, and was higher for patients with preoperative spondylolisthesis (9.3%) and for those treated with open laminectomy (4.1%).

CONCLUSIONS Instability following lumbar decompression is a common occurrence. This is particularly true if decompression alone is selected as a surgical approach in patients with established spondylolisthesis. This complication may occur less commonly with the use of minimally invasive techniques; however, larger prospective cohort studies are necessary to more thoroughly explore these findings.

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KEY WORDS instability; laminectomy; lumbar stenosis; spondylolisthesis

SYMPTOMATIC lumbar spinal stenosis (LSS) can cause progressive neurogenic claudication, radicular pain, and weakness. Surgical intervention can provide for improvements in pain, disability, and health-related quality of life.⁴⁹ The pathoanatomy underlying the cross-sectional narrowing of the vertebral canal includes varying degrees of disc herniation and/or bulging, zygoapophyseal facet joint hypertrophy and cyst formation, and ligamentum flavum hypertrophy and buckling. In some cases, the degenerative disc disease permits spondylolisthesis as well.^{4,24} Neural element compression can cause neurogenic claudication from central canal stenosis or radiculopathy from lateral recess encroachment. Superimposed mechanical back symptoms may occur secondary to dynamic instability.

Although surgical decompression for neurogenic claudication has been shown to be efficacious, the role of fusion remains less clear. In certain subgroups, particularly those with degenerative spondylolisthesis or dynamic instability, there has been suggestion of benefit.^{18,25,42} Preoperative patient assessment prognosticating for postoperative instability may include overt instability or facet and disc morphology where decompression would be expected to cause iatrogenic instability.^{43,44} Segmental spinal stability is compromised by the very nature of the surgical approach, with the likelihood of excessive motion augmented when wider decompressions are performed, greater ligamentous disruption occurs, or multiple levels are included.^{11,31} Indeed, postlaminectomy instability is one of the most common indications for reoperation following decompression.

ABBREVIATIONS LSS = lumbar spinal stenosis; MIS = minimally invasive surgery; ODI = Oswestry Disability Index.

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sion.^{23,36} Minimally invasive surgery (MIS) techniques for the spine purport, among other advantages, to preserve the posterior osseoligamentous structures, and may minimize destabilization while achieving adequate decompression of the neural elements.^{2,28,30,37,39,47,54} Critics of MIS techniques note the possibility of inadequate decompression with some of these procedures.⁵¹

The goal of this review was to evaluate the incidence of postlaminectomy instability among patients with LSS who were symptomatic with neurogenic claudication, and whose condition was managed by decompression without fusion. The objectives were to compare the relative incidences of this complication by surgical technique and also to assess whether the reported rates of instability were affected by study design.

Illustrative Case

A patient was referred to the senior author with symptomatic flexion-induced radicular leg pain and paraspinal muscle spasm following a posterior lumbar decompression for neurogenic claudication. This 45-year-old man presented 3 months after L4–5 laminectomy and discectomy for left L-5 radiculopathy, with positional bilateral claudicant symptoms and disabling mechanical back pain. His symptoms were exacerbated by flexion, with dynamic spinal imaging demonstrating translational instability on supine to upright transition. Further investigations revealed the cause, with Fig. 1A—an axial CT scan—revealing the extensive decompression involving removal of the left L-4 inferior articular process. Revision decompression and transforaminal lumbar interbody fusion (Fig. 1B and C) provided him with a good clinical result for both back and leg symptoms.

Methods

We conducted a systematic search in MEDLINE, EMBASE, Scopus, Web of Science, and Google Scholar for literature published through May 2015, limiting the search results to human studies published in the English language. Search terms included “neurogenic claudication,” “lumbar spinal stenosis,” “decompression,” “laminectomy,” and “surgery,” as well as derivatives therefrom. Reference lists of key articles were also systematically checked to identify additional eligible articles. The specific question

asked focused on the incidence of postlaminectomy instability and whether it was variable by surgical technique, the presence of preoperative spondylolisthesis, and how instability was variably reported by retrospective and prospective studies. Case reports or case series that consisted of fewer than 10 patients were excluded. Other works that were excluded were animal, cadaveric, and biomechanical studies. Figure 2 summarizes this selection process.

Studies were included if a minimum mean follow-up of 12 months was achieved and reporting of pre- and postoperative sagittal lumbar alignment and reoperation rates was included. When multiple studies were found from the same cohort, only the report with the longer follow-up was included. Patients who were treated with fusion at the index operation were excluded from analysis.

Data Extraction

We extracted the following data from the included articles: study design, patient demographic information, diagnosis, and surgical procedure. From these studies, we also compiled the reported outcomes of new or progressive spondylolisthesis (radiographic findings), and of reoperation for postoperative instability (clinical findings). Furthermore, clinical outcomes extracted from the studies included those used by 3 or more studies: the Physical Function and Bodily Pain components of the 36-Item Short Form Health Survey, the Japanese Orthopaedic Association lumbar score,²⁶ the Oswestry Disability Index (ODI), and the visual analog scale for back and leg pain. Bias was assessed at the study level by using the Cochrane Risk of Bias tool, with each study thereafter assigned a grade of evidence reported in Table 1 alongside study characteristics.

Data Analysis

Because of the variable mechanisms of neurological outcome reporting, clinical outcomes were described in a systematic review format, with pooled estimates for dichotomous outcomes where feasible. Summary statistics regarding overall reported complication rates of instability and reoperation for stabilization were generated by pooled estimates based on study size. Two-factor weighted nominal logistic regression analysis was performed to define the dependence of both radiographic translational listhesis and repeated spinal operation for stabilization on the

FIG. 1. Postlaminectomy axial CT scan (A) reveals extensive lateral decompression with resection of the left inferior articular process of L-4. Postoperative anteroposterior (B) and lateral (C) radiographs show acceptable alignment of instrumentation after a transforaminal lumbar interbody fusion.

FIG. 2. Study selection flowchart of the search for articles pertaining to surgical management of LSS and incidence of postoperative instability.

presence of preoperative spondylolisthesis versus stenosis alone and the use of MIS versus open surgical intervention. The 0.05 level of significance was used with post hoc Tukey's analysis.

Results

Study Characteristics

The search strategy yielded 241 relevant citations, of which 198 were excluded based on title and/or abstract. Forty-three were selected for full-text review, of which 18 more were excluded due to lack of postoperative radiographic data in 11 studies, inclusion of only patients undergoing fusion in 6, or follow-up period less than 12 months in 1. Twenty-five papers were considered appropriate, of which 2 publications reported on differing follow-ups of the same cohort,^{33,49} so only the study with the longer follow-up was included. The flow of this process defining the final 24 studies is shown in Fig. 2, and the fundamental characteristics are shown in Table 1.

Fifteen of the studies were conducted prospectively,^{1,5–8,15,16,21,32,33,35,37,46,47,52} and 9 were conducted retrospectively.^{10,14,19,20,27,38–41} Postoperative instability was defined variably across studies, including increase in sagittal translation between flexion-extension radiographs by 2 mm,^{1,8,14} 3 mm,¹⁶ 5 mm,⁴⁷ 5%,²¹ or 8%,¹⁹ or an increase in sagittal angulation by more than 15° between flexion and extension.⁴¹ Reoperation rates were considered positive if the procedure was explicitly cited to be a fusion for instability, although studies rarely stated the specific indication motivating such fusion. Furthermore, reoperation for residual stenosis was not consistently reported across the studies reviewed herein.

Patient Characteristics

Table 2 summarizes the pooled characteristics of all the study patients. The mean patient age was 65.7 years, and 51% were male. The radiographic pattern was reportedly stenosis only in 42% of cases, stenosis and spondylolisthesis in 11% of cases, and the remainder was not defined between the two. Following surgical intervention, the mean follow-up across all studies was 43.5 months; 37.1 months for prospective studies and 54.1 months for retrospective studies.

Clinical Outcomes

Pooled clinical outcomes are summarized in Table 3. More than 50% improvement after surgery was seen in all metrics across the total cohort. Patients with stenosis exhibited greater improvement in ODI scores than those with both stenosis and spondylolisthesis, although both groups reached the minimum clinically important difference for improvement. Outcomes between open laminectomy and minimally invasive procedures were similar across all outcome measures.

Radiographic Progression and Reoperation

Table 4 delineates the radiographic outcome of progressive deformity and the incidence of reoperation. The overall incidence of new or increased postoperative spondylolisthesis was 5.5%, with a reoperation rate for instability of 1.8%, roughly one-third of patients in whom radiographic slip was detected. The radiographic progression was seen nearly twice as frequently in patients with preoperative Grade I–II spondylolisthesis compared with those having stenosis alone.

Retrospective studies reported the incidence of radiographic progression at 6.8% compared with 6.5% for prospective studies. There was a higher incidence of progression among patients with preexisting spondylolisthesis (17%) versus stenosis alone (5.3%, $p < 0.001$) and among patients in whom open decompression was performed (13%) compared with minimally invasive decompression (3.2%, $p < 0.001$). Reoperation rates were likewise similar between retrospective (1.2%) and prospective (2.3%) studies. There was a higher incidence of reoperation among patients with preexisting spondylolisthesis (8.9%) versus stenosis alone (1.1%, $p < 0.001$) and among patients in whom open decompression was performed (11%) compared with a minimally invasive decompression (0.7%, $p < 0.001$).

Discussion

Lumbar spinal stenosis is predominantly a disease of the elderly, and the most common indication for spine surgery in patients older than 65 years.⁹ Surgical decompression for symptomatic disease has been shown to improve quality-of-life outcomes in multiple randomized and non-randomized trials;^{3,34,50} however, there remains no consensus on the optimal surgical technique. In the US alone there is significant regional variation in technique, specifically whether to perform an arthrodesis.⁴⁸ Despite relative stability of the overall number of operations performed, there is a nationwide trend in the US increasingly toward

TABLE 1. Literature review of studies on degenerative lumbar stenosis

Authors & Year	Study Design	No. of Pts	M/F (%)	Mean Age (yrs)	Mean FU (mos)	Definition of Instability	Grade of Evidence*
Lurie et al., 2015	Prospective	358	62:38	63.9	96.0	Not defined	High (High)
Nomura et al., 2014	Retrospective	124	59:41	71.0	31.0	Increased translation	Very Low (Low – 1)
Chang et al., 2014	Prospective	165	57:43	68.7	40.0	Increased translation (>2 mm)	Moderate (High – 1)
Arai et al., 2014	Prospective	94	62:38	68.8	24.0	Increased translation (>2 mm)	Moderate (High – 1)
Minamide et al., 2013	Prospective	310	48:52	68.7	24.0	Increased translation	Low (High – 2)
Blumenthal et al., 2013	Prospective	40	25:75	68.2	43.0	Not defined	High (High)
Morgalla et al., 2011	Retrospective	108	47:53	71.0	12.0	Not defined	Very Low (Low – 1)
Hong et al., 2011	Retrospective	53	53:47	62.4	49.3	Flex/ext translation (>8%)	Low (Low)
Celik et al., 2010	Prospective	71	46:54	60.0	60.0	Flex/ext translation (>4 mm)	Moderate (High – 1)
Kelleher et al., 2010	Retrospective	75	52:48	68.0	47.5	Increased translation (>6%)	Low (Low)
Yagi et al., 2009	Prospective	41	34:66	72.1	18.2	Not defined	Low (High – 2)
Castro-Menendez et al., 2009	Prospective	50	58:42	56.0	48.0	Not defined	Moderate (High – 1)
Fu et al., 2008	Prospective	152	46:54	57.6	40.0	Not defined	Moderate (High – 1)
Ikuta et al., 2008	Prospective	37	35:65	69.0	38.0	Flex/ext translation (>5%) or angulation (>5°)	Moderate (High – 1)
Ofluoglu et al., 2007	Retrospective	34	41:59	57.5	23.0	Flex/ext angulation (>15°)	Low (Low)
Costa et al., 2007	Retrospective	374	49:51	64.7	30.3	Not defined	Very Low (Low – 1)
Oertel et al., 2006	Retrospective	102	55:45	63.4	67.2	Not defined	Low (Low)
Lin et al., 2006	Prospective	18	50:50	67.0	14.0	Not defined	Moderate (High – 1)
Thomé et al., 2005	Prospective	120	44:56	68.0	15.5	Flex/ext translation (>5 mm)	Moderate (High – 1)
Ghogawala et al., 2004	Prospective	20	32:68	68.8	12.0	Flex/ext translation (>3 mm)	Moderate (High – 1)
Mariconda et al., 2002	Prospective	22	27:73	62.6	47.0	Panjabi/White criteria	Moderate (High – 1)
Iguchi et al., 2000	Retrospective	37	51:49	60.9	157.2	Increased translation (>3 mm)	Low (Low)
Thomas et al., 1997	Prospective	26	NR	68.0	36.7	Not defined	High (High)
Fox et al., 1996	Retrospective	95	52:48	67.5	69.6	Flex/ext translation (>2 mm)	Low (Low)

Flex/ext = flexion/extension; FU = follow-up; NR = not reported; pts = patients.

* Grade—i.e., quality of evidence—is stated; the initial quality assessment and any modifiers are stated in parentheses.

complex fusion, which is associated with 2–3 times the upfront cost and often higher subsequent reoperation rates than decompression alone.^{12,13,29} Reflective of the lack of consensus, surgeon preference often outweighs patient clinical and radiographic factors as the primary determinant for whether fusion is performed.^{22,25}

Postoperative instability after lumbar decompression remains one of the primary motivators of arthrodesis performed during the index procedure, or in reoperations after decompression.²³ The incidence of postdecompression instability varies widely in the literature, ranging from 0% to 63%,^{1,14} due partly to the lack of standardized radiographic criteria.⁵³ In our review alone, 10 of 24 studies reported incidences of postoperative instability without specifying its definition; the remaining studies varied widely in their stated criteria. Patient heterogeneity also contributes to the variability in postoperative instability. Multiple observational studies have combined patients with and without preexisting degenerative spondylolisthesis, although the influence of preexisting spondylolisthesis on subsequent instability remains debatable.¹⁶

Biomechanical work has demonstrated increased segmental mobility following disruption of the posterior osseoligamentous structures in bilateral laminectomy.^{17,45} Several MIS procedures intended to preserve the posterior

tension band have been developed over the past 2 decades. The few existing studies directly comparing an MIS technique to open laminectomy have demonstrated superiority in pain and functional status, along with reduced blood loss, length of hospital stay, and cost, at relatively short fol-

TABLE 2. Summary of characteristics in patients with degenerative lumbar stenosis

Variable	Value
Age in yrs, mean ± SD	65.7 ± 4.7
% M/F	51:49
Surgical indication	
Stenosis	1039 (42%)
Stenosis & spondylolisthesis	285 (11%)
Undefined	1172 (47%)
Surgical technique	
Laminectomy	777 (31%)
Spinous process–splitting laminectomy	189 (7.5%)
Open ULBD	947 (37%)
Endoscopic ULBD	417 (17%)
Bilat laminotomy	196 (7.8%)

ULBD = unilateral laminotomy with bilateral decompression.

TABLE 3. Summary of clinical outcomes in patients with degenerative lumbar stenosis*

Subgroup	SF-36 PF			SF-36 BP			ODI			JOA		
	Preop	Postop	% Δ	Preop	Postop	% Δ	Preop	Postop	% Δ	Preop	Postop	% Δ
Stenosis	32.4 ± 1.2	61.2 ± 2.3	88.9	30.2 ± 2.1	57.6 ± 3.1	90.7	42.2 ± 10.7	6.3 ± 7.8	85.1	15.0 ± 0.0	24.7 ± 0.0	64.7
Stenosis & spondylolisthesis	29.1 ± 3.6	66.4 ± 7.2	128.2	25.3 ± 4.7	66.4 ± 6.8	162.4	39.6 ± 7.2	23.3 ± 3.5	41.2	14.7 ± 0.8	23.8 ± 0.4	61.9
Laminectomy	31.1 ± 6.5	51.4 ± 9.7	65.3	18.1 ± 0.0	44.9 ± 0.0	148.1	44.2 ± 2.9	8.4 ± 17.0	81.0	15.1 ± 0.5	24.1 ± 0.6	59.6
MIS decompression	29.0 ± 7.3	59.5 ± 11.8	105.2	23.6 ± 5.8	58.2 ± 8.1	146.6	43.8 ± 16.9	15.5 ± 12.6	64.6	14.8 ± 0.7	23.6 ± 0.4	59.4
Total cohort	30.3 ± 5.9	58.5 ± 9.9	93.1	27.4 ± 6.2	56.4 ± 9.3	105.8	43.5 ± 12.0	14.4 ± 10.6	66.9	14.4 ± 0.6	23.4 ± 0.92	62.5

(continued)

TABLE 3. Summary of clinical outcomes in patients with degenerative lumbar stenosis* (continued)

Subgroup	VAS Leg Pain (cm)			VAS Back Pain (cm)		
	Preop	Postop	% Δ	Preop	Postop	% Δ
Stenosis	6.0 ± 2.3	1.3 ± 1.8	78.3	3.0 ± 2.6	1.8 ± 2.2	40.0
Stenosis & spondylolisthesis	NR	NR	NR	7.3 ± 0.0	3.0 ± 0.0	58.9
Laminectomy	6.4 ± 1.9	2.0 ± 1.8	68.8	3.0 ± 4.1	2.0 ± 1.9	33.3
MIS decompression	7.9 ± 1.3	3.2 ± 1.2	59.5	5.2 ± 2.7	2.6 ± 1.4	50.0
Total cohort	7.7 ± 1.5	3.0 ± 1.3	61.0	4.5 ± 2.9	2.4 ± 1.4	46.7

JOA = Japanese Orthopaedic Association (lumbar pain score); SF-36 PF/BP = 36-Item Short Form Health Survey.

Physical Functioning/Bodily Pain component; VAS = visual analog scale.

* % Δ denotes percent change between pre- and postoperative scores; positive values indicate improvement in clinical outcome. All other values are expressed as the mean ± SD.

TABLE 4. Summary of patient outcomes for radiographic progression and need for stabilization surgery

Subgroup	New/Increased Spondylolisthesis at Mean FU (% of pts)	Reop for Postop Instability (% of pts)
Stenosis	6.8%	0.72%
Stenosis & spondylolisthesis	12.6%	9.3%
Laminectomy	12.0%	4.1%
MIS decompression	2.6%	0.81%
Total cohort	5.5%	1.8%

low-up intervals.^{15,46,47,52} Our review suggests no significant differences in clinical outcomes between MIS techniques and open laminectomy, although postoperative instability and reoperation rates were consistently reported to be lower for the less invasive techniques. What remains unclear is whether MIS approaches are associated with higher rates of reoperation for residual stenosis that was not adequately addressed in the indexed operation. Regrettably, the studies included in this analysis do not address acutely residual stenosis and cannot answer the question of surgical quality beyond the equivalence of reported clinical outcomes.

No significant differences in postoperative instability or reoperation rate were found between studies conducted prospectively or retrospectively in our review. Retrospective studies had a longer mean follow-up duration of 54.1 months, relative to 37.1 months for prospective studies, during which additional reoperative cases might be expected. However, the quality of follow-up in these retrospective series was often poor, with postoperative radiographs usually performed only in symptomatic patients. Because randomized controlled trials are also difficult with a heterogeneous patient group, studies of large, population-based, prospectively observed cohorts are required to identify significant predictors of radiographic and clinical outcomes in the neurogenic claudication population.²⁹

Study Limitations

This is a narrative review of retrospective and prospective clinical studies, in which the patient management was nonrandomized, subject to surgeon assessment of patient candidacy for secondary surgical intervention, and with unpredictable recording of complications. It is nevertheless reassuring that many of the complication rates for these studies are in line with magnitudes observed in reported national databases. The cost burden of this complication has not been rigorously addressed by any of the reviewed literature, and should be included in future prospective work so that both the patient outcome and economic burden are understood in the context of lumbar decompressive surgery. In parallel, though, the potential for postlaminectomy instability must be ruled in or out in the workup of every patient who has persistent postoperative pain following structurally decompressive spinal surgery before the diagnosis of failed back surgery syndrome or persistent postoperative neuropathic pain can be assigned.

Conclusions

Iatrogenic instability following decompression for

symptomatic LSS occurs in 5%–6% of patients. Interestingly, the rates reported have been consistent between both prospective and retrospective studies. Patients with preoperative spondylolisthesis undergoing decompression are nearly 10 times more likely to undergo a subsequent additional stabilization procedure than their stenosis-only counterparts. Minimally invasive surgical procedures may help protect patients from this complication, although more prospective studies with longer follow-up durations are necessary to better define whether this theoretical benefit will be realized in the longer term.

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