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Clinical Study

Lumbar degenerative spondylolisthesis: factors associated with the decision to fuse

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Abstract

BACKGROUND CONTEXT: The indication to perform a fusion and decompression surgery as opposed to decompression alone for lumbar degenerative spondylolisthesis (LDS) remains controversial. A variety of factors are considered when deciding on whether to fuse, including patient demographics, radiographic parameters, and symptom presentation. Likely surgeon preference has an important influence as well.

PURPOSE: The aim of this study was to assess factors associated with the decision of a Canadian academic spine surgeon to perform a fusion for LDS.

STUDY DESIGN/SETTING: This study is a retrospective analysis of patients prospectively enrolled in a multicenter Canadian study that was designed to evaluate the assessment and surgical management of LDS.

PATIENT SAMPLE: Inclusion criteria were patients with: radiographic evidence of LDS and neurogenic claudication or radicular pain, undergoing posterior decompression alone or posterior decompression and fusion, performed in one of seven, participating academic centers from 2015 to 2019.

OUTCOME MEASURES: Patient demographics, patient-rated outcome measures (Oswestry Disability Index [ODI], numberical rating scale back pain and leg pain, SF-12), and imaging parameters were recorded in the Canadian Spine Outcomes Research Network (CSORN) database. Surgeon factors were retrieved by survey of each participating surgeon and then linked to their specific patients within the database.

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METHODS: Univariate analysis was used to compare patient characteristics, imaging measures, and surgeon variables between those that had a fusion and those that had decompression alone. Multivariate backward logistic regression was used to identify the best combination of factors associated with the decision to perform a fusion.

RESULTS: This study includes 241 consecutively enrolled patients receiving surgery from 11 surgeons at 7 sites. Patients that had a fusion were younger (65.3±8.3 vs. 68.6±9.7 years, p=.012), had worse ODI scores (45.9±14.7 vs. 40.2±13.5, p=.007), a smaller average disc height (6.1±2.7 vs. 8.0±7.3 mm, p=.005), were more likely to have grade II spondylolisthesis (31% vs. 14%, p=.008), facet distraction (34% vs. 60%, p=.034), and a nonlordotic disc angle (26% vs. 17%, p=.038). The rate of fusion varied by individual surgeon and practice location (p<.001, respectively). Surgeons that were fellowship trained in Canada more frequently fused than those who fellowship trained outside of Canada (76% vs. 57%, p=.027). Surgeons on salary fused more frequently than surgeons remunerated by fee-for-service (80% vs. 64%, p=.004). In the multivariate analysis the clinical factors associated with an increased odds of fusion were decreasing age, decreasing disc height, and increasing ODI score; the radiographic factors were grade II spondylolisthesis and neutral or kyphotic standing disc type; and the surgeon factors were fellowship location, renumeration type and practice region. The odds of having a fusion surgery was more than two times greater for patients with a grade II spondylolisthesis or neutral and/or kyphotic standing disc type (opposed to lordotic standing disc type). Patients whose surgeon completed their fellowship in Canada, or whose surgeon was salaried (opposed to fee-for-service), or whose surgeon practiced in western Canada had twice the odds of having fusion surgery.

CONCLUSIONS: The decision to perform a fusion in addition to decompression for LDS is multifactorial. Although patient and radiographic parameters are important in the decision-making process, multiple surgeon factors are associated with the preference of a Canadian spine surgeon to perform a fusion for LDS. Future work is necessary to decrease treatment variability between surgeons and help facilitate the implementation of evidence-based decision making.

Keywords: Lumbar degenerative spondylolisthesis; Decompression; Instrumented fusion

Introduction

Lumbar degenerative spondylolisthesis (LDS) in association with spinal stenosis is a common indication for surgery with good outcomes compared to nonoperative treatment options [1]. Spondylolisthesis has been an accepted indication to fuse, however more recent anatomy sparing procedures have demonstrated good results for decompression alone [2]. Conflicting, limited level I evidence comparing laminectomy plus fusion to laminectomy alone for the treatment of degenerative spondylolisthesis continues to complicate considerations towards a standardized approach to LDS [3,4]. Although recent studies demonstrate that decompression without fusion for patients meeting specific indications leads to satisfactory outcomes [5−8], many spine surgeons hold the general view that spondylolisthesis is a sign of instability and thus a mandatory indication for additional fusion surgery [3]. A recent randomized controlled trial (Spinal Laminectomy vs. Instrumented Pedicle Screw; SLIP trial) found that a lumbar laminectomy without fusion had significantly greater reoperation rates [4]. By contrast, a contemporaneous randomized controlled trial, showed similar rates of reoperation in the fusion group versus decompression only group, and equivalent clinical outcomes at 2 and 5 years follow-up periods [3].

Given the controversy surrounding the treatment of degenerative lumbar spondylolisthesis we sought to evaluate the factors associated with a surgeon's decision to perform a fusion with the decompression. North American Spine Society 2014 clinical guidelines for the Diagnosis and Treatment of Degenerative Lumbar Spondylolisthesis" states that "treatment should be based on the individual patient needs and the professional judgement of the treating physician" [2]. Our study sought to evaluate which factors are associated with an academic Canadian spine surgeon's decision to perform a fusion for management of LDS. We investigated clinically relevant factors that the authors thought may be considered in the clinical decision-making process which included patient demographics, preoperative patient symptoms and function as evaluated using patient rated outcome measures, and radiographic parameters. We also included surgeon factors more indicative of a surgeon's preference or training.

Methods and materials

Design

Our study used data from an ongoing prospective multicenter trial at seven academic centers, evaluating the preoperative assessment and surgical management of LDS. We used a study-specific cross-sectional survey of those surgeons (de-identified) participating in this study. The study is under the umbrella of the Canadian Spine Research

Outcomes Network (CSORN), but is independent of the CSORN Registry. Canadian Spine Research Outcomes Network is comprised of Neurosurgical and Orthopedic spine surgeons across Canada and was created to answer research questions and facilitate the implementation of best practices. Details on the CSORN registry data set and data collection have been described elsewhere [9]. Local IRB approval was obtained for the multicentered prospective trial at all sites.

This study represents a consecutive series of patients prospectively enrolled between January 1, 2015 and April 30, 2019, in the CSORN multicentered study on the assessment and management of LDS. Patients enrolled met the following inclusion criteria: radiographic evidence of LDS at one or two levels with symptoms of neurogenic claudication or radiculopathy with or without back pain, undergoing posterior decompression alone or posterior decompression and fusion, and unresponsive to at least 6 weeks of nonoperative management. Patients were excluded if they had tumors, isthmic spondylolisthesis, or spinal fracture, previous lumbar spine surgery other than a remote discectomy or laminectomy; concomitant cervical or thoracic myelopathy,

Outcome measures

Patient demographics and clinical characteristics were collected at the initial surgical consultation. Procedural data regarding the type of procedure (decompression vs. decompression and fusion) were collected at the time of surgery. Preoperative radiographic variables were measured by each participating surgeon on standing and recumbent lumbar lateral radiographs and standing 36-inch lateral radiographs of the entire spine. This included grade of slip, mobility of slip (mm), number of involved levels, disc height, disc angle (lordotic or neutral and/or kyphotic), facet distraction on MRI (yes or no), pelvic tilt, pelvic incidence (PI), lumbar lordosis (LL), and sagittal vertical axis. Pelvic parameters were measured according to that described previously [10].

Patient-rated outcome measures included the Oswestry Disability Index (ODI), the numeric rating scale for back pain and leg pain, and patient health questionnaire-9 (PHQ9). The ODI evaluates physical disability secondary to back and leg pains on a scale of 0 to 100 with a higher score indicating worsening function [11]. The numeric rating scale for back pain ranges from 0 to 10, with lower scores indicating less severe symptoms [12]. The PHQ9 is a validated measure of depression, and is categorized into one of five groups: Minimal (score 0−4), mild (score 5−9), moderate (score 10−14), moderate-severe (score 15−19), and sever (score 20−27) [13].

Survey instrument

In the winter of 2019, a self-administered survey was distributed to all surgeons participating in the LDS prospective study that had enrolled a minimum of five consecutive patients. Participation in the survey was voluntary and no direct incentive was provided for completing it. Surgeon demographic and practice-specific data were collected including years of practice, surgical specialty (orthopedic vs. neurosurgeon), practice type (academic vs. community), hospital location, practice region (east vs. west; six out of 11 surgeons are located in the west), location of fellowship training (Canada vs. elsewhere), length of surgical wait list, years of practice, remuneration (salaried vs. fee-for-service), and spine subspecialty (ie, deformity, minimally invasive surgery (MIS), tumor, etc.). If a surgeon received fellowship training at more than one location, but had fellowship training in Canada the surgeon was considered Canadian trained.

Statistical analysis

Patient characteristics, Patient-rated outcome measures, radiographic measures, and surgeon variables were compared between patients that had decompression with a fusion (fusion group) and those that had decompression without a fusion (decompression alone group) using the Student *t* test for continuous parametric variables or the Mann-Whitney *U* test for continuous nonparametric variables. Comparisons for categorical variables were made using the chi-square test or the Fisher's exact test. For analysis pelvic tilt was dichotomized into two groups <20 or ≥ 20 and Sagittal Vertical axis into <50mm or ≥ 50mm, PI to LL mismatch into LL$<$PI-10° or LL $\geq$PI$\geq$10°.

Variables that that were deemed to be statistically significant ($p<.05$) or were clinically meaningful were included in the multivariate analysis. Collinearity was evaluated by calculation of tolerance and covariates were excluded if collinearity was detected. Hospital location was dichotomized to practice region (western Canada vs. eastern Canada). Multivariate backward stepwise, conditional, logistic regression was used to identify the best combination of variables that are associated with fusion versus decompression only. Individual predictor variables were eliminated in a backward fashion if the corresponding p value was $<.10$. Cases with missing data were excluded from the model. The discriminative ability was assessed using Reciever operator Curve and by comparing the predicted versus the observed by area under the curve. Data analysis was performed using SPSS 24 (IBM, SPSS Inc., Chicago, IL, USA).

Results

Between January 1, 2015 and April 30, 2019, 310 consecutive patients were prospectively enrolled in the CSORN DLS study. Of these patients, 241 were patients of the 11 surgeons who agreed to complete the survey. Baseline demographic characteristics, health-measures and radiographic findings are shown in Table 1. Sixty-five patients had a decompression only procedure and 176 patients had a decompression and fusion. The majority of the study population was women and overweight with an average BMI of 29 kg/m^2. Most patients were nonsmokers and more than

Table 1.
Baseline demographic characteristics, health-related measures and radiographic findings

Variable	No fusion (n=65)	Fusion (n=176)	p value
Demographic variables			
Age, years, mean±SD	68.6±9.7	65.3±8.3	.012
Gender, woman, n (%)	37 (56.9)	115 (65.3)	.233
Number of comorbidities, mean±SD	3.4±1.9	3.2±1.8	.529
Body mass index, kg/m^2, mean±SD	28.7±5.2	28.7±6.8	.977
Work status, n (%)			.285
Currently working	18/63 (28.6)	38/171 (22.2)	
Employed but not working	2/63 (3.2)	17/171 (9.9)	
Retiree	37/63 (58.7)	90/171 (52.6)	
Other	4/63 (6.3)	14/171 (8.2)	
Not employed	2/63 (3.2)	12/171 (7.0)	
Current smoker, n (%)	6/62 (9.7)	26/170 (15.3)	.389
Opioid use, n (%)	16/48 (33.3)	63/131 (48.1)	.091
Patient-rated health outcome measures			
Back pain, mean±SD	6.71±2.3	7.1±2.1	.184
Leg pain, mean±SD	6.8±2.6	7.5±2.2	.044
ODI, mean±SD	40.2±13.5	45.9±14.7	.007
PHQ9, mean±SD	6.3±4.6	9.1±6.0	.001
Radiographic variables			
Grade of slip, n (%)			.008
Grade I	56 (86.2)	122 (69.3)	
Grade II*	9 (13.8)	54 (30.7)	
Level(s) involved, n (%)			.618
L2−3	1/65 (1.5)	0/173 (0.0)	
L3−4	9/65 (13.8)	22/173 (12.7)	
L3−4−5	0/65 (0.0)	1/173 (0.6)	
L4−5	54/65 (83.1)	147/173 (85.0)	
L4−5−S1	0/65 (0.0)	1/173 (0.6)	
L5−S1	1/65 (1.5)	2/173 (1.2)	
†Mobility of slip ≥3 mm, n (%)	10/57 (17.5)	37/156 (23.7)	.455
Average disc height at Affected level, mm, mean±SD	8.0±7.3	6.1±2.7	.005
Disc angle, n (%)			.005
Kyphotic	2/65 (3.1)	26/168 (15.5)	
Lordotic	52/65 (80.0)	99/168 (58.9)	
Neutral	11/65 (16.9)	43/168 (25.6)	
Facet distraction, n (%)	9/26 (34.6)	42/70 (60.0)	.038
Pelvic tilt PT>20^0, n (%)	44/62 (71.0)	103/164 (62.8)	.277
PI-LL≥10^0, n (%)	36/62 (58.1)	91/164 (55.5)	.756
SVA ≥50 mm, n (%)	8/53 (15.1)	36/152 (23.7)	.244

LL, lumbar lordosis; ODI, Oswestry Disability Index; PHQ9, patient health questionnaire-9; PI, pelvic incidence.

Varying denominators indicate missing data for patients in some categories.

For Back pain and Leg Pain data was available for 63 patients in the no fusion group and n=170 in the fusion group.

For PHQ9 and ODI data was available for n=63 patients in the no fusion group and n=172 for the fusion group.

For BMI data was available for n=62 patients in the no fusion group and 170 patients in the fusion group.

For comorbidities data was available for 63 patients in the no fusion group and 172 patients in the fusion group.

For Ave Disc Height data was available for 61 patients in the no fusion group and 166 patients in the fusion group.

* Included 1 Grade III.

† Mobility = degree of translation standing - degree of translation supine ≥3 mm.

half had at least 3 or more comorbidities. The demographic characteristics were not different between the decompression alone group and fusion group except there was a tendency for increased opioid use in the latter cohort (33% vs. 48%, p=.091), and patients that had a fusion were younger (65.3±8.3 vs. 68.6±9.7 years, p=.012). The fusion group included 32 (18 %) interbody fusions and 144 (82 %) posterolateral fusions. Forty nine percent of patients in the decompression alone cohort and 21% of patients in the fusion group had a minimally invasive approach. 35% of patients in the decompression alone cohort and 19% of patients in the fusion cohort had an operation that involved multiple levels.

Baseline patient-rated outcome measures

Accordingly, leg pain (6.8±2.6 vs. 7.5±2.2, p=.044) and disability (ODI score, 40.2±13.5 vs. 45.9±14.7, p=.007) were significantly worse in patients in the fusion group. Additionally, PHQ9 scores were significantly higher in the decompression and fusion cohort indicating worse mental functioning (p=.001). Back pain, however, was similar between the two groups (decompression alone, 6.71±2.3 vs. fusion, 7.1±2.1, p=.184).

Radiographic measures

The majority of patients in the decompression alone group had a grade I slip whereas more patients in the decompression and fusion cohort had a grade II slip (p=.008). In both cohorts L4−5 was the most common level involved (p=.618). Eighteen percent of patients in the decompression alone cohort and 24% of patients in the decompression and fusion group had mobility of the slip ≥3 mm (p=.455). The average disc height at the affected level was smaller in patients in the decompression and fusion cohort compared to the decompression alone group (6.1±2.7 vs. 8.0±7.3, p=.005). Additionally, more patients in the decompression and fusion group had a kyphotic or neutral disc angle whereas the majority of patients in the decompression alone group had a lordotic disc angle (p=.005). Facet distraction or effusion was more common in patients in the decompression and fusion group (60% vs. 35%, p=.038); however, data was missing for nearly half of the patients on this measure. Pelvic parameters including pelvic tilt ≥20°, PI-LL≥10°, and Sagital vertical Axis ≥ 50 mm were not different between the two groups.

Surgeon factors

Eleven of the 13 surgeons (85%) completed the questionnaire. All surgeons were fellowship trained and were working at an academic center. The rate of decompression and fusion as compared to decompression alone varied according to surgeon (p<.001; Fig. 1, Top), hospital location, (p<.001; Fig. 1, Middle), and practice region (p=.013). Surgeons average length of practice was

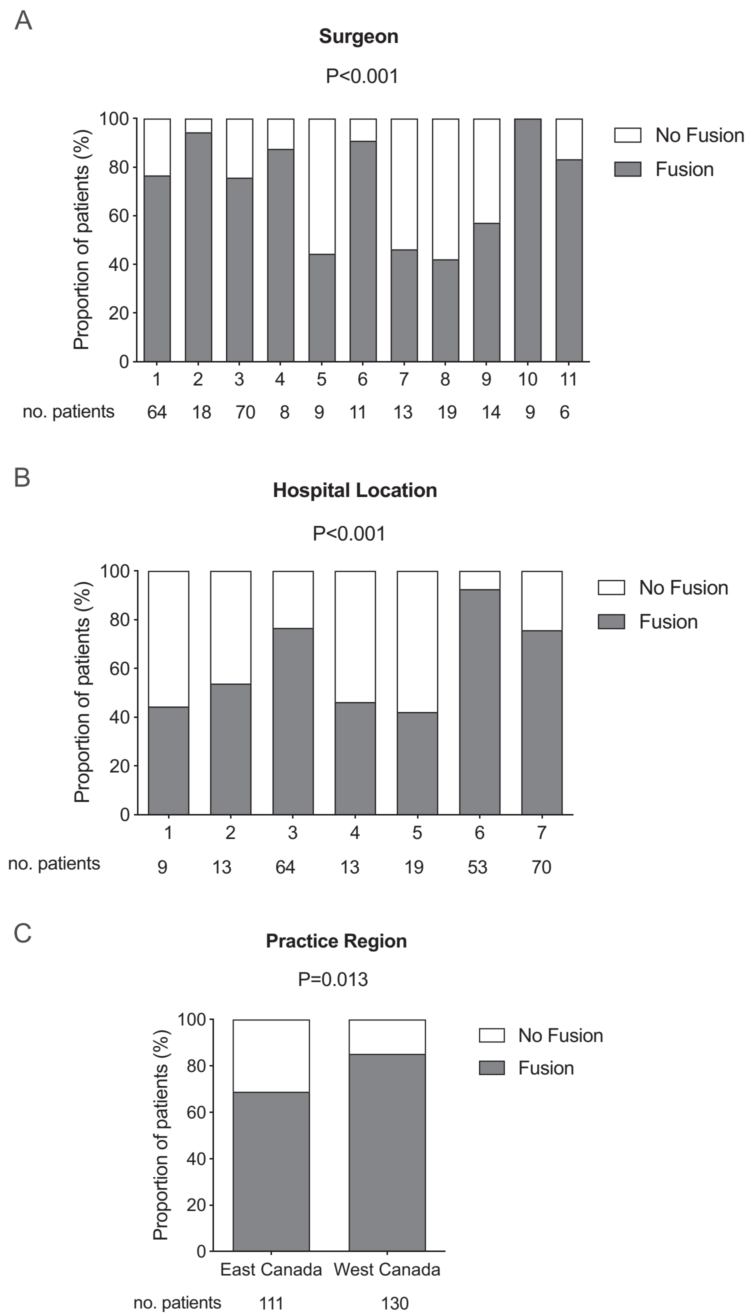

Fig. 1. The proportion of patients that had a decompression and fusion compared to the proportion of patients that had a decompression only according to (Top) surgeon and (Middle) hospital location and (Bottom) practice region (East Canada vs. West Canada; 50% of surgeons in the West).

12.5 years and this was not different between treatment groups (p=.950; Fig. 2, A). The length of surgical wait list was on average 16 months and was not different between the groups (p=.951; Fig. 2, B). Surgeons that subspecialized in minimally invasive surgery were more likely to perform minimally invasive surgery (74% vs. 26%, p=.001), and they were less likely to fuse (35.4% vs. 15.3%; Fig. 2, C). Surgeons who were on salary were more likely to fuse compared to those remunerated by fee-for-service (80% vs. 64%, p=.004; Fig. 2, D). Surgeons who were fellowship trained in Canada were more likely to fuse than those who trained elsewhere (76% vs. 60%, p=.027; Fig. 2, E). The rate of fusion among neurosurgeons and orthopedic surgeons was similar (93% vs. 72%, p=.076; Fig. 2, F).

Multivariable results

The multivariable logistic regression results are shown in Table 2. Two hundred and seventeen cases were included in the logistic regression analysis. ODI and PHQ9 score as well as fellowship location and MIS subspecialty were highly colinear so PHQ9 and MIS subspecialty were not

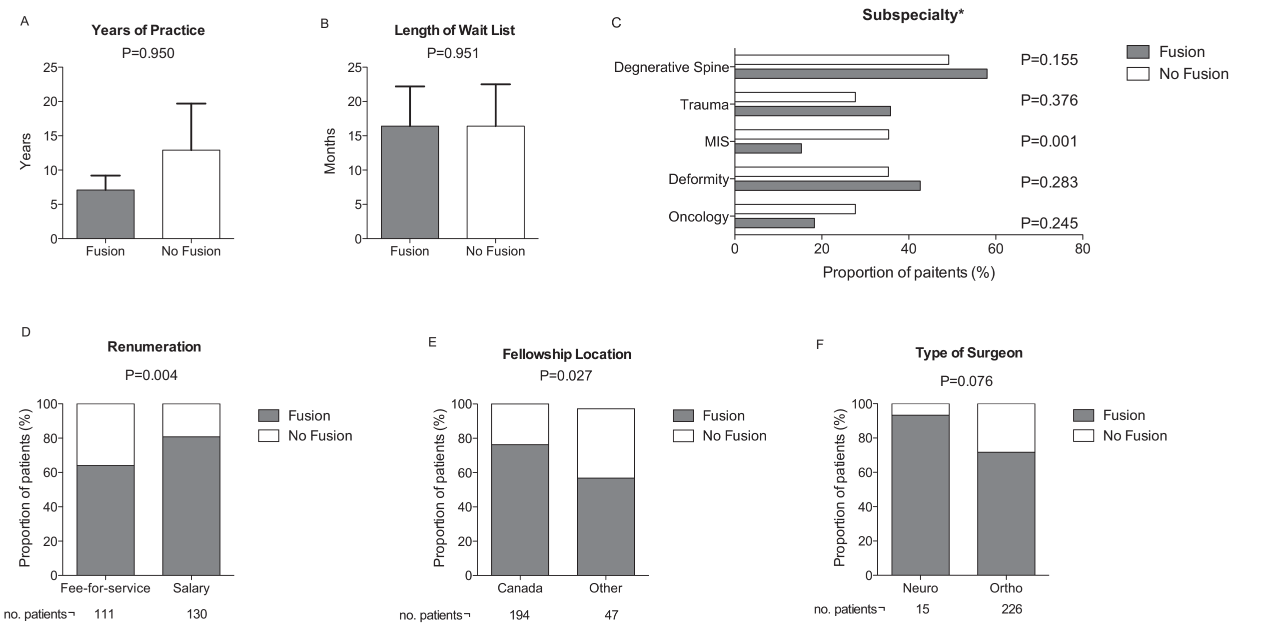

Fig. 2. Surgeon factors associated with decompression alone and decompression and fusion. (A) years of practice, (B) length of wait list, (C) subspecialty, (D) renumeration, (E) fellowship location, and (F) type of surgeon (neuro= neurosurgeon; ortho = orthopedic surgeon). Values are mean ± standard deviation or proportion. *, surgeons could have more than one subspecialty.

included as covariates in the analysis. Variable entered into the model were age, spondylolisthesis grade (grade I or II), disc height, ODI score at baseline, remuneration (salary vs. fee for service), standing disc type (neutral or kyphotic vs. lordotic), fellowship in Canada (yes or no) and practice region (western vs. eastern Canada). All variables entered into the analysis were included in the final model showing association with performing a fusion surgery. Clinical factors associated with an increased odds of fusion included decreasing age, decreasing disc height, and increasing ODI score. Radiographic factors associated with an increased odds of having fusion surgery included grade II spondylolisthesis and neutral or kyphotic standing disc type (as compared to lordocitc standing disc type). Surgeon factors associated with an increased odds of fusion included fellowship location, renumeration type and practice region. Patients whose surgeon completed their fellowship in Canada had 2.6 times the odds of having fusion surgery. Surgeons on salary had 2.1 times the odds of performing fusion surgery compared to those that were on fee-for-service. Surgeons who practiced in western Canada had 2.7 times the odds of performing fusion surgery compared to those who practice in eastern Canada. The Hosmer and Lemeshow test suggested a good fit to the data (chi-square 9.435, p=.307). The area under the receiver operator characteristic curve was 0.785±0.033 suggesting the model had acceptable modest discriminative ability.

Discussion

Our study has identified a number of variables that are associated with a surgeon's decision to choose decompression

Table 2.
Multivariate logistic regression analysis: patient, radiographic, and surgeon factors predictive of fusion surgery

	β±S.E.	p value	Odds Ratio	95% CI	
				Lower	Upper
Age, years	−0.04±0.02	.083	0.96	0.924	1.00
Spondylolisthesis grade II	1.1±0.5	.012	3.30	1.30	8.38
Disc height, mm	−0.07±0.04	.037	0.93	0.87	0.99
Renumeration - salary	0.7±0.4	.058	2.09	0.98	4.48
Noniordotic disc angle	0.8±0.4	.040	2.29	1.09	5.09
Fellowship in Canada	0.9±0.5	.030	2.56	1.109	6.00
ODI score	0.02±0.01	.076	1.02	0.99	1.04
Practice region - West	0.9±0.4	.036	2.68	1.06	6.76

ODI, Oswestry Disability Index.

Complete case analysis n=217.

Variable entered into the model: Age, spondylisthesis grade (grade I or II), disc height, ODI score at baseline, remuneration (salary vs. fee for service), standing disc type (neutral or kyphotic vs. lordotic), and fellowship in Canada (yes or no), and practice region (western Canada vs. eastern Canada).

and fusion when treating LDS. Of the patient demographic variables analyzed only patient age was associated with the decision to fuse. Younger patients were more likely to be fused than older patients. The result is expected if one considers the longer life expectancy of a young patient and are of the belief that over time a decompression only surgery might result in reoperation. In fact, there is little evidence which compares the long term repeat surgery rates between decompression and decompression and/or fusion in LDS and that evidence is contradictory [14]. Another explanation for age being an important factor in the decision-making process is that fusions are more invasive procedures of which older patients may be more frail and less tolerant. However, associated comorbidities were not different between the fusion and no fusion group and thus may represent a surgeon bias [15]. Furthermore, older patients generally are more likely to have a stiff multilevel degenerative spine that might indicate a more stable situation. Gender, BMI, occupation, working status also did not correlate with the decision to fuse. Although gender has been found in previous studies to be a negative prognostic factor it was not found to be influential toward the decision to fuse [16].

A number of patient-rated health outcome measures correlated with the decision to fuse including leg pain, PHQ9, and ODI. In the multivariable analysis, a higher ODI (greater disability) correlated with the preference for fusion in our population. Traditionally, a patient with greater degree of back pain has been considered for a fusion procedure whereas a patient with leg dominant symptoms a decompression [7]. The SLIP trial demonstrated a nearly double rate of revision surgery within 4 years of the initial surgery in the decompression (complete laminectomy) alone group, which may be explained by a revision fusion being performed by a surgeon to address residual back pain or related disability [4]. Interestingly, in contrast to the perception that fusions should be considered for the LDS patients with more significant back pain, it has been recently demonstrated that back pain is responsive to decompression surgery without a fusion [17].

A number of radiographic parameters were associated with a surgeon's decision to perform a fusion including the grade of slip, disc height at the affected level, disc angle, and facet distraction. These factors are generally felt to correlate with greater instability, and an increased likelihood a fusion surgery being required [18]. A kyphotic or neutral disc was more likely to receive a fusion than a lordotic disc. Presumably, these patients were treated with interbody devices in hopes of correcting the segmental alignment if the disc did not correct into lordosis with positioning on the operative table. Facet distraction may be a sign of mobility of the spondylolisthesis and a grade 2 slip was more likely to undergo fusion than a grade 1 [19]. Loss of disc height is often considered a reflection of increased stability as opposed to a higher disc height that has potential to collapse and lead to progression of the spondylolisthesis. In our study, decreased disc height was found to correlate with fusion. A decreased disc height can be associated with foraminal stenosis; which may be the explanation for why it correlated with fusion in this patient cohort. Unfortunately, foraminal stenosis was not prospectively evaluated in this study.

It was not surprising to identify a number of surgeon dependent factors correlating with the decision to fuse, as the literature is controversial regarding the indications and outcomes of fusion versus no fusion for LDS [2−4,20]. Surgeon factors associated with fusion in the univariate analysis included hospital location, practice region, location of fellowship training, remuneration type, and subspecialty training in MIS. Multivariate analysis revealed strong regional preferences exist within Canada with respect to a surgeon's decision to perform fusion in addition to decompression for LDS. Similar region preference for fusion has been demonstrated in the United States [21,22]. These preferences also appear to be associated with a surgeon's decision making when a fellowship has been completed within Canada as opposed to internationally. A surprising finding was that salaried surgeons were more likely to perform a fusion in addition to decompression than surgeons paid on a fee-for-service basis. However, the study surgeons from western Canada are mostly salaried and are more likely to perform a fusion, as opposed to the study surgeons in eastern Canada who are mostly fee for service. Intuitively, a widely held belief is that fusion surgery would be more favorable financially in a fee-for-service model as it pays more than decompression only surgery, even after factoring in the additional time required. The multivariate analysis found that location of fellowship training and remuneration type as surgeon factors best correlated with decision to fuse.

Our study has a number of strengths including a large sample size of consecutively collected patients with an associated robust dataset providing insight into the important demographic, clinical, and radiographic factors correlated with the decision to fuse. However, our data was limited in that our surgeon survey sample size was small, the majority were fellowship trained orthopedic spine, and all the surgeons worked in one of five academic institutions. In that respect, our findings are well generalized to academic institutions across Canada and likely North America, but less so to a community-based practice. Importantly, the majority of spine surgery in Canada is performed at academic affiliated centers. In spite of the numerous efforts taken to avoid biases our study is limited by its retrospective design. Confounding biases may still exist in the study population and selection of variables which may affect our conclusions. Other potential factors associated with the decision to fuse which were not collected in this study included foraminal stenosis, patient frailty, and etiology of stenosis such as large synovial cysts. Another limitation is that this study is not predictive but rather demonstrates association between surgeon-related factors and the decision to fuse.

This study identified a number of important factors that are associated with a spine surgeon's decision to perform a fusion in addition to decompression for management of LDS. Although evidence based radiographic and patient variables were associated with this decision-making, the results of this study also confirmed that surgeon specific factors, which represent training and treatment preference, also had a significant association. This study is the first to illustrate the inconsistent approach that exists for the treatment of LDS across Canada, which is likely generalizable to other countries as well. Due to the ongoing controversy in high level evidence surrounding fusion for LDS and the evolving treatment philosophies and techniques, nonscientific factors such as surgeon preference and training are potentially influential, Therefore, this study illustrates why it is important that further well-designed robust studies examine the longer-term outcomes of the surgical treatment of LDS and further evaluate clinical factors, such as those elucidated in this study, so to identify those essential to evidence based decision making.

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