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Clinical Studies

Laminoplasty versus laminectomy with fusion for treating multilevel degenerative cervical myelopathy

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ABSTRACT

Background: Laminectomy with fusion (LF) and laminoplasty (LP) are common posterior decompression procedures used to treat multilevel degenerative cervical myelopathy (DCM). There is debate on their relative efficacy and safety for treatment of DCM. The goal of this study is to examine outcomes and costs of LF and LP procedures for DCM.

Methods: This is a retrospective review of adult patients (<18) at a single center who underwent elective LP and LF of at least 3 levels from C3-C7. Outcome measures included operative characteristics, inpatient mobility status, length of stay, complications, revision surgery, VAS neck pain scores, and changes in radiographic alignment. Oral opioid analgesic needs and hospital cost comparison were also assessed.

Results: LP cohort (n=76) and LF cohort (n=59) reported no difference in neck pain at baseline, 1, 6, 12, and 24 months postoperatively (p>.05). Patients were successfully weaned off opioids at similar rates (LF: 88%, LP: 86%). Fixed and variable costs respectively with LF cases hospital were higher, 15.7% and 25.7% compared to LP cases (p=.03 and p<.001). LF has a longer length of stay (4.2 vs. 3.1 days, p=.001). Wound-related complications were 5 times more likely after LF (13.6% vs. 5.9%, RR: 5.15) and C5 palsy rates were similar across the groups (LF: 11.9% LP: 5.6% RR: 1.8). Ground-level falls requiring an emergency department visit were more likely after LF (11.9% vs. 2.6%, p=.04).

Conclusions: When treating multilevel DCM, LP has similar rates of new or increasing axial neck pain compared to LF. LF was associated with greater hospital costs, length of stay, and complications compared to LP. LP may in fact be a less morbid and more cost-effective alternative to LF for patients without cervical deformity.

Introduction

Degenerative cervical myelopathy (DCM) is a debilitating neurological condition with diverse symptoms, including radiculopathy, decreased manual dexterity, weakness, and gait imbalance. The pathophysiology of DCM involves degenerative changes which cause narrowing of the spinal canal and compression of the spinal cord. Aging is a primary risk factor, but genetic polymorphisms and chronic conditions have also been implicated [1]. Surgical decompression remains the most effective treatment for progressive or severe forms of this condition, and demand for these surgeries is expected to continue growing [2,3]. Cervical decompression procedures utilize either anterior, poste-

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rior, or combined approaches. Anterior approaches are indicated for focal or anterior disease while posterior approaches are often indicated for multilevel or posterior pathologies [4]. The most common techniques for posterior decompression include laminectomy with spinal fusion (LF) and laminoplasty (LP).

While laminoplasty was initially pioneered in Japan specifically for the treatment of ossification of the posterior longitudinal ligament (OPLL), some authors have suggested that patients with laminoplasty may have more postoperative neck pain than those patients' undergoing laminectomy with fusion [5,6]. Additionally, some North American surgeons may not have had surgical training which included laminoplasty especially since there is a strong reimbursement incentive of LF over LP in most health systems, adding to the bias surgeons may have toward LF. In a survey of North American surgeons, 70% preferred LF for treating DCM, compared to 22% who preferred LP [7]. While laminectomy with fusion is clearly indicated in patients with spinal instability, there is added concern that adjacent segment disease will be a greater issue after instrumented fusion [2].

LP is currently understood to be a viable surgical alternative to LF when cervical deformity and instability are precluded. Contradictory to early claims that LP is associated with worse postoperative neck pain, several studies have observed that there may be no statistically significant difference [8–10]. Postoperative C5 palsy was also thought to be more likely with LP, but other studies found no such association [11,12]. In select centers, LP has been associated with lower cost and shorter hospital stays [13]. Despite these observations, the relative utility and efficacy of LF and LP for patients with multilevel DCM remains controversial. Considering the expected continued increase in the number of surgical procedures performed to treat DCM with an aging population, further review of costs and benefits of these procedures is warranted. This single-center retrospective study aims to improve understanding regarding the relative efficacy of LF and LP with a focus on cost, complications, and postoperative neck pain.

Methods

Cohort selection

This retrospective study was approved by an institutional review board. The authors' hospital information technology service provided a preliminary list containing patients who were at least 18 years of age at the time of surgery and received either LF or LP between January 1, 2014, and September 30, 2020. Patients included in this study received elective surgery for a primary diagnosis of DCM. Exclusion criteria were prior history of cervical spine surgery, any anterior component to the surgery, and any diagnosis of metastatic disease, tumor, acute trauma, or infection. Preoperative and postoperative evaluations and radiographs were conducted at one outpatient spine clinic. The LF cohort included 59 patients and the LP cohort included 76 patients.

Surgical details

All procedures involved 3 or more vertebral levels. Decompression with either laminectomy or open door laminoplasty were performed on any level of the subaxial cervical spine (C3–7). Some patients receiving LF required fusion instrumentation at C2, T1, or T2 as indicated at the discretion of the treating spinal surgeons.

Data collection

Clinical data were obtained by retrospective review of patient's electronic medical records. Clinical data including patient-reported visual analog scale (VAS) neck pain scores and complications were obtained from clinical visit notes. Fixed and relative hospital costs were obtained from the hospital billing department for procedures performed after 2015. Financial records before 2015 were not available due to a change in storage systems. In total, the costs analysis subgroup involved 38 LF and 47 LP patients. Fixed costs represent the charges incurred by the hospital to maintain regular facility operations during the length of a patient's hospital stay. Variable costs represent the charges incurred by the hospital in direct management of a patient during their stay, including consumable equipment, implants, and staff wages.

Costs were adjusted for inflation to the currency value on January 01, 2020. Potential variations over time in vendor prices and charges for line items were unadjusted. Opioid analgesic requirement data was obtained from physician orders placed from and accessible by our medical record system. An adaptation of the Consortium to Study Opioid Risks and Trends (CONSORT) system was used to classify opioid prescription patterns into one of 4 categories: none, short-term, episodic, and long-term. Successful management of opioid needs was defined as either achievement of a lower CONSORT class or maintaining a status of no opioid use if no opioids were needed preoperatively. Opioid data was available for a subgroup of 44 LF patients and 52 LP patients. Values were standardized to morphine milligram equivalents per guidelines from the Centers for Disease Control and Prevention [14]. For patients who required a revision procedure, no additional clinical data was collected after their revision procedure.

Radiographic measurements

Three radiographic measurements were made from neutral upright radiographs: C2–7 cervical lordosis angle, cervical sagittal vertical axis (cSVA), and T1 slope angle. The last preoperative image was selected for each patient's preoperative measurements. Postoperative images were taken 6 to 10 weeks after discharge. Cervical lordosis angle was measured as a modified Cobb angle from the inferior endplate of the C2 vertebral body to the superior endplate of the C7 vertebral body on a lateral radiograph. cSVA was measured as the distance drawn by a plumb line from the middle of the C2 vertebral body to the superior-posterior corner of the C7 body. T1 slope angle was determined by the angle between the superior endplate of the C2 body and a horizontal line.

Statistical analysis

Statistical analysis was performed using SPSS version 27.0 (SPSS Inc). A mixed-effects model was used to model serial VAS neck pain scores over postoperative time, which was treated as a fixed effect. Preoperative VAS scores were considered a random effect. Two other factors examined in the mixed-effects model were the involvement of the C7 level and the number of operative levels. Within- and between-group differences of other outcomes were compared with the chi-square test, paired and unpaired t-test, and mixed-model ANOVA. Results were described as means, incidence rates (%), and 2 standard deviations (±). Statistical significance was assigned to p values £ 0.05.

Results

Cohort Characteristics

The average follow-up time in this study was 14.4 months. Patients in the LF group were followed for an average of 15.32±10.10 months and LP patients were followed for 13.69±10.52 months. There was no significant difference in average follow up time between groups (p=.37). There were 2 significant differences in the baseline characteristics of cohorts (Table 1). The mean age of LP patients was approximately 5 years below the mean age of LF patients. There were also fewer females in the LP cohort (35.5% compared to 57.6%, p=.01).

Operative details

Table 2 summarizes the operative details of the 2 cohorts. On average, LF procedures were more extensive with more levels involved per

Table 1
Preoperative characteristics of patients in each group.

Measure	LF	LP	p value
Number of cases	59	76	
Age at surgery (years)	65.5±9.0	60.5±12.0	**.007***
Gender (female rate)	57.6%	35.5%	**.010***
BMI (kg/m^2)	30.7±6.7	31.6±6.3	.389*
Tobacco use 1 year preceding surgery	25.4%	23.7%	.816†
ASA Physical Status: class 1-2, 3-4	22.0%, 78.0%	35.5%, 64.5%	.089†
Diabetes status (rate of diabetics)	25.4%	21.1%	.549†

* T-test.
† Chi-square test.

Table 2
Intraoperative characteristics.

Measure	LF	LP	p value
Number of operative levels	6.9 ± 1.4	4.2 ± 0.6	**<.001***
Number of decompressed levels	4.8 ± 0.9	4.2 ± 0.6	**<.001***
Number of fused levels	6.9 ± 1.5		
C7 level involvement	52 (88.1%)	24 (31.6%)	**<.001†**
Operation time (minutes)	284 ± 67	197 ± 72	**<.001***
EBL (mL)	263 ± 215	250 ± 304	.785*
Fluid replacement (mL)	2488 ± 827	2200 ± 1012	.078*

EBL, estimated blood loss.
* Unpaired T-test.
† Chi-square test.

procedure (6.9–4.2). This is mostly due to extension of posterior spinal fusion above or below decompressed levels in LF (6.9 levels fused, on average). When comparing only the number of decompressed levels, LF was only slightly more extensive (4.8–4.2). Most LF cases involved or crossed the C7 level whereas most LP procedures were limited to the subaxial spine. Although operation time was greater in the LF group, there were no differences in blood loss or fluid replacement.

Radiographic measurements of cervical alignment

For radiographic measurements, all patients with limited postoperative follow-up under 3 months were excluded from analysis resulting in a total of 132 patients with 57 LF and 75 LP. The average follow-up time for LF group was 12 months and average follow-up time for LP group was 13.3 months (p= .249). Preoperative and postoperative radiographic measurements are displayed in Table 5. Patients selected for LP had greater cervical lordosis at baseline (11.8° vs. 6.9°, p=.017) and both groups lost similar lordosis with surgery (-4.5° to -1.7°, p=.166). Ultimately, postoperative lordosis was comparable between groups (LF = 5.3°, LP=7.3°, p=.262). The average cSVA was similar between groups both preoperatively and postoperatively. The cSVA was significantly increased in both groups, and the degree of change was similar regardless of procedure type (LF = +9.6 mm, LP = +6.8 mm, p=.183). LF and LP groups had comparable T1 slope at baseline. After surgery the T1 slope decreased in LP group (-4.4, p<.01) but did not change appreciably in LF group. Procedure type had a significant effect on the degree of change to T1 slope (p=.005).

Hospitalization, discharge, and hospital costs

Length of hospitalization was approximately one day shorter in the LP group than in the LF group (Table 3). A similar rate of patients in both groups achieved independent mobility before discharge, and the time to mobility was similar between groups. Rates of discharge to home versus either rehabilitation or skilled nursing facilities were also similar (p=.792). In the subgroup analysis of hospital costs from 38 patients in the LF group and 47 patients in the LP group, LP cases incurred 18.6% and 34.5% lower fixed and variable costs compared to LF cases (p=.03 and p<.001).

Complications, readmissions, and revisions

Complication rates, readmissions, and revision rates are summarized in Table 4. Of note, the C5 palsy rates were 11.9% for LF and 5.6% for LP patients with a RR of 1.8. While rates of deltoid (C5) palsy, neurogenic bowel or bladder, myocardial infarction or deep-vein thrombosis, and other palsies were similar between groups, the wound infection or dehiscence was significantly more common in the LF group (13.6%–5.9%). Patients who received LF were approximately 5 times more likely to experience wound infection or dehiscence. There were 2 occurrences of dural tears in the LF group and one occurrence of sepsis, systemic inflammatory response syndrome, or septic shock. Neither cohort reported any incidence of dysphagia, seroma, or hematoma. LP trended lower rates of readmission and lower rates of unplanned return to the operating room, although only the latter statistic was significant (p=.041). Observed rates of revision surgery were not statistically significant between groups. While patients who received LP were equally likely to visit an emergency department (ED) for neck pain as patients who received LF, they were significantly less likely to require ED visits following a ground-level fall.

Neck pain

There were no differences in VAS neck pain scores between groups at baseline and at 1, 6, 12, and 24 months of follow up (Table 6). Comparing the average of all postoperative VAS scores to baseline values, both groups reported a modest net improvement in neck pain. The mixed-model analysis found that postoperative scores improved with

Table 3
Hospitalization outcomes and subgroup analysis of hospital costs.

Measure	LF	LP	p value
Length of hospitalization (days)	4.2 ± 2.2	3.1 ± 1.5	**.001***
Mobilized independently before discharge	76.3%	80.3%	.575†
Time to independent mobility (days)‡	3.2 ± 2.4	2.4 ± 1.6	.065*
Discharge location			.192†
Home	81.4%	78.9%	.729†
SNF or rehab facility	18.6%	21.1%	
Subgroup size for cost analysis§	38	47	
Fixed costs to hospital‖	$21,941 ± 6,149	$18,500 ± 7,926	**.031***
Variable costs to hospital‖	$25,972 ± 7,856	$19,310 ± 6,229	**<.001***

SNF skilled nursing facility.
* Unpaired T-test.
† Chi-square.
‡ Includes only patients who mobilized independently prior to discharge.
§ Includes cases since January 2015.
‖ Currency value adjusted for inflation.

Table 4
Postoperative complications, readmissions, and revisions.

Measure	LF	LP	p value	Risk ratio (95% CI)
Any complication	18 (30.5%)	12 (15.8%)	**.041***	1.93 (1.01 - 3.69)
Deltoid or C5 palsy	7 (11.9%)	5 (6.6%)	.284*	1.80 (.60 - 5.40)
Wound infection or dehiscence	8 (13.6%)	2 (5.9%)	**.021***	5.15 (1.14 - 23.37)
Neurogenic bowel or bladder	3 (5.1%)	2 (2.6%)	.653*	1.93 (.33 - 11.19)
MI or DVT requiring therapy	2 (3.4%)	3 (3.9%)	1.000*	.86 (.15 - 4.97)
Other palsy or paresthesia	1 (1.7%)	2 (2.6%)	1.000*	.64 (.06 - 6.93)
Dural tear	2 (3.4%)	0	.189*	
Sepsis, SIRS, or Septic shock	1 (1.7%)	0	.437*	
Dysphagia	0	0		
Seroma or hematoma	0	0		
Readmitted for complication within 30 d	11 (18.6%)	6 (7.9%)	.062*	2.36 (.93 - 6.01)
Unplanned return to OR within 30 d	7 (11.9%)	2 (2.6%)	**.041***	4.51 (.97 - 20.91)
Required a revision surgery	2 (3.4%)	6 (7.9%)	.465*	.43 (.09 - 2.1)
Mean time to revision (months)	7.2	5.5	.457†	
Visited ED for neck pain within 24 mo	8 (13.6%)	7 (9.2%)	.425*	1.47 (.57 - 3.83)
Visited ED following GLF within 24 mo	7 (11.9%)	2 (2.6%)	.041*	4.51 (.97 - 20.91)

MI, myocardial infarction; DVT, deep-vein thrombosis; GLF, ground-level fall; SIRS, Systemic Inflammatory Response Syndrome;
OR, operating room; ED, emergency department.
* Chi-square test.
† Unpaired T-test.

Table 5
Radiographic outcomes within and between groups.

			Preop vs. Postop	
	Preop	Postop	Change	p value
Cervical lordosis angle (°)				
LF	6.9±11.6	5.3±9.9	-1.7±11.6	.287*
LP	11.8±11.3	7.3±10.5	-4.5±11.6	**.001***
LF versus LP (p value)	**.017**†	.262†	.166‡	
SVA (mm)				
LF	32.6±16.6	42.2±16.4	+9.6±14.0	**<.001***
LP	34.7±15.4	41.5±18.3	+6.8±10.5	**<.001***
LF versus LP (p value)	.440†	.824†	.183‡	
T1 slope angle (°)				
LF	31.6±10.5	31.8±11.8	+.2±9.8	.908a
LP	33.2±9.7	28.8±10.3	-4.4±8.6	**<.001***
LF versus LP (p value)	.374b	.125b	**.005**‡	

cSVA cervical sagittal vertical axis.
* Paired T-test.
† Unpaired T-test.
‡ Mixed-design ANOVA of alignment change between groups.

Table 6
Patient-reported axial neck pain.

Mean VAS neck pain	LF	LP	p value*
Preoperative	5.6±3.0	4.7±2.9	.082
1 mo postop	4.4±3.1	4.4±3.0	.984
6 mo postop	3.5±3.0	3.7±3.1	.705
12 mo postop	3.5±2.9	3.8±3.1	.595
24 mo postop	3.6±2.9	3.8±3.1	.668
All postop, averaged	3.8±2.5	3.9±2.7	.799
Net change from preop	-1.8±2.3	-0.8±2.4	**.016**
Net change from preop (p value)	**<.001**†	**<.001**†	
Effect of key factors on change to VAS	p value‡		
Procedure type: LF or LP	.663		
Time since procedure	**.001**		
C7 Involvement	.313		
Operative levels: 3–5 vs. 6–8 levels	.869		
Absolute changes to neck pain after surgery	LF	LP	p value§
New-onset neck pain	4 (6.8%)	8 (10.5%)	.448
Resolution of neck pain	4 (6.8%)	6 (7.9%)	.806

VAS, visual analog scale for pain.
* Unpaired T-test.
† Paired T-test.
‡ Mixed-effects model of postoperative VAS neck pain scores over time.
§ Chi-square test.

time (p=.001). There was no significant difference to this effect between LF and LP groups (p=.663). Neither the involvement of the C7 level nor the number of operative levels were significant factors on reported neck pain (p=.313 and p=.869, respectively). Patients who underwent LP were not more likely to report new-onset neck pain after surgery (10.5% vs. 6.8%, p=.448). Complete resolution of preoperative neck pain was equally likely after LF or LP (p=.806).

Opioid requirements

Table 7 shows opioid analgesic requirements compared between LF and LP. Using the CONSORT classification, groups had a similar proportion of patients with short-term, episodic, and long-term opioid needs, both preoperatively and postoperatively (p=.661 and p=.405, respectively). The rate of patients achieving a lower opioid needs classification after surgery was 88.1% in the LF group and 85.5% in the LP group (p=.658). The prevalence of patients still requiring opioids at 3 months was 23.7% in the LF group and 17.1% in the LP group (p=.340). At one year follow-up, this prevalence declined to 8.5% and 10.5%, respectively (p=.689). There was no difference between groups in the maximum prescribed daily dose of opioids before or after surgery (p=.068 and p=1.000, respectively). Early postoperative analgesic needs were also similar at the time of discharge, as represented by the total dose and length of opioid prescriptions supplied (p=.899 and p=.289, respectively).

Discussion

Laminoplasty and laminectomy with fusion are both recognized as viable and effective posterior surgical procedures for multilevel DCM. The choice of treatment is still subject to debate and equally subject to practitioner bias. With this study, we compared complication rates, postoperative pain, hospitalization length of stay, costs, and adverse events between patients treated with LP as compared to LF. Previous literature suggests that LP patients have more axial neck pain after operation than

Table 7
Opioid analgesic prescription requirements and outcomes.

Measure	LF	LP	p value
Preoperative CONSORT opioid availability			
None	40 (67.8%)	49 (64.5%)	.661*
Short-term or episodic	16 (27.1%)	20 (26.3%)	
Long-term	3 (5.1%)	7 (9.2%)	
Postoperative CONSORT opioid availability			
None	52 (88.1%)	63 (82.9%)	.405*
Short-term or episodic	5 (8.5%)	6 (7.9%)	
Long-term	2 (3.4%)	7 (9.2%)	
Success†			
No	7 (11.9%)	11 (14.5%)	.658*
Yes	52 (88.1%)	65 (85.5%)	
Point prevalence‡			
3 mo postoperatively	14 (23.7%)	13 (17.1%)	.340*
1 year postoperatively	5 (8.5%)	8 (10.5%)	.689*
Maximum prescribed daily dose (MME/day)			
Preoperative, median and IQR	44 (23–60)	30 (20–52)	.068§
Postoperative, median and IQR	23 (17–40)	30 (19–57)	1.000§
Opioid prescriptions at Discharge			
Total prescription MME, median and IQR	900 (60–1,350)	900 (450–1337)	.899§
Total days supplied, median and IQR	9 (5–15)	8 (5–15)	.289§

CONSORT, Consortium to Study Opioid Risks and Trends; MME, Morphine Milligram Equivalents; IQR, Interquartile Range.

* Chi-square test.

† Defined as either achieving an improved CONSORT opioid availability classification postoperatively compared to preoperatively, or maintaining a status of no opioid use.

‡ The prevalence of opioid availability between 83-97 and 358-372 days after discharge, respectively.

§ Wilcoxon rank sum test.

those patients who undergo LF. In addition, LP has a perceived association amongst surgeons for a greater risk of C5 palsy compared to LF [15].

In our study, VAS neck pain scores significantly improved shortly following both LF and LP, and then improved slightly further with a maximal effect seen between 6 and 12 months postoperatively. There was no significant difference in reported pain between groups at each post-op interval up to 24 months. The average improvement in overall pain was slightly greater in the LF group (1.8 points compared to 0.8 points for the LP group); however, this difference is likely attributed to a trend of greater baseline pain in the LF group, Other studies have seen a similar pattern of slightly greater pain improvement with LF in the setting of higher pain at baseline [16,17]. This phenomenon remains difficult to interpret due to the wide range of values of VAS score changes published by other comparison studies, varying between 0.2 and 4 points; in contrast, other studies observed greater pain improvement after LP [18]. Meta-analyses and systemic reviews have found no meaningful difference between LF and LP in postoperative neck pain [11,19]. When also examining the involvement of the C7 level and the number of operative levels in our cohorts, neither parameter was a significant factor on reported neck pain. This finding agrees with Wang et al. [20] who did not find an association between C7 involvement and pain in their systematic review involving laminoplasty cases. Overall, our results support the notion that there are no clear or consistent differences related to neck pain to warrant influencing the decision between LF and LP.

A major concern regarding the use of LP remains the risk for postoperative cervical kyphosis. Patients who received LP at our institution had adequate reserve of cervical lordosis at baseline, suggesting an appropriate selection of surgical candidates. Postoperatively, lordosis and cSVA both converged when comparing LF and LP. Considering the relationship between neck alignment and pain, the similarity of postoperative alignments seen here may help explain the similarity of our pain outcomes. This relationship was described in detail by Lau et al. [9] as they found no difference in postoperative pain in their cohorts with matched lordosis and cSVA. We suggest that risks to cervical alignment (and associated worse pain) after LP may be sufficiently mitigated with careful surgical selection.

Although we found equivalent pain outcomes between LP and LF, performance of these procedures should be examined in the context of their overall safety and cost efficiency. The lower complication profile observed with laminoplasty is largely a product of lower rates of would infection and dehiscence, which are likely attributed to the inherently less expansive and invasive technique of the laminoplasty procedure. The LP cohort experienced half as many total complications (15.8% vs. 30.5%), including a significantly lower rate of wound infection or dehiscence. Furthermore, LP was not associated with greater rates of C5 palsy as many believe to be true. Patients in the LP group were significantly less likely to have an unplanned return to the OR (2.6% vs. 11.9%, $p<.05$). Length of hospitalization was approximately one day shorter in the LP group than in the LF group, aligning with numerous other studies from hospitals in the United States [9,10,13,21]. Despite the longer hospitalization time of the LF group, both groups achieved an equivalent rate of independent mobility before discharge. Time to mobility was similar between groups, and a similar proportion of patients were discharged home. The shorter hospitalization time was likely a major contributor to decreased incurred costs within the LP cohort, which is consistent with findings from Warren at al. and Highsmith [13,22]. Highsmith et al. also attributed the difference in costs to higher prices of LF implants, but we cannot directly confirm this association from our data. Our LP cohort also likely incurred lower hospital costs due to fewer complications [22].

Postoperative ED visits incur a financial burden on the healthcare system which has not been previously investigated in the comparison of LF and LP. ED visits occurring after surgery can also serve as an indicator of patient safety and satisfaction. In this study, patients who received LP were equally likely to visit an ED for neck pain as patients who received LF, further suggesting there is little difference in postoperative neck pain between procedures. Additionally, patients who received LP were approximately 4 times less likely to visit the ED following a ground-level fall, highlighting the potential safety benefits of the motion-sparing technique. Our findings suggest the LP procedure may have a safer recovery period due to fewer falls requiring emergency care.

Postoperative pain and opioid analgesic use are intertwined. It has been published that more than half of patients who used opioids before spine surgery will continue to require opioids 12 months after surgery [23–25]. In comparison, roughly 20% of opioid naïve patients may continue to need opioids postoperatively up to the 12-month mark [23–25]. Our LF and LP cohorts had a lower prevalence of opioid availability of 8.5% and 10.5% at the 12-month mark, with no significant difference detected between groups. Furthermore, 88.1% and 85.5% of patients in LF and LP cohorts, respectively, successfully modified opioid needs. These success rates are consistent with the pooled success rate of all spine procedure types as a whole as published by Warner et al. [25] Our analysis appears to be the first direct comparison of opioid requirements after LF and LP. Our results suggest no difference in the pattern of opioid requirements between these procedures.

Limitations

The limitations of this study are largely related to the retrospective design. Another inherent limitation of our study is that the laminectomy with fusion group represented a cohort in whom more levels were treated surgically. In the laminectomy and fusion group, LF, 90 % of patients had C7 treated surgically with likely extension of the fusion to T2. The reflexive bias of always spanning the cervico-thoracic junction and never stopping fusion at C7 (obligatory C2–T2) is another bias that leads to longer, more costly operative procedures that are not driven by current evidence but by surgical dogma. Less than one-third of the laminoplasty patient group in this study involved extension to C7 and therefore the surgical comparison groups are not perfectly matched. There is an inherent patient selection bias when comparing surgical procedures because indications for laminoplasty and laminectomy tend to be different. Each patient is evaluated on a case-by-case basis and patient desires are considered in the decision-making process. As in all retrospective reviews, there are various unknown confounders that cannot be assessed or accounted for that may affect the outcomes of interest. In our study of all qualifying cases at one institution, the composition of cohorts differed in age, gender, and the number of levels decompressed. The cause of age and gender differences is not clear but may reflect an association between gender and presentation of DCM pathology. Regarding the cost analysis, financial data was only available for a subset of each cohort, and these subsets may not be representative samples of cohorts. Costs data may also be affected by hospital-specific factors such as potential vendor discounts for certain hardware. Such discounts were unknown from the data available. Lastly, the analysis of opioid requirements used data available from documented opioid prescriptions, but those prescriptions are not necessarily dispensed by a pharmacy or used by patients. Furthermore, we assumed the maximum dose utilized by the number *prescribed*, which may have contributed to an overestimation of opioid use.

Conclusions

LP and LF are safe and effective procedures for treating multilevel DCM. Despite previous presumptions, LP does not appear to be associated with new or increasing severity of axial neck pain when compared to LF. Instead, patients experienced similar and significantly reduced pain levels after undergoing either procedure, which was also indicated by improvements in patterns of opioid needs. There was also no difference in ED visits for neck pain between groups. The overall similarity in pain outcomes may indicate that effective spinal cord decompression can be achieved with either technique. Moreover, similarities in postoperative cervical alignment mirrored (and likely contributed to) the similarities in postoperative neck pain. Considering the relationship between neck alignment and pain, sufficient reserve of cervical lordosis is a plausible predictor of better postoperative pain after LP.

When cervical deformity and baseline cervical lordosis are not prohibitive, LP could offer a less morbid and cost-efficient option for treating DCM. LP was associated with an overall lower complication rate compared to LF; this included significantly lower rates of infection or dehiscence, and fewer unplanned returns to the OR. LP was thus associated with significantly shorter and less expensive hospitalizations. Fewer ED visits for ground-level falls occurred after LP, and we recommend this factor be considered in predicting patient safety and quality of life.

DCM operations are increasing without a proportional increase in the utilization of LP [5,26]. However, our study suggests there are lost benefits to patients. Patients with spinal stability and adequate cervical lordosis may benefit from LP over LF with similar pain reduction, lower chances of complication, lower cost, and shorter hospital stays. In comparison, patients with spinal instability or a lack of cervical lordosis reserve may benefit more from LF. Modern patient-reported outcomes and randomized controlled trials are still needed to optimize the utility and surgical decision making for both procedures.

Declaration of Competing Interest

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms.

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