

Clinical Study

Laminectomy and fusion versus laminoplasty for the treatment of degenerative cervical myelopathy: results from the AOSpine North America and International prospective multicenter studies

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Received 31 March 2016; revised 20 July 2016; accepted 9 August 2016

Abstract

BACKGROUND CONTEXT: It remains unclear whether cervical laminoplasty (LP) offers advantages over cervical laminectomy and fusion (LF) in patients undergoing posterior decompression for degenerative cervical myelopathy (DCM).

PURPOSE: The objective of this study is to compare outcomes of LP and LF.

STUDY DESIGN/SETTING: This is a multicenter international prospective cohort study.

PATIENT SAMPLE: A total of 266 surgically treated symptomatic DCM patients undergoing cervical decompression using LP (N=100) or LF (N=166) were included.

FDA device/drug status: Not applicable.

Author disclosures: **MGF:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **CS:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **LT:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **PA:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript; Royalties: Evoke Medical (Nonfinancial), outside the submitted work; Stock Ownership: Evoke Medical, Z-Plasty (A), outside the submitted work; Consulting: Medtronic Sofamor Danek (B), Stryker Spine (D), FzioMed (C), outside the submitted work; Trips/Travel: AOSpine North America (F, Reimbursement only), outside the submitted work. **GB:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **HD:** Other: AOSpine (D, collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **SK:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript. **QZ:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially

by AOSpine International and North America), pertaining to submitted manuscript. **TSY:** Grant: AOSpine (F, Paid to the institution), pertaining to submitted manuscript; Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript; Royalties: Stryker Spine (D, Paid to the institution), outside the submitted manuscript; Trips/Travel: ISSLS (B), outside the submitted work; Research Support (Investigator Salary, Staff/Materials): NuVasive (Paid to the institution, Implants for biomechanical testing), Medtronic (Paid to the institution, Implants for biomechanical testing), outside the submitted work; Grants: Biomet Spine (F, Paid to the institution), outside the submitted work; Fellowship Support: AOSpine (F, Paid to the institution), outside the submitted work; Stock Ownership: Meditech Spine (<1% ownership at some point during the last 3 years), Medyssey (<1% ownership at some point during the last 3 years), Phygen (<1% ownership at some point during the last 3 years), Alphatec (<1% ownership at some point during the last 3 years). **BK:** Other: AOSpine (F, Paid to the institution, Collection of the data was supported financially by AOSpine International and North America), pertaining to submitted manuscript.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

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OUTCOME MEASURES: The outcome measures were the modified Japanese Orthopaedic Association score (mJOA), Nurick grade, Neck Disability Index (NDI), Short-Form 36v2 (SF36v2), length of hospital stay, length of stay in the intensive care unit, treatment complications, and reoperations.

METHODS: Differences in outcomes between the LP and LF groups were analyzed by analysis of variance and analysis of covariance. The dependent variable in all analyses was the change score between baseline and 24-month follow-up, and the independent variable was surgical procedure (LP or LF). In the analysis of covariance, outcomes were compared between cohorts while adjusting for gender, age, smoking, number of operative levels, duration of symptoms, geographic region, and baseline scores.

RESULTS: There were no differences in age, gender, smoking status, number of operated levels, and baseline Nurick, NDI, and SF36v2 scores between the LP and LF groups. Preoperative mJOA was lower in the LP compared with the LF group (11.52 ± 2.77 and 12.30 ± 2.85 , respectively, $p = .0297$). Patients in both groups showed significant improvements in mJOA, Nurick grade, NDI, and SF36v2 physical and mental health component scores 24 months after surgery ($p < .0001$). At 24 months, mJOA scores improved by 3.49 (95% confidence interval [CI]: 2.84, 4.13) in the LP group compared with 2.39 (95% CI: 1.91, 2.86) in the LF group ($p = .0069$). Nurick grades improved by 1.57 (95% CI: 1.23, 1.90) in the LP group and 1.18 (95% CI: 0.92, 1.44) in the LF group ($p = .0770$). There were no differences between the groups with respect to NDI and SF36v2 outcomes. After adjustment for preoperative characteristics, surgical factors and geographic region, the differences in mJOA between surgical groups were no longer significant. The rate of treatment-related complications in the LF group was 28.31% compared with 21.00% in the LP group ($p = .1079$).

CONCLUSIONS: Both LP and LF are effective at improving clinical disease severity, functional status, and quality of life in patients with DCM. In an unadjusted analysis, patients treated with LP achieved greater improvements on the mJOA at 24-month follow-up than those who received LF; however, these differences were insignificant following adjustment for relevant confounders. © 2016 Elsevier Inc. All rights reserved.

Keywords:

Decompression/surgical; Efficacy/treatment; Laminectomy; Laminoplasty; Myelopathy/compressive; Outcome/treatment

Introduction

Degenerative cervical myelopathy (DCM) is a progressive degenerative spine disease and the most common cause of spinal cord dysfunction in adults worldwide [1]. The term DCM encompasses all forms of degenerative changes to the cervical spine, including spondylosis, hypertrophy or ossification of the spinal ligaments, disc herniation, or subluxation. These changes lead to impingement of spinal nerve roots and the spinal cord, and may cause upper motor neuron symptoms in the upper and lower extremities, gait disorders, and bowel and bladder dysfunction. Signs and symptoms of DCM are often managed surgically with anterior decompression and fusion, laminectomy with instrumented fusion (LF), or laminoplasty (LP) [2]. The ideal surgical approach remains unclear and is a source of ongoing debate. Factors that influence surgical decision making include location of compression (dorsal vs. ventral), sagittal alignment, extent of disease (focal vs. diffuse), the presence or absence of radiculopathy or axial pain, and various patient demographics (eg, age and comorbidities) [3]. In a study by Fehlings et al., patients treated anteriorly had more focal pathology, were younger, and had less severe myelopathy than those treated posteriorly. Following adjustment for these differences in baseline characteristics, there were no significant differences in surgical outcomes between the two approaches [4].

Posterior surgical techniques include LF and LP. The LF technique involves the expansion of the spinal canal through the removal of the lamina, as well as stabilization of the spine

through screw fixation in subaxial lateral masses or pedicles (eg, for C7), with possible extension to C2 or the upper thoracic spine with pars or pedicle screw fixation [5]. There are diverse methods of LP, all of which result in cervical decompression through expansion of the lamina to increase the area available for the spinal cord [5]. In contrast to LF, LP maintains cervical range of motion and preserves the posterior elements which serve as sites for muscle attachment. When determining what posterior procedure to use, one of the most important factors for decision making is surgeon familiarity and experience with each technique [3]; specifically, surgeons from East Asia prefer LP, whereas those in North America are more accustomed to LF. With respect to outcomes, the literature is inconclusive as to whether one approach offers any advantages compared with the other [6–9]. Studies on this subject include only retrospective or small prospective studies. The objective of this analysis was to compare outcomes of LF and LP using one of the largest prospective multicenter datasets on surgical DCM patients.

Materials and methods

Subjects

This study was conducted in accordance with STROBE research guidelines (Appendix S1).

Seven hundred fifty-seven patients participated in either the cervical spondylotic myelopathy (CSM)-North America (clinicaltrials.gov NCT00285337) or CSM-International

EVIDENCE & METHODS

Context

There are a variety of options for the treatment of patients with cervical myelopathy, including posterior decompression and fusion or laminoplasty. The authors present a retrospective review of prospectively collected data from the AOSpine North America and International Prospective Multicenter Studies.

Contribution

The study included 266 patients, with 100 treated using laminoplasty and 166 with decompression and fusion. Patients improved following both treatments. In adjusted analysis, there were no differences between the two treatment groups in terms of the outcomes evaluated.

Implications

The authors' analysis adds to the current literature, demonstrating that patients with myelopathy can benefit from treatments they are selected to receive. The design of this study cannot speak to the equivalence between treatments, however, as given this retrospective review of prospective data there is still the potential for selection as well as indication biases. There was not necessarily clinical equipoise at the time of treatment selection between these two cohorts. Results should be viewed as Level III–IV evidence in light of these facts.

—The Editors

([clinicaltrials.gov](https://clinicaltrials.gov/NCT00565734) NCT00565734) prospective observational multicenter studies. A specified aim of these studies was to evaluate surgical outcomes and rates of complications between patients treated with LF versus LP; as a result, relevant data were collected to directly address this clinical question. Both studies were conducted under the same investigational protocol and the merging of collected data was preplanned. The CSM-North America study enrolled 278 patients between December 2005 and September 2007 from 12 sites in the United States and Canada. The CSM-International study was conducted between November 2007 and January 2011 and included 479 subjects from 16 sites in Asia Pacific, Europe, North America, and Latin America. The study protocols were approved by the ethics review boards at each contributing site. The main results from these studies are reported elsewhere [2,10].

Patients were eligible for these studies if they met the following inclusion criteria: (1) aged 18 years or older, (2) presenting with symptomatic DCM with at least one clinical sign of myelopathy, and (3) objective imaging evidence of cervical cord compression. Relevant symptoms included numb hands, clumsy hands, impaired gait, bilateral arm paresthesia, Lhermitte phenomena, and weakness. Relevant signs of myelopathy included corticospinal distribution motor defi-

cits, atrophy of intrinsic hand muscles, hyperreflexia, positive Hoffman sign, upgoing plantar responses, lower limb spasticity, and broad-based unstable gait (Table 1). Exclusion criteria included prior surgery for DCM, active infection, neoplastic disease, rheumatoid arthritis, ankylosing spondylitis, trauma, and concomitant lumbar stenosis. All participants provided written informed consent.

Of these subjects, 286 were treated with a posterior-only surgical approach. Twenty patients received laminectomy without fusion and were excluded from this analysis. Of the remaining 266 participants, 100 were treated with LP and 166 received LF.

Outcome measures

Patients were evaluated preoperatively and at 6, 12, and 24 months postoperatively using a variety of validated outcome measures, including the Neck Disability Index (NDI) [11], Nurick scale [12], modified Japanese Orthopaedic Association score (mJOA) [13,14], and the physical and mental component scores (PCS and MCS) of the Short-Form 36v2 (SF36v2) [15]. This analysis focused on comparing change scores from baseline with 24-month follow-up between surgical cohorts. Secondary outcomes included length of hospital stay, length of stay in the intensive care unit (ICU), and surgery-related adverse events. Adverse events were documented using standardized

Table 1
Signs and symptoms of degenerative cervical myelopathy

Signs and symptoms of myelopathy	Definition
Symptoms	
Numb hands	Loss of sensation or feeling in hands or fingers
Clumsy hands	Lacking dexterity and fine motor movements in hands
Impairment of gait	Any dysfunction in walking
Bilateral arm paresthesia	Non-specific numbness and tingling in both arms
Lhermitte phenomena	Sudden transient electric-like shocks down the spine triggered by forward head flexion
Weakness	Lack of physical strength, energy, or vigor
Signs	
Corticospinal distribution motor deficits	Motor paralysis or weakness
Atrophy of intrinsic hand muscles	Thenar and hypothenar muscle wasting
Hyperreflexia	Overactive or overresponsive reflexes
Positive Hoffman sign	When tapping the nail or flicking the terminal phalanx of the middle or ring finger elicits flexion of the terminal phalanx of the thumb
Babinski sign	When stimulating the sole of the foot with a blunt instrument elicits extension of the hallux
Lower limb spasticity	Increased, involuntary, velocity-dependent muscle tone of the lower limbs that causes resistance to motion
Broad-based, unstable gait	A staggering gait in which the patient walks with a wide base

forms with a predetermined list of 30 anticipated complications as well as an “other” option. This list included pseudoarthrosis, hardware failure, screw malposition, non-union, C5 radiculopathy, axial pain, new intractable neck pain, adjacent segment degeneration, instability, reoperation, dural tear, epidural hematoma, deep or superficial infection, iatrogenic fracture, deep venous thrombosis, graft site pain, dysphagia, dysphonia, progression of myelopathy, new radiculopathy, perioperative worsening of myelopathy, graft dislodgement or migration, graft site pain, postoperative kyphosis, cardiopulmonary event, relevant bleeding complications, thromboembolism, stroke, and cortical blindness. These complications were defined in a previous publication. Adverse events were adjudicated by a panel of investigators and classified as related to surgery, related to myelopathy, or unrelated.

Data were collected using electronic Case Report Forms and processed at a central data management center. External monitors performed both on- and off-site monitoring to ensure compliance with study protocol and that the data were authentic, accurate, and complete.

Statistical analysis

Differences in baseline characteristics between surgical cohorts were assessed using a *t* test for continuous variables and a chi-square test for categorical factors. At 24-month follow-up, 10 subjects withdrew, 2 died due to unrelated causes, and 53 missed their follow-up visit. The final follow-up rate was 79.13% overall, 74.47% in the LP cohort and 81.88% in the LF group. Missing outcome scores at 24-month follow-up were imputed by multiple imputation method. The imputation procedure was performed by SAS/STAT PROC MI Markov Chain model, and multiple-chain, full-imputation, and 10 imputed samples were generated. After imputation, data were available for 98% of the LP (with two deaths) and 100% of the LF patients.

Using imputed data, differences in outcomes between the LP and LF groups were analyzed by analysis of variance and analysis of covariance. The dependent variable in all analyses was the change score between baseline and 24-month follow-up, and the independent variable was surgical procedure (LP or LF). In the analysis of covariance, outcomes were compared between groups while adjusting for gender, age, smoking, number of operative levels, geographic region, duration of symptoms, and baseline scores. The statistical results from the imputed data were combined by SAS/STAT PROC MIANALYZE to generate the final statistical inferences. Statistical analyses were performed on SAS 9.4 (SAS Institute, Inc, Cary, NC, USA), and $p < .05$ was considered statistically significant. The study had 80% power to detect a difference of 1 point on the mJOA and 90% power to detect a difference of 8 out of 100 on the NDI between the groups. The minimum clinically important differences (MCID) have been established for the SF36v2 PCS and MCS, NDI, and mJOA in a degenerative spine population but not for the Nurick scores. The reported MCID for the NDI is 7.5, 4.1 for the SF36v2 PCS [16], 5.7 for the SF36v2 MCS [17], and 1.11 for mJOA [18].

Results

Demographics

Baseline and surgical characteristics were similar between treatment groups with a few exceptions (Table 2). The mean age at presentation was 60.68 (± 11.32) in the LP group and 61.36 (± 10.59) in the LF group ($p = .6208$). There was no significant difference in gender between surgical techniques: 33.00% and 31.93% of patients were female in the LP and LF groups, respectively ($p = .8563$). The LP cohort had a lower proportion of smokers (19.00% vs. 27.11%, $p = .134$) than the LF cohort, although this difference did not reach statistical significance. The Asia Pacific region contributed a disproportionate number of patients treated with LP (53.00% of study population), whereas sites from North America mainly contributed patients undergoing LF (62.65%, $p < .0001$). Baseline mJOA scores were more severe in the LP group (11.52 vs. 12.30, $p = .0297$). Nurick grades, NDI, and SF36 v2 PCS and MCS were similar between cohorts. There was a trend toward a shorter duration of symptoms in the LP group (23.12 months vs. 31.96 months, $p = .0662$). There were no differences in the number of levels decompressed between patients treated with LP versus LF (4.78 ± 0.85 and 4.96 ± 0.88 , respectively, $p = .0955$); however, the LF procedures were on average longer (215.66 ± 70.27 minutes) than the LP procedures (139.44 ± 58.47 minutes, $p < .0001$).

Outcomes

Subjects in both groups demonstrated significant improvements at 24-month follow-up. Patients treated with LF exhibited the following mean improvements: mJOA score, 2.39 (95% confidence interval [CI]: 1.91, 2.86); Nurick grade, 1.18 (95% CI: 0.92, 1.44); NDI, 10.45 (95% CI: 7.13, 13.77); SF36v2 PCS, 5.43 (95% CI: 2.97, 7.90); and SF36v2 MCS, 4.08 (95% CI: 2.28, 5.88) (Table 3). Subjects who underwent LP achieved the following mean improvement: mJOA score, 3.49 (95% CI: 2.84,

Table 2
Baseline and surgical characteristics of study participants by surgical approach

	Laminoplasty (N=100)	Laminectomy and fusion (N=166)	p Value
Age (y)	60.68 (11.32)	61.36 (10.59)	.6208
Female sex	33.00%	31.93%	.8563
Current smoker	19.00%	27.11%	.1340
Region AP/Eu/LA/NA	53.00%/1.00%/11.00%/35.00%	1.81%/10.24%/25.30%/62.65%	<.0001
Symptom duration (mo)	23.12 (33.36)	31.96 (39.86)	.0662
Nurick score	3.57 (1.25)	3.39 (1.19)	.2304
mJOA	11.52 (2.77)	12.30 (2.85)	.0297
Neck Disability Index	41.84 (20.66)	39.20 (20.90)	.3694
SF-36 version 2 MCS	38.93 (12.49)	41.03 (14.62)	.2376
SF-36 version 2 PCS	35.08 (10.10)	33.12 (9.30)	.1134
No. of levels operated	4.78 (0.85)	4.96 (0.88)	.0955
Operation length (min)	139.44 (58.47)	215.66 (70.27)	<.0001

AP, Asia Pacific; Eu, Europe; LA, Latin America, NA, North America; mJOA, modified Japanese Orthopaedic Association; SF-36, Short-Form 36; MCS, Mental Component Score; PCS, Physical Component Score.

Note: Numbers in parentheses are standard deviations.

Table 3
Improvement in outcomes at 24 months by surgical approach

	Laminoplasty (N=98)	Laminectomy and fusion (N=166)	p Value
mJOA	3.49 (2.84, 4.13)	2.39 (1.91, 2.86)	.0069
Nurick score	1.57 (1.23, 1.90)	1.18 (0.92, 1.44)	.0770
Neck Disability Index	14.33 (9.50, 19.17)	10.45 (7.13, 13.77)	.2039
SF-36 version 2 MCS	6.71 (3.71, 9.72)	5.43 (2.97, 7.90)	.2169
SF-36 version 2 PCS	5.56 (3.07, 8.05)	4.08 (2.28, 5.88)	.3058

mJOA, modified Japanese Orthopaedic Association; SF-36, Short-Form 36; MCS, Mental Component Score; PCS, Physical Component Score.

Note: Numbers in parentheses are 95% confidence intervals.

4.13); Nurick grade, 1.57 (95% CI: 1.23, 1.90); NDI, 14.33 (95% CI: 9.50, 19.17); SF36v2 PCS, 6.71 (95% CI: 3.71, 9.72); and SF36v2 MCS, 5.56 (95% CI: 3.07, 8.05). These improvements in mJOA scores were significantly higher in the LP compared with LF group (3.49 and 2.39, respectively, $p=.0069$). Furthermore, the improvements in Nurick grade were also higher in the LP compared with the LF group (1.57 and 1.18, respectively, $p<.0770$). Improvements in NDI and SF36 PCS and MCS did not differ between surgical groups. In the adjusted model, there were no significant differences in any of these outcomes between the LP and LF cohorts (Table 4).

Length of stay and adverse events

Patients who underwent LP had a longer hospital stay compared with those treated with LF (11.61 ± 8.89 vs. 7.83 ± 7.22 , $p=.0004$). Length of stay in the ICU was also longer in the LP cohort (0.30 ± 0.58 days) than in the LF cohort (0.14 ± 0.59 days) ($p=.0306$).

Sixty complications occurred in 47 (28.31%) subjects treated with LF compared with 22 complications in 21 (21.00%) patients undergoing LP ($p=.1078$) (Table 5). Adverse events included C5 radiculopathy (three subjects in LP group, four subjects in LF group), dural tear (three subjects in LP group, five subjects in LF group), deep infection (two subjects in LF group), superficial infection (two subjects in LP group, five subjects in LF group), postoperative kyphosis (one subject in LP group, five subjects in LF group), instrumentation

Table 4
Improvement in outcomes at 24 months by surgical approach adjusted for baseline characteristics*

	Laminoplasty (N=98)	Laminectomy and fusion (N=166)	p Value
mJOA	2.82 (2.07, 3.57)	2.18 (1.61, 2.75)	.1520
Nurick score	1.18 (0.68, 1.67)	0.94 (0.56, 1.31)	.3019
Neck Disability Index	10.76 (5.26, 16.26)	9.94 (5.57, 14.31)	.5252
SF-36 version 2 MCS	6.26 (2.73, 9.79)	4.44 (1.28, 7.61)	.2518
SF-36 version 2 PCS	2.33 (−0.86, 5.52)	3.21 (0.83, 5.60)	.3439

mJOA, modified Japanese Orthopaedic Association; SF-36, Short-Form 36; MCS, Mental Component Score; PCS, Physical Component Score.

Note: Numbers in parentheses are 95% confidence intervals.

* Adjusted for preoperative value of the outcome measures (eg, baseline mJOA) age, gender, number of operated levels, smoking status, geographic region, and duration of symptoms.

Table 5
Length of stay by surgical approach

	Laminoplasty (N=100)	Laminectomy and fusion (N=166)	p Value
Length of hospital stay (d)	11.61 (8.89)	7.83 (7.22)	.0004
Duration in intensive care unit (d)	0.30 (0.58)	0.14 (0.59)	.0306

malposition (two subjects in LF group), and neck or arm pain (seven subjects in LP group, thirteen subjects in LF group). Three subjects had subsequent cervical surgery: two from the LF group (one for progression of myelopathy and one for progressive kyphosis) and one from the LP group (progression of myelopathy) (Table 6).

Discussion

This study aimed to compare outcomes, length of stay, and adverse events between patients treated with LP and those who received LF. Based on our results, LP and LF are both effective at improving disease severity, functional status, and quality of life in patients with DCM. In both surgical cohorts, change in mJOA scores exceeded the MCID of this metric [18], and the average improvements on the Nurick were greater than one grade. Patients treated with LF or LP also exhibited clinically meaningful gains on the NDI (14.33 in the LP and 10.45 in the LF cohort). In the LP cohort, gains in the SF36v2 MCS and PCS also exceeded the MCIDs of these metrics (5.7 and 4.1, respectively); however, patients treated with LF did not quite reach this threshold. Patients treated with LP were more severe preoperatively based on the mJOA. A study by Highsmith et al. also reported worse preoperative JOA and Nurick scores in an LP cohort compared with an LF cohort [8]. Interestingly,

Table 6
Complications by surgical approach

	Laminoplasty (N=100)		Laminectomy and fusion (N=166)	
Hardware failure	0	0.00	1	0.60
C5 radiculopathy	3	3.00	4	2.41
Adjacent segment degeneration	0	0.00	4	2.41
Dural tear	3	3.00	5	3.01
Deep infection	0	0.00	2	1.21
Superficial infection	2	2.00	5	3.01
Dysphagia	0	0.00	2	1.21
New radiculopathy (not C5)	1	1.00	3	1.81
Postoperative kyphosis	1	1.00	5	3.01
Cardiopulmonary event	0	0.00	1	0.60
Relevant bleeding	0	0.00	3	1.81
Instrumentation malposition/ migration	0	0.00	2	1.21
Neck/arm pain	7	7.00	13	7.83
Surgical wound problems (eg, hematoma, dehiscence)	0	0.00	1	0.60
Other*	5	5.00	9	5.42
Any	21	21.00	47	28.31

* Other complications included angioedema, cognitive dysfunction, pseudoaneurysm, neck fatigue, acute renal failure, shoulder weakness, and edematous airway.

LP patients had better preoperative neck pain visual analog scale scores than LF patients. These findings are in contrast to other studies that indicated similar preoperative myelopathy severity scores between surgical treatment groups [6,19,20]. In our study, patients treated with LF (31.96 ± 39.86 months) had a longer duration of symptoms than those who underwent LP (23.12 ± 33.36 months). This 8.7-month difference was not statistically significant; furthermore, the large standard deviations associated with each mean reflect the variable natural history of DCM, which can range from a relatively slow and insidious neurologic decline to rapid progression [21]. There were no differences between the surgical cohorts with respect to gender, smoking status, and age.

Surgical decision making is influenced by a number of factors, including source of compression, presence of axial neck pain, extent of pathology, and sagittal alignment [3]. Posterior decompression is indicated in multilevel compression and when fixed cervical kyphosis is <10 – 13° [21]. Both posterior techniques (LF and LP) are contraindicated in patients with significant kyphosis, whereas LP should be avoided in patients with instability resulting from trauma or rheumatologic disease and neck pain. Given similar indications for LF and LP, one of the major driving factors for decision making is surgeon preference or experience with each technique. In our study, patients treated with LP were predominantly from the Asia Pacific region; as a result, genetic, racial, and culture factors may contribute to differences in disease causation, management strategies, and outcomes.

In our unadjusted analysis, patients undergoing LP had significantly greater improvements in the mJOA at 24 months than those treated with LF. However, there were no differences in mJOA outcomes between surgical cohorts after adjusting for preoperative myelopathy severity, age, gender, number of operated levels, smoking status, and duration of symptoms. In previous studies, duration of symptoms, smoking status, age, and baseline severity score have been identified as significant predictors of surgical outcomes [22,23]. It is, therefore, essential to control for these factors when comparing the effectiveness of surgery between treatment groups.

These results must be interpreted in the context of existing literature. In a systematic review, Yoon et al. identified four retrospective comparative cohort studies that evaluated outcomes following LF and LP [5]. Study limitations included (1) the lack of independent or blind outcome assessment, (2) inadequate control of confounding variables, (3) $<80\%$ follow-up rate, and (4) inadequate sample sizes. A study by Chen et al. reported significantly greater improvements in long-term JOA scores following LF compared with LP in patients with severe ossification of the posterior longitudinal ligament [24]. In contrast, results from Highsmith et al. indicated no significant differences in long-term improvement on the mJOA or Nurick scores in patients with multilevel cervical spondylotic myelopathy treated with LP or LF [8]. Furthermore, pain outcomes were similar between surgical cohorts. In a meta-analysis by Lee et al., pooled results from seven studies demonstrated no significant differences in JOA

improvements between LP and LF cohorts; however, patients in the LP group exhibited greater gains in visual analog scale scores than those in the LF group [25]. Our study differs from those previously published as it (1) was prospective, (2) had sufficient statistical power to compare differences between LP and LF, and (3) evaluated outcomes using a wide spectrum of validated assessment tools with established MCIDs.

Length of hospital stay and duration of stay in the ICU were both significantly longer in patients treated with LP, even though LF was a longer operation. This is in contrast to a cost analysis study published by Warren et al. that reported a shorter length of stay following LP (3.7 ± 2.2 days) than LF (5.9 ± 3.2 days) [26]. The differences between our surgical cohorts likely reflect cultural differences in postoperative management strategies. A disproportionate number of the LP cases were patients treated in Asia Pacific, where it is common to delay discharge from the hospital.

There were no significant differences in the rates of complications or reoperations between surgical cohorts. Only three subjects underwent a subsequent cervical surgery: two from the LF group and one from the LP group. These rates were significantly lower than those observed in previous studies. Furthermore, in studies by Heller et al. and Highsmith et al., reoperation was significantly lower in the LP (0% and 13%) group than in the LF (15% and 27%) group [8,9]. Previous studies have also reported slightly higher infection rates in patients treated with LF compared with those who received LP [5]; this was not apparent in our study but is likely a result of a longer operative duration for LF. There are conflicting results in the literature with respect to differences in rates of progressive kyphotic deformity; in our sample, we observed a slightly higher frequency in the LP cohort, although this association did not reach statistical significance. Reports on complications must be interpreted cautiously given the lack of standardized definitions and varying rates across centers.

Radiographic outcomes are also important to consider when comparing the effectiveness of LF and LP. Unfortunately, we were not able to evaluate change in sagittal alignment, loss of lordosis, junctional kyphosis, or range of motion. In a study by Woods et al., patients treated with LF experienced a larger loss of lordosis (2.57°) than those in the LP group, which actually gained 0.57° of lordosis [7]. A meta-analysis by Lee et al., however, reported no significant difference in lordotic alignment perseveration between the LP and LF groups [25]. Heller et al. indicated a greater reduction in sagittal plane motion from C2 to C7 in the LF cohort (69% decreased) compared with the LP cohort (35% decrease) [9]. Finally, based on a single study, there was no difference in junctional kyphosis between surgical cohorts.

Strengths and limitations

The main limitation of this study was the lack of randomization. However, a randomized controlled trial would have been less feasible given the magnitude and global scale of this study. Furthermore, our study design better reflects

clinical practice as surgeons often select an approach based on their own familiarity with the technique as well as patient characteristics; this may introduce potential selection bias. Other strengths of our study include (1) a high follow-up rate of >80%, (2) the use of a multiple imputation method to account for missing data, and (3) our adjusted analysis. Further research is required to determine factors that influence surgical decision making, such as the presence of ossification of the posterior longitudinal ligament, sagittal alignment, and spondylolisthesis. Furthermore, outcomes should be compared between various types of LPs.

Conclusions

In conclusion, both LP and LF are effective at improving clinical disease severity, functional status, and quality of life in patients with DCM. In an unadjusted analysis, patients treated with LP achieved greater improvements on the mJOA at 24-month follow-up than those who received LF; however, these differences were insignificant following adjustment for relevant baseline and surgical characteristics.

Acknowledgment

The study was funded by AOSpine International, which had no role in the design of the study, analysis of the results, or the decision to publish.

Supplementary material

Supplementary material related to this article can be found at <http://dx.doi.org/10.1016/j.spinee.2016.08.019>.

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