

Cervical laminoplasty versus laminectomy and posterior cervical fusion for cervical myelopathy: propensity-matched analysis of 24-month outcomes from the Quality Outcomes Database

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Eunice Yang, BS,¹ Praveen V. Mummaneni, MD, MBA,² Dean Chou, MD,¹ Mohamad Bydon, MD,³ Erica F. Bisson, MD, MPH,⁴ Christopher I. Shaffrey, MD,⁵ Oren N. Gottfried, MD,⁵ Anthony L. Asher, MD,⁶ Domagoj Coric, MD,⁶ Eric A. Potts, MD,⁷ Kevin T. Foley, MD,⁸ Michael Y. Wang, MD,⁹ Kai-Ming Fu, MD, PhD,¹⁰ Michael S. Virk, MD, PhD,¹⁰ John J. Knightly, MD,¹¹ Scott Meyer, MD,¹¹ Paul Park, MD,¹² Cheerag D. Upadhyaya, MD, MBA, MS,¹³ Mark E. Shaffrey, MD,¹⁴ Avery L. Buchholz, MD, MPH,¹⁴ Luis M. Tumialán, MD,¹⁵ Jay D. Turner, MD, PhD,¹⁵ Giorgos D. Michalopoulos, MD,³ Brandon A. Sherrod, MD,⁴ Nitin Agarwal, MD,¹⁶ Regis W. Haid Jr., MD,¹⁷ and Andrew K. Chan, MD¹

¹Department of Neurological Surgery, Columbia University Vagelos College of Physicians and Surgeons, The Ochsner Spine Hospital at New York-Presbyterian, New York, New York; ²Department of Neurosurgery, University of California, San Francisco, California; ³Department of Neurologic Surgery, Mayo Clinic, Rochester, Minnesota; ⁴Department of Neurosurgery, University of Utah, Salt Lake City, Utah; ⁵Department of Neurosurgery, Duke University, Durham, North Carolina; ⁶Neuroscience Institute, Carolinas Healthcare System and Carolina Neurosurgery & Spine Associates, Charlotte, North Carolina; ⁷Goodman Campbell Brain and Spine, Indianapolis, Indiana; ⁸Department of Neurosurgery, University of Tennessee, Semmes-Murphey Neurologic and Spine Institute, Memphis, Tennessee; ⁹Department of Neurosurgery, University of Miami, Florida; ¹⁰Department of Neurosurgery, Weill Cornell Medical Center, New York, New York; ¹¹Atlantic Neurosurgical Specialists, Morristown, New Jersey; ¹²Department of Neurosurgery, University of Michigan, Ann Arbor, Michigan; ¹³Marion Bloch Neuroscience Institute, Saint Luke's Health System, Kansas City, Missouri; ¹⁴Department of Neurosurgery, University of Virginia, Charlottesville, Virginia; ¹⁵Barrow Neurological Institute, Phoenix, Arizona; ¹⁶Department of Neurosurgery, University of Pittsburgh, Pennsylvania; and ¹⁷Atlanta Brain and Spine Care, Atlanta, Georgia

OBJECTIVE Compared with laminectomy with posterior cervical fusion (PCF), cervical laminoplasty (CL) may result in different outcomes for those operated on for cervical spondylotic myelopathy (CSM). The aim of this study was to compare 24-month patient-reported outcomes (PROs) for laminoplasty versus PCF by using the Quality Outcomes Database (QOD) CSM data set.

METHODS This was a retrospective study using an augmented data set from the prospectively collected QOD Registry Cervical Module. Patients undergoing laminoplasty or PCF for CSM were included. Using the nearest-neighbor method, the authors performed 1:1 propensity matching based on age, operated levels, and baseline modified Japanese Orthopaedic Association (mJOA) and visual analog scale (VAS) neck pain scores. The 24-month PROs, i.e., mJOA, Neck Disability Index (NDI), VAS neck pain, VAS arm pain, EQ-5D, EQ-VAS, and North American Spine Society (NASS) satisfaction scores, were compared. Only cases in the subaxial cervical region were included; those that crossed the cervicothoracic junction were excluded.

RESULTS From the 1141 patients included in the QOD CSM data set who underwent anterior or posterior surgery for cervical myelopathy, 946 (82.9%) had 24 months of follow-up. Of these, 43 patients who underwent laminoplasty and 191 who underwent PCF met the inclusion criteria. After matching, the groups were similar for baseline characteris-

ABBREVIATIONS CL = cervical laminoplasty; CSM = cervical spondylotic myelopathy; mJOA = modified Japanese Orthopaedic Association; NASS = North American Spine Society; NDI = Neck Disability Index; PCF = posterior cervical fusion; PRO = patient-reported outcome; PSM = propensity score matching; QOD = Quality Outcomes Database; VAS = visual analog scale.

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tics, including operative levels (CL group: 4.0 ± 0.9 vs PCF group: 4.2 ± 1.1 , $p = 0.337$) and baseline PROs ($p > 0.05$), except for a higher percentage involved in activities outside the home in the CL group (95.3% vs 81.4%, $p = 0.044$). The 24-month follow-up for the matched cohorts was similar (CL group: 88.4% vs PCF group: 83.7%, $p = 0.534$). Patients undergoing laminoplasty had significantly lower estimated blood loss (99.3 ± 91.7 mL vs 186.7 ± 142.7 mL, $p = 0.003$), decreased length of stay (3.0 ± 1.6 days vs 4.5 ± 3.3 days, $p = 0.012$), and a higher rate of routine discharge (88.4% vs 62.8%, $p = 0.006$). The CL cohort also demonstrated a higher rate of return to activities (47.2% vs 21.2%, $p = 0.023$) after 3 months. Laminoplasty was associated with a larger improvement in 24-month NDI score (-19.6 ± 18.9 vs -9.1 ± 21.9 , $p = 0.031$). Otherwise, there were no 3- or 24-month differences in mJOA, mean NDI, VAS neck pain, VAS arm pain, EQ-5D, EQ-VAS, and distribution of NASS satisfaction scores ($p > 0.05$) between the cohorts.

CONCLUSIONS Compared with PCF, laminoplasty was associated with decreased blood loss, decreased length of hospitalization, and higher rates of home discharge. At 3 months, laminoplasty was associated with a higher rate of return to baseline activities. At 24 months, laminoplasty was associated with greater improvements in neck disability. Otherwise, laminoplasty and PCF shared similar outcomes for functional status, pain, quality of life, and satisfaction. Laminoplasty and PCF achieved similar neck pain scores, suggesting that moderate preoperative neck pain may not necessarily be a contraindication for laminoplasty.

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KEYWORDS cervical spondylotic myelopathy; laminoplasty; posterior cervical laminectomy and fusion; propensity-matched analysis; patient-reported outcomes; Quality Outcomes Database

CERVICAL spondylotic myelopathy (CSM) is a widespread degenerative condition affecting approximately 605 million adults in North America.¹ Already the most common cause of adult spinal cord impairment, CSM continues to increase in prevalence within the aging global population.² Patients present with a broad range of clinical features, including gait instability, loss of manual dexterity, weakness, sensory disturbance, urinary incontinence, and neck pain and stiffness.³ If the symptoms are disabling or nonoperative management fails (or is not preferred by the patient), surgical decompression can limit disease progression, with many patients noting functional improvement.^{4,5}

There are both anterior and posterior approaches for treatment, with surgeons typically considering factors such as the location of compression, lordotic curvature, and number of levels involved.⁶ Approach-related risks are also considered (e.g., dysphagia or dysphonia during anterior approaches).^{7,8} When there is involvement of three or more cervical levels, some surgeons may favor posterior approaches. These include laminectomy alone, laminectomy with posterior cervical fusion (PCF) (Fig. 1), and cervical laminoplasty (CL) (Fig. 2). Laminectomy alone is no longer widely used given the risk of postlaminectomy kyphosis.⁹

The choice between PCF and laminoplasty presents a significant area of research, with indications for each ap-

proach depending on various clinical and radiographic factors. Because fusion can realign and fuse the spinal column, it has traditionally been preferred in patients with cervical kyphosis or those experiencing significant neck pain.¹⁰ In comparison, laminoplasty is a nonfusion approach that is typically less invasive and can better preserve range of motion.^{11,12} Reports suggest that laminoplasty remains an underutilized procedure in the US.¹³ Thus, evaluation of laminoplasty outcomes in a US setting with specific comparison to laminectomy with fusion may address an important gap in knowledge.¹⁴ Recently, a number of studies have suggested that both approaches may show similar clinical improvement and complication rates.¹⁵⁻¹⁷ In a randomized clinical trial subgroup analysis of an anterior versus posterior approach for CSM, Ghogwala et al. observed an association between laminoplasty and greater 1- and 2-year quality of life based on SF-36 Physical Component Summary scores, when compared with laminectomy with fusion.¹⁷ However, there is a lack of additional contemporaneous research comparing laminoplasty and laminectomy with fusion and, in particular, few studies including long-term patient-reported outcomes (PROs).¹⁴

In this study, we compare the 24-month outcomes of laminectomy with fusion and laminoplasty for CSM using the prospective Quality Outcomes Database (QOD)

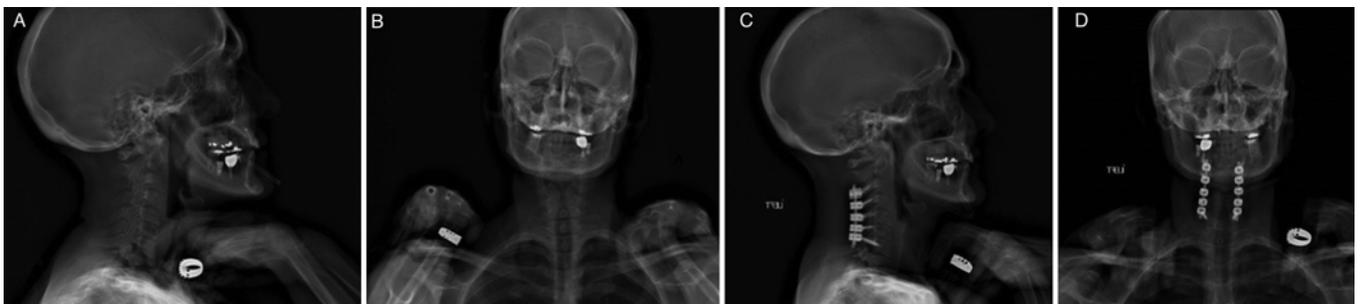


FIG. 1. Preoperative lateral (A) and anteroposterior (B) radiographs and postoperative lateral (C) and anteroposterior (D) radiographs depicting a C3–7 laminectomy and PCF.

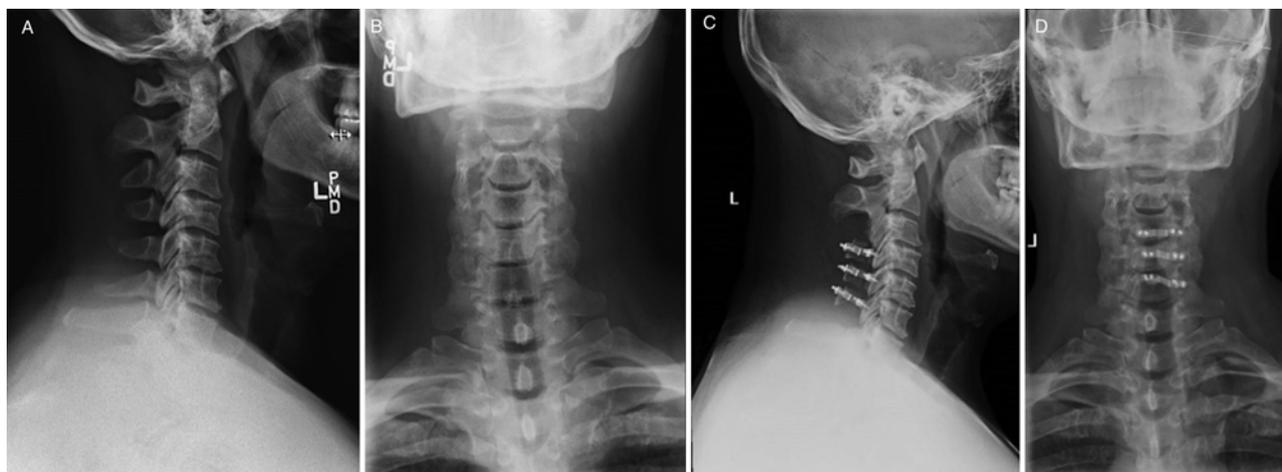


FIG. 2. Preoperative lateral (A) and anteroposterior (B) and postoperative lateral (C) and anteroposterior (D) radiographs depicting a Hirabayashi (single-hinge door) CL including C3 laminectomy and partial laminectomy of C7.

CSM data set in a propensity-matched analysis. Propensity score matching (PSM) is a particularly relevant tool for spine surgery research to account for imbalances in observational nonrandomized data.¹⁸

Methods

Patient Population

This was a retrospective study using an augmented data set from the prospectively collected QOD Registry Cervical Module. Columbia University Institutional Review Board approval was obtained, and patient consent was waived given the study's design.

This augmented data set represents the coordination of 14 high-enrollment sites that combined their QOD Cervical Module data and collected additional data points. Data were audited by both a central team and the individual sites. Individual operative notes were reviewed by a central team of spine surgeons to confirm operative procedures. The inclusion criteria of this augmented data set (the QOD CSM cohort) have been described previously.¹⁹ Specifically, we included adult patients aged ≥ 18 years with 1) a surgical indication of CSM, 2) a predominant symptom of myelopathy, and 3) a modified Japanese Orthopaedic Association (mJOA) score < 17 , and 4) who underwent elective surgery between January 2016 and December 2018. Patients were excluded if they had spinal infection, tumor, fracture, traumatic dislocation, deformity, or neurological paralysis due to preexisting spine disease or injury.

Patients who underwent a CL or laminectomy with PCF were selected from the QOD CSM cohort. We included only subaxial cases in the cervical region, excluding cases that involved C2 or crossed the cervicothoracic junction.

Outcome Measures

We compared PROs collected at 3 and 24 months between fusion and laminoplasty patients. We studied seven clinical outcomes that serve as the primary outcomes of interest in this study, all of which were derived from vali-

dated questionnaires: mJOA, visual analog scale (VAS) arm pain, VAS neck pain, Neck Disability Index (NDI), EQ-VAS, EQ-5D, and North American Spine Society (NASS) Patient Satisfaction Index scores.^{20–22} The mJOA scores ranged from 0 to 18, where lower scores indicate greater neurological impairment and disability. The mJOA scores < 17 warranted inclusion in the QOD CSM module. Relieved cervical myelopathy is defined as achieving an mJOA score ≥ 17 at the designated time point. VAS arm and neck pain scores ranged from 0 to 10, where higher scores indicate more pain. Pain-free status is defined as achieving a VAS score of 0 at the designated time point. NDI scores ranged from 0% to 100%, where higher percentages indicate greater interference from neck pain on a patient's activities of daily living. EQ-VAS scores ranged from 0 to 100, where lower scores indicate lower patient assessment of their own health status. EQ-5D scores ranged from -0.11 to 1.0, where lower scores indicate more quality-of-life impairment. NASS Patient Satisfaction Index scores ranged from 1 to 4, with lower scores corresponding to more satisfaction with surgery (1: "The treatment met my expectations"; 2: "I did not improve as much as I had hoped, but I would undergo the same treatment for the same outcome"; 3: "I did not improve as much as I had hoped, and I would not undergo the same treatment for the same outcome"; and 4: "I am the same or worse than before treatment"). Our secondary outcomes of interest were perioperative outcomes (blood loss, length of stay, discharge disposition), 30-day and 3-month related readmissions, 30-day and 24-month related reoperations, 3-month return to work, and 3-month ability to return to previous levels of physical activity.

Statistical Analysis

Continuous variables were summarized using means \pm SD, and descriptive categorical variables were summarized using frequencies and proportions. For continuous variables, paired and unpaired t-tests were used as appropriate. For categorical variables, chi-square analyses were used, and Yates' correction and Fisher's exact test

were implemented as appropriate. We used PSM to create two equal groups of patients undergoing laminoplasty and fusion. Patients were matched based on the variables of age, operated levels, and baseline mJOA and VAS neck pain scores. The 1:1 nearest-neighbor method without replacement was performed using Python's PsmPy package (version 0.3.13). Sensitivity analyses were conducted using multivariable regression on 1) the matched cohorts ($n = 86$) and 2) the full cohorts of laminoplasty and fusion patients ($n = 234$). Covariates reaching $p < 0.20$ on univariate analysis were used to compare PROs between the CL and PCF cohorts, with the PCF group used as the reference group. Missing data were handled using the MissForest algorithm through Python's missingpy package (version 0.2.0), which initially fills in missing values with the column mean/mode and subsequently fits a random forest model to impute missing values in an iterative fashion. We tested the null hypothesis that patients undergoing laminoplasty and laminectomy with fusion have similar outcomes. All p values were two-tailed, and $p < 0.05$ was the threshold for statistical significance. Statistical analyses were performed using Python version 3.9.

Results

Baseline Characteristics

A total of 1141 patients underwent anterior or posterior surgery for cervical myelopathy and were included in the QOD CSM data set; 946 (82.9%) had 24 months of follow-up. Of these patients, 282 (24.7%) underwent a CL or laminectomy with PCF. After excluding surgeries that involved C2 or the thoracic spine, we identified 43 patients who underwent CL and 191 patients who underwent PCF. Both cohorts had similar 24-month follow-up rates (CL group: 88.4% vs PCF group: 84.3%, $p = 0.498$). The proposed PSM covariates—age, operated levels, baseline mJOA scores, and baseline VAS neck pain scores—did not differ significantly between the CL and PCF cohorts ($p > 0.05$) (Table 1). However, the CL cohort reported fewer subjective complaints of a radicular motor deficit (11.6% vs 25.7%, $p = 0.049$), radicular arm pain (9.3% vs 37.7%, $p < 0.001$), numbness (25.6% vs 50.8%, $p = 0.003$), and neck pain (44.2% vs 63.4%, $p = 0.021$). The PCF cohort had fewer patients with subjective complaints of myelopathy (100% vs 90.1%, $p = 0.028$). Patients undergoing laminoplasty were also more likely to participate in activities outside of the home at baseline (95.3% vs 79.1%, $p = 0.012$).

After matching, there were 86 patients, with 43 in the PCF group and 43 in the CL group. The 24-month follow-up rates remained similar between the two groups (CL group: 88.4% vs PCF group: 83.7%, $p = 0.534$). All demographic variables were also similar between the PCF and CL cohorts ($p > 0.05$) (Table 1). Patients undergoing laminoplasty reported higher participation in activities outside the home at baseline (95.3% vs 81.4%, $p = 0.044$). The percentage of patients presenting with complaints of radicular arm pain remained lower in laminoplasty patients (9.3% vs 27.9%, $p = 0.027$). However, the presentations of radicular motor deficit, numbness, myelopathy, and neck pain were no longer significantly different between the two cohorts after PSM. All other clinical variables,

including comorbidities and baseline PROs, were similar between the matched cohorts.

Perioperative Parameters, Readmission Rates, and Reoperation Rates

Table 2 shows a comparison of perioperative and secondary outcomes between patients undergoing PCF versus laminoplasty. Estimated blood loss was significantly higher in the PCF cohort (186.7 ± 142.7 vs 99.3 ± 91.7 , $p = 0.003$). Patients undergoing PCF also had a longer length of stay (4.5 ± 3.3 vs 3.0 ± 1.6 , $p = 0.012$) and were less likely to be discharged to home (62.8% vs 88.4%, $p = 0.006$). There were no readmissions within 30 days and no difference in 3-month readmission rates (2.3% vs 2.3%, $p > 0.99$). There was only 1 reoperation within 30 days in the PCF cohort (1 patient who fell and developed central cord syndrome requiring a decompression and extension of PCF). Within 24 months, there were 3 reoperations (7.0%) in the CL group (3 conversions to anterior cervical discectomy and fusion) and 2 reoperations (4.7%) in the PCF group (the 30-day reoperation mentioned above and 1 for adjacent-segment disease) ($p > 0.99$).

Univariate Analysis of Postoperative Outcomes

Figure 3 shows the improvement from baseline at 3, 12, and 24 months for all PROs between the PCF and CL cohorts.

Table 3 summarizes clinical outcomes at 3- and 24-month follow-ups for patients in the CL and PCF cohorts. The rate of return to activities after 3 months was higher among the CL cohort than the PCF cohort (47.2% vs 21.2%, $p = 0.023$). Whereas NDI scores did not differ between the two cohorts at 24 months (CL group: 18.7 ± 20.4 vs PCF group: 23.6 ± 21.8 , $p = 0.328$), the 24-month change in NDI score from baseline was significantly greater in magnitude in the CL cohort (-19.6 ± 18.9 vs -9.1 ± 21.9 , $p = 0.031$).

There were no other significant differences between the CL and PCF cohorts for all other PROs at 3 and 24 months, including NASS satisfaction, mJOA, VAS neck pain, VAS arm pain, EQ-5D, and EQ-VAS scores ($p > 0.05$) (Table 3). Again, baseline VAS neck pain was used as a covariate in PSM and was similar across both groups (CL group: 4.8 ± 3.1 vs PCF group: 4.1 ± 3.5 , $p = 0.343$). The CL and PCF cohorts did not have significantly different mean neck pain scores at 3 months (CL group: 3.3 ± 2.9 vs PCF group: 2.8 ± 2.8 , $p = 0.503$) or 24 months (CL group: 2.4 ± 2.9 vs PCF group: 2.7 ± 2.6 , $p = 0.731$). The change in neck pain scores was also not significantly different between the groups at 3 months (CL group: -1.7 ± 3.1 vs PCF group: -1.5 ± 3.4 , $p = 0.831$) and 24 months (CL group: -2.4 ± 3.6 vs PCF group: -1.1 ± 3.2 , $p = 0.108$). The percentage of patients reaching pain-free status was also similar between the CL and PCF cohorts at 3 months (CL group: 27.8% vs PCF group: 35.3%, $p = 0.498$) and 24 months (CL group: 43.2% vs PCF group: 28.6%, $p = 0.195$).

Sensitivity Analyses: Multivariable Analysis of Postoperative Outcomes

Table 4 shows the results of our multivariable analysis

TABLE 1. Demographic and baseline characteristics of patients undergoing PCF or laminoplasty, matched and unmatched cohorts

	Unmatched Cohorts			Matched Cohorts		
	PCF (n = 191)	CL (n = 43)	p Value	PCF (n = 43)	CL (n = 43)	p Value
Age, yrs	64.7 ± 9.8	62.9 ± 12.8	0.376	64.0 ± 9.4	62.9 ± 12.8	0.633
Female sex	86 (45.0)	23 (53.5)	0.315	16 (37.2)	23 (53.5)	0.129
BMI	29.7 ± 6.3	30.2 ± 7.0	0.702	29.5 ± 5.9	30.2 ± 7.0	0.628
24-mo follow-up	161 (84.3)	38 (88.4)	0.498	36 (83.7)	38 (88.4)	0.534
Comorbidities						
Diabetes mellitus	43 (22.5)	13 (30.2)	0.284	9 (20.9)	13 (30.2)	0.323
Coronary artery disease	20 (10.5)	4 (9.3)	0.819	5 (11.6)	4 (9.3)	0.725
Peripheral vascular disease	2 (1.0)	2 (4.7)	0.100	0	2 (4.7)	0.494
Anxiety	37 (19.4)	13 (30.2)	0.116	7 (16.3)	13 (30.2)	0.126
Depression	54 (28.3)	9 (20.9)	0.327	13 (30.2)	9 (20.9)	0.323
Arthritis	46 (24.1)	9 (20.9)	0.659	13 (30.2)	9 (20.9)	0.323
Caucasian race	147 (77.0)	35 (81.4)	0.528	31 (72.1)	35 (81.4)	0.307
≥4 yrs of college-level education*	62 (34.1)	17 (40.5)	0.433	17 (40.5)	17 (40.5)	>0.999
Participation in activities outside the home	151 (79.1)	41 (95.3)	0.012	35 (81.4)	41 (95.3)	0.044
Employed or employed & on leave*	55 (28.9)	13 (30.2)	0.867	16 (37.2)	13 (30.2)	0.494
Insurance			0.676			0.633
Medicare	102 (53.4)	21 (48.8)		23 (53.5)	21 (48.8)	
Medicaid	18 (9.4)	3 (7.0)		2 (4.7)	3 (7.0)	
Private	65 (34.0)	18 (41.9)		15 (34.9)	18 (41.9)	
Uninsured	2 (1.0)	1 (2.3)		1 (2.3)	1 (2.3)	
Patient subjective presentation of symptoms						
Radicular deficit	49 (25.7)	5 (11.6)	0.049	8 (18.6)	5 (11.6)	0.366
Radicular arm pain	72 (37.7)	4 (9.3)	<0.001	12 (27.9)	4 (9.3)	0.027
Numbness	97 (50.8)	11 (25.6)	0.003	18 (41.9)	11 (25.6)	0.110
Neck pain	121 (63.4)	19 (44.2)	0.021	20 (46.5)	19 (44.2)	0.829
Myelopathy	172 (90.1)	43 (100.0)	0.028	39 (90.7)	43 (100.0)	0.116
Predominant location of pain			0.107			0.076
Neck	75 (39.3)	18 (41.9)		10 (23.3)	18 (41.9)	
Arm	25 (13.1)	11 (25.6)		7 (16.3)	11 (25.6)	
Neck & arm	45 (23.6)	5 (11.6)		8 (18.6)	5 (11.6)	
No pain	46 (24.1)	9 (20.9)		18 (41.9)	9 (20.9)	
Symptom duration <12 mos*	85 (50.6)	20 (50.0)	0.946	19 (45.2)	20 (50.0)	0.666
Motor deficit at baseline	130 (68.1)	25 (58.1)	0.214	29 (67.4)	25 (58.1)	0.372
Independently ambulatory	133 (69.6)	31 (72.1)	0.750	28 (65.1)	31 (72.1)	0.486
ASA grade*			0.994			0.449
I or II	77 (44.3)	19 (44.2)		21 (52.5)	19 (44.2)	
III or IV	97 (55.7)	24 (55.8)		19 (47.5)	24 (55.8)	
Preop mJOA score	11.6 ± 3.0	11.5 ± 3.3	0.929	11.7 ± 3.0	11.5 ± 3.3	0.810
Preop VAS neck pain score	5.4 ± 3.3	4.8 ± 3.1	0.255	4.1 ± 3.5	4.8 ± 3.1	0.343
Preop VAS arm pain score	4.5 ± 3.6	4.0 ± 3.5	0.354	3.9 ± 3.5	4.0 ± 3.5	0.870
Preop EQ-5D score	0.5 ± 0.2	0.6 ± 0.2	0.644	0.5 ± 0.2	0.6 ± 0.2	0.742
Preop EQ-VAS score	58.5 ± 21.5	55.2 ± 24.0	0.431	60.3 ± 17.1	55.2 ± 24.0	0.280
Preop NDI score	38.4 ± 21.4	37.5 ± 19.3	0.770	32.7 ± 22.4	37.5 ± 19.3	0.298
Mean no. of levels treated	4.2 ± 1.2	4.0 ± 0.9	0.299	4.2 ± 1.1	4.0 ± 0.9	0.337

ASA = American Society of Anesthesiologists.

Values are given as mean ± SD or number of patients (%) unless otherwise indicated. Boldface type indicates statistical significance.

* Data were missing for some patients.

TABLE 2. Perioperative outcomes of patients undergoing PCF or laminoplasty, propensity score matched

	PCF (n = 43)	CL (n = 43)	p Value
Estimated blood loss, mL	186.7 ± 142.7	99.3 ± 91.7	0.003
Length of stay, days	4.5 ± 3.3	3.0 ± 1.6	0.012
Discharged to home	27 (62.8)	38 (88.4)	0.006
Readmission w/in 30 days	0 (0)	0 (0)	>0.99
Readmission w/in 3 mos	1 (2.3)	1 (2.3)	>0.99
Reop w/in 30 days	1 (1.3)	0 (0)	>0.99
Central cord syndrome*	1 (1.3)		
Reop w/in 24 mos	2 (4.7)	3 (7.0)	>0.99
Central cord syndrome*	1 (1.3)	0 (0)	
Adjacent-segment disease	1 (1.3)	0 (0)	
Persistent stenosis requiring ACDF	0 (0)	3 (7.0)	

ACDF = anterior cervical discectomy and fusion.
 Values are given as mean ± SD or number of patients (%) unless otherwise indicated. Boldface type indicates statistical significance.
 * Central cord syndrome developed in a patient who fell, requiring decompression and extension of fusion.

conducted on our propensity score–matched CL and PCF cohorts (n = 86). The variables reaching p < 0.20 in univariate analysis of the matched groups were accounted for as covariates: sex; anxiety; baseline participation in activities outside the home; predominant location of pain; and the subjective presentation of radicular arm pain, numbness, and myelopathy. The CL cohort was again associated with increased return to activities after 3 months (OR 5.7 [95% CI 1.6–20.6], adjusted p = 0.01). In contrast to the univariate analysis, however, laminoplasty did not reach a statistically significant association with NDI change after 24 months ($\beta = -4.5$ [95% CI -13.8 to 4.7], adjusted p = 0.33). Laminoplasty was associated with similar long-term outcomes compared with PCF for all PROs, including mJOA, VAS neck pain, VAS arm pain, NDI, EQ-5D, EQ-VAS, and NASS satisfaction scores (adjusted p > 0.05).

Table 5 shows the results of an additional multivariable analysis conducted on our entire cohort of laminoplasty and PCF patients, prior to any matching (n = 234). Variables reaching p < 0.20 in univariate analysis of the entire patient cohort were accounted for as covariates: peripheral vascular disease; anxiety; baseline participation in activities outside the home; predominant location of pain; and the subjective presentation of radicular arm pain, radicular deficit, numbness, neck pain, and myelopathy. Again, no significant differences were observed across any of our 3- and 24-month outcomes (adjusted p > 0.05).

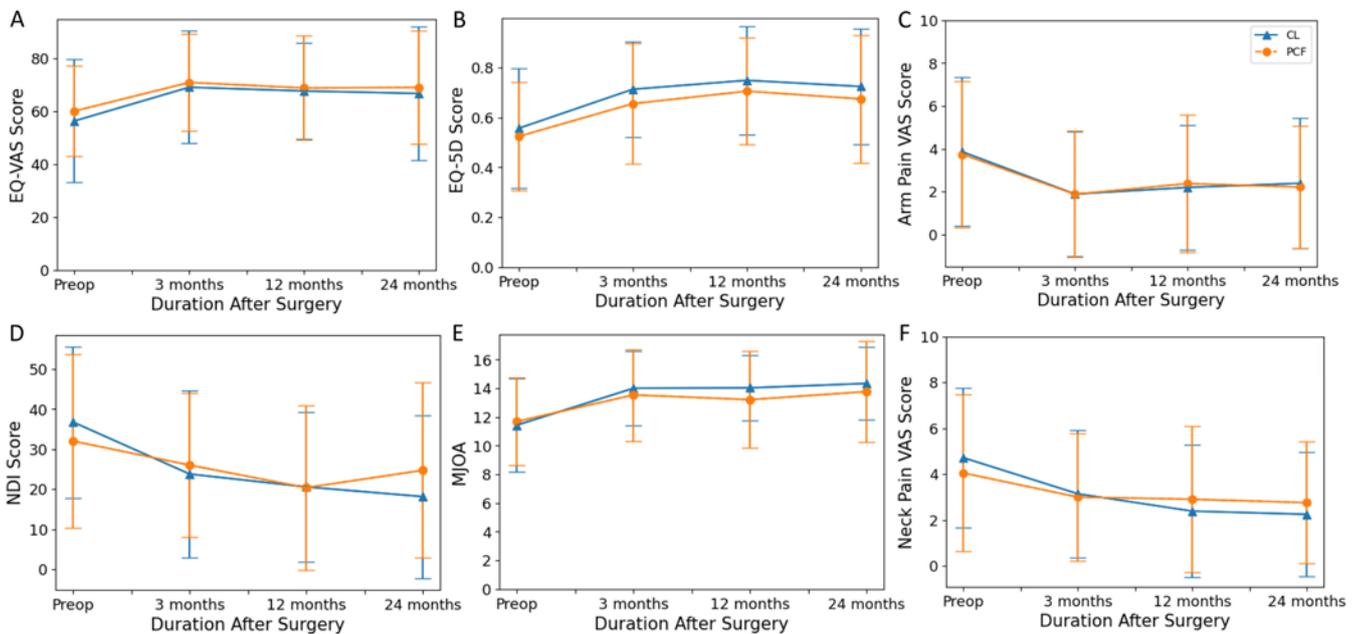


FIG. 3. Comparison of PROs between patients undergoing PCF and those undergoing laminoplasty at 3, 12, and 24 months. **A:** For laminoplasty, the EQ-VAS was significantly improved from baseline at all time points (p < 0.05). For PCF, the EQ-VAS was significantly improved from baseline at 3 months (p = 0.007) but did not reach statistical significance at 12 months (p = 0.073) and 24 months (p = 0.066). **B:** For the CL and PCF cohorts, EQ-5D improvements were significant at all time points (p < 0.05). **C:** For the CL and PCF cohorts, VAS arm pain was significantly improved from baseline at all time points (p < 0.05). **D:** For laminoplasty, NDI was significantly improved from baseline at all time points (p < 0.05). For PCF, NDI was significantly improved at 12 months (p = 0.002) and 24 months (p = 0.045) but not at 3 months (p = 0.060). **E:** For laminoplasty, mJOA was significantly improved compared with baseline at all time points (p < 0.05). For PCF, mJOA was significantly improved at 3 months (p = 0.015) and 24 months (p = 0.008) but not at 12 months (p = 0.080). **F:** For laminoplasty, VAS neck pain was significantly improved from baseline at all time points (p < 0.05). For PCF, VAS neck pain was significantly improved from baseline at 3 months (p = 0.039) but not at 12 months (p = 0.278) and 24 months (p = 0.104).

Discussion

Our study compared perioperative and postoperative outcomes from propensity score–matched cohorts of patients undergoing either laminoplasty or laminectomy with fusion for CSM. We found laminoplasty to be associated with decreased estimated blood loss, decreased length of hospitalization, and increased rates of discharge to home. Clinically, laminoplasty was associated with superior return to activities at 3 months and a larger improvement in 24-month NDI scores (but similar 24-month mean NDI scores). Otherwise, at 24 months, laminoplasty and laminectomy with fusion were associated with similar mean scores for all other PROs, including mJOA, VAS neck and arm pain, EQ-5D, and EQ-VAS scores. Both procedures had similar postoperative NASS satisfaction scores at 3 and 24 months.

Although increasing in prevalence, laminoplasty has remained notably underutilized in the US. Many existing studies characterizing laminoplasty outcomes have been focused on Japanese and Korean populations, where the procedure is more frequently performed.^{13,23,24} Comparisons between laminoplasty and laminectomy with PCF in the unique US healthcare setting are important but lacking. Notably, Ghogawala et al. recently found in a randomized clinical trial subgroup analysis that patients undergoing laminoplasty showed a significantly higher estimated mean change in SF-36 Physical Component Summary outcomes after 1 year (CL group: 9.6 vs PCF group: 4.6, $p = 0.02$) and 2 years (CL group: 10.1 vs PCF group: 4.3, $p = 0.01$).¹⁷ Additionally, the mean change in EQ-5D scores after 2 years was significantly higher in the CL cohort than the PCF cohort (0.20 ± 0.17 vs 0.14 ± 0.22 , $p = 0.01$). Our analysis did not, however, show a similar association between laminoplasty and long-term superiority in quality of life, as the change in EQ-5D after 2 years was similar between both our cohorts. This inconsistency could be a reflection of the small cohort sizes across both studies (Ghogawala et al.:¹⁷ $n = 28$ laminoplasty, $n = 69$ laminectomy with fusion; present study: $n = 43$ laminoplasty, $n = 191$ laminectomy with fusion). Future studies comparing laminoplasty and fusion outcomes with a larger cohort may help in this regard.

On the other hand, our study does suggest that laminoplasty may hasten recovery, given that the CL cohort exhibited higher rates of home discharge, reduced length of hospitalization, and superior 3-month return-to-activity rates after surgery. Traditionally, fusion has been regarded by surgeons to be a more invasive procedure—with additional lateral exposure, bony resection, and arthrodesis resulting in greater blood loss and postoperative pain.^{25,26} This was confirmed in our cohort by the significantly greater estimated blood loss in the PCF cohort, which is indicative of the increased invasiveness of the fusion procedure.

Regarding neck pain, 1) both the CL and PCF cohorts had similar baseline neck pain (moderate neck pain), and 2) the cohorts demonstrated similar changes in neck pain, mean neck pain scores, and achievement of neck pain freedom. Our findings here stand in contrast to prior studies reporting long-term worsening of neck pain in patients after laminoplasty, as well as the long-held belief that fusion

TABLE 3. Postoperative outcomes of patients undergoing PCF or laminoplasty, propensity score matched

	PCF (n = 43)	CL (n = 43)	p Value
mJOA			
3-mo score	13.5 ± 3.1	14.1 ± 2.6	0.407
3-mo change	2.0 ± 4.2	2.5 ± 2.6	0.573
3-mo relieved cervical myelopathy	4 (12.5)	6 (17.1)	0.594
24-mo score	13.8 ± 3.4	14.4 ± 2.5	0.398
24-mo change	2.2 ± 4.1	3.1 ± 2.8	0.287
24-mo relieved cervical myelopathy	8 (25.0)	7 (18.9)	0.541
VAS neck pain			
3-mo score	2.8 ± 2.8	3.3 ± 2.9	0.503
3-mo change	-1.5 ± 3.4	-1.7 ± 3.1	0.831
3-mo pain free	12 (35.3)	10 (27.8)	0.498
24-mo score	2.7 ± 2.6	2.4 ± 2.9	0.731
24-mo change	-1.1 ± 3.2	-2.4 ± 3.6	0.108
24-mo pain free	10 (28.6)	16 (43.2)	0.195
VAS arm pain			
3-mo score	2.1 ± 3.2	1.9 ± 2.9	0.846
3-mo change	-1.9 ± 3.2	-2.0 ± 3.2	0.850
3-mo pain free	21 (61.8)	20 (55.6)	0.598
24-mo score	2.2 ± 2.8	2.6 ± 3.2	0.635
24-mo change	-1.6 ± 3.3	-1.6 ± 3.0	0.941
24-mo pain free	18 (51.4)	16 (43.2)	0.487
NDI			
3-mo score	24.5 ± 18.6	24.5 ± 21.0	0.998
3-mo change	-9.0 ± 22.6	-14.8 ± 19.4	0.253
24-mo score	23.6 ± 21.8	18.7 ± 20.4	0.328
24-mo change	-9.1 ± 21.9	-19.6 ± 18.9	0.031
EQ-5D			
3-mo score	0.6 ± 0.2	0.7 ± 0.2	0.233
3-mo change	0.1 ± 0.2	0.2 ± 0.2	0.275
24-mo score	0.7 ± 0.3	0.7 ± 0.2	0.461
24-mo change	0.1 ± 0.3	0.2 ± 0.3	0.491
EQ-VAS			
3-mo score	69.7 ± 19.4	68.3 ± 21.5	0.774
3-mo change	8.8 ± 20.3	12.8 ± 23.3	0.466
24-mo score	70.1 ± 21.1	65.1 ± 26.9	0.393
24-mo change	10.1 ± 26.5	10.1 ± 24.1	0.991
NASS satisfaction score 1 or 2			
3 mos	26 (76.5)	32 (86.5)	0.276
24 mos	31 (83.8)	34 (87.2)	0.674
Return to work*			
3 mos	13 (86.7)	4 (44.4)	0.082
Return to activities			
3 mos	7 (21.2)	17 (47.2)	0.023

Values are given as mean ± SD or number of patients (%) unless otherwise indicated. Boldface type indicates statistical significance. Data were missing for some patients.

* Return to work assessed for eligible patients.

TABLE 4. Multivariable comparison of postoperative outcomes for PCF versus laminoplasty after PSM

	β	95% CI	Adjusted p Value
mJOA			
3-mo score	0.2	-1 to 1.4	0.75
3-mo change	0.6	-0.9 to 2.2	0.44
3-mo relieved cervical myelopathy	0.9*	0.2 to 4.1	0.93
24-mo score	0.2	-1.1 to 1.5	0.80
24-mo change	0.6	-0.9 to 2.1	0.44
24-mo relieved cervical myelopathy	1.4*	0.4 to 4.8	0.64
VAS neck pain			
3-mo score	-0.3	-1.6 to 1	0.64
3-mo change	-0.8	-2.2 to 0.7	0.30
3-mo pain free	0.5*	0.2 to 1.7	0.30
24-mo score	-0.5	-1.7 to 0.7	0.44
24-mo change	-1.2	-2.8 to 0.4	0.15
24-mo pain free	0.5*	0.2 to 1.5	0.23
VAS arm pain			
3-mo score	-0.4	-1.8 to 0.9	0.54
3-mo change	-0.4	-1.9 to 1	0.57
3-mo pain free	0.7*	0.3 to 1.9	0.47
24-mo score	0.3	-1 to 1.7	0.64
24-mo change	-0.3	-1.7 to 1.2	0.71
24-mo pain free	1.4*	0.5 to 3.8	0.54
NDI			
3-mo score	-1.8	-10.3 to 6.8	0.68
3-mo change	-4.2	-13.7 to 5.3	0.38
24-mo score	-2.0	-10.7 to 6.6	0.64
24-mo change	-4.5	-13.8 to 4.7	0.33
EQ-5D			
3-mo score	0.04	0 to 0.1	0.36
3-mo change	0.005	-0.1 to 0.1	0.92
24-mo score	0.03	-0.1 to 0.1	0.54
24-mo change	0.01	-0.1 to 0.1	0.85
EQ-VAS			
3-mo score	0.2	-8.5 to 9	0.96
3-mo change	2.9	-6.8 to 12.6	0.55
24-mo score	-2.8	-13.4 to 7.7	0.59
24-mo change	-2.6	-14 to 8.8	0.65
NASS satisfaction score 1 or 2			
3-mo	0.3*	0.1 to 1.4	0.13
24-mo	5.4*	0.6 to 47.2	0.12
3-mo return to work	0.8*	0.2 to 2.4	0.67
3-mo return to activities	5.7*	1.6 to 20.6	0.01

Boldface type indicates statistical significance.

* Odds ratio.

may be more appropriate to treat patients with CSM who have a component of axial neck pain.²⁷⁻³⁰ A retrospective study of 56 patients found a slight increase in VAS neck pain after laminoplasty, but a significant decrease after PCF (CL group: mean baseline score 3.2 ± 2.8 vs mean postoperative score 3.4 ± 2.6, p = 0.50; PCF group: mean baseline score 5.8 ± 3.2 vs mean postoperative score 3.0 ± 2.3, p < 0.1), with follow-up of approximately 41.3–42.3 months.³⁰ However, the study had a PCF cohort with higher preoperative neck pain, suggesting an influence of selection bias on the findings. Our study shows, in an analysis of 14 high-volume spine centers in the US, that patients operated on with laminoplasty versus PCF had similar baseline neck pain in an unmatched comparison. Furthermore, after PSM on neck pain—creating two cohorts with moderate VAS neck pain—we observed similar neck pain outcomes. This is consistent with a report by Lau et al. comparing 101 patients undergoing CL to 44 patients undergoing laminectomy with PCF with a mean follow-up of 17.3 months.³¹ Our work shows an association between laminoplasty and reduction in neck pain, implying that the presence of preoperative neck pain may not necessarily be an indication for PCF in patients with moderate neck pain. Moreover, the finding that laminoplasty was associated with greater improvements in 24-month neck pain–related disability (i.e., NDI change) supports this notion. These results are in line with more recent studies that have found no difference in VAS neck pain scores postoperatively.³¹

Overall, the results of our study demonstrate long-term equivalence of the laminoplasty and PCF approaches across a range of clinical outcomes. PCF appears to be well tolerated by patients, although our findings do indicate that laminoplasty may be associated with an accelerated recovery process for patients with CSM across perioperative metrics and 3-month initial superiority in return to activities. This finding may be multifactorial and stem from the less invasive nature of laminoplasty and differences in postoperative restrictions, prolonged collar use, after PCF compared with laminoplasty, wherein the former may have longer periods of activity restrictions and longer latencies to initiate postoperative physical therapy.

Limitations

This study is inherently limited by its nature as a retrospective analysis of a prospective registry. First, as a registry study, patients are lost to follow-up. However, our follow-up rates at 24 months were 88.4% and 83.7% for laminoplasty and laminectomy with PCF, respectively. Prior investigation demonstrates that loss to follow-up is not considered a significant threat to outcome validity until the rate exceeds 20%.³² Second, we performed an observational nonrandomized comparison of two surgical procedures, which inherently presents selection bias. Surgeons may have different indications or preferences for laminoplasty versus fusion procedures (e.g., unilateral vs bilateral radicular arm pain, absence of neck or arm pain, and smoking status). Patients with severe neck pain and loss of cervical lordosis are traditionally regarded as poor candidates for laminoplasty and tend to be offered decompression with fusion. Patients themselves may even influence the decision-making process (i.e., if a patient ex-

presses disinclination for PCF), and not every surgeon performs both procedures. We attempted to control for these baseline differences and the resulting selection bias by using PSM. However, while PSM is a powerful technique to account for confounding, it may not account for all possible confounders. Our matched CL and PCF cohorts significantly differed on two baseline factors: participation in activities outside the home and subjective presentation of radicular arm pain. Although we included these variables as covariates in multivariable analysis, potential effects of confounding may still remain. For instance, laminoplasty patients may have been more active preoperatively—driving the faster return to activity after surgery in the CL cohort.

Additionally, our study is constrained by the limited number of patients who underwent laminoplasty in the QOD CSM data set, which may reflect the overall underutilization of laminoplasty in the US. Subsequent studies may expand on our analysis of PROs between CL and PCF groups with a larger cohort. A randomized clinical trial focusing solely on dorsal approaches may be ideal. Finally, our study was focused primarily on assessing the PROs already available in the QOD. There are data that the QOD does not collect, particularly pre- and postoperative radiographic imaging. Future analysis may benefit from the inclusion of key radiographic parameters such as cervical lordosis (C2–7 Cobb angle), T1 slope, center of gravity of the head to the C7 sagittal vertical axis, cervical range of motion including proportion that is flexion and extension, and modified K-line.

Conclusions

In our CSM cohort, both patients undergoing laminoplasty and those undergoing laminectomy with fusion showed significant improvements across PRO measures. Compared with PCF, laminoplasty was associated with lower estimated blood loss, shorter length of hospitalization, higher rates of home discharge, and increased return to activities after 3 months. At 24 months, the NDI change was greater for the CL cohort (although the mean 24-month NDI scores were similar). Otherwise, there were no significant differences in all remaining 24-month PRO scores: functional status, pain, quality of life, and satisfaction with surgery were similar between both laminoplasty and laminectomy with fusion patients. Both cohorts had similar VAS neck pain outcomes at 3 and 24 months—suggesting that the long-held belief that neck pain is a contraindication for laminoplasty may need to be reconsidered. Overall, although 24-month outcomes are largely comparable, patients undergoing laminoplasty may demonstrate faster return to preoperative activities.

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TABLE 5. Multivariable comparison of postoperative outcomes for PCF versus laminoplasty in full cohort (n = 234)

	β	95% CI	Adjusted p Value
mJOA			
3-mo score	0.7	-0.3 to 1.6	0.16
3-mo change	0.9	-0.1 to 2	0.07
3-mo relieved cervical myelopathy	0.5*	0.2 to 1.5	0.22
24-mo score	0.7	-0.2 to 1.7	0.13
24-mo change	1.0	-0.1 to 2.1	0.07
24-mo relieved cervical myelopathy	0.8*	0.3 to 2.3	0.73
VAS neck pain			
3-mo score	0.2	-0.7 to 1.1	0.74
3-mo change	0.6	-0.5 to 1.7	0.32
3-mo pain free	1.0*	0.4 to 2.3	0.95
24-mo score	-0.1	-1.2 to 0.9	0.77
24-mo change	0.002	-1.2 to 1.2	>0.99
24-mo pain free	0.9*	0.4 to 2	0.85
VAS arm pain			
3-mo score	-0.2	-1.2 to 0.8	0.69
3-mo change	-0.2	-1.4 to 1.1	0.79
3-mo pain free	1.0*	0.5 to 2	0.97
24-mo score	0.2	-0.8 to 1.2	0.71
24-mo change	0.005	-1.3 to 1.3	0.99
24-mo pain free	1.7*	0.8 to 3.6	0.18
NDI			
3-mo score	-0.3	-6.5 to 5.9	0.92
3-mo change	-1.8	-8.7 to 5.1	0.60
24-mo score	-1.6	-8.5 to 5.4	0.66
24-mo change	-4.3	-11.9 to 3.4	0.27
EQ-5D			
3-mo score	-0.3	-7.5 to 7	0.94
3-mo change	2.5	-5.6 to 10.5	0.55
24-mo score	-4.3	-12 to 3.4	0.27
24-mo change	-2.4	-11.8 to 7	0.62
EQ-VAS			
3-mo score	0.01	-0.1 to 0.1	0.75
3-mo change	-0.03	-0.1 to 0	0.38
24-mo score	0.01	-0.1 to 0.1	0.73
24-mo change	-0.01	-0.1 to 0.1	0.78
NASS satisfaction score 1 or 2			
3-mo	0.7*	0.2 to 2.2	0.56
24-mo	0.9*	0.3 to 2.7	0.86
3-mo return to work	0.7*	0.3 to 1.5	0.31
3-mo return to activities	1.4*	0.6 to 2.9	0.42

* Odds ratio.

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Author Contributions

Conception and design: Chan, Yang, Mummaneni, Bisson, Potts, Virk, Meyer, Buchholz, Haid. Acquisition of data: Chan, Mummaneni, Chou, Bisson, CI Shaffrey, Asher, Coric, Potts, Foley, Wang, Fu, Virk, Park, Upadhyaya, Buchholz, Tumialán, Sherrod. Analysis and interpretation of data: Chan, Yang, Coric, Wang, Virk, Meyer, Buchholz, Haid. Drafting the article: Chan, Yang, Knightly, ME Shaffrey, Buchholz. Critically revising the article: Chan, Yang, Mummaneni, Chou, Bydon, Bisson, CI Shaffrey, Foley, Wang, Upadhyaya, ME Shaffrey, Turner, Sherrod, Agarwal, Haid. Reviewed submitted version of manuscript: Chan, Yang, Mummaneni, Chou, Bydon, Bisson, CI Shaffrey, Gottfried, Asher, Coric, Potts, Foley, Wang, Fu, Virk, Knightly, Meyer, Park, Upadhyaya, ME Shaffrey, Tumialán, Turner, Michalopoulos, Sherrod, Agarwal, Haid. Approved the final version of the manuscript on behalf of all authors: Chan. Statistical analysis: Yang. Administrative/technical/material support: Chan, Michalopoulos, Haid. Study supervision: Chan, Mummaneni, Bydon, Bisson, Potts, Meyer.

Supplemental Information

Previous Presentations

The work was previously presented as a podium presentation at the 2023 AANS/CNS Section on Disorders of the Spine and Peripheral Nerves Spine Summit, March 18, 2023, Miami, Florida.

Correspondence

Andrew K. Chan: Columbia University Vagelos College of Physicians and Surgeons, The Ochsner Hospital at NewYork-Presbyterian, New York, NY. ake2136@columbia.edu.