Are There Differences in 2-Year Outcomes Between Two-Level Anterior Cervical Diskectomy and Fusion Versus Single-Level Anterior Cervical Corpectomy and Fusion to Treat Cervical Myelopathy? A Quality Outcomes Database Study

Connor Berlin, MD *, **Sufyan Ibrahim, MBBS**‡, **Praveen V. Mummaneni, MD, MBA**§, **Andrew K. Chan, MD**‖, **Dean Chou, MD**‖, **Kai-Ming Fu, MD, PhD**¶, **Mohamad Bydon, MD**‡, **Erica F. Bisson, MD, MPH**#, **Christopher I. Shaffrey, MD****, **Oren N. Gottfried, MD****, **Anthony L. Asher, MD**††, **Domagoj Coric, MD**††, **Eric Potts, MD**‡‡, **Kevin T. Foley, MD**§§, **Michael Y. Wang, MD**‖‖, **Michael S. Virk, MD, PhD**¶, **John J. Knightly, MD**¶¶, **Scott Meyer, MD**¶¶, **Paul Park, MD**§§, **Cheerag Upadhyaya, MD**##, **Luis M. Tumialán, MD***, **Jay Turner, MD, PhD***, **Juan Uribe, MD***, **Regis W. Haid Jr, MD**†††, **Chun-Po Yen, MD***, **Mark E. Shaffrey, MD** *

*Department of Neurosurgery, University of Virginia, Charlottesville, Virginia, USA; **(Continued on next page)**

Presented at AANS/CNS Spine Section Oral Presentation in Las Vegas, NV from February 21-24, 2024. Presented at IMAST/SRS 2024 Annual Meeting Presentation in San Diego, CA from April 10-13, 2024. Presented at Neurosurgical Society of the Virginias in Greenbrier, WV from January 24-27, 2024.

Correspondence: Connor Berlin, MD, Department of Neurosurgery, University of Virginia, PO Box 800212, Charlottesville, VA 22908, USA. Email: cdb5zm@uvahealth.org

Received, October 04, 2024; **Accepted,** February 10, 2025; **Published Online,** May 19, 2025.

Neurosurgery 00:1–9, 2025 https://doi.org/10.1227/neu.0000000000003518

BACKGROUND AND OBJECTIVES: There has been limited assessment between anterior cervical diskectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF) on patient-reported outcome measures (PROMs) in the treatment of cervical spondylotic myelopathy. We sought to compare PROMs from two-level ACDF with single-level ACCF procedures. We evaluate these results in the context of minimum clinically important difference (MCID) thresholds, which have not been performed previously.

METHODS: This retrospective analysis of prospectively collected data from the Quality Outcomes Database Spine Collaborative Research Study Group compared two-level ACDF and single-level ACCF at 3-, 12-, and 24 months postoperatively. PROMs included arm pain Numeric Rating Scale, neck pain Numeric Rating Scale, Neck Disability Index, and North American Spine Society Patient Satisfaction Index. Multivariate logistic regression was used to determine differences in perioperative outcomes, as well as the impact of two-level ACDF vs one-level ACCF on PROMs. MCID thresholds were based off previously established limits.

RESULTS: Three hundred and thirty patients were included (236 ACDF, 94 ACCF), and the follow-up rate was 82% at 2 years. There was a significantly higher baseline age, American Society of Anesthesiologists grade, proportion of diabetes, osteoarthritis, ambulation dependence, and myelopathy severity in the ACCF cohort. On multivariable analysis, the ACCF group had greater average length of stay and estimated blood loss. There were no significant differences between reoperation rates or nonroutine discharge. There were similar rates of MCID achievement for PROMs at all time points.

CONCLUSION: This study suggests that both ACDF and ACCF procedures for cervical spondylotic myelopathy are able to achieve similar, clinically meaningful improvements in PROMs by 2 years. Patients undergoing single-level ACCF have more estimated blood loss and longer length of stay, as well as worse baseline myelopathy. Both procedures have efficacious, durable outcomes. It is reasonable that other factors, such as radiographic characteristics and patient symptoms, may influence patient selection for ACDF vs ACCF.

KEY WORDS: Cervical, Corpectomy, Diskectomy, Myelopathy, Decompression, Spine

ABBREVIATIONS: ACCF, anterior cervical corpectomy and fusion; **ACDF,** anterior cervical diskectomy and fusion; **AP-NRS,** arm pain Numeric Rating Scale; **CORe,** collaborative research; **CSM,** cervical spondylotic myelopathy; **EBL,** estimated blood loss; **LOS,** length of stay; **MCID,** minimum clinically important difference; **mJOA,** modified Japanese Orthopaedic Association; **NASS,** North American Spine Society; **NDI,** Neck Disability Index; **NPA,** NeuroPoint Alliance; **NP-NRS,** neck pain Numeric Rating Scale; **NREF,** Neurosurgery Research & Education Foundation; **PROMs,** patient-reported outcome measures; **QOD,** Quality Outcomes Database; **SES,** socioeconomic status.

Cervical spondylotic myelopathy (CSM) is the most common cause of nontraumatic spinal cord injury worldwide, with related hospitalizations alone estimated at 4.04 per 100 000 person-years.[1] As one of the most common spinal cord disorders in the elderly,[2,3] CSM is also the most important risk factor for those who later develop traumatic central cord syndrome.[4] The prevalence of CSM is only expected to further increase over time.[4]

As a blanket term to describe degeneration of the cervical spine, CSM can encompass pathophysiological processes such as cervical stenosis, progressive spondylosis, degenerative disk disease, spinal malalignment, and others.[1] The subsequent narrowing of the cervical spine and compression of the spinal cord can lead to classic symptoms of cervical myelopathy, such as motor dysfunction, loss of sensation, urinary incontinence, and gait dysfunction.[4,5] When conservative management (such as cervical immobilization, restriction of high-risk activities, pharmacologic pain management, etc.[6,7]) fails, myelopathy is significant, or there is risk of further neurological decline, surgical decompression has become standard of care.[4,8-11]

Options for surgical decompression in CSM include posterior approaches such as laminoplasty or laminectomy with fusion, anterior approaches such as anterior cervical diskectomy and fusion (ACDF) or anterior cervical corpectomy and fusion (ACCF), or a combination of anterior and posterior approaches.[10,12-14] Although multiple factors will determine surgeon choice of operation (eg, surgeon experience, number of levels, bone quality, location of compression, etc.) these approaches are all safe and effective at improving clinical outcomes in patients with CSM.[1,8,9]

When it comes to consideration of anterior approaches such as ACDF and ACCF, there seem to be sufficient data on perioperative complications and postoperative radiographic outcomes.[12,15] In general, ACCF procedures have higher rates of perioperative complications and blood loss, but both procedures are able to decompress the spinal cord and restore lordosis in the cervical spine (albeit to varying amounts).[12,15,16] However, when determining whether two-level ACDF vs one-level ACCF can achieve similar, durable improvements in patient-reported outcome measures (PROMs), there are lack of sufficient data. A limited number of prior studies have attempted to address this question but have been restricted by small follow-up interval (1 year),[16] single institutional experience,[16,17] retrospective data collection,[15,18,19] limited scope/focus on PROMs,[15,18,19] or no minimum clinically important difference (MCID) comparison of PROMs.[15-19] In addition, the meta-analyses cited do not provide specific clarity on the number of levels for ACDF vs ACCF comparison.[15,18,19]

The objective of the present study was to assess PROMs in patients undergoing two-level ACDF vs single level ACCF for CSM. Surgeons typically choose an ACDF if the compressive pathology is located at the disk level, whereas an ACCF is generally chosen if the compressive pathology is located posterior the vertebral body. For the purpose of comparison, a two-level ACDF is most equivalent to a single-level ACCF, as both procedures span two-disk spaces and 1 entire vertebral body in length/scope (Figure 1). We hypothesized that there would be no differences between PROMs when comparing these 2 procedures.

To address this hypothesis, we used data on PROMs from the Spine Collaborative Research (CORe) Study Group. The Spine CORe Study Group comprises the 14 highest enrolling neurosurgical centers within the NeuroPoint Alliance (NPA) Quality Outcomes Database (QOD), a multicenter surgical spine registry in North America that prospectively enrolls patients undergoing spine surgery.[9,20-41] Importantly, we sought to evaluate these results in the context of MCID thresholds.

METHODS

Data Source and Patient Cohort

This was a retrospective analysis of prospectively collected data using the cervical spine QOD registry. Institutional review board authorization (University of California, San Francisco # 17-22109) was obtained, and because of study design, patient consent was waived.

This data set represents the combined cervical QOD data from 14 high-volume hospital sites. Data auditing was conducted by both a central team and individual sites. Operation notes were reviewed by a team of spine surgeons for verification. Inclusion criteria of this QOD CSM cohort have been described previously:[9] adult patients aged 18 years or older with (1) a surgical indication of CSM, (2) a predominant symptom of myelopathy, (3) modified Japanese Orthopaedic Association (mJOA) score <17, and (4) who underwent elective surgery between January 2016 and December 2018.[9] Exclusion criteria were as follows: spinal infection, neurological paralysis due to preexisting spine disease or injury, tumor, deformity, fracture, traumatic dislocation, or combined anterior-posterior cases.[9] For this comparative study, patients who underwent either a two-level ACDF or single-level ACCF were included (Figure 1). Radiographic data were not available for analysis.

Outcomes of Interest

Baseline disease severity and outcomes after either two-level ACDF or one-level ACCF for CSM were compared. PROMs included arm pain Numeric Rating Scale (AP-NRS), neck pain Numeric Rating Scale (NP-NRS), Neck Disability Index (NDI), and North American Spine Society (NASS) Patient Satisfaction Index. These PROMs were documented at baseline and postoperative follow-up at 3-, 12- and 24 months.

(Continued from previous page)

[‡]Department of Neurosurgery, Mayo Clinic Neuro-Informatics Lab, Mayo Clinic, Rochester, Minnesota, USA; [§]Department of Neurological Surgery, University of California, San Francisco, California, USA; [‖]Department of Neurosurgery, Columbia University, New York, New York, USA; [¶]Department of Neurological Surgery, Weill Cornell Medicine, New York, New York, USA; [#]Department of Neurosurgery, University of Utah, Salt Lake City, Utah, USA; [**]Department of Neurosurgery, Duke University Medical Center, Durham, North Carolina, USA; [††]Carolina Neurosurgery & Spine Associates, Carolinas Medical Center, Charlotte, North Carolina, USA; [‡‡]Goodman Campbell Brain and Spine, Carmel, Indiana, USA; [§§]Semmes Murphey Neurologic and Spine Institute, Memphis, Tennessee, USA; [‖‖]Department of Neurological Surgery, University of Miami, Miami, Florida, USA; [¶¶]Atlantic Neurosurgical Specialists, Altair Health Spine & Wellness Center, Morristown, New Jersey, USA; [##]Department of Neurosurgery, University of North Carolina, Chapel Hill, North Carolina, USA; [***]Department of Neurosurgery, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, Arizona, USA; [†††]Atlanta Brain and Spine Care, Atlanta, Georgia, USA

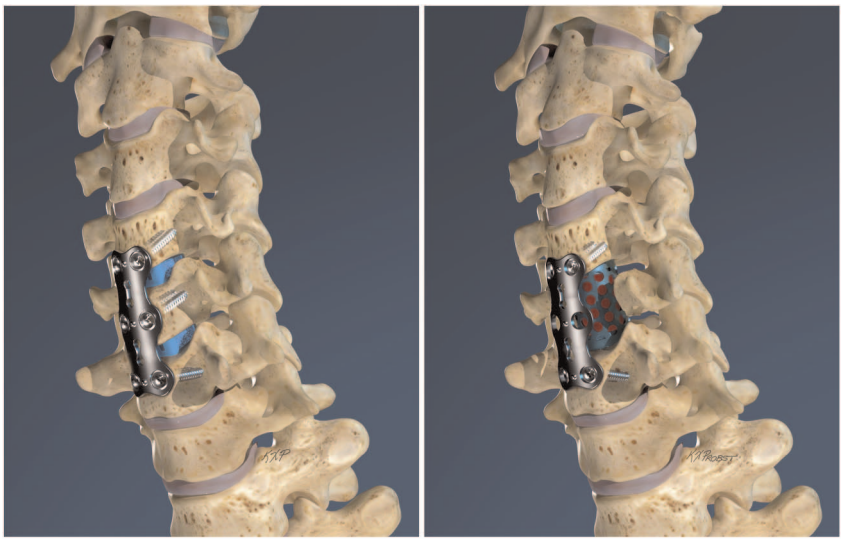

FIGURE 1. *On the left side is depicted a standard two-level anterior cervical diskectomy and fusion spanning at C4 to C5 and C5 to C6 with anterior plate secured with vertebral body screws bilaterally in C4, C5, and C6, respectively. On the right side is depicted a standard single-level anterior cervical corpectomy and fusion at C5 with interbody cage spanning from C4 to C6 and an anterior plate secured with vertebral body screws bilaterally at C4 and C6. Material of the interbody devices can differ based on surgeon preference. "Stand-alone" cages with no anterior plate were not compared in this investigation. Copyright Praveen V. Mummaneni. Published with permission.*

NDI score, ranging from 0% to 100%, was used to assess how neck pain affects a patient's ability to perform daily activities. Scores between 0% and 8% indicate no disability, whereas scores from 70% to 100% indicate complete disability. For arm and neck pain, the numeric rating scale represents an 11-point scale ranging from 0 (no pain) to 10 (worst possible pain). These PROMs were used, alongside clinical symptom data at presentation, to evaluate disease severity at baseline and during follow-ups.

Similarly, at each follow-up time point after surgery, patients were asked to complete the NASS questionnaire to gauge their satisfaction with the surgical procedure. The NASS scores were transformed into a binary variable, where scores of 1 to 2 denoted 'satisfaction,' whereas scores of 3 to 4 indicated 'no satisfaction' postsurgery, which is common practice.[22,42] Patient-reported satisfaction after surgery and the rates of achieving the MCID in PROMs were compared between patients who received two-level ACDF vs one-level ACCF. The MCID for NDI, AP-NRS, and NP-NRS scores was defined previously as a 30% improvement from the baseline observations of these respective outcomes, which has been shown to predict patient satisfaction with more accuracy than absolute point-change values in a multi-institutional US cohort of 13 179 patients who underwent cervical spine surgery for degenerative disease.[43]

Statistical Analysis

Continuous variables are presented as mean + SD, and categorical variables are expressed as frequency with percentages. *T*-tests were used to compare continuous variables, and the Pearson χ^2 test with Yates correction was used for categorical variables, as necessary. Missing data in the baseline data were managed with the Multivariate Imputation by Chained Equations algorithm.

For assessing differences in perioperative outcomes including length of stay (LOS), estimated blood loss (EBL), nonroutine discharge (home vs other), and reoperation rates, multivariable regression analyses were performed after adjusting for age, sex, body mass index (BMI), insurance payor, socioeconomic status (SES) index, employment status, smoking status, baseline comorbidities, ambulation status, baseline radicular deficit symptoms, listhesis, baseline American Society of Anesthesiologists (ASA) grade, and baseline mJOA score.

Multivariable regression analysis was also used to evaluate the influence of the chosen surgical procedure (using one-level ACCF as the reference against two-level ACDF) on achieving postoperative patient-reported satisfaction and meeting MCIDs in respective PROMs. All multivariable analyses were adjusted for various patient-specific factors (all with $P < .20$ from univariate analysis for choice of surgery) including age, BMI, insurance type, race, SES index, employment status, workers' compensation, ambulation status, radicular motor-deficit symptoms, and comorbidities at baseline. All *P*-values were two-tailed, and a significance level of 0.05 was considered statistically significant. The statistical analyses were conducted using RStudio 2023.03 (2023 Posit Software, PBC formerly RStudio, PBC).

RESULTS

Patient Population

One thousand one hundred and forty-one patients across 14 institutions underwent surgical intervention for CSM. Of these, 330 patients were considered eligible for our study: 236 underwent two-level ACDF, and 94 underwent one-level ACCF. The follow-up rate was 82% at 2 years.

TABLE 1. Baseline Demographics in Patients Undergoing Two-Level ACDF Versus One-Level Corpectomy

Variables	One-level ACCF (N = 94)	Two-level ACDF (N = 236)	*P* value
Age, mean (SD)	60.340 (10.970)	57.250 (11.495)	**.03**
Sex, n (%)			.58
Female	47 (50.0)	126 (53.4)	
Male	47 (50.0)	110 (46.6)	
BMI, mean (SD)	30.717 (6.807)	30.209 (6.480)	.53
Insurance payor, n (%)			.27
Medicaid	3 (3.2)	20 (8.5)	
Medicare	30 (31.9)	59 (25.0)	
Private	57 (60.6)	147 (62.3)	
Uninsured	2 (2.1)	2 (0.8)	
Virginia/government	2 (2.1)	8 (3.4)	
Educational level, n (%)			.71
Graduate level	39 (41.5)	87 (36.9)	
High school or less	41 (43.6)	109 (46.2)	
Postgraduate level	10 (10.6)	33 (14.0)	
Prefer not to answer/NA	4 (4.3)	7 (3.0)	
Race, n (%)			.10
White	76 (81.7)	178 (75.4)	
Black	14 (15.1)	30 (12.7)	
Other	2 (2.2)	11 (4.7)	
Prefer not to answer	1 (1.1)	17 (7.2)	
SES index, mean (SD)	52.370 (4.712)	53.155 (4.944)	.19
Workers' compensation, n (%)	2 (2.2)	4 (1.7)	.78
Liability claim, n (%)	5 (5.4)	10 (4.4)	.70
Employment status, n (%)			.61
Employed	43 (46.2)	118 (50.0)	
Employed on short-term leave	8 (8.6)	25 (10.6)	
Unemployed	42 (45.2)	93 (39.4)	
Smoking, n (%)	16 (17.0)	41 (17.4)	.94
Diabetes mellitus, n (%)	24 (25.5)	31 (13.1)	**<.01**
Depression, n (%)	22 (23.4)	46 (19.5)	.43
Anxiety, n (%)	17 (18.1)	44 (18.6)	.91
Coronary artery disease, n (%)	10 (10.6)	16 (6.8)	.24
Osteoarthritis, n (%)	37 (39.4)	62 (26.3)	**.02**
COPD, n (%)	4 (4.3)	17 (7.2)	.32
Dependent ambulation, n (%)	21 (22.3)	17 (7.2)	**<.01**
Radicular motor deficit, n (%)	20 (21.3)	97 (41.1)	**<.01**
Radicular arm pain, n (%)	44 (46.8)	142 (60.2)	**.03**
Radicular numbness, n (%)	59 (62.8)	159 (67.4)	.43
Motor deficit, n (%)	51 (54.3)	137 (58.1)	.53
Symptom duration, n (%)			.33
N-miss	45	94	
<3 mo	6 (12.2)	26 (18.3)	
>12 mo	43 (87.8)	116 (81.7)	
Listhesis/dynamic instability, n (%)	23 (25.3)	51 (23.1)	.68
ASA grade, n (%)			**.01**
N-miss	1	14	
1	0 (0.0)	5 (2.3)	
2	38 (40.9)	125 (56.3)	
3	52 (55.9)	90 (40.5)	
4	3 (3.2)	2 (0.9)	
Baseline mJOA score, mean (SD)	11.819 (2.548)	12.669 (2.572)	**<.01**

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical diskectomy and fusion; ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; mJOA, modified Japanese Orthopaedic Association; NA, not applicable; SES, socioeconomic status.
Bold indicates statistical significance ($P < .05$).

Baseline demographics and any significant differences among cohorts are summarized in Table 1. In brief, patients undergoing ACCF were significantly older and demonstrated a higher proportion of diabetes, osteoarthritis, ASA grade 3 or 4, ambulation dependence, and baseline myelopathy severity (mJOA score). Patients undergoing ACDF were significantly more likely to have radicular motor deficits and radicular arm pain. Factors such as symptom duration (which tended to be >12 months) or presence of preoperative listhesis/dynamic instability did not differ between the 2 groups.

Postoperative and Patient-Reported Outcome Measures

The ACCF group had significantly greater LOS (2.0 ± 1.6 vs 1.2 ± 1.6 days, $P < .01$) and intraoperative EBL (102 mL vs 50 mL, $P < .01$). There were no differences in short-term perioperative outcomes including 30-day ($P = .77$) and 3-month readmissions ($P = .46$). At 2 years, there were no significant differences between reoperation rates (14.3% ACDF vs 19.5% ACCF, $P = .51$) or nonroutine discharges (3.0% ACDF vs 9.6% ACCF, $P = .23$) when controlling for other covariates. A multivariable regression analysis of these postoperative outcomes is summarized in Table 2.

In addition, there was no significant differences in NASS satisfaction and PROMs between the ACDF and ACCF cohorts at all time points (Table 3), indicating that neither cohort improves more than the other at any time point observed. At 24 months, the number of patients achieving MCID in the ACDF cohort vs the ACCF cohort for each PROM was similar: NDI = 127 (67.2%) vs 56 (66.7%), AP-NRS = 108 (60.3%) vs 49 (59.0%), NP-NRS = 110 (59.8%) vs 53 (63.9%), $P > .05$ for all comparisons. Multivariable regression analysis confirmed this finding by showing no significant difference in the adjusted odds of achieving MCIDs in any of the PROMs or NASS satisfaction at all time points (Table 4). This would indicate that both cohorts achieve similar rates of MCID cutoff at all time points.

DISCUSSION

This study is the first comprehensive, multicenter comparison of two-level ACDF vs single-level ACCF procedures in North America from a prospectively collected database, with MCID analysis of validated PROMs. Importantly, the follow-up rate of 2 years for the cervical QOD data set used in this study is >82%. Multivariable analyses demonstrated that the corpectomy group had a longer LOS and higher EBL. Importantly, we did not find a difference in reoperation rates or nonroutine discharge between the 2 groups, highlighting the similar safety and efficacy of both procedures and possibly similar fusion rates, although specific outcomes on fusion rates are still pending.

Multivariate regression revealed no differences in achieving MCID cutoff thresholds between the ACDF and ACCF groups in NDI, NP-NRS, and AP-NRS at all time points. These results indicate that patients undergoing two-level ACDF or single-level ACCF are able to achieve similar improvements in PROMs and that these improvements are durable out to at least 2 years.

Comparison to Prior Investigations

Prior investigations comparing two-level ACDF with single-level ACCF are lacking in the current literature. In our search, 2

TABLE 2. Multivariable Linear Regression Analysis of Postoperative Outcomes Among Patients Undergoing One-Level ACCF Versus Two-Level ACDF

One-level ACCF vs two-level ACDF	Coefficient/OR	95% CI	*P*-value
EBL[a]	−49.3	−68.7 to −29.8	**<.01**
LOS[a]	−0.46	−0.85 to −0.07	**.02**
Nonroutine discharge[b]	0.51	0.16 to 1.56	.23
24-mo reoperations[b]	0.79	0.39 to 1.58	.51

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical diskectomy and fusion; ASA, American Society of Anesthesiologists; BMI, body mass index; EBL, estimated blood loss; LOS, length of stay; mJOA, modified Japanese Orthopaedic Association; OR, odds ratio; SES, socioeconomic status.

[a]The multivariable analyses have been adjusted for age, sex, BMI, insurance payor, SES index, employment status, smoking status, baseline comorbidities, ambulation status, baseline radicular deficit symptoms, listhesis, baseline ASA grade, and mJOA score.

[b]Covariates included age, SES index, and ambulation status, to avoid overfitting, by stepwise backward elimination.

Bold indicates statistical significance ($P < .05$).

TABLE 3. Comparison of PROMs for Each Time Point

Variables	One-level ACCF (n = 94)	Two-level ACDF (n = 236)	*P* value
Baseline AP-NRS, mean (SD)	5.24 (3.50)	5.09 (3.34)	.72
Baseline NP-NRS, mean (SD)	5.58 (3.03)	5.30 (3.14)	.46
Baseline NDI, mean (SD)	40.48 (18.86)	39.11 (21.24)	.59
3-mo AP-NRS, mean (SD)	2.56 (3.01)	2.23 (2.89)	.39
3-mo NP-NRS, mean (SD)	2.85 (2.79)	2.76 (2.60)	.78
3-mo NDI, mean (SD)	26.04 (19.40)	22.83 (17.92)	.19
3-mo satisfaction (NASS 1-2), n (frequency)	69 (84.1%)	160 (86.0%)	.69
12-mo AP-NRS, mean (SD)	2.23 (2.54)	2.39 (2.83)	.69
12-mo NP-NRS, mean (SD)	2.58 (3.04)	2.52 (2.72)	.89
12-mo NDI, mean (SD)	22.86 (20.19)	19.68 (19.10)	.27
12-mo satisfaction (NASS 1-2), n (frequency)	49 (81.7%)	138 (85.2%)	.52
24-mo AP-NRS, mean (SD)	2.42 (3.14)	2.22 (2.93)	.62
24-mo NP-NRS, mean (SD)	2.70 (2.82)	2.63 (2.85)	.84
24-mo NDI, mean (SD)	20.01 (16.88)	20.99 (18.73)	.68
24-mo satisfaction (NASS 1-2), n (frequency)	69 (85.2%)	163 (86.7%)	.74

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical diskectomy and fusion; AP-NRS, arm pain Numeric Rating Scale; NASS, North American Spine Society; NDI, Neck Disability Index; NP-NRS, neck pain Numeric Rating Scale; PROMs, patient-reported outcome measures.

NASS is score based on satisfaction from surgery; therefore, there is no baseline (preoperative) score for this measure.

TABLE 4. Multivariate Analysis Assessing the Likelihood of Satisfaction or MCID Being Achieved in Single-Level ACCF Versus Two-Level ACDF for Respective PROMs

Variables	OR	95% CI	*P*-value
Satisfaction (NASS 1-2), months			
3	1.19	0.53-2.67	.67
12	1.24	0.52-2.96	.63
24	1.2	0.51-2.85	.67
MCID in NDI, months			
3	1.22	0.7-2.14	.48
12	0.92	0.46-1.85	.82
24	1.17	0.64-2.14	.61
MCID in NP-NRS, months			
3	0.99	0.57-1.74	.98
12	0.81	0.41-1.62	.56
24	0.81	0.44-1.48	.49
MCID in AP-NRS, months			
3	1.02	0.58-1.8	.95
12	0.57	0.28-1.15	.12
24	1.12	0.61-2.04	.71

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical diskectomy and fusion; AP-NRS, arm pain Numeric Rating Scale; BMI, body mass index; MCID, minimum clinically important difference; NASS, North American Spine Society; NDI, Neck Disability Index; NP-NRS, neck pain Numeric Rating Scale; OR, odds ratio; PROMs, patient-reported outcome measures; SES, socioeconomic status.
The multivariable analyses have been adjusted for age, BMI, insurance payor, race, SES index, employment status, worker's compensation, coronary artery disease, arthritis, ambulation status, and radicular deficit symptoms at baseline.

studies directly compared these exact procedures. Burkhardt et al[16] demonstrated similar improvements in multidimensional Core Outcomes Measures Index, global treatment outcome, and satisfaction at 12 months for both two-level ACDF and single-level ACCF. Similarly, Oh et al[17] found no differences in Visual Analog Score for neck pain and arm pain or Japanese Orthopaedic Association scores among two-level ACDF vs one-level ACCF. Both studies also demonstrated greater EBL in the ACCF cohort.[16,17] The observation of no difference in PROMs (although assessed PROMs were different) and higher EBL in the ACCF group is supportive of our present findings. However, both cited investigations were limited to single institutional experiences without MCID assessment.[16,17] Indeed, while other investigations (that did not directly compare two-level ACDF vs single-level ACCF) that have attempted to address the question of differences between ACDF and ACCF observed no differences in various PROMs, we could not find any studies that included an MCID appraisal of their results.[12,16-19,44] The importance of assessing patient-reported outcomes in the context of MCID thresholds cannot be overstated, as differences in PROMs may be statistically significant but not clinically meaningful or relevant to the patient.[9,21,45]

Nonetheless, additional studies (not directly comparing two-level ACDF vs single-level ACCF) have observed increased LOS and EBL in patients undergoing ACCF compared with ACDF, and we have demonstrated similar results here.[15,16,18] Although we did not observe differences in nonroutine discharges or reoperations, prior studies suggest that ACCF is sometimes associated with a higher rate of complications,[15,18,19] although other investigations have found that this may not be true.[12,16] If there are differences in complication rates between the 2 procedures, without properly conducted trials, it is difficult to determine if this is related to surgeon experience, implant failure, patient factors, or multifactorial reasons.

Overall, as guidelines for assessing PROMs in surgical studies have advanced, generally 2 years minimum of follow-up and a follow-up rate of around 80% are now accepted standards.[23,24,36] The strengths of this study are demonstrated by achieving these standards of follow-up time, response rate, and MCID analysis.

Patient Selection and Clinical Relevance

Patients undergoing ACCF tend to have more comorbidities and more severe myelopathy at baseline, whereas those undergoing ACDF tended to have higher radicular motor deficits and radicular arm pain. This may reflect distinct preoperative anatomical differences in each subgroup and surgeon selection bias, where ACCF is used for cases of stenosis behind the vertebral body and ACDF is used for cases of retrodiscal disease. Without available radiographic data, it is hard to confirm these anatomical differences but is the target of ongoing investigations by our group. Nonetheless, our findings may be applied to the subgroup of cases where there is clinical equipoise between the 2 procedures.

In addition, patients undergoing corpectomy had longer hospital LOS. This increased LOS is likely because of a higher rate of preoperative comorbidities in ACCF patients (Table 1), an increased rate of postoperative complications from intrinsic factors of the corpectomy procedure itself, and surgeon selection bias.

On the other hand, patients undergoing ACDF procedures had higher rates of preoperative radicular motor deficits and radicular arm pain. Again, this finding may be explained by differences in underlying CSM disease pathophysiology,[1] surgeon selection bias, or may be multifactorial.

The importance of the present results demonstrates that, despite difference in preoperative comorbidities or surgeon preference, patients receiving either two-level ACDF or single-level ACCF for CSM do not differ in their PROMs 2 years after surgery. It can therefore be concluded that both procedures have effective outcomes.

Limitations

This study was not designed to investigate the relative risk of undergoing ACCF vs ACDF surgery, which may be useful in

determining why a patient is selected for 1 procedure over the other. Classically, ACCF is thought to be more suitable for compression dorsal to the vertebral body and ACDF is better suited (although not always) for compression ventral to the disk space/presence of disk osteophyte complexes. The effect of surgeon selection bias on choice of procedure cannot be discounted. Furthermore, although multivariate analyses were used to control for demographic variables, there may be other covariates that were not controlled for in the original study population.

There was also no evaluation of radiographic data or fusion status, factors that could influence both surgical decision making and patient outcomes, and will be the focus of our group's future investigations once these data are available. Of note, others have retrospectively reported similar low rates of pseudoarthrosis when comparing ACDF with ACCF (7.1% vs 6.3%),[12] and until radiographic data are available for our cohorts, we would presume similar low rates as well. Finally, although bias in PROMs was minimized by the use of standardized questionnaires administered by trained providers, bias can never be fully eliminated because of the multi-institutional nature of the QOD registry.

CONCLUSION

This multivariate analysis of prospectively collected data from the Spine CORe Study Group suggests that both single-level ACCF and two-level ACDF for CSM can attain similar improvements in PROMs by 2 years, per MCID thresholds. ACCF patients are on average older, have more comorbidities, and worse baseline myelopathy than those chosen to undergo two-level ACDF. EBL and average LOS are significantly higher in single-level ACCF. Our results demonstrate that both procedures have effective, durable outcomes. It is reasonable that other factors, such as radiographic characteristics and patient symptoms, may influence patient selection for 1 procedure over the other.

Funding

This research was supported by the NPA and the Neurosurgery Research & Education Foundation (NREF). The NPA is a 501(c) (6) affiliate nonprofit organization of the American Association of Neurological Surgeons dedicated to the improvement of the quality of care in neurosurgical practice via the institution of national quality registries, such as the 1 utilized for this study. The NREF is the philanthropic arm of the American Association of Neurological Surgeons and has financially supported the creation and maintenance of the QOD. The Spine Section is a neurosurgical community aiming at advancing spine and peripheral nerve patient care through education, research, and advocacy.

Disclosures

Praveen V. Mummaneni: Consultant for Depuy Synthes and Globus; received Honoraria from BK Medical, Brainlab, SI Bone, Medtronic; received grants from Neurosurgery Research & Education Foundation, International Spine Study Group, AO Spine, National Institutes of Health, Patient-Centered Outcomes Research Institute, SLIP II, Pacira, and Department of Defense; owns stock in Discgenics; and received royalties from Springer Publisher and Thieme Publisher. Andrew K. Chan received honoraria from Spineart. Dean Chou receives funding from Globus and Medtronic. Kai-Ming Fu received money from Johnson and Johnson, Stryker, and Bioventus. Erica F. Bisson receives funding from Stryker, Medtronic, MiRus, nView, Proprio, and SeeAll. Christopher Shaffrey receives funding from Medtronic, Globus/NuVasive, SI Bone, and Proprio. Oren N. Gottfried receives funding from Pioneer Medical and Medtronic. Anthony Asher receives funding from Globus Medical. Domagoj Coric received money from Medtronic, Globus Medical, Spine Wave, Accelus, and Stryker; owns stock or stock options from Pressio Spine, Premia Spine, and 3Spine. Eric Potts receives funding from Medtronic. Kevin T. Foley received funding from Medtronic and Discgenics; sits on the board of directors and is a stockholder for Curiteva, DuraStat, nView, RevBio, and True Digital Surgery. Michael Wang receives funding from Stryker, Globus, Spineology, Medtronic, Pacira, and Depuy-Synthes. Michael S. Virk receives funding from DePuy Synthes. Scott Meyer is a consultant for Globus Medical. Paul Park received money from Medtronic, Alphatec, and Globus; is a consultant for NuVasive, Accelus, and Depuy; received sponsored grants from Society of Minimally Invasive Spine Surgery, International Spine Study Group, Cerapedics, Depuy, and SI Bone. Jay Turner receives funding from Alphatec, SeaSpine, and SI Bone. Juan Uribe is a consultant for Alphatec. Regis W. Haid Jr. receives funding from Globus Medical, Medtronic, NuVasive, SpineWave, and Remedy Health. Chun-Po Yen receives funding from Life Spine, Carlsmed, and Medtronic. The other authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. *Spine (Phila Pa 1976).* 2015;40(12):e675-e693.
2. New PW, Cripps RA, Bonne Lee B. Global maps of non-traumatic spinal cord injury epidemiology: towards a living data repository. *Spinal Cord.* 2014;52(2): 97-109.
3. Moore AP, Blumhardt LD. A prospective survey of the causes of non-traumatic spastic paraparesis and tetraparesis in 585 patients. *Spinal Cord.* 1997;35(6): 361-367.
4. Kalsi-Ryan S, Karadimas SK, Fehlings MG. Cervical spondylotic myelopathy: the clinical phenomenon and the current pathobiology of an increasingly prevalent and devastating disorder. *Neuroscientist.* 2013;19(4):409-421.
5. Benzel EC, Lancon J, Kesterson L, Hadden T. Cervical laminectomy and dentate ligament section for cervical spondylotic myelopathy. *J Spinal Disord.* 1991;4(3): 286-295.
6. Kadanka Z, Bednarík J, Vohánka S, et al. Conservative treatment versus surgery in spondylotic cervical myelopathy: a prospective randomised study. *Eur Spine J.* 2000;9(6):538-544.
7. Yoshimatsu H, Nagata K, Goto H, et al. Conservative treatment for cervical spondylotic myelopathy. prediction of treatment effects by multivariate analysis. *Spine J.* 2001;1(4):269-273.
8. Fehlings MG, Tetreault LA, Riew KD, et al. A clinical practice guideline for the management of patients with degenerative cervical myelopathy: recommendations for patients with mild, moderate, and severe disease and nonmyelopathic patients with evidence of cord compression. *Glob Spine J.* 2017;7(3 Suppl):70s–83s.
9. Berlin C, Marino AC, Mummaneni PV, et al. Determining the time frame of maximum clinical improvement in surgical decompression for cervical spondylotic myelopathy when stratified by preoperative myelopathy severity: a cervical Quality Outcomes Database study. *J Neurosurg Spine.* 2022;37(5):758-766.

10. Fehlings MG, Wilson JR, Kopjar B, et al. Efficacy and safety of surgical decompression in patients with cervical spondylotic myelopathy: results of the AOSpine North America prospective multi-center study. *J Bone Joint Surg Am.* 2013;95(18):1651-1658.
11. Li Z, Chen L, Li B, Wei J. Efficacy and safety of surgical interventions for treating multilevel cervical spondylotic myelopathy via anterior approach: a network meta-analysis. *Pain Physician.* 2019;22(4):E275–E286.
12. Lau D, Chou D, Mummaneni PV. Two-level corpectomy versus three-level discectomy for cervical spondylotic myelopathy: a comparison of perioperative, radiographic, and clinical outcomes. *J Neurosurg Spine.* 2015;23(3):280-289.
13. Lau D, Winkler EA, Than KD, Chou D, Mummaneni PV. Laminoplasty versus laminectomy with posterior spinal fusion for multilevel cervical spondylotic myelopathy: influence of cervical alignment on outcomes. *J Neurosurg Spine.* 2017;27(5):508-517.
14. Yoon ST, Hashimoto RE, Raich A, Shaffrey CI, Rhee JM, Riew KD. Outcomes after laminoplasty compared with laminectomy and fusion in patients with cervical myelopathy: a systematic review. *Spine (Phila Pa 1976).* 2013;38(22 Suppl 1):S183-S194.
15. Zhao CM, Chen Q, Zhang Y, Huang AB, Ding WY, Zhang W. Anterior cervical discectomy and fusion versus hybrid surgery in multilevel cervical spondylotic myelopathy: a meta-analysis. *Medicine (Baltimore).* 2018;97(34):e11973.
16. Burkhardt JK, Mannion AF, Marbacher S, et al. A comparative effectiveness study of patient-rated and radiographic outcome after 2 types of decompression with fusion for spondylotic myelopathy: anterior cervical discectomy versus corpectomy. *Neurosurg Focus.* 2013;35(1):e4.
17. Oh MC, Zhang HY, Park JY, Kim KS. Two-level anterior cervical discectomy versus one-level corpectomy in cervical spondylotic myelopathy. *Spine (Phila Pa 1976).* 2009;34(7):692-696.
18. Han YC, Liu ZQ, Wang SJ, Li LJ, Tan J. Is anterior cervical discectomy and fusion superior to corpectomy and fusion for treatment of multilevel cervical spondylotic myelopathy? A systemic review and meta-analysis. *PLoS One.* 2014;9(1):e87191.
19. Wang T, Wang H, Liu S, An HD, Liu H, Ding WY. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in multilevel cervical spondylotic myelopathy: a meta-analysis. *Medicine (Baltimore).* 2016;95(49):e5437.
20. Alliance N. *QOD Spine Registries*; 2023. Accessed October 1, 2023. https://www.neuropoint.org/registries/qod-spine/#
21. Asher AL, Kerezoudis P, Mummaneni PV, et al. Defining the minimum clinically important difference for grade I degenerative lumbar spondylolisthesis: insights from the Quality Outcomes Database. *Neurosurg Focus.* 2018;44(1):e2.
22. Mummaneni PV, Bydon M, Alvi MA, et al. Predictive model for long-term patient satisfaction after surgery for grade I degenerative lumbar spondylolisthesis: insights from the Quality Outcomes Database. *Neurosurg Focus.* 2019;46(5):e12.
23. Mummaneni PV, Bydon M, Knightly JJ, et al. Identifying patients at risk for nonroutine discharge after surgery for cervical myelopathy: an analysis from the Quality Outcomes Database. *J Neurosurg Spine.* 2021;35(1):25-33.
24. Yang E, Mummaneni PV, Chou D, et al. Cervical laminoplasty versus laminectomy and posterior cervical fusion for cervical myelopathy: propensity-matched analysis of 24-month outcomes from the Quality Outcomes Database. *J Neurosurg Spine.* 2023;39(5):671-681.
25. Asher AL, Knightly J, Mummaneni PV, et al. Quality Outcomes Database Spine Care Project 2012-2020: milestones achieved in a collaborative North American outcomes registry to advance value-based spine care and evolution to the American Spine Registry. *Neurosurg Focus.* 2020;48(5):e2.
26. Park C, Shaffrey CI, Than KD, et al. Does the number of social factors affect long-term patient-reported outcomes and satisfaction in those with cervical myelopathy? A QOD study. *J Neurosurg Spine.* 2024;40(4):428-438.
27. Park C, Shaffrey CI, Than KD, et al. What factors influence surgical decision-making in anterior versus posterior surgery for cervical myelopathy? A QOD analysis. *J Neurosurg Spine.* 2024;40(2):206-215.
28. Ambati VS, Macki M, Chan AK, et al. Three-level ACDF versus 3-level laminectomy and fusion: are there differences in outcomes? An analysis of the Quality Outcomes Database cervical spondylotic myelopathy cohort. *Neurosurg Focus.* 2023;55(3):e2.
29. Chan AK, Park C, Shaffrey CI, et al. What predicts the best 24-month outcomes following surgery for cervical spondylotic myelopathy? A QOD prospective registry study. *J Neurosurg Spine.* 2024;40(4):453-464.
30. Patel A, Kondapavulur S, Umbach G, et al. Greater improvement in Neck Disability Index scores in women after surgery for cervical myelopathy: an analysis of the Quality Outcomes Database. *Neurosurg Focus.* 2023;55(5):e7.
31. Park C, Mummaneni PV, Gottfried ON, et al. Which supervised machine learning algorithm can best predict achievement of minimum clinically important difference in neck pain after surgery in patients with cervical myelopathy? A QOD study. *Neurosurg Focus.* 2023;54(6):e5.
32. Asher AL, Haid RW, Stroink AR, et al. Research using the Quality Outcomes Database: accomplishments and future steps toward higher-quality real-world evidence. *J Neurosurg.* 2023;139(6):1757-1775.
33. Bydon M, Sardar ZM, Michalopoulos GD, et al. Representativeness of the American Spine Registry: a comparison of patient characteristics with the National Inpatient Sample. *J Neurosurg Spine.* 2023;39(2):228-237.
34. Chan AK, Shaffrey CI, Park C, et al. Do comorbid self-reported depression and anxiety influence outcomes following surgery for cervical spondylotic myelopathy? *J Neurosurg Spine.* 2023;39(1):11-27.
35. Bisson EF, Mummaneni PV, Michalopoulos GD, et al. Sleep disturbances in cervical spondylotic myelopathy: prevalence and postoperative outcomes-an analysis from the quality outcomes database. *Clin Spine Surg.* 2023;36(3):112-119.
36. Zaki MM, Joshi RS, Ibrahim S, et al. How closely are outcome questionnaires correlated to patient satisfaction after cervical spine surgery for myelopathy? *J Neurosurg Spine.* 2023;38(5):521-529.
37. Bergin SM, Michalopoulos GD, Shaffrey CI, et al. Characteristics of patients who return to work after undergoing surgery for cervical spondylotic myelopathy: a Quality Outcomes Database study. *J Neurosurg Spine.* 2023;38(5):530-539.
38. Sherrod BA, Michalopoulos GD, Mulvaney G, et al. Development of new postoperative neck pain at 12 and 24 months after surgery for cervical spondylotic myelopathy: a Quality Outcomes Database study. *J Neurosurg Spine.* 2023;38(3):357-365.
39. Yee TJ, Upadhyaya C, Coric D, et al. Correlation of the modified Japanese orthopedic association with functional and quality-of-life outcomes after surgery for degenerative cervical myelopathy: a quality outcomes database study. *Neurosurgery.* 2022;91(6):952-960.
40. Chan AK, Shaffrey CI, Gottfried ON, et al. Cervical spondylotic myelopathy with severe axial neck pain: is anterior or posterior approach better? *J Neurosurg Spine.* 2023;38(1):42-55.
41. Croci DM, Sherrod B, Alvi MA, et al. Differences in postoperative quality of life in young, early elderly, and late elderly patients undergoing surgical treatment for degenerative cervical myelopathy. *J Neurosurg Spine.* 2022;37(3):339-349.
42. Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH, Liang MH. The North American spine society lumbar spine outcome assessment Instrument: reliability and validity tests. *Spine (Phila Pa 1976).* 1996;21(6):741-749.
43. Khan I, Pennings JS, Devin CJ, et al. Clinically meaningful improvement following cervical spine surgery: 30% reduction versus absolute point-change MCID values. *Spine (Phila Pa 1976).* 2021;46(11):717-725.
44. Wen ZQ, Du JY, Ling ZH, Xu HD, Lin XJ. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in the treatment of multilevel cervical spondylotic myelopathy: systematic review and a meta-analysis. *Ther Clin Risk Manag.* 2015;11:161-170.
45. Parker SL, Godil SS, Shau DN, Mendenhall SK, McGirt MJ. Assessment of the minimum clinically important difference in pain, disability, and quality of life after anterior cervical discectomy and fusion: clinical article. *J Neurosurg Spine.* 2013;18(2):154-160.

Acknowledgments

We would like to recognize our senior author Dr Mark Shaffrey's tragic passing away while this manuscript was in revision. He provided tremendous support to many in our research group and his contributions to neurosurgery will not be forgotten. Author Contribution: CB: Study design, data analysis, manuscript composition, and revising submission/responding to reviewers. SI: Data analysis, manuscript composition, and revising submission. PVM: Data collection, study oversight, study design, manuscript composition, and revising submission/responding to reviewers. AKC: Data collection, study oversight, revising submission/responding to reviewers. DC: Data collection, manuscript composition. KMF: Data collection, manuscript composition. MB: Data collection, manuscript composition; study oversight, study design. EFB: Data

collection, manuscript composition, revising submission/response to reviewers. CIS: Data collection, manuscript composition. ONG: Data collection, manuscript composition. ALA: Data collection, manuscript composition. DC: Data collection, manuscript composition. EP: Data collection, manuscript composition. KTF: Data collection, manuscript composition. MYW: Data collection, manuscript composition. MSV: Data collection, manuscript composition. JJK: Data collection, manuscript composition. SM: Data collection, manuscript composition. PP: Data collection, manuscript composition. CU: Data collection, manuscript composition. LMT: Data collection, manuscript composition. JT: Data collection, manuscript composition. JU: Data collection, manuscript composition. RH: Data collection, manuscript composition. CPY: Data collection, manuscript composition. MES: Data collection, study oversight, study design, manuscript composition, and revising submission/responding to reviewers.