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How Do Patients With Predominant Neck Pain Improve After Anterior Cervical Discectomy and Fusion for Cervical Radiculopathy?

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ABSTRACT

Background: The presence of predominant pain in the arm vs the neck as a predictor of postoperative outcomes after anterior cervical discectomy and fusion (ACDF) has been seldom reported; therefore, the purpose of this study was to determine whether patients with predominant neck pain improve after surgery compared to patients with predominant arm pain or those with mixed symptoms in patients undergoing ACDF for radiculopathy.

Methods: A retrospective cohort study was conducted on patients who underwent ACDF at a single center from 2016 to 2018. Patients were split into groups based on preoperative neck and arm pain scores: neck (N) pain dominant group (visual analog scale [VAS] neck ≥ VAS arm by 1.0 point); neutral group (VAS neck < VAS arm by 1.0 point); or arm (A) pain dominant group (VAS arm ≥ VAS neck by 1.0 point), using a threshold difference of 1.0 point. Subsequently, individuals were substratified into 2 groups based on the arm to neck pain ratio (ANR): non-arm pain dominant defined as ANR ≤1.0 and arm pain dominant (APD) defined as ANR >1.0. Patient-reported outcome measurements including Neck Disability Index (NDI), Physical Component Score-12, and Mental Component Score (MCS-12) were compared between groups.

Results: No significant differences between groups when stratifying patients using a threshold difference of 1.0 point. When stratifying patients using the ANR, those in the APD group had significantly higher postoperative MCS-12 ($P = 0.008$) and NDI ($P = 0.011$) scores. In addition, the APD group showed a greater magnitude of improvement for MCS-12 and NDI scores ($P = 0.043$ and $P = 0.038$, respectively). Multiple linear regression showed that the A and the APD groups were both independent predictors of improvement in NDI.

Conclusion: Patients with dominant arm pain showed significantly greater improvement in terms of MCS-12 and NDI scores compared to patients with dominant neck pain.

Clinical Relevance: To compare the impact of ACDF on arm and neck pain in the context of cervical radiculopathy using patient-reported outcome measures as an objective measurement.

Level of Evidence: 3.

Cervical Spine

Keywords: PROMs, ACDF, VAS neck, VAS arm, radiculopathy

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is one of the most commonly performed procedures for cervical degenerative disease.[1,2] In the United States, roughly 132 000 ACDFs are performed annually to address cervical radiculopathy and myelopathy.[3] More controversial however is performing ACDF for predominant axial neck pain. Initial studies have shown that these patients often exhibit little to no improvement in neck pain after cervical fusion.[4,5] Consequently, surgical management has been routinely reserved for patients with predominantly neurological findings resulting in high success rates, with up to 80%–90% of patients experiencing relief in arm pain in some studies.[6–9] In contrast, patients undergoing ACDFs with neck pain predominant symptoms have demonstrated less reliable outcomes and lower satisfaction.[5,10]

Existing studies regarding cervical fusion have focused on preoperative variables such as age, smoking, medical comorbidities, and psychosocial factors as predictors of surgical outcome improvement with a relative paucity of information on additional characteristics.[11–13] Patient-reported outcome measures (PROMs)—originally validated for their ability to track a patient's postoperative course through self-reported

outcome surveys—have only recently started to become widely used for studying the magnitude of clinical improvement and effectiveness of surgical intervention overall.[14,15] 2 important PROMs for assessing the amount of arm and neck pain being experienced by the patient include the visual analog score (VAS) arm and VAS neck scores. Most patients with cervical disease have some component of both; however, the presence of predominant pain in the arm vs the neck as a predictor of postoperative outcomes has been seldom reported. Therefore, the purpose of the present study was to elucidate whether, and to what extent, patients with neck pain dominant symptoms improve after ACDF surgery for radiculopathy symptoms compared to patients with arm pain dominant (APD) or mixed symptoms.

METHODS

After approval from the Institutional Review Board, patients who underwent a 1-level to 3-level ACDF at a single academic center between 2016 and 2018 were retrospectively identified through a structured query language search through the current institution's electronic health records. Individuals were retained in the study if they met the following inclusion criteria: (1) age >18 years and (2) at least 1 year of documented clinical follow-up. Anyone with the following characteristics were subsequently excluded from the present analysis: (1) surgery for a preoperative diagnosis other than cervical radiculopathy (ie, myelopathy, tumor, infection, or trauma) and (2) surgical revision of a prior fusion.

Demographic data and surgical characteristics for each individual were identified and recorded, including age, sex, body mass index, smoking status (never, current, or former smoker), months until final clinical follow-up, workers' compensation status, and the total number of levels involved in the fusion construct. PROMs were then queried from the institution's patient outcomes database (OBERD, Columbia, MO). The following PROMs were considered in the present study: Short Form-12 Physical Component Score (PCS-12) and Mental Component Score (MCS-12), the Neck Disability Index (NDI), and the VAS neck and VAS arm pain scores.

Two separate methods were used to determine neck or arm pain dominance. In the first method, patients were split into 3 groups based on their baseline VAS neck and arm pain scores: (1) neck predominant (N) group (VAS neck – VAS arm ≥ 1.0 point); (2) neutral (NE) group (−1.0 point < VAS neck – VAS arm < 1.0 point); and (3) arm predominant (A) group (VAS arm – VAS neck ≥ 1.0 point).[16] For the second method, a ratio of baseline VAS arm to VAS neck pain (ANR) was used: (1) nonarm pain dominant (NAPD) group (ANR ≤ 1.0) or (2) APD group (ANR >1.0).[17]

Statistical Analysis

Differences between groups were compared using Mann-Whitney *U* test or Kruskal-Wallis *H* testing with post hoc analysis for continuous variables and either Pearson χ^2 analysis or Fisher exact test for categorical variables. Differences within groups were compared using a paired samples *t* test. Two additional measures of improvement were also calculated: (1) recovery ratios—defined as (delta score/["optimal" score – baseline score]), using 0 and 100 as "optimal" scores for NDI and PCS-12/MCS-12, respectively; and (2) the percentage of patients who ended up achieving minimal clinically important difference at final follow-up using 8.1 points, 4.7 points, and 15.0 points as thresholds for improvement at the 1-year postoperative mark for PCS-12, MCS-12, and NDI, respectively.[18–20] Finally, multiple linear regression analysis was performed to determine whether arm or neck pain predominance was an independent predictor of PCS-12, MCS-12, or NDI. All statistical analyses were performed with the Statistical Package for the Social Sciences version 24 (IBM Corporation, Armonk, NY) and a *P* value of <0.05 was considered to be statistically significant.

RESULTS

A total of 122 patients were included, with 46 (37.7%) in the N group, 57 (46.7%) in the NE group, and 19 (15.6%) in the A group (Table 1). Using the secondary method, 91 patients were in the NAPD group (ANR ≤ 1.0) and 31 patients were in the APD group (ANR > 1.0). The mean age of patients in the overall cohort was 50.0 (48.0, 52.0) years, mean body mass index was 29.2 (28.2, 30.2) kg/m^2, and total number of men was 59 (48.4%) patients. There were 65 (53.3%) never smokers, 23 (18.9%) current smokers, and 34 (25.8%) former smokers. Patients demonstrated an average of 19.8 (18.8, 20.9) months of follow-up. A total of 19 (15.6%) patients were receiving workers' compensation benefits before surgery, and most patients underwent surgery at 1 (42 patients—34.4%) or2 level (58 patients—47.5%).

When considering change within each group (pre to post) in PCS-12, MCS-12, or NDI, paired samples *t* test revealed all patients demonstrated a significant improvement in NDI scores (Table 2). Patients in the N and NE groups showed significant improvement in PCS-12 scores

Table 1. Demographic data and surgical characteristics between visual analog scale pain groups.

Demographic	Neck (n = 46)	Neutral (n = 57)	Arm (n = 19)	Univariate Analysis, P Value[a]
Age	52.0 (49.0, 54.0)	48.0 (46.0, 51.0)	49.0 (45.0, 53.0)	0.307
Sex				
Men	24 (52.2%)	28 (49.1%)	7 (36.8%)	0.525
Women	22 (47.8%)	29 (50.9%)	12 (63.2%)	
Body mass index	28.5 (27.0, 30.1)	29.4 (27.8, 31.0)	30.1 (27.3, 32.8)	0.497
Smoking status				
Never	25 (45.3%)	29 (50.9%)	11 (57.9%)	0.824
Current	8 (17.4%)	13 (22.8%)	2 (10.5%)	
Former	13 (37.3%)	15 (26.3%)	6 (31.6%)	
Follow-Up, mo	20.2 (18.2, 22.3)	19.2 (18.0, 20.4)	20.7 (17.2, 24.2)	0.989
Worker's compensation received prior to surgery?				
No	37 (80.4%)	49 (86.0%)	17 (89.5%)	0.598
Yes	9 (19.6%)	8 (14.0%)	2 (10.5%)	
Levels fused				
1	19 (41.3%)	18 (31.6%)	5 (26.3%)	0.357
2	17 (37.0%)	32 (56.1%)	9 (47.4%)	
3	10 (21.7%)	7 (12.3%)	5 (26.3%)	
Revision surgery?				
No	42 (91.3%)	51 (89.5%)	17 (89.5%)	—
Yes	4 (8.7%)	6 (10.5%)	2 (10.5%)	

Data presented as n (%) and median (IQR). Kruskal-Wallis H test, Pearson X^2 analysis, or Fisher exact test were used to compare baseline demographics and surgical characteristics between groups.
[a]$P < 0.05$.

($P < 0.05$) with a trend toward improvement in the A group ($P = 0.064$). None of the 3 groups showed improvement in MCS-12 scores postoperatively. Using the ANR method (Table 3), both NAPD and APD groups showed improvement after surgery ($P < 0.05$) for all measures except for the NAPD group and MCS-12 scores ($P = 0.903$). All patients

Table 2. Patient-reported outcome measurements between VAS pain groups.

PROM	Interval	N (n = 46)	NE (n = 57)	A (n = 19)	Univariate Analysis, P Value: Paired Samples t Test	Univariate Analysis, P Value: Kruskal-Wallis H Test or χ^2 Analysis	Multivariate Regression, β Coefficient (95% CI), P Value
PCS-12	Preoperative	32.7 (31.0, 34.5)	32.9 (30.9, 34.8)	35.3 (30.7, 39.9)	N: <0.001[a]	0.762	N: -
	Postoperative	39.4 (35.9, 42.8)	41.4 (38.5, 44.4)	40.0 (34.1, 46.0)	NE: <0.001[a]	0.617	NE: 2.300 (−1.707, 6.306), 0.258
	Delta	6.6 (3.3, 10.0)	8.3 (6.0, 10.6)	4.7 (−0.3, 9.8)	A: 0.064	0.323	
	RR	9.6%	12.1%	6.8%	—	0.419	A: −0.532 (−6.015, 4.951), 0.848
	% MCID	39.1%	50.9%	36.8%		0.382	
MCS-12	Preoperative	47.6 (43.8, 51.4)	46.4 (43.0, 49.7)	46.2 (40.8, 51.6)	N: 0.401	0.836	N: -
	Postoperative	45.8 (42.4, 49.2)	49.6 (46.7, 52.5)	49.8 (43.0, 56.6)	NE: 0.076	0.072	NE: 3.772 (−0.551, 8.096), 0.087
	Delta	−1.8 (−6.0, 2.4)	2.8 (−0.7, 6.4)	3.6 (−3.8, 11.1)	A: 0.318	0.161	
	RR	−7.7%	1.9%	4.3%	—	0.130	A: 4.791 (−1.066, 10.648), 0.108
	% MCID	26.1%	40.4%	42.1%		0.255	
NDI	Preoperative	45.0 (41.0, 50.0)	47.0 (41.0, 52.0)	37.0 (28.0, 46.0)	N: <0.001[a]	0.177	N: -
	Postoperative	33.6 (26.6, 40.5)	27.5 (20.9, 34.1)	19.7 (10.6, 28.8)	NE: <0.001[a]	0.063	NE: −7.554 (−15.211, 0.103), 0.053
	Delta	−11.6 (−17.4, −5.9]	−19.3 (−25.0, −13.5)	−17.4 (−25.8, −9.0)	A: <0.001[a]	0.330	
	RR	25.6%	40.0%	51.7%	—	0.106	A: −10.571 (−21.102, −0.041), 0.049[a]
	% MCID	45.7%	50.9%	52.6%		0.825	
VAS neck	Preoperative	6.5 (6.0, 7.0)	6.8 (6.2, 7.4)	4.3 (3.0, 5.5)	N: <0.001[a]	0.001[a]	N: -
	Postoperative	4.2 (3.3, 5.1)	3.2 (2.4, 3.9)	2.5 (1.2, 3.7)	NE: <0.001[a]	0.065	NE: −1.020 (−2.128, 0.087), 0.071
	Delta	−2.3 (−3.2, −1.4)	−3.6 (−4.4, −2.7)	−1.8 (−3.4, −0.2)	A: 0.025[a]	0.082	
	RR	34.2%	51.1%	29.1%	—	0.197	A: −1.170 (−2.782, 0.442), 0.153
	% MCID	47.8%	59.6%	42.1%		0.302	
VAS arm	Preoperative	3.0 (2.2, 3.9)	6.8 (6.2, 7.4)	6.3 (5.1, 7.5)	N: 0.362	<0.001[a]	N: -
	Postoperative	3.5 (2.6, 4.5)	2.8 (2.0, 3.6)	3.1 (1.6, 4.6)	NE: <0.001[a]	0.541	NE: −1.521 (−2.921, −0.121), 0.034[a]
	Delta	0.5 (−0.6, 1.7)	−4.0 (−4.8, −3.2)	−3.1 (−4.8, −1.5)	A: 0.001[a]	<0.001[a]	
	RR	36.2%	58.7%	51.1%	—	0.263	A: −1.505 (−3.219, 0.210), 0.085
	% MCID	19.6%	63.2%	42.1%		<0.001[a]	

Abbreviations: A, arm; MCID, minimum clinically important difference; MCS-12, Mental Component Score of the Short Form-12 Survey; N, neck; NDI, Neck Disability Index; NE, neutral; PCS-12, Physical Component Score of the Short Form-12 Survey; RR, recovery ratios; VAS, visual analog scale.
Note: NPreoperative, postoperative, and delta data are presented as mean (95% CI). Neck, neutral, and arm pain dominant groups outcomes compared with univariate analysis—paired samples t test, Kruskal-Wallis H testing with Dunn multiple pairwise comparisons conducted for post hoc analysis, or Pearson X^2 analysis—and multivariate regression. RR were defined as: (delta outcome score/[optimal outcome score – observed outcome score]), where the following optimal outcome scores were used: 100 (PCS-12 and MCS-12) or 0 (NDI). The percentage of patients reaching the MCID was based on the following threshold values: PCS-12, 8.1 points; MCS-12, 4.7 points; and NDI, 15 points. Multivariate regression analysis conducted using the neck pain dominant group as a baseline for comparison—controlling for age, sex, body mass index, smoking status, (never, current, and former), follow-up (mo), and No. of levels fused.
[a]Indicates statistical significance ($P < 0.05$).

Table 3. Patient-reported outcome measurements between VAS ANR groups.

PROM	Interval	NAPD (ANR ≤1.0) (n = 91)	APD (ANR >1.0) (n = 31)	Univariate Analysis, P Value		Multivariate Regression, β Coefficient (95% CI), P Value
				Paired Samples t Test	Independent Samples t Test or χ^2 Analysis	
PCS-12	Preoperative	33.1 (31.6, 34.5)	33.6 (30.6, 36.5)	NAPD: <0.001[a]	0.691	NAPD: -
	Postoperative	40.0 (37.6, 42.4)	41.8 (37.5, 46.0)	APD: <0.001[a]	0.412	APD: 0.675 (−3.647, 4.998), 0.757
	Delta	6.9 (4.8, 9.0)	7.7 (3.9, 11.6)		0.522	
	RR	10.2%	10.7%	—	0.661	
	% MCID	41.8%	51.6%		0.340	
MCS-12	Preoperative	47.0 (44.4, 49.7)	46.0 (41.9, 50.2)	NAPD: 0.903	0.615	NAPD: -
	Postoperative	46.9 (44.5, 49.3)	52.1 (47.9, 56.3)	APD: 0.031[a]	0.008[a]	APD: 4.179 (−0.466, 8.823), 0.077
	Delta	−0.2 (−3.0, 2.7)	5.5 (−0.1, 11.0]		0.043[a]	
	RR	0.0%	0.1%	—	0.114	
	% MCID	30.8%	48.4%		0.076	
NDI	Preoperative	46.0 (42.0, 50.0)	42.0 (35.0, 48.0)	NAPD: <0.001[a]	0.243	NAPD: -
	Postoperative	31.9 (26.8, 37.0)	18.8 (12.2, 25.4)	APD: <0.001[a]	0.011[a]	APD: −9.808 (−18.053, −1.563), 0.020[a]
	Delta	−13.9 (−18.0, −9.7)	−22.8 (−30.2, −15.4)		0.038[a]	
	RR	31.1%	51.7%	—	0.059	
	% MCID	45.1%	61.3%		0.118	
VAS neck	Preoperative	6.5 (6.0, 7.0)	5.6 (4.8, 6.5)	NAPD: <0.001[a]	0.041[a]	NAPD: -
	Postoperative	3.8 (3.1, 4.4)	2.5 (1.6, 3.3)	APD: 0.001[a]	0.076	APD: −0.704 (−1.929, 0.552), 0.258
	Delta	−2.8 (−3.4, −2.1)	−3.0 (−4.1, −1.8)		0.504	
	RR	41.2%	42.1%	—	0.331	
	% MCID	51.6%	54.8%		0.748	
VAS arm	Preoperative	4.7 (4.1, 5.4)	7.0 (6.3, 7.7)	NAPD: <0.001[a]	0.001[a]	NAPD: -
	Postoperative	3.3 (2.7, 4.0)	2.5 (1.5, 3.5)	APD: <0.001[a]	0.264	APD: −0.942 (−2.268, 0.384), 0.162
	Delta	−1.4 (−2.2, −0.6)	−4.4 (−5.6, −3.2)		0.001[a]	
	RR	48.3%	57.4%	—	0.499	
	% MCID	37.4%	61.3%		0.020[a]	

Abbreviations: ANR, arm neck ratio; APD, arm pain dominant; MCID, minimum clinically important difference; MCS-12 , Mental Component Score of the Short Form-12 Survey; NAPD, non-arm pain dominant; NDI , Neck Disability Index ; PCS-12 , Physical Component Score of the Short Form-12 Survey; RR, recovery ratios; VAS, visual analog scale.
Note: Preoperative, postoperative, and delta data are presented as mean (95% CI). VAS ANR group outcomes compared with univariate analysis—paired samples t test, Kruskal-Wallis H testing with Dunn multiple pairwise comparisons conducted for post hoc analysis, or Pearson X^2 analysis—and multivariate regression. RR were defined as: (delta outcome score/[optimal outcome score – observed outcome score]), where the following optimal outcome scores were used: 100 (PCS-12 and MCS-12) or 0 (NDI).[2] The percentage of patients reaching the % MCID was based on the following threshold values: PCS-12, 8.1 points; MCS-12, 4.7 points; and NDI, 15 points.[3,4] Multivariate regression analysis conducted using the neck pain dominant group as a baseline for comparison—controlling for age, sex, Body Mass Index, smoking status, (never, current, former), follow-up (months), and No. of levels fused.
[a]Indicates statistical significance ($P < 0.05$).

showed improvement in neck or arm pain regardless of the group or analysis method. When comparing outcomes between groups using the first method, there were no significant differences with regard to PCS-12, MCS-12, or NDI scores. Using the second method, the APD group demonstrated greater improvement and less disability in terms of postoperative and delta MCS-12 (52.1 vs 46.9, $P = 0.008$ and 5.5 vs −0.2, $P = 0.043$, respectively) and NDI (18.8 vs 31.9, $P = 0.011$ and −22.8 vs −13.9, $P = 0.038$, respectively). Using multiple linear regression analysis with the first method, arm pain dominance (A group) was an independent predictor of improvement in NDI (β = −10.571 [−21.102, −0.041], $P = 0.049$), compared to the N group. Similarly, with the second method, the APD group predicted greater improvement in NDI (β = −9.808 [−18.053,−1.563], $P = 0.020$).

DISCUSSION

Cervical radiculopathy is one of the most common reasons for presentation to a spine surgeon, with an annual incidence of 107.3 per 100,000 in men and 63.5 per 100,000 in women.[21–23] Often times, these patients have significant cervical degenerative disease and have concomitant neck pain. While ACDF is a successful procedure for the treatment of radiculopathy, it is controversial in the treatment of axial neck pain.[4,5] Few studies have addressed patient outcomes in those undergoing surgery for radiculopathy vs axial pain and show conflicting results.[12,17,24–29] The goal of this study was to determine whether patients with predominant neck pain improve after ACDF surgery to a similar degree as patients with predominant arm pain when doing surgery for radiculopathy.

In this study, all groups demonstrated improvement after surgery for each outcome except for the N, NE, and A groups and MCS-12 scores (first method) as well as the NAPD group and MCS-12 scores (second method). Using the first method, there were no differences between groups; however, using the second method, postoperative MCS-12 and NDI scores and overall magnitude of improvement were significantly better in the APD group. In addition, using both methods, multivariate analysis revealed that having APD symptoms (being in the A group or APD group) was an independent predictor of improvement in NDI ($P = 0.049$ and $P = 0.020$, respectively). These results are similar to a recently published retrospective study by Passias et al.[17] The authors of that study noted that

arm pain greater than neck pain at baseline was associated with increased odds of arm pain improvement and PCS scores after surgery. In addition, a higher baseline NDI score was associated with reduced odds of improvement in neck pain postoperatively.

Similar studies comparing surgery for radicular symptoms or low back predominant symptoms have been conducted in the lumbar spine. In a subanalysis of the Spine Patient Outcomes Research Trial, Pearson et al showed that patients with predominant leg pain fared better with surgery for degenerative spondylolisthesis and lumbar spinal stenosis than patients with predominant low back pain.[30] Furthermore, in a prospective study of lumbar patients with 12-month follow-up, Kleinstück et al showed that overall greater back pain relative to leg pain at baseline was associated with significantly worse outcomes after lumbar decompression.[31]

A limited number of studies exist investigating the role ACDF for neck pain. Oitment et al performed a systematic review and meta-analysis investigating the role of ACDF in relieving axial neck pain in single level cervical disease.[32] The authors noted improvement in axial symptoms following ACDF as measured by VAS and NDI scores in patients undergoing surgery for radiculopathy or myelopathy at one level.[32] However, unlike the present study, the authors did not differentiate patients who had predominant neck pain symptoms. Similarly, in recent literature, patients who underwent ACDF for axial neck pain were found to have demonstrated greater pain reduction and improved functional outcomes at final follow-up.[27,29,33] Eck et al noted improved VAS and functional capacity evaluations in a subanalysis of patients with neck pain only.[27] Palit et al showed that in 38 patients with discography proven axial neck pain, the Numeric Rating Scale for neck pain improved significantly after surgery and 79% of the patient cohort was satisfied with the outcome compared to 21% that were not satisfied.[29] Garvey et al reported an overall self-perceived satisfaction rate of 82% and pain improvement in 93% of patients.[33] However, these studies all included mixed patient populations. The studies by Eck et al and Palit et al included patients with neck pain only, whereas the study by Garvey et al included patients with self-reported neck pain predominance.

There are several limitations to this study. Given its retrospective nature, selection bias may be present due to variable survey response rates. The use of self-reported PROMs introduces recall bias, where patients may overestimate or underestimate their current pain. In addition, since patients at this institution undergo ACDF for neurologic symptoms exclusively, all of the patients included in this cohort had cervical radiculopathy and did not include patients with axial neck pain without radicular symptoms. This makes it more difficult to directly compare to prior studies that included patients with axial neck pain only.

CONCLUSION

In this study, ACDF was shown to overall reduce pain and disability in both neck and APD patients. However, those with APD symptoms showed improved postoperative MCS-12 and NDI scores as well as a larger magnitude of improvement perioperatively. Arm pain dominance was also found to be an independent predictor for increased improvement in NDI using 2 different methods of analysis

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