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Comparing ACDF Outcomes by Cervical Spine Level: A Single Center Retrospective Cohort Study

DAVIS MARTIN, BS[1*]; RYAN SCHROEDER, BS[1*]; COLLIN TOUPS, BS[1]; CLIFTON DAIGLE, BS[1]; MATTHEW SPITCHLEY, BS[1]; CLAUDIA LEONARDI, PhD[2,3]; BERJE SHAMMASSIAN, MD[4]; AND AMIT K. BHANDUTIA, MD[2]

[1]*Louisiana State University Health Sciences Center School of Medicine, New Orleans, LA, USA;* [2]*Department of Orthopedic Surgery, Louisiana State University Health Sciences Center School of Medicine, New Orleans, LA, USA;* [3]*Department of Behavioral and Community Health, Louisiana State University Health Sciences Center School of Medicine, New Orleans, LA, USA;* [4]*Department of Neurosurgery, Louisiana State University Health Sciences Center School of Medicine, New Orleans, LA, USA*

[*]Davis Martin and Ryan Schroeder contributed equally to the work.

ABSTRACT

Background: Previous research suggests a relationship between complications associated with anterior cervical discectomy and fusion and level involvement; however, there is limited research comparing postoperative outcomes of upper cervical fusions (UCFs) with middle-to-lower cervical fusions (MLCFs). This study aims to compare the outcomes of UCF with MLCF.

Methods: A retrospective medical record review was conducted on 835 anterior cervical discectomy and fusion patients from 2012 to 2022. Patients were classified as UCF, defined as inclusion of C3 to C4 disc space, or MLCF, defined as lacking C3 to C4 disc space. Demographics were compared using χ^2 or Fisher exact tests. Clinical characteristics were compared in univariable analysis using χ^2 tests, linear-mixed effects models, or generalized linear-mixed models depending on distribution. Significant pre- and intraoperative characteristics were included in multivariable models to minimize confounding.

Results: Of the 835 patients included, 562 underwent MLCF and 281 underwent UCF. Median follow-up time was 211 days for UCF and 200 days for MLCF. UCF led to a 1.5-day longer length of stay in both univariable (1.5 vs 3.1, $P < 0.0001$) and multivariable analysis (2.3 days [95% CI: 1.8, 3.0] vs 3.3 days [2.6, 4.2], $P < 0.0001$). MLCF patients reported symptom improvement or resolution more often than UCF patients (0.43 [95% CI: 0.30, 0.62] and 0.46 [95% CI: 0.30, 0.70]). Additionally, a significantly higher rate of dysphagia was reported in the UCF group on both univariate and multivariable analysis, respectively (1.72 [95% CI: 1.18, 2.49] and 1.66 [95%CI: 1.08, 2.56]).

Conclusions: To our knowledge, this is the first study to investigate the link between cervical fusion level and outcomes. UCF patients demonstrated greater rates of dysphagia, longer length of stay, and lower likelihood of improvement in neurological symptoms postoperatively both before and after controlling for differences in pre- and intraoperative characteristics.

Clinical Relevance: This study highlights that UCFs may be associated with worse postoperative outcomes when compared to MLCFs, which can inform surgical decision-making and patient counseling.

Level of Evidence: The study represents Level 3 evidence due to its retrospective design and potential biases, indicating a need for future prospective randomized controlled trials to validate these findings.

Cervical Spine

Keywords: ACDF, myelopathy, radiculopathy, dysphagia

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is 1 of the most common procedures utilized for the treatment of cervical radiculopathy and myelopathy.[1] The rate of ACDF procedures performed in the United States increased by approximately 5.7% from 2006 to 2013, totaling 127,500 ACDF procedures overall in 2013.[1] The average cost of an individual ACDF also increased over this same period from $13,453 in 2006 to $17,932 in 2013.[1] Along with this procedure comes many possible complications, including postoperative dysphagia, recurrent laryngeal nerve palsy, hematomas of varying locations, dural penetration, esophageal perforation, and worsening of myelopathy/radiculopathy symptoms.[2]

Previous research has shown an increased risk of postoperative dysphagia, pain, and narcotic use in 4- vs 3-level ACDF, suggesting a relationship between complications and level involvement.[3] Additionally, anterior fusion of C2 to C3 or C3 to C4 may pose an increased risk for postoperative dysphagia.[4] Despite this preliminary data, there is still limited research comparing the postoperative outcomes of upper cervical fusions (UCF)

with middle-to-lower cervical fusions (MLCF). With the rate of ACDFs consistently rising, further elucidating this relationship will help medical decision-making to decrease complications and financial burden.[5] This study aims to compare the overall outcomes of UCF—defined as fusions involving the C3 to C4 disc space—with MLCF defined as the remainder of the cervical spine. Due to the more complex anatomy of the neck at the superior cervical spine[6] and reports of increases in dysphagia after UCF,[4] we hypothesize that UCFs will result in longer hospitalizations, increased rates of postoperative dysphagia, and an increased need for postoperative rehabilitation services.

METHODS

A retrospective medical record review was conducted of adult patients (>18 years old at the time of surgery) diagnosed with cervical myelopathy or radiculopathy and treated with ACDF between 1 January 2012 and 31 September 2022 at an academic hospital (University Medical Center New Orleans LCMC Health). Patients younger than 18 years, patients with a history of previous cervical spine surgery, patients with pathology resulting from tumor or trauma, and patients undergoing revision surgery were excluded. Additionally, ACDF, including the C2 to C3 level or thoracic decompression fusion (C7–T1 level) anteriorly, was excluded from the study. Patients undergoing posterior instrumentation during the same hospital stay were excluded from the study.

Patient information was collected through manual medical record review within the electronic medical record. Patients were classified based on whether they underwent C3 to C4 level fusion within the ACDF construct. Those with UCF had C3 to C4 level fusion, while those lacking C3 to C4 level fusion were designated as MLCF.

Demographic characteristics, such as age, sex, race, ethnicity, height, weight, insurance type, and marital status, were collected. Clinical characteristics, including length of surgery from anesthesia induction to closure, hospital length of stay (LOS), discharge location, American Society of Anesthesiologist (ASA) classification, graft type inserted, type of fusion device utilized, use of neuromonitoring and/or approach surgeon, presence of cord signal change or spondylolisthesis on preoperative radiographs, neurological symptoms pre- and postoperatively, postoperative complications, and follow-up visits, were also collected. Given the previous literature on ACDF outcomes, significant efforts were made to collect and account for all common confounding variables that may affect surgical outcomes. Spinal cord signal change, diagnosis of spondylolisthesis, and neurological symptom characterization (radiculopathy vs myelopathy; upper vs lower extremity involvement) were collected to attempt to account for differences in disease severity that might affect surgical outcomes. Additionally, the type of fusion device, type of graft used, use of neuromonitoring, and use of approach surgeon were collected to account for surgical planning and decision-making differences and their possible effects on outcomes. Finally, ASA scores were collected to control for patient comorbidity status at the time of surgery. Follow-up characteristics were measured between the procedure date and the last recorded follow-up date, and this interval was used to calculate the median follow-up time for each group. The primary outcome of the study was postoperative complication rates, with secondary outcomes including LOS, discharge location, and changes in preoperative neurological symptoms after surgery.

All postoperative complications were recorded and categorized as major or minor based on the classification by Campbell et al.[7] Details of each patient's surgery were directly collected from the physician's operative report. The ASA classification was obtained from the anesthesiology report for each patient's surgery. Cord signal changes and the presence of spondylolisthesis were obtained from radiology reports attached to each patient's imaging. Neurological symptoms and postoperative complications were recorded from physician notes at preoperative and follow-up visits. Due to the retrospective nature of this study, standardized scoring of dysphagia was unable to be obtained. However, dysphagia was only recorded as a complication if it persisted for greater than 1 month postoperatively. All clinical characteristics were initially assessed by a practicing orthopedic spinal surgeon or neurosurgeon. No independent determinations were made by the data collectors to maximize the accuracy of the extracted data.

Study data were collected and managed using REDCap electronic data capture tools hosted at Louisiana State University Health Science Center.[8,9] Data were analyzed using the SAS/STAT software, version 9.4 of the SAS System for PC (SAS Institute Inc., Cary, NC, USA). Demographic and baseline characteristics were compared between the groups using either χ^2 tests or Fisher exact tests for categorical variables and Student's t test for continuous normally distributed variables. Postintervention outcomes were compared in univariable analysis using either χ^2 tests or linear-mixed effects models or generalized linear-mixed models, depending on their

Table 1. Baseline patient demographics.[a]

Characteristics	MLCF (n = 562)	UCF (n = 281)	P
Age, y, mean (SD)	53.7 (10.8)	58.3 (9.4)	**<0.0001**
BMI, kg/m^2, mean (SD)	30.3 (7.3)	29.3 (6.8)	0.063
Sex, % (n)			**<0.0001**
Woman	53.0 (298)	29.2 (82)	
Man	47.0 (264)	70.8 (199)	
Race, % (n)			**<0.0001**
Black or African American	35.6 (200)	56.9 (160)	
White or Caucasian	60.9 (342)	39.5 (111)	
Other	3.0 (17)	2.5 (7)	
Not available	0.5 (3)	1.1 (3)	
Insurance, % (n)			**0.005**
Medicaid	27.2 (153)	18.9 (53)	
Medicare	32.4 (182)	44.5 (125)	
Self-pay	20.8 (117)	16.7 (47)	
Private	12.3 (69)	11.7 (33)	
Other	7.3 (41)	8.2 (23)	
Married or with partner, % (n)	39.2 (220)	41.3 (115)	0.786
Psychiatric diagnosis, % (n)			
Anxiety	36.7 (206)	27.8 (78)	**0.014**
Depression	33.3 (187)	23.8 (67)	**0.005**
Psychotic	2.7 (15)	2.5 (7)	0.879

Abbreviations: ACDF, anterior cervical discectomy and fusion; BMI, body mass index; MLCF, middle-to-lower cervical fusion; UCF, upper cervical fusion.
Note: Boldface indicates statistically significant comparison.
[a]Patients were classified as UCF or MLCF based on the inclusion of C3 to C4 level in the ACDF construct.

Table 2. Clinical and surgical characteristics of patients undergoing ACDF with either UCF or MLCF.[a]

Characteristics	MLCF (n = 562)	UCF (n = 281)	P
Neurological diagnosis, % (n)			**<0.0001**
Myelopathy	48.8 (274)	63.0 (177)	
Radiculopathy	33.1 (186)	11.4 (32)	
Myelopathy and radiculopathy	18.2 (102)	25.6 (72)	
SCSC observed presurgery, % (n)	14.8 (83)	22.8 (64)	**0.004**
Spondylolisthesis diagnosis, % (n)	9.4 (53)	13.5 (38)	0.071
Extremities with NS, % (n)			0.061
Upper	66.7 (375)	58.0 (163)	
Lower	2.7 (15)	3.9 (11)	
Upper and lower	28.6 (161)	36.7 (103)	
Not available	2.0 (11)	1.4 (4)	
ASA classification, % (n)			0.377
I	0.7 (4)	0.7 (2)	
II	50.0 (281)	43.8 (123)	
III	48.0 (270)	54.5 (153)	
IV	1.3 (7)	1.1 (3)	
Approach surgeon utilized, % (n)	3.9 (22)	3.6 (10)	0.800
Graft used, % (n)	92.7 (521)	94.7 (266)	0.282
Neuromonitoring used, % (n)	53.9 (303)	49.8 (140)	0.262
Fusion device, % (n)			0.884
Plate alone	50.0 (281)	50.5 (142)	
Plate + cage	50.0 (281)	49.5 (139)	

Abbreviations: ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists; MLCF, middle-to-lower cervical fusion; NS, neurological symptoms; SCSC, spinal cord signal change; UCF, upper cervical fusion.
Note: Boldface indicates statistically significant comparison.
[a]Patients were classified as UCF or MLCF based on the inclusion of C3 to C4 level in the ACDF construct.

distribution. Age, sex, race, insurance type, number of levels fused, spinal cord signal change, and neurological diagnosis were included in the overall multivariable models as covariates to minimize confounding. Multivariable models included only African American/Black and Caucasian/White patients as logistic models failed to converge when including other race categories due to small cell counts. Statistical significance was defined as P value < 0.05.

RESULTS

A total of 835 patients were included in the current analysis, comprising 562 in the MLCF group and 281 in the UCF group. The demographic characteristics and psychiatric diagnoses of the patients are reported in Table 1. MLCF patients were significantly younger than UCF patients (53.7 vs 58.3 years old, $P < 0.0001$), predominately women (53.0% vs 29.2%, $P < 0.0001$), and white or Caucasian (60.9% vs 39.5%, $P < 0.0001$). Following the age trend, a difference in primary insurance distribution was observed between the groups ($P = 0.008$; Table 1). UCF patients tended to have Medicare (44.5% vs 32.4%) more often than Medicaid (18.9% vs 27.2%) listed as their primary insurance. No significant difference was observed in body mass index. Regarding psychiatric diagnosis, there was no significant difference in psychotic disorders ($P = 0.879$). However, individuals who received MLCF showed higher rates of depression (33.3% vs 23.8%, $P = 0.005$) and anxiety (36.7% vs 27.8%, $P = 0.014$) when compared with UCF patients. Demographic variables that demonstrated a statistically significant difference between groups including age, sex, race, and insurance status were used in subsequent multivariable analysis to control for possible confounders.

Pre- and intraoperative characteristics of each group are reported in Table 2. The 2 fusion groups demonstrated a significant difference in neurological diagnosis ($P < 0.0001$). Myelopathic symptoms alone were most prevalent in UCF (63.0% vs 48.8%), while radiculopathy alone was more prevalent in MLCF (33.1% vs 11.4%). Rates of concurrent myelopathy and radiculopathy were more comparable between groups, with UCF at 25.6% and MLCF at 18.2%. UCF patients exhibited spinal cord signal change on preoperative imaging significantly more often than MLCF patients (22.8% vs 18.2%). Additionally, UCF patients had more patients with preoperative diagnosis of spondylolisthesis; however, the difference did not reach significance. No significant differences were observed between the 2 groups in ASA classifications, approach surgeon utilization, graft utilization, neuromonitoring utilization, and fusion device type. Pre- and intraoperative differences that reached statistical significance

Table 3. Spine levels involved in ACDF of patients diagnosed with either UCF or MLCF.[a]

	MLCF (*n* = 562)						UCF (*n* = 281)			
Spine Level	***n* = 63**	***n* = 117**	***n* = 65**	***n* = 104**	***n* = 134**	***n* = 79**	***n* = 85**	***n* = 80**	***n* = 70**	***n* = 46**
C3										
C4										
C5										
C6										
C7										

Abbreviations: ACDF, anterior cervical discectomy and fusion; MLCF, middle-to-lower cervical fusion; UCF, upper cervical fusion.
The cells highlighted in black are a visualization of the cervical levels involved within the construct, not statistical significance. The associated *P* values are provided in the Results section.
[a]Patients were classified as UCF or MLCF based on the inclusion of C3 to C4 level in the ACDF construct.

including neurological diagnosis and spinal cord signal change were used in subsequent multivariable analysis as covariates to control for confounding.

Table 3 demonstrates the number of levels involved within the fusion construct of patients within each group. The MLCF group comprised 562 total patients, 245 of whom received a 2-level fusion, 238 of whom received a 3-level fusion, and 79 of whom underwent 4-level fusion. Of the 245 patients who underwent 2-level fusion, 63 of the constructs involved C4 to C5, 117 involved C5 to C6, and 65 involved C6 to C7. Of the 238 patients undergoing 3-level fusions, 104 involved C4 to C6, and the remaining 134 involved C5 to C7. The remaining 79 patients underwent 4-level fusion of C4 to C7. The UCF group consisted of 281 patients, including 85 2-level ACDF involving C3 to C4, 80 3-level involving C3 to C5, 70 4-level including C3 to C6, and 46 5-level fusions spanning C3 to C7. There was a significantly increased number of patients in the MLCF with 1- or 2-level fusions, while the UCF contained more patients receiving 3- or 4-level fusions ($P < 0.0001$). These differences in number of levels fused were considered in the multivariable analysis to control for possible confounding.

There was no significant difference in the median follow-up time between the 2 groups. Specifically, the median follow-up time for UCF was 211 days (range: 0–3347) and for MLCF was 200 days (range: 0–3820). Approximately 75% of the patients had at least 1 follow-up 30 days after discharge (78.3% for UCF and 74.2% for MLCF, $P = 0.192$). The median surgery time was extended when C3 to C4 was involved ($P = 0.0006$), measuring 3 hours and 4 minutes (range: 44 minutes to 7 hours and 39 minutes) for UCF cases and 2 hours and 44 minutes (range: 43 minutes to 8 hours and 22 minutes) for MLCF cases.

Univariable comparisons and prevalence of postoperative outcomes are reported in Table 4 for the entire sample. UCF led to an approximately 1.5 days longer LOS compared with MLCF (1.5 vs 3.1, $P < 0.0001$). MLCF patients were more often discharged home (92.7% vs 84.0%), with the remaining patients requiring either inpatient rehabilitation (1.6% and 9.3%), outpatient rehabilitation (5.3% vs 5.7%), or nursing facility care (0.4% and 1.1%). Of the 843 patients included in the statistical analysis, 628 had neurological symptoms in the postoperative period recorded in their electronic medical record. A subset of patients lacked information regarding their neurological symptoms in the postoperative period: 147 (26.3%) MLCF patients and 66 (23.5%) UCF patients; however, the prevalence did not significantly differ ($P = 0.385$). There was no significant difference observed in rates of major complications including new neurological deficits and requirement for revision surgery between the 2 groups. However, the UCF group exhibited a significantly higher rate of minor complications (29.5% vs 18.7%, $P = 0.0004$), including dysphagia (22.1% vs 15.0%, $P = 0.010$). Additionally, a higher percentage of MLCF patients

Table 4. Primary and secondary outcomes of patients undergoing ACDF with either UCF or MLCF.[a]

Characteristics	**MLCF (*n* = 562)**	**UCF (*n* = 281)**	***P***
LOS, mean (95% CI)	1.6 (1.4–1.8)	3.0 (2.6–3.5)	**<0.0001**
Discharge location, % (*n*)			**<0.0001**
Home	92.7 (521)	84.0 (236)	
Nursing facility	0.4 (2)	1.1 (3)	
In-patient	1.6 (9)	9.3 (26)	
Outpatient	5.3 (30)	5.7 (16)	
NS postsurgery (*n* = 628), % (*n*)			**<0.0001**
Resolved/improved	75.8 (313)	60.5 (130)	
No change/worsen	24.2 (100)	39.5 (85)	
Complications, % (*n*)			
At least 1 major complication	13.0 (73)	15.1 (42)	0.435
New neurological deficit	5.2 (29)	5.3 (15)	0.913
Revision surgery	3.0 (17)	4.3 (12)	0.350
At least 1 minor complication	18.7 (105)	29.5 (83)	**0.0004**
Dysphagia	15.0 (84)	22.1 (62)	**0.010**

Abbreviations: ACDF, anterior cervical discectomy and fusion; CI, confidence interval; LOS, length of stay; MLCF, middle-to-lower cervical fusion; NS, neurological symptoms; UCF, upper cervical fusion.
Note: Boldface indicates statistically significant comparison.
[a]Patients were classified as UCF or MLCF based on the inclusion of C3 to C4 level in the ACDF construct.

reported improvement or resolution in their symptoms than UCF patients (75.8% vs 60.5%, $P < 0.0001$).

Adjusted OR (aOR) derived from multivariable analysis is provided in Table 5. Multivariable analysis accounted for all statistically significant demographic, preoperative, and intraoperative characteristics. These variables include age, sex, race, insurance type, number of levels fused, spinal cord signal change, and neurological diagnosis. All other demographic and operative variables showed no significance between the UCF and MLCF groups, eliminating any confounding effect these variables might have had on the results. UCF patients demonstrated a longer LOS on univariable analysis, a difference that remained within the multivariate analysis (2.3 vs 3.3 days, $P < 0.0001$). Although significant on univariable analysis, aOR for postoperative requirement for inpatient or outpatient rehabilitation failed to reach significance (aOR = 1.7; 95% CI: 0.99, 2.90; $P = 0.055$) on multivariable analysis. The aOR for at least 1 minor complication was 83% higher in the UCF group compared with the MLCF group (aOR = 1.83; 95% CI: 1.24, 2.72; $P = 0.003$). Additionally, for dysphagia, the odds were 66% higher in the UCF group than in the MLCF group (aOR = 1.66; 95% CI: 1.08, 2.56; $P = 0.021$). Finally, MLCF patients were more likely to experience resolution in their neurological symptoms, as aOR was calculated for these variables (aOR = 0.46; 95% CI: 0.30, 0.70; $P = 0.0003$).

DISCUSSION

The current literature consists of many studies analyzing the effect of factors such as type of fusion device and number of levels fused on ACDF outcomes; however, to our knowledge, there is no current literature assessing the relationship of location and outcomes in cervical fusions. Anecdotally, there seems to be consensus among surgeons within the spine surgery community that UCF patients seem to have worse overall outcomes when compared with their MLCF counterparts. This retrospective review of 853 ACDF patients diagnosed with cervical myelopathy or radiculopathy serves as preliminary evidence suggesting that UCF patients may demonstrate worse overall outcomes when compared with MLCF patients. Specifically, patients who underwent UCF had longer LOS, higher rates of dysphagia, and increased needs for rehabilitation services and were less likely to experience improvement of their neurological symptoms postoperatively when compared with MLCF patients. After multivariable analysis was conducted to control statistically significant differences in demographics, number of fusion levels, presence of spinal cord signal change on radiographs, and diagnosis of radiculopathy and/or myelopathy, UCF patients still had higher rates of dysphagia and longer LOS and were less likely to self-report improvement of their neurological symptoms postoperatively.

The first of the significant findings following UCF was increased rates of dysphagia, which is the most common complication following ACDF.[10–12] The incidence of dysphagia following ACDF is highest in the early postoperative period and tends to decrease in the first 8 to 12 weeks.[13] Although all surgical procedures carry some risk for dysphagia due to factors such as laryngeal stretch and esophageal edema following intubation, anterior cervical procedures have been shown to carry an additional risk attributed to associated pharyngeal wall edema or recurrent laryngeal nerve paralysis.[11,14] The risk of dysphagia following ACDF has been previously linked to a number of factors, including female gender, younger age, increased operative time, increased ASA score, and a greater number of cervical level involvement increasing risk.[13,15–18] This study demonstrated a significantly increased risk following UCF after controlling for additional previously suggested risk factors for dysphagia when compared with MLCF. This is in line with previous indirect data from a 2007 prospective study investigating the effects of plate thickness demonstrating a trend of higher rates of dysphagia with plates at the level of C3.[19] Conversely, Kalb et al found an increased risk at C4 to C5 and C5 to C6, although the power of this finding was admittedly low based on the patient population studied.[20]

Table 5. OR and aOR of event for a subgroup[a] of patients undergoing ACDF with upper cervical fusion (UCF) or middle-lower cervical fusion (MLCF).[b]

Characteristics	OR (95% CI)	aOR[c] (95% CI)
Inpatient/outpatient rehabilitation discharge	**2.43 (1.54, 3.84)**	1.70 (0.99, 2.90)
Postsurgery NS resolved/got better ($n = 618$)	**0.43 (0.30, 0.62)**	**0.46 (0.30, 0.70)**
Complications		
At least 1 major complication	1.20 (0.79, 1.82)	1.22 (0.75, 1.98)
New neurological deficit	1.00 (0.52, 1.93)	1.66 (0.76, 3.63)
Revision surgery	1.47 (0.69, 3.15)	0.99 (0.40, 2.43)
At least 1 minor complication	**1.89 (1.34, 2.66)**	**1.83 (1.24, 2.72)**
Dysphagia	**1.72 (1.18, 2.49)**	**1.66 (1.08, 2.56)**

Abbreviations: ACDF, anterior cervical discectomy and fusion; aOR, adjusted OR; MLCF, middle-to-lower cervical fusion; NS, neurological symptoms; UCF, upper cervical fusion.

Note: Estimates that are bolded are significantly different from 1 ($P < 0.05$).

[a]The current analysis included only African American/Black and Caucasian/White patients. The models failed to converge when including other race categories due to small cell counts.

[b]Patients were classified as UCF or MLCF based on the inclusion of C3 to C4 level in the ACDF construct.

[c]aOR was calculated including age, sex, race, insurance type, number of levels fused, spinal cord signal change, and diagnosis as covariates.

With rates of dysphagia demonstrated to vary depending on cervical level involvement, an additional consideration for perioperative preventive measures may be indicated. A variety of strategies to decrease postoperative dysphagia currently exist within the literature. A 2013 study investigating a medial vs lateral dissection to the omohyoid muscle found that there were no differences between the 2 approaches until a subanalysis revealed that C3 to C4 patients reported fewer symptoms when using the medial approach.[6] Additionally, intraoperative retropharyngeal steroid injections can decrease local soft tissue swelling without increasing the risk of infection.[21] Finally, fusion device choice may also be used with data suggesting that lower profile fusion devices or various anchor-spacer constructs reduce the risk of dysphagia without a reduction in the integrity of the construct.[22–24] While many of these methods have shown efficacy in the literature, they are far from ubiquitous among ACDF procedures. However, the findings of this study suggest additional consideration of these dysphagia prevention, and management strategies may be necessary in patients undergoing UCF to improve patient outcomes.

In addition to increased rates of dysphagia, UCF patients were also less likely to report improvements in their neurological symptoms postoperatively. As the current gold standard treatment, ACDF has been shown to improve myelopathy and/or radiculopathy symptoms associated with cervical degenerative disc disease.[25–27] There are multiple methods of measuring success in ACDF, with the most patient-centered outcome metrics being postoperative satisfaction scores and neurological outcome measures. In a clinical context, patient satisfaction has been shown to depend primarily on improvement in preoperative pain, while the current academic literature largely measures treatment success in terms of improvement in neurological symptoms.[2,28–30] The present study found UCF patients to be less likely to report improvement in their neurological symptoms, which lends both clinical and academic implications. Clinically, a lower rate of neurological improvement and consequent lower likelihood of patient satisfaction based on the location of the fusion being performed suggests that counseling is indicated to manage expectations of postoperative outcomes. This is specifically important in the context of patient satisfaction also being highly related to preoperative expectations of improvement.[31,32] Academically, with many studies using objective measures of neurological improvement to quantify treatment success, the location of fusion may prove to be an important covariant to control in multivariable analyses when comparing outcomes of different cervical fusion procedures.

Finally, UCF patients demonstrated longer lengths of stay when compared with MLCF patients. When considering factors that increase LOS, previous data suggest that preoperative characteristics such as increased ASA score, older age, and insurance status seem to play more significant roles than intraoperative characteristics.[33–35] However, the present analysis suggests that intraoperative characteristics may play a role when these patient variables are controlled for. Longer LOS leads to adverse outcomes including increased hospital costs and worse overall postoperative course.[33,34] Thus, given the increased LOS demonstrated following UCF, there exists a clinical and financial incentive to further elucidate the interplay between cervical level and LOS in ACDF procedures.

Further elucidating the relationship between cervical fusion level and patient outcomes has both clinical and academic implications. Clinically, understanding all the variables that affect outcomes allows for better patient education and counseling. The findings of this study further suggest that the level of fusion should be considered when counseling patients on their chances of neurological symptom improvement postoperatively as well as their risk for common complications. Academically, this study highlights the potential importance of controlling for cervical fusion level in future studies. Similarly, as previous research has underscored the importance of controlling for the number of levels included in a fusion (hence its inclusion in our multivariable analysis for this study), future studies should control for fusion level when concluding that their device, surgical technique, or other variable improves or worsens outcomes.

While this study had many strengths, including its large sample size and extensive statistical analysis to control confounding variables known to affect ACDF outcomes, it is not without limitations. Given its retrospective nature, the accuracy of the data cannot be confirmed with complete certainty despite the authors' efforts to maximize accuracy. In addition, some of the metrics of postoperative outcomes such as dysphagia and postoperative neurological symptoms were collected from clinical notes rather than standardized scoring systems for these metrics. Unfortunately, the retrospective nature of the study meant that sufficient information was not available in patient medical records to calculate standardized scores for these variables at the time the study was conducted. Another unique, yet potentially limiting, aspect of this study is the patient population. While the high rates of African American patients

and patients with Medicare/Medicaid make it unique for understanding ACDF outcomes in these nderstudied populations, this sample is not generalizable to the United States at large. Future studies should aim to use populations that account for this limitation in our findings.

Overall, to our knowledge, this study is the first to directly investigate the link between cervical fusion level and postoperative outcomes. While the data suggest that UCF has worse outcomes compared with MLCF, the authors view this as a pilot study intended to highlight the potential implications of fusion location on outcomes and encourage follow-up studies to confirm these findings before using these results to change academic or clinical procedure. Specifically, prospective studies using standardized scores for measuring postoperative dysphagia and neurological symptoms should be conducted for better elucidation of the relation between anterior cervical fusion level and patient outcomes.

CONCLUSION

UCF may be associated with an increased likelihood of postoperative dysphagia, longer LOS, increased likelihood of nonhome discharge from hospital, and a lower likelihood of improvement in neurological symptoms compared with MLCF. Future prospective studies utilizing standardized scoring metrics for tracking complications are needed to further elucidate the relationship.

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Corresponding Author: Davis Martin, Louisiana State University Health Sciences Center School of Medicine, 2021 Perdido St, New Orleans, LA 70112, USA; rschr1@lsuhsc.edu