

What is a better value for your time? Anterior cervical discectomy and fusion versus cervical disc arthroplasty

ABSTRACT

Introduction: Compared to anterior cervical discectomy and fusion (ACDF), the motion preservation of cervical disc arthroplasty (CDA) provides an attractive alternative with similar short-term results. However, there is a paucity of the economics of performing CDA over ACDF.

Study Design: This was retrospective study.

Objective: The objective of this study is to evaluate relative-value-units (RVUs), operative time, and RVUs-per-minute between single-level ACDF and CDA. Secondary outcomes included 30-day readmission, reoperation, and morbidity.

Methods: Adults who underwent ACDF or CDA in 2011–2019 National Surgical Quality Improvement Program database datasets. Multivariate quantile regression was utilized.

Results: There were 26,595 patients (2024 CDA). ACDF patients were older, more likely to be female, discharged to inpatient rehabilitation, and have a history of obesity, smoking, diabetes, steroid use, and the American Society of Anesthesiologists-class ≥ 3 . ACDF had greater median RVUs-per-case (41.2 vs. 24.1) and RVUs-per-minute (0.36 vs. 0.27), despite greater operative-time (109 min vs. 92 min) ($P < 0.001$). ACDF predicted a 16.9 unit increase in median RVUs per case ($P < 0.001$, confidence interval [CI]⁹⁵: 16.3–17.5), an 8.81 min increase in median operative time per case ($P < 0.001$, CI⁹⁵: 5.69–11.9), and 0.119 unit increase in median RVUs-per-minute ($P < 0.001$, CI⁹⁵: 0.108–0.130). ACDF was associated with greater unadjusted rates of readmission (3.2% vs. 1.4%) morbidity (2.3% vs. 1.1%) ($P < 0.001$), but similar rates of reoperation (1.3% vs. 0.8%, $P = 0.080$). After adjusting for significant patient-related and procedural factors, readmission (odds ratio [OR] = 0.695, $P = 0.130$, CI⁹⁵: 0.434–1.113) and morbidity (OR = 1.102, $P = 0.688$, CI⁹⁵: 0.685–1.773) was similar between ACDF and CDA.

Conclusions: Median RVUs-per-minute increased by 0.119 points for ACDF over CDA, or \$257.7/h for each additional-hour of surgery. Adjusted 30-day outcomes were similar between procedures. Reimbursement for CDA does not appear to be in line with ACDF and may be a barrier to widespread usage.

Keywords: Anterior, arthroplasty, cervical, comparative, fusion, morbidity, national surgical Quality Improvement Program Database, relative-value-units

INTRODUCTION

Cervical disc arthroplasty (CDA) is a relatively novel technique used to manage the cervical degenerative disease. Conventionally, anterior cervical discectomy and fusion (ACDF) has been the treatment of choice for anterior cervical surgery, but CDA has become increasingly utilized.^[1] The unique aspect of disc replacement is its motion-preserving ability, contrasting it with fusion. Initial arthroplasty designs utilized a ball-and-socket prosthesis to replicate physiologic motion in all rotational planes, but have evolved to include

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at least seven Food and Drug Administration-approved devices for single-level arthroplasty.^[2] The touted benefit of maintaining motion is that it may reduce the risk of adjacent segment disease, although whether this holds true in practice remains unclear.^[3-7] In addition, CDA is not without its own set of complications, including instability and heterotopic ossification.^[8]

ACDF has persisted as one of the tried-and-true surgical solutions for treating degenerative cervical disease. Although the number of ACDFs performed annually continues to far outpace the number of CDAs, there has been an increasingly greater demand for CDA.^[9,10] Niedzielak *et al.* performed a trend analysis of CDA in the Medicare database which revealed a high annual growth rate of CDA utilization of 20.54%.^[11] A greater expansion of CDA however has been in part limited by surgical indications. Although there are no strict criteria for the degree of facet degeneration as a contraindication to CDA, it is generally avoided in patients with facet arthritis or a kyphotic deformity > 15°. But with indications equal, are there value-related benefits to performing one over the

other? As health-care systems shift toward value-based care and alternative payment models, it is crucial to understand the economic implications of treatments in spine surgery.

Although the usage of CDA has been increasing, there is a paucity of literature on the economics of performing CDA over ACDF. This is particularly relevant considering the similar short-term outcomes observed between the two procedures in recent studies.^[12-14] Although prior studies have evaluated the cost-effectiveness of CDA, there is no study comparing the reimbursement rate between ACDF and CDA.^[15,16] Therefore, the purpose of this study was to compare relative-value-units (RVUs)-per-minute between single-level ACDF and CDA. We also compared 30-day readmission, reoperation, and morbidity rates.

METHODS

Study design and population

This retrospective cohort study utilizes data obtained from the American College of Surgeons National Surgical Quality

Table 1: Baseline differences in patient demographic, comorbidity, laboratory, and procedural factors by procedure

	ACDF (n=24,571; 92.4%), n (%)	CDA (n=2024; 7.6%), n (%)	P	Cases available 26,595
Demographics				
Mean age (years; SD)	54.5 (11.5)	45.2 (10.3)	<0.001	26,587
Nonwhite race	3117 (13.7)	217 (12.1)	0.054	24,506
Hispanic ethnicity	1215 (5.4)	90 (5.0)	0.452	24,476
Female gender	12,240 (49.8)	932 (46.0)	0.001	26,592
Comorbidities				
Obese	12,463 (50.9)	921 (45.7)	<0.001	26,489
Smoker	6693 (27.2)	407 (20.1)	<0.001	26,595
Dyspnea	1275 (5.2)	31 (1.5)	<0.001	26,595
Diabetes mellitus	3960 (16.1)	145 (7.2)	<0.001	26,595
Dependent functional status	340 (1.4)	6 (0.3)	<0.001	26,476
COPD	1054 (4.3)	29 (1.4)	<0.001	26,595
Heart failure	69 (0.3)	2 (0.1)	0.127	26,595
Hypertension	11,023 (44.9)	476 (23.5)	<0.001	26,595
Chronic steroid use	799 (3.3)	49 (2.4)	0.041	26,595
Bleeding disorder	243 (1.0)	5 (0.2)	0.001	26,595
Discharged to rehabilitation	710 (2.9)	12 (0.6)	<0.001	26,555
ASA-class ≥3	10,352 (42.2)	440 (21.8)	<0.001	26,562
Lab values (mean; SD)				
Elevated creatinine	0.91 (0.47)	0.89 (0.30)	0.111	22,859
White cell count	7.44 (2.46)	7.26 (2.08)	0.003	23,823
Hematocrit	41.8 (4.13)	42.4 (3.95)	<0.001	24,163
Procedural factors, median (IQR)				
Operative time (min)	109 (79-150)	92 (71-122)	<0.001	26,595
Length of stay (days)	1 (1-1)	1 (0-1)	<0.001	26,582
Total RVUs	41.2 (31.7-45.7)	24.1 (24.1-24.1)	<0.001	26,595
RVUs (/min)	0.36 (0.25-0.51)	0.27 (0.20-0.35)	<0.001	26,595
Outpatient surgery	8315 (33.8)	1055 (52.1)	<0.001	26,595

Fisher's exact test. Bold values indicate significance ($P < 0.05$). ASA - American Society of Anesthesiologists; COPD - Chronic obstructive pulmonary disease; RVUs - Relative value units; ACDF - Anterior cervical discectomy and fusion; CDA - Cervical disc arthroplasty; SD - Standard deviation; IQR - Interquartile range

Improvement Program database (NSQIP). NSQIP has been shown to have excellent validity, reliability, and a low rate of reporting error.^[17,18] Patients ≥ 18 years old who underwent ACDF or CDA between 2011 and 2019 were identified and included based on Current Procedural Terminology (CPT) codes 22856 and 22551, respectively. Patients were excluded if they underwent >1 level of surgery; had nonelective/emergency, deformity, tumor, or revision surgery; or had CPT codes for laminectomy/laminotomy, thoracic, lumbar, pelvic, or posterior procedures, or corpectomy. Patients with missing outcome data were also excluded to prevent biases in the results.

Outcomes and variables

Primary outcomes included RVUs per case, RVUs per minute, and operative time. Secondary outcomes included 30-day readmission, reoperation, morbidity, and specific complications. Readmission was defined as any inpatient stay in the same or another hospital related to the surgical procedure. Reoperation was defined as all major surgical procedures requiring return to the operating room for the intervention of any kind. Morbidity was defined as the occurrence of one or more complications reported in the NSQIP dataset, including infectious, cardiopulmonary, renal, neurological, hematologic, and thromboembolic complications.

Statistical analysis

All statistical analyses were performed using SPSS software (version 28, IBM, Armonk, New York, USA). Demographic, comorbidity, laboratory, and procedural factors were individually analyzed for baseline differences between ACDF and CDA using Student's *t*-test, Kruskal–Wallis H-test, Chi-squared, or Fisher's exact test as appropriate. The above factors were also individually analyzed for any associations with the primary outcomes using univariate logistic regression. Baseline variables that significantly ($P < 0.05$) differed between ACDF and CDA were included and controlled for in multivariate analysis. Multivariate analysis of readmission, reoperation, and morbidity was performed using logistic regression. The assumption of normality for RVUs per case, RVUs per minute, and operative time was assessed using the Kolmogorov–Smirnov test and was not met. Therefore, regression coefficients for RVUs-per-case, RVUs-per-minute, and ORT were estimated through quantile (median) regression.

RESULTS

A total of 26,595 patients (24,571 ACDF; 2,024 CDA) were included in the study. ACDF patients were older (55 years vs. 45 years), more likely to be female (50% vs. 46%), more

Table 2: Univariate and multivariate analyses of primary outcomes and specific complications by procedure

	Univariate			Multivariate	
	ACDF ($n=24,571$), n (%)	CDA ($n=2024$), n (%)	<i>P</i>	OR (95% CI)	<i>P</i>
Primary outcomes					
Readmission	779 (3.2)	28 (1.4)	<0.001	0.695 (0.434-1.113)	0.130
Reoperation	317 (1.3)	17 (0.8)	0.080	1.666 (0.942-2.947)	0.079
Morbidity	572 (2.3)	23 (1.1)	<0.001	1.102 (0.685-1.773)	0.688
Specific complications					
Dehiscence	8 (0.03)	1 (0.05)	0.510 [#]		
Superficial infection	79 (0.3)	10 (0.5)	0.196		
Deep infection	24 (0.1)	2 (0.1)	1.000 [#]		
Organ space infection	22 (0.1)	0	0.407 [#]		
Pneumonia	126 (0.5)	0	0.001	0	0.988
Unplanned intubation event	86 (0.4)	2 (0.1)	0.059		
Pulmonary embolism	40 (0.2)	0	0.072 [#]		
Prolonged intubation	52 (0.2)	0	0.034[#]	0	0.988
Renal failure	5 (0.02)	0	1.000 [#]		
Acute kidney injury	3 (0.01)	1 (0.05)	0.271 [#]		
Urinary tract infection	115 (0.5)	4 (0.2)	0.080		
Stroke	17 (0.1)	0	0.635 [#]		
Myocardial infarction	30 (0.1)	0	0.167 [#]		
Cardiac arrest	18 (0.1)	0	0.393 [#]		
Transfusion	51 (0.2)	1 (0.05)	0.184 [#]		
Deep venous thrombosis	55 (0.2)	1 (0.05)	0.127 [#]		
Sepsis/septic shock	42 (0.2)	1 (2.3)	0.256 [#]		

Fischer's exact test. Bold values indicate significance ($P < 0.05$). Data from the complete multivariate analyses for readmission, reoperation, and morbidity are provided in Tables 3-5, respectively. ACDF - Anterior cervical discectomy and fusion; CDA - Cervical disc arthroplasty; CI - Confidence interval; OR - Odds ratio

likely to be discharged to an inpatient rehabilitation facility (3% vs. 0.6%), and had greater rates of medical comorbidities including obesity, smoking history, diabetes, steroid use, and the American Society of Anesthesiologists-class ≥ 3 [Table 1].

In univariate analysis, ACDF had greater median RVUs per case (41.2 vs. 24.1) and RVUs-per-minute of OR time (0.36 vs. 0.27), despite having greater odds ratio (OR) time per case (109 min vs. 92 min) ($P < 0.001$). ACDF was associated with longer mean hospital stay (1.5 days vs. 1.0 days) and fewer outpatient procedures (34% vs. 52%) ($P < 0.001$). ACDF was also associated with greater unadjusted rates of readmission (3.2% vs. 1.4%) and morbidity (2.3% vs. 1.1%) ($P < 0.001$), but similar rates of reoperation (1.3% vs. 0.8%, $P = 0.080$) [Table 2].

After adjusting for significant patient-related and procedural factors in multivariate logistic regression analysis, readmission (OR = 0.695, $P = 0.130$, confidence interval [CI]⁹⁵:

0.434–1.113) and morbidity (OR = 1.102, $P = 0.688$, CI⁹⁵: 0.685–1.773) no longer statistically differed between ACDF and CDA [Tables 3-5]. Variables that independently predicted readmission, reoperation, and morbidity are provided in Tables 3-5, respectively.

Multivariate quantile regression analysis revealed that ACDF predicted a 16.9 unit increase in median RVUs per case ($P < 0.001$, CI⁹⁵: 16.3–17.5), an 8.81 min increase in median operative time per case ($P < 0.001$, CI⁹⁵: 5.69–11.9), and a 0.119 unit increase in median RVUs per minute ($P < 0.001$, CI⁹⁵: 0.108–0.130).

DISCUSSION

As the United States healthcare shifts toward value-based systems, RVUs are increasingly utilized to determine physician reimbursements nationally.¹¹⁹ This reimbursement system has been designed to better correlate compensation with the amount of physician work involved in providing the

Table 3: Univariate and multivariate analysis of predictors of readmission

	Univariate			Multivariate	
	Readmitted ($n=807$), n (%)	Not readmitted ($n=25,788$), n (%)	P	OR (95% CI)	P
Demographics					
Mean age (years; SD)	58.6 (12.1)	53.6 (11.7)	<0.001	1.014 (1.006-1.023)	<0.001
Nonwhite race	116 (15.2)	3218 (13.6)	0.181		
Hispanic ethnicity	55 (7.2)	1250 (5.3)	0.021	1.331 (0.971-1.826)	0.076
Female gender	369 (45.7)	12,803 (49.7)	0.028	0.827 (0.734-1.037)	0.122
Comorbidities					
Obese	418 (52.0)	12,966 (50.5)	0.399	0.840 (0.711-0.993)	0.041
Smoker	230 (28.5)	6870 (26.6)	0.239	1.187 (0.984-1.431)	0.073
Dyspnea	72 (8.9)	1234 (4.8)	<0.001	1.138 (0.852-1.519)	0.381
Diabetes mellitus	204 (25.3)	3901 (15.1)	<0.001	1.215 (1.001-1.476)	0.049
Dependent functional status	28 (3.5)	318 (1.2)	<0.001	1.486 (0.949-2.326)	0.083
COPD	83 (10.3)	1000 (3.9)	<0.001	1.631 (1.229-2.165)	0.001
Heart failure	7 (0.9)	64 (0.2)	0.006 [#]	1.441 (0.597-3.476)	0.416
Hypertension	478 (59.2)	11,021 (42.7)	<0.001	1.219 (1.014-1.466)	0.035
Chronic steroid use	44 (5.5)	804 (3.1)	<0.001	1.423 (1.022-1.982)	0.037
Bleeding disorder	18 (2.2)	230 (0.9)	<0.001	1.580 (0.927-2.692)	0.093
Discharged to rehabilitation	65 (8.1)	657 (2.6)	<0.001	1.654 (1.208-2.263)	0.002
ASA-class ≥ 3	515 (64.1)	10,277 (39.9)	<0.001	1.796 (1.489–2.166)	<0.001
Lab values (mean; SD)					
Creatinine	1.03 (0.84)	0.94 (0.44)	<0.001	1.180 (1.076-1.293)	<0.001
White cell count	7.66 (2.42)	7.42 (2.44)	0.010	1.024 (0.998-1.050)	0.066
Hematocrit	41.2 (4.62)	41.2 (4.10)	<0.001	0.980 (0.961-0.999)	0.038
Procedural factors					
Operative time	131 (67)	120 (62)	<0.001	1.000 (0.998-1.002)	0.747
Length of stay	2.1 (2.5)	1.5 (4.0)	0.005	1.005 (0.995-1.015)	0.353
Total RVUs	39.4 (11.5)	38.7 (11.2)	0.068	1.000 (0.991-1.009)	0.932
RVUs (/min)	0.37 (0.20)	0.39 (0.22)	0.001	0.702 (0.355-1.385)	0.307
Outpatient surgery	190 (23.5)	9180 (35.6)	0.001	0.643 (0.530-0.780)	<0.001

[#]Fischer's exact test. Bold values indicate significance ($P < 0.05$). Table 2 for univariate and multivariate results for procedure (ACDF vs. CDA) as a predictor of readmission.

ASA - American Society of Anesthesiologists; COPD - Chronic obstructive pulmonary disease; SD - Standard deviation; CI - Confidence interval; OR - Odds ratio; ACDF - Anterior cervical discectomy and fusion; CDA - Cervical disc arthroplasty; RVUs - Relative value unit

Table 4: Univariate and multivariate analysis of predictors of reoperation

	Univariate			Multivariate	
	Reoperation (n=334), n (%)	No reoperation (n=25,788), n (%)	P	OR (95% CI)	P
Demographics					
Mean age (years; SD)	59.8 (11.4)	53.7 (11.7)	<0.001	1.026 (1.013-1.038)	<0.001
Nonwhite race	48 (15.4)	3286 (13.6)	0.356		
Hispanic ethnicity	18 (5.9)	1287 (5.3)	0.677		
Female gender	139 (41.6)	13,033 (49.6)	0.004	0.801 (0.613-1.047)	0.105
Comorbidities					
Obese	159 (48.0)	13,225 (50.6)	0.362	0.816 (0.634-1.050)	0.114
Smoker	101 (30.2)	6999 (26.7)	0.141	1.372 (1.038-1.814)	0.026
Dyspnea	27 (8.1)	1279 (4.9)	0.007	1.119 (0.707-1.772)	0.630
Diabetes mellitus	78 (23.4)	4027 (15.3)	<0.001	1.029 (0.758-1.395)	0.856
Dependent functional status	9 (2.7)	337 (1.3)	0.044 [#]	0.960 (0.471-1.960)	0.912
COPD	26 (7.8)	1057 (4.0)	0.001	1.031 (0.633-1.678)	0.908
Heart failure	3 (0.9)	68 (0.3)	0.060 [#]		
Hypertension	198 (59.3)	11,301 (43.0)	<0.001	1.100 (0.835-1.450)	0.498
Chronic steroid use	15 (4.5)	833 (3.2)	0.173	1.064 (0.601-1.886)	0.831
Bleeding disorder	7 (2.1)	241 (0.9)	0.038 [#]	1.154 (0.462-2.879)	0.759
Discharged to rehabilitation	48 (14.5)	674 (2.6)	<0.001	3.184 (2.171-4.667)	<0.001
ASA-class ≥3	212 (63.9)	10,580 (40.3)	<0.001	1.741 (1.313-2.309)	<0.001
Laboratory values (mean; SD)					
Creatinine	1.01 (0.82)	0.91 (0.45)	0.001	1.148 (0.987-1.336)	0.072
White cell count	7.72 (2.41)	7.42 (2.44)	0.033	1.025 (0.993-1.058)	0.121
Hematocrit	41.9 (4.36)	41.9 (4.12)	0.763	1.019 (0.988-1.051)	0.233
Procedural factors					
Operative time	136 (70)	120 (62)	<0.001	1.000 (0.997-1.003)	0.906
Length of stay	4.5 (7.2)	1.4 (3.8)	<0.001	1.018 (1.008-1.028)	<0.001
Total RVUs	40.4 (11.5)	38.7 (11.2)	0.007	1.013 (1.000-1.027)	0.053
RVUs (/min)	0.37 (0.20)	0.39 (0.22)	0.043	0.734 (0.263-2.048)	0.555
Outpatient surgery	60 (18.0)	9310 (35.5)	<0.001	0.532 (0.387-0.733)	<0.001

[#]Fischer's exact test. Bold values indicate significance ($P < 0.05$). Table 2 for univariate and multivariate results for procedure (ACDF vs. CDA) as a predictor of reoperation.

ASA - American Society of Anesthesiologists; COPD - Chronic obstructive pulmonary disease; SD - Standard deviation; CI - Confidence interval; OR - Odds ratio; ACDF - Anterior cervical discectomy and fusion; CDA - Cervical disc arthroplasty; RVUs - Relative value unit

service. In general, higher RVUs are assigned to more complex procedures because the RVU payment model considers the physician's work, practice expenses, and professional liability insurance.^[20] Despite these considerations, several studies have found inappropriate RVU assignments to certain procedures, characterized by failures to accurately capture the degree of complexity involved.^[21-24] Therefore, a thorough assessment of RVUs for cervical spine surgical procedures is necessary.

The aim of the current study was to compare the mean RVUs, operative time, and RVUs per minute between single-level ACDF and CDA. Our findings showed that single-level ACDF was associated with greater operative time than CDA. However, ACDF also had greater median RVUs per case, yielding greater RVUs per minute of operative time. Our analysis also revealed no statistical difference in readmission, reoperation, and morbidity between the two procedures after adjusting for patient-related factors.

Some cost analyses comparing ACDF and CDA have been performed. McAnany *et al.* evaluated the 5-year cost-effectiveness of ACDF and CDA using a Markov analysis, which revealed that although both procedures are cost-effective strategies at 5 years, CDA was the dominant treatment strategy at higher utility values.^[25] A database analysis by Radcliff *et al.* also favored CDA due to significant monthly cost reductions compared to ACDF.^[26] However, no study has previously compared the physician reimbursement rates of the two procedures. Our model showed that after adjusting for patient-related and procedural factors, the median RVU/minute increased by 0.119 points for ACDF compared to CDA. This equates to \$257.7/h for each additional hour of operative time using the 2020 Medicare conversion factor (\$36.09).^[27,28] While this value is general and does not apply to all surgeon reimbursement structures, this is a significant finding given that physician reimbursement for a procedure may affect the rate at which CDA is performed and therefore its utilization, advancement, and technological perfection.

Table 5: Univariate and multivariate analysis of predictors of morbidity

	Univariate			Multivariate	
	Morbidity (n=595), n (%)	No morbidity (n=26,000), n (%)	P	OR (95% CI)	P
Demographics					
Mean age (years; SD)	59.1 (12.3)	53.7 (11.7)	<0.001	1.014 (1.005-1.023)	0.002
Nonwhite race	86 (15.7)	3248 (13.6)	0.154		
Hispanic ethnicity	29 (5.3)	1276 (5.3)	0.975		
Female gender	275 (46.2)	12,897 (49.6)	0.102	0.866 (0.711-1.054)	0.151
Comorbidities					
Obese	290 (49.0)	13,094 (50.6)	0.448	0.803 (0.665-0.970)	0.023
Smoker	139 (23.4)	6961 (26.8)	0.063	0.921 (0.737-1.151)	0.471
Dyspnea	56 (9.4)	1250 (4.8)	<0.001	1.408 (1.026-1.934)	0.034
Diabetes mellitus	142 (23.9)	3963 (15.2)	<0.001	1.063 (0.846-1.335)	0.602
Dependent functional status	28 (4.8)	318 (1.2)	<0.001	1.154 (0.710-1.874)	0.563
COPD	51 (8.6)	1032 (4.0)	<0.001	1.385 (0.983-1.952)	0.063
Heart failure	5 (0.8)	66 (0.3)	0.021[#]	1.285 (0.448-3.686)	0.641
Hypertension	344 (57.8)	11,155 (42.9)	<0.001	1.010 (0.821-1.242)	0.924
Chronic steroid use	35 (5.9)	813 (3.1)	<0.001	1.404 (0.964-2.045)	0.077
Bleeding disorder	12 (2.0)	236 (0.9)	0.005	1.319 (0.693-2.513)	0.399
Discharged to rehabilitation	98 (16.9)	624 (2.4)	<0.001	3.535 (2.656-4.705)	<0.001
ASA-class ≥3	371 (62.6)	10,421 (40.1)	<0.001	1.639 (1.327-2.025)	<0.001
Laboratory values (mean; SD)					
Creatinine	1.01 (0.82)	0.91 (0.44)	<0.001	1.092 (0.960-1.241)	0.179
White cell count	7.57 (2.30)	7.42 (2.44)	0.169	1.019 (0.991-1.049)	0.189
Hematocrit	40.9 (4.69)	41.9 (4.10)	<0.001	0.972 (0.951-0.994)	0.013
Procedural factors					
Operative time	143 (76)	120 (61)	<0.001	1.002 (1.000-1.004)	0.039
Length of stay	4.3 (6.5)	1.4 (3.8)	<0.001	1.045 (1.027-1.064)	<0.001
Total RVUs	40.4 (11.7)	38.7 (11.2)	<0.001	1.009 (0.999-1.018)	0.076
RVUs (/min)	0.36 (0.20)	0.39 (0.22)	<0.001	0.908 (0.447-1.844)	0.790
Outpatient surgery	119 (20.0)	9215 (35.6)	<0.001	0.615 (0.486-0.777)	<0.001

[#]Fischer's exact test. Bold values indicate significance ($P < 0.05$). Table 2 for univariate and multivariate results for procedure (ACDF vs. CDA) as a predictor of morbidity.

ASA - American Society of Anesthesiologists; COPD - Chronic obstructive pulmonary disease; SD - Standard deviation; CI - Confidence interval; OR - Odds ratio; ACDF - Anterior cervical discectomy and fusion; CDA - Cervical disc arthroplasty; RVUs - Relative value unit

The present study also compared 30-day outcomes between ACDF and CDA. After adjusting for baseline patient and procedural characteristics in multivariate analysis, there was no statistically significant difference in readmission, reoperation, and morbidity rates between the two procedures. Similar findings regarding clinical outcomes of ACDF and CDA have been previously reported.^[29] Kumar *et al.* examined ACDF and CDA outcomes with a 5-year follow-up period and found no difference in reoperation, readmission, or health-care utilization between the procedures during the study.^[30]

Interestingly, current literature comparing ACDF to CDA is conflicted, and several studies have reported contrasting results demonstrating significant differences in outcomes, often favoring CDA over ACDF. Xie *et al.* performed a meta-analysis on CDA and ACDF including 37 articles with 20 randomized-controlled trials.^[4] The authors reported that ACDF was associated with higher complication and reoperation rates compared to CDA. Shillingford *et al.*

performed a propensity score-matched comparison of CDA and ACDF and found that ACDF was associated with significantly higher readmission rate and length of stay.^[31] Bhashyam *et al.* also reported a higher readmission rate for single-level CDA compared to single-level ACDF but this difference was limited to the 41–60-year age group.^[32] These conflicting findings may be related to learning curves and surgeon experience, considering the significantly lower number of CDAs performed. Given the differing findings in the literature, further investigations comparing the outcomes of ACDF and CDA are warranted.

Several limitations must be considered when interpreting the current study. The NSQIP database is largely comprised of academic medical centers, which may introduce generalizability bias. There was also a disproportionately small number of patients who underwent CDA compared to ACDF. Nevertheless, the NSQIP database allowed for a large sample size and an adequately powered study with a large breadth of surgeons performing an overall less common

procedure, CDA. Operative time may not be a perfect indicator of physician work and likely varied significantly depending on several nonprocedural factors, such as the presence of trainees and the frequency of ACDF and CDA procedures performed by the surgeon. This study is also limited by the differences in indications inherent to ACDF and CDA. While the NSQIP database does not provide a way to control for radiographic-based indications, our rigorous CPT-based exclusion criteria and multivariate analyses controlling for procedural and patient-related factors provide reassurance that both groups are comparable.

CONCLUSIONS

The current study determined that ACDF offers a significantly greater value per minute of operative time than CDA despite requiring longer operative times on a national scale. Specifically, ACDF predicted a median RVU per minute increased by 0.119 points compared to CDA, equating to \$257.7/h for each additional hour of operative time. In addition, while CDA appears to have a more favorable 30-day outcome safety profile, adjusting for patient-related and procedural factors revealed statistically similar outcomes in readmission, reoperation, and morbidity. The significance of this study is underscored by advancements in modern disc arthroplasty technology as well as by changes in the health system, ultimately necessitating greater efficiency. The results of this study can help guide surgical solution to treating cervical disease that may be amenable to either fusion or arthroplasty by a surgeon with similar skill and comfort level in either procedure.

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Conflicts of interest

There are no conflicts of interest.

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