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Revision Anterior Cervical Discectomy and Fusion and Revision Cervical Arthroplasty Are Associated with Similar Outcomes: Real-World Analysis from a National Quality Registry

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ABSTRACT

AIM: To utilize a national surgical quality registry to compare 30-day quality outcomes between repeat anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA).

MATERIAL and METHODS: The National Surgical Quality Improvement Project (NSQIP) Participant User Files (PUF) for the years 2005-2018 were queried for patients undergoing repeat ACDF and CDA using current procedural terminology (CPT) and International Classification of Disease (ICD)-9th version codes. We compared demographic and baseline clinical characteristics, operative characteristics, 30-day readmissions, reoperations, and complications between the two groups. We also performed multivariable analyses to assess the impact of the type of repeat procedure on outcomes of interest.

RESULTS: A total of 3,957 patients were identified, of which 182 underwent revision/removal of arthroplasty, while 3,775 underwent revision or removal of fusion. Up to 4.6% of patients (n=179) in the repeat ACDF group had a complication, compared to 0.5% (n=1) in the CDA group. The 30-day readmission rate was found to be similar between the two groups (repeat-ACDF, 3.8% (n=145), vs. repeat-CDA, 2.2% (n=4); p=0.23). Similarly, 30-day reoperation rate was also not found to be different between the two groups (repeat-ACDF, 3.9% (n=149) vs. repeat-CDA, 2.7% (n=5); p=0.39). On multivariable analysis, removal or revision ACDF was found to be only significantly associated with an increased risk of 30-day complications (OR, 8.00; 95% CI, 1.07-59.79; p=0.04).

CONCLUSION: Repeat ACDF or repeat CDA can be performed safely and are associated with optimal 30-day outcomes, comparable to those of index procedures. However, patients undergoing revision ACDF may be slightly more likely to have complications than those undergoing revision CDA.

KEYWORDS: repeat ACDF, CDA, Cervical fusion, Cervical spine, Spine, Outcomes, NSQIP, 30-day outcomes, Cervical disc replacement, Cervical disc arthroplasty

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INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA) are routinely performed surgical approaches for managing degenerative cervical pathologies. Both procedures are associated with excellent outcomes; however, some patients may require reoperation. According to a recent meta-analysis, reoperation rate at the index level was found to be 8% for ACDF and 4% for arthroplasty, while the reoperation rate for adjacent segment disease was found to be 7% for ACDF and 3% for arthroplasty (32).

Some of the most common reasons for reoperation include adjacent segment disease (ASD), infection, recurrent symptoms, dysphagia, kyphosis, and pseudarthrosis (15,18). Reoperations following primary CDA have been attributed to suboptimal patient selection, whereas reoperations after ACDF surgeries are mostly required due to the development of pseudarthrosis and adjacent segment disease (23,31). Previous studies have investigated the patient-reported outcomes of revision surgery following ACDF or arthroplasty. However, the current literature is sparse on 30-day quality outcomes following revision ACDF or CDA.

Given the recent shift towards fee-for-value-based healthcare models and the importance of quality outcomes for benchmarking the standard of care delivered to patients undergoing this procedure, we sought to investigate and compare clinical characteristics and 30-day clinical outcomes between patients undergoing revision surgery after ACDF and those undergoing revision procedures after a CDA.

METHODS

Cohort

For the current retrospective study, we queried the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) participant user files (PUF) for the years 2005-2018. The NSQIP is the largest surgical quality registry, and currently collects data from 708 academic centers. The registry contains data from up to two million surgical records. (1,33). The data constitute a random sample of all surgical procedures performed by various surgical specialties at each of the participating institutions. Data abstractors at each site undergo extensive training and are responsible for documenting data every eight days. The registry contains de-identified data; therefore, institutional review board (IRB) approval was neither required nor sought.

Inclusion/exclusion

For the current study, patients were included if they had CPT codes 22864 (removal of total disc arthroplasty (artificial disc), anterior approach, single interspace), 22861 (revision including replacement of total disc arthroplasty (artificial disc), anterior approach, single interspace), 22849 (reinsertion of spinal fixation device), or 22855 (removal of anterior instrumentation) (Supplemental Table). For codes 22849, 22855, and 22852, we included only those cases in which the International Classification of Disease (ICD) Clinical Modification (ICD-CM) versions 9 and 10 reflected cervical spine disease. Furthermore, only patients aged 18 years and older were included in the study. We excluded patients who had previously undergone a hybrid procedure; these were identified as cases that had a code for revision or removal of arthroplasty along with a code for revision or exploration of cervical fusion. We also excluded patients who had concurrent CPT codes for cervical corpectomy and lumbar or thoracic spine procedures. Lastly, we excluded patients with a diagnosis code for tumor or spinal epidural abscess.

Procedural Groups

Using various combinations of CPT codes, we identified several procedural groups. For arthroplasty cases, we identified the following groups: 1) only removal of arthroplasty device, where only the CPT code for removal of arthroplasty device was present; 2) revision arthroplasty alone, where only the CPT code for revision arthroplasty code was present; 3) removal arthroplasty and fusion, where a CPT code for removal of arthroplasty device was present along with a code for anterior or posterior cervical fusion; 4) revision arthroplasty and fusion, where a code for revision arthroplasty was present along with a code for anterior or posterior cervical fusion; and 5) removal of arthroplasty device, and revision arthroplasty and anterior fusion, where a code each was present for removal arthroplasty device, revision arthroplasty device, and revision anterior fusion. For fusion cases, the following groups were identified: 1) exploration or removal of instrumentation alone, where only the CPT code for exploration of fusion or removal of anterior instrumentation were present; 2) exploration or removal of instrumentation and revision fusion, where a code was present for exploration for removal of anterior instrumentation was present along with a code for revision anterior fusion; and 3) revision fusion only, where only a code for anterior revision fusion was present.

Outcomes of Interest

Outcomes of interest included complications, readmission, and reoperation within 30 days. Complications included surgical site infection (SSI) (superficial, deep, or organ space infection), bleeding requiring transfusion, deep vein thrombosis (DVT) or pulmonary embolism (PE), sepsis, and septic shock. We have also reported the reasons for readmission and reoperation.

Covariates of Interest

Covariates of interest included age, sex, race/ethnicity, body mass index (BMI), outpatient or inpatient status, surgeon specialty, smoking status, functional status, diabetes, dyspnea, dialysis, steroid use, bleeding disorder, and disseminated cancer.

Statistical Analysis

Continuous variables were summarized using means and standard deviation and compared between the revision/removal arthroplasty and revision/removal fusion groups using t-test or Wilcoxon rank-sum test. Categorical variables were summarized using frequencies and proportions, and were compared between the two groups using chi-square or Fisher's exact tests. We also performed multivariable analysis,

adjusting for age, sex, race, comorbidities, surgical specialty, and inpatient or outpatient status, to assess the impact of the groups on outcomes of interest, including complication rate, surgical site infection (SSI), and 30-day readmission and reoperation. Results are presented as odds ratios (ORs) and their 95% confidence intervals. Statistical significance was set at $p<0.05$. The analysis was performed using R version 3.6.3 (R Foundation for Statistical Computing).

RESULTS

Procedure Groups

A total of 3,957 patients were identified, of which 182 underwent revision/removal of arthroplasty, while 3,775 underwent revision or removal of fusion. Among the patients who underwent revision arthroplasty or removal arthroplasty, 14.3% (n=26) underwent removal of the arthroplasty device alone, 44% (n=80) underwent revision arthroplasty alone, 26.4 % (n=48) underwent removal of arthroplasty and subsequent fusion (anterior fusion, 46 patients; posterior fusion, 2), 14.8% (n=27) underwent revision arthroplasty cervical fusion (anterior fusion, 26 patients; posterior fusion, 1), and 0.5% (n=1) underwent removal of arthroplasty device, revision arthroplasty, and anterior fusion. Among cases that underwent revision or removal of fusion, 62.8% (n=2,369) underwent exploration or removal of anterior instrumentation alone; 2.2% (n=82) underwent exploration or removal of fusion and subsequent fusion, of which 23 (0.6%) patients only had the same level fusion as the removal 27 (0.7%) patients had same-level revision and extended anterior fusion; 22 (0.6%) patients had same-level anterior revision and posterior fusion; and 22 patients had same-level revision, extended anterior fusion plus posterior fusion; and 35.1% (n=1,324) underwent revision fusion alone without removal of previous instrumentation, of which 471 (12.5%) patients had the same level revision; 188 patients (5%) had same-level revision and extension of anterior fusion, 547 (14.5%) patients had same-level revision and extension of posterior fusion, and 118 (3.1%) patients had same-level revision and extension of both anterior and posterior fusion. The results are summarized in Table I.

Table I: Operation details of Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

Variable	n (% within group)
1. Cervical Arthroplasty Removal / Revision (N=182)	
Only removal of arthroplasty device	26 (14.3)
Revision arthroplasty only	80 (44.0)
Removal arthroplasty and fusion	48 (26.4)
Anterior fusion	46 (25.3)
Posterior fusion	0 (0.0)
Anterior fusion and Posterior fusion	2 (1.1)
Revision arthroplasty and fusion	27 (14.8)
Anterior fusion	26 (14.3)
Posterior fusion	0 (0.0)
Anterior fusion and Posterior fusion	1 (0.5)
Removal of arthroplasty device and revision arthroplasty and anterior fusion	1 (0.5)
2. Cervical Instrumentation Removal / Revision after ACDF (N=3775)	
Exploration/removal instrumentation only	2356 (62.4)
Anterior instrumentation	
Exploration/removal instrumentation and revision fusion	82 (2.2)
No extension	23 (0.6)
Extended anterior fusion	27 (0.7)
Posterior fusion	22 (0.6)
Extended anterior fusion and posterior fusion	10 (0.3)
Revision fusion only	1324 (35.1)
No extension	471 (12.5)
Extended anterior fusion	188 (5.0)
Posterior fusion	547 (14.5)
Extended anterior fusion and posterior fusion	118 (3.1)

Demographic and Clinical Characteristics

Patients undergoing revision or removal arthroplasty were more likely to be younger (47.7 (SD=11) vs. 55.96 (SD=12), p<0.001), more likely to undergo an outpatient procedure (29.7%, n=54 vs. 16.6%, n=627, p<0.001) and less likely to have diabetes (8.8%, n=16 vs. 16.4%, n=637, p<0.001). No significant differences were observed between the two groups in terms of sex, race/ethnicity, BMI, surgeons' specialty, smoking status, functional status, presence of steroid use, dyspnea, dialysis, bleeding disorder, and disseminated bleeding. The results are summarized in Tables II and III.

Thirty-day outcomes:

Up to 4.4% of patients (n=167) in the removal or revision fusion group had at least one complication, compared to 0.5% (n=1). The most common complication in the removal or revision fusion group was sepsis n=39, 1%), followed by deep SSI, organ-space SSI (0.9%, n=33) and DVT (0.8%, n=32). The only patient with a complication in the removal or revision arthroplasty group had deep SSI (Table IV).

The 30-day readmission rate in the removal or revision fusion group was 3.8% (n=145), compared to 2.2% (n=4) in the revision or removal arthroplasty group; the difference was not significant (0.23). Similarly, the 30-day reoperation rate was 3.9% (n=149) in the removal or revision fusion group compared to 2.7% (n=5) in the removal or revision arthroplasty group; the difference was not significant (Table V).

On multivariable analysis, removal or revision fusion was found to be significantly associated with an increased risk of 30-day complications (OR: 8.00; 95% CI: 1.07-59.79; p=0.03) (Table VI).

Reasons for Readmission and Reoperation

The most common cause of readmission in the removal or

Table II: Demographics Between Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	All N=3957	Cervical Arthroplasty Removal / Revision N=182	Cervical Instrumentation Removal / Revision N=3775	p
Age (Mean, SD)	55.57 (12.1)	47.70 (11.0)	55.96 (12.0)	**<0.001**
Gender, n (%)				0.068
Female	2216 (56.0)	90 (49.5)	2126 (56.3)	
Male	1741 (44.0)	92 (50.5)	1649 (43.7)	
Race/ethnicity, n (%)				0.087
White	3233 (81.7)	142 (78.0)	3091 (81.9)	
Black or African American	360 (9.1)	19 (10.4)	341 (9.0)	
Asian	37 (0.9)	4 (2.2)	33 (0.9)	
American Indian or Alaska Native	18 (0.5)	3 (1.6)	15 (0.4)	
Native Hawaiian, or Pacific Islander,	4 (0.1)	0 (0.0)	4 (0.1)	
Other or unknown	305 (7.7)	14 (7.7)	291 (7.7)	
BMI (Mean, SD)	29.98 (6.6)	29.72 (5.6)	29.99 (6.6)	0.59
Patient Status, n (%)				**<0.001**
Inpatient	3276 (82.8)	128 (70.3)	3148 (83.4)	
Outpatient	681 (17.2)	54 (29.7)	627 (16.6)	
Surgeon Specialty, n (%)				0.13
Neurosurgery	2410 (60.9)	111 (61.0)	2299 (60.9)	
Orthopedics	1490 (37.7)	69 (37.9)	1421 (37.6)	
Other	57 (1.4)	2 (1.1)	55 (1.5)	
Readmission, n (%)	149 (3.8)	4 (2.2)	145 (3.8)	0.26
Reoperation, n (%)	154 (3.9)	5 (2.7)	149 (3.9)	0.41

revision fusion group was wound-related complications (1.5%, n=54), followed by postoperative pain (0.16%, n=9), implant complications, and DVT/PE (0.15%, n=8). Two patients (1%) in the removal or revision arthroplasty group were readmitted due to postoperative pain, while one patient was admitted due to DVT/PE and another was admitted for an unrelated cause (Table VII).

The most common revision procedure in the removal or revision fusion group was wound-related procedures (1.2%, n=53), followed by revision fusion (1%, n=42), dysphagia-related procedures (0.2%, n=9), and revision decompression (0.2%, n=8). Two patients in the removal or revision arthroplasty group underwent revision arthroplasty within 30 days (1%), while one patient underwent a revision decompression and another underwent a wound-related procedure.

Table III: Comorbidities and Clinical Characteristics Between Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	All N=3957	Cervical Arthroplasty Removal / Revision N=182	Cervical Instrumentation Removal / Revision N=3775	p
Smoker, n (%)				0.24
No	2918 (73.7)	141 (77.5)	2777 (73.6)	
Yes	1039 (26.3)	41 (22.5)	998 (26.4)	
Functional Status, n (%)				0.069
Independent	3815 (96.4)	182 (100.0)	3633 (96.2)	
Partially Dependent	105 (2.7)	0 (0.0)	105 (2.8)	
Totally Dependent	12 (0.3)	0 (0.0)	12 (0.3)	
Unknown	25 (0.6)	0 (0.0)	25 (0.7)	
Diabetes, n (%)				**0**.052
No	3322 (84.0)	166 (91.2)	3156 (83.6)	
Yes	635 (16)	16 (8.8)	619 (16.4)	
Dyspnea, n (%)				0.53
At rest	19 (0.5)	1 (0.5)	18 (0.5)	
Moderate	229 (5.8)	6 (3.3)	223 (5.9)	
No	3708 (93.7)	175 (96.2)	3533 (93.6)	
Unknown	1 (<1)	0 (0.0)	1 (<1)	
Dialysis, n (%)				0.47
No	3946 (99.7)	182 (100.0)	3764 (99.7)	
Yes	11 (0.3)	0 (0.0)	11 (0.3)	
Steroid use, n (%)				0.18
No	3793 (95.9)	178 (97.8)	3615 (95.8)	
Yes	164 (4.1)	4 (2.2)	160 (4.2)	
Bleeding Disorder, n (%)				0.10
No	3900 (98.6)	182 (100.0)	3718 (98.5)	
Yes	57 (1.4)	0 (0.0)	57 (1.5)	
Disseminated Cancer, n (%)				0.27
No	3932 (99.4)	182 (100.0)	3750 (99.3)	
Yes	25 (0.6)	0 (0.0)	25 (0.7)	

Table IV: Analysis of 30-day Complications Between Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	All N=3957	Cervical Arthroplasty Removal / Revision N=182	Cervical Instrumentation Removal / Revision N=3775	p
Any complications, n (%)	180 (4.4)	1 (0.5)	167 (4.4)	**0.01**
Superficial SSI, n (%)	29 (0.7)	0 (0.0)	29 (0.8)	0.24
Deep SSI, n (%)	34 (0.9)	1 (0.5)	33 (0.9)	0.64
Organ Space SSI, n (%)	33 (0.8)	0 (0.0)	33 (0.9)	0.21
Wound Dehiscence, n (%)	9 (0.2)	0 (0.0)	9 (0.2)	0.51
Bleeding Requiring Transfusion, n (%)	16 (0.4)	0 (0.0)	16 (0.4)	0.39
DVT, n (%)	32 (0.8)	0 (0.0)	32 (0.8)	0.67
Sepsis, n (%)	39 (1.0)	0 (0.0)	39 (1.0)	0.17
Septic Shock, n (%)	10 (0.3)	0 (0.0)	10 (0.3)	0.49

Table V: Analysis of 30-Day Reoperations, Related Return to the Operating Room, Readmissions, and Unplanned Readmissions Between Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	All N=3957	Cervical Arthroplasty Removal / Revision N=182	Cervical Instrumentation Removal / Revision N=3775	p
Readmission, n (%)				0.26
No	3808 (96.2)	178 (97.8)	3630 (96.2)	
Yes	149 (3.8)	4 (2.2)	145 (3.8)	
Reoperation, n (%)				0.41
No	3803 (96.1)	177 (97.3)	3626 (96.1)	
Yes	154 (3.9)	5 (2.7)	149 (3.9)	

Table VI: Effect Estimate of Outcomes Between Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	Unadjusted OR (95% CI)	p	Adjusted OR (95% CI)	p
30 day readmission				
Removal / Revision arthroplasty	Ref	0.26	Ref	0.59
Removal / Revision instrumentation	1.78 (0.65, 4.85)		1.32 (0.48, 3.68)	
30 day reoperation				
Removal / Revision arthroplasty	Ref	0.42	Ref	0.68
Removal / Revision instrumentation	1.45 (0.60, 3.59)		1.22 (0.48, 3.10)	
Surgical Site Infection				
Removal / Revision arthroplasty	Ref	0.13	Ref	0.13
Removal / Revision instrumentation	4.67 (0.65, 33.70)		4.96 (0.64, 38.33)	
Complications				
Removal / Revision arthroplasty	Ref	**0.04**	Ref	**0.04**
Removal / Revision instrumentation	8.38 (1.20, 60.16)		8.00 (1.07, 59.79)	

*****_adjusted for age, sex, race, comorbidities, surgical specialty, in and outpatient._

Table VII: Readmission Reasons for Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	Cervical Arthroplasty Removal / Revision	Cervical Instrumentation Removal / Revision
	N=182	N=3,775
Preoperative Symptom Recurrence	0	5 (0.1%)
Dysphagia	0	6 (0.1%)
Implant Complication	0	8 (0.15%)
DVT/PE	1 (0.5%)	8 (0.15%)
SSI/Wound related Complication	0	54 (1.5%)
Postoperative Pain	2 (1%)	9 (0.16%)
Other unrelated causes	1 (0.5%)	43 (1.2%)

Table VIII: Reoperation CPT Codes for Patients Undergoing Removal / Revision of Cervical Arthroplasty and Removal / Revision of Cervical Instrumentation

	Cervical Arthroplasty Removal / Revision	Cervical Instrumentation Removal / Revision
	N=182	N=3,775
CSF Leak Repair	0	2 (0.1%)
Dysphagia related Procedure	0	9 (0.2%)
Kyphoplasty	0	1 (0.1%)
Repeat Arthroplasty	2 (1%)	0
Revision Corpectomy	0	4 (0.1%)
Revision Decompression	1 (0.5%)	7 (0.2%)
Revision Fusion	0	38 (1%)
Wound related Procedure	1 (0.5%)	50 (1.1%)

DISCUSSION

In a recent meta-analysis, the average revision rate for CDA was reported to be 3.88%, compared to 8.19% for ACDF (5,32). While we were unable to delineate the level at which the repeat surgery was performed (same-level vs. adjacent level), previous studies have reported higher rates for both same-level and adjacent segments after an ACDF, compared to CDA (2,10,16,30). However, the outcomes of the second surgery have not been reported in the literature.

Our analyses indicate that patients undergoing removal or revision arthroplasty had a lower within-30-day complication rate than patients undergoing removal or revision fusion. The finding was sustained in our multivariable analysis after adjusting for age, sex, race, comorbidities, surgical specialty, and in- or out-patient status. Removal or revision fusion was associated with an eight-fold increase in the odds of 30-day complications. Sepsis (1%, n=41), deep SSI (0.9%, n=36), organ-space SSI (0.9%, n=36), and DVT (0.8%, n=34) were higher in the removal or revision fusion group compared to only one patient with a deep SSI in the removal or revision arthroplasty group. The difference between the two groups may be attributed to the longer operation time and higher likelihood of comorbidities in patients undergoing ACDF, which predisposes patients to developing SSI (28). The longer operative time for ACDF may, in turn, be attributed to the requirement for cutting or removal of plates from fusion constructs (25). The wound infection rate for primary ACDF reported in the literature was between 0.1% and 1.6%, and most of the infections occurred in the early postoperative phase with poor wound care (8,9,26). Interestingly, the rate of 30-day SSI did not differ from those with primary ACDF. Late infections following ACDF procedures are rare and commonly associated with esophageal perforation (9,13,19,27,29). Therefore, late deep cervical infection should be considered if the patient had a previous history of ACDF and with dysphagia (6).

In a large study that compared primary ACDF and TDA, there was no significant difference between complications, including

cardiac complications and PE rate (7). However, Shah et al. observed a statistical difference in these two adverse events, with the highest rates of cardiac complications and PEs among patients belonging to the ACDF-TDA cohort compared to the others (21).They also found significant wound disruption in the ACDF-TDA cohort, followed by the ACDF and TDA cohorts alone. Failures of revision/removal fusions should allow the surgeon to address issues such as pseudarthrosis, bone graft collapse or hardware migration, and surgical site infections, leading to a longer surgical time for the procedure and higher risk of DVT, cardiac complications, and PEs (20). Our findings also identified higher complication rates in patients undergoing a second surgery, when comparing fusion to arthroplasty.

Due to the higher complication rates after removal or revision fusion, surgeons should identify potential risk factors such as increased ASA class, preoperative anemia, increased age, anesthesia duration, extended operative time, and male sex (11,14). The 30-day readmission rate and 30-day reoperation rate were not statistically significant, although rates were higher in the removal or revision fusion group. The importance of assessing these outcomes is due to the higher financial penalties by the Center for Medicaid and Medicare Services for hospitals with higher than average readmission and reoperation rates (3,24). Quality improvement efforts should focus on targeting this procedure. Bhashyam et al. reported that 2.6% of ACDF patients were readmitted within 30 days, compared with 0.4% of TDA patients (p=0.003); however, a meta-analysis comparing these two procedures concluded that there was no significant difference in short- or long-term readmission rates (4,17). Our rates for readmission after the second surgery were 3.9% for the cervical instrumentation removal/revision group, compared to 2.2% for the cervical arthroplasty removal/revision group. The most common causes of readmission in the removal or revision fusion group were wound-related complications (1.5%, n=54), postoperative pain (0.16%, n=9), implant complications (0.15%, n=8), and DVT/PE (0.15%, n=8).

In our study, we found that the most common reasons for reoperation in the removal or revision fusion group were wound-related procedures (1.2%, n=53), revision fusion (1%, n=42), dysphagia-related procedures (0.2%, n=9), and revision decompression (0.2%, n=8). Bhashyam et al. reported that the type of procedure was not an independent predictor of reoperation, although Shah et al. found that TDA was a significant predictor of reoperation at least two years postoperatively (OR=2.293, p=0.001) (4,21). Jackson et al. reported that the most common reasons for reoperations at the index level for one- and two-level ACDF with patients of 5-year follow up were radiculopathy, neck pain, and pseudarthrosis, with radiculopathy as the most common indication for secondary surgery among patients who underwent CDA (12).

Although a large sample size from a national, prospectively collected database is one of the main strengths of this study, several limitations should be addressed. First, the lack of information regarding the removal or revision procedures, including operation levels, timing of the removal or revision surgery after the index procedure, and specific reasons for removal or revision remain significant limitations. Similarly, due to coding limitations, we were unable to determine whether the revision procedures were performed at the same level or at an adjacent level. Lastly, miscoding and non-coding by providers are potential sources of error.

CONCLUSION

In summary, we found a significantly higher complication rate for removal or revision fusion than for removal or revision arthroplasty. These results were obtained from a surgical quality registry, thereby providing "real-world" evidence. Ultimately, these results can help spine surgeons and care teams identify patients at risk of complications and readmission after undergoing repeat cervical arthroplasty or repeat cervical fusion.

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Supplemental Table: Current Procedural Codes (CPT) used for devices.

Procedure	CPT Code(s)
Removal Cervical Arthroplasty Device	22864
Revision Cervical Arthroplasty Device	22861
Cervical Arthroplasty	22856, 22858
Anterior Cervical Discectomy and Fusion	22845, 22853, 22552, 22558, 22554, 22846
Cervical Corpectomy	63081, 63082, 22854
Exploration of Previous Cervical Fusion	22830, 49010
Cervical Laminectomy/Laminoplasty	63048, 63045, 63001
Posterior Cervical Fusion	22612, 22633, 22614, 22630, 22842, 22610, 22840, 22600, 22632, 22843, 22804
Reinsertion of Spinal Fixation Device	22849
Removal of Anterior Instrumentation	22855
Removal of Posterior Instrumentation	22850, 22852