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Trends in National Use of Anterior Cervical Discectomy and Fusion from 2006 to 2016

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Abstract

OBJECTIVE: Anterior cervical discectomy and fusion (ACDF) is the most common procedure for the treatment of degenerative cervical conditions. The objective of this study is to determine time-dependent trends in patient outcomes following ACDF for degenerative disease from 2006 to 2016.

METHODS: We used the National Surgical Quality Improvement Program (NSQIP) database to retrospectively review all patients who underwent elective ACDF between 2006 and 2016. A descriptive statistical analysis followed by time trend analysis was performed on demographics, comorbidities, perioperative, and outcome variables. Primary outcomes were reoperation and readmission rates. Secondary outcomes were medical and surgical complications reported within 30 days of operation.

RESULTS: A total of 36,854 patients underwent elective ACDF from the 2006 to 2016 NSQIP database. Mean age increased from 48.19 years [standard error: 1.49] in 2006 to 54.08 years [standard error: 0.12] in 2016 ($P < 0.001$). There was a significantly greater number of outpatient procedures from 2012 to 2016 ($P < 0.001$). The proportion of patients with American Society of Anesthesiologists classes 3/4 significantly increased over time ($P < 0.001$, $P < 0.001$, $P = 0.005$, respectively). Readmission risk, first documented in NSQIP in 2011, increased over time from 2011 to 2016 ($P < 0.001$). Unplanned reoperations have remained consistent at about 1.4%. Postoperative complications varied over time with no discernable patterns or trends.

CONCLUSIONS: Since the establishment of the NSQIP database, there have been no considerable improvements in reoperation or postoperative complication rates based on available

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CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Hannah K. Weiss: Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft. **Jonathan T. Yamaguchi:** Methodology, Formal analysis, Investigation, Resources, Data curation. **Roxanna M. Garcia:** Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft. **Wellington K. Hsu:** Writing - review & editing. **Zachary A. Smith:** Writing - review & editing. **Nader S. Dahdaleh:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision.

data, however, there have been increased rates of readmission. Changes in data collection and an aging patient population with greater burden of comorbidities could confound these trends.

Keywords

Anterior cervical discectomy and fusion; Degenerative spine disease; NSQIP; Outcomes; Readmission; Reoperation; Trends

INTRODUCTION

Operations for degenerative cervical spine disease are among the most common elective surgical operations performed in the United States.¹ Anterior cervical discectomy and fusion (ACDF) is the most frequently performed surgery for degenerative cervical disease.² ACDF, a procedure involving decompression of the spinal cord and fusion between vertebrae to decrease movement, has been shown to decrease symptoms and significantly increase health-related quality of life.^{2,3} Rates of spinal surgery for cervical disease have been consistently increasing over the last 4 decades.^{1,4-6} As more individuals continue to undergo these procedures, it is paramount to continuously improve patient outcomes.

Large administrative databases can provide significant patient information and outcome data on surgical trends at a national level. The American College of Surgeons' National Surgical Quality Improvement Program (NSQIP) is a national, outcomes-based and risk-adjusted database designed to measure and improve surgical care.⁷ The NSQIP database, launched initially for the National Veterans Affairs Surgical Risk Study in 1992, was expanded nationally in 2004, adding novel data points and participating hospitals annually, representing 680 hospitals by the year 2016.^{8,9} NSQIP provides risk-adjusted 30-day outcomes data, in turn supplying a method for unbiased comparisons between a wide variety of participating hospitals. Ultimately, the main objective of NSQIP is to improve cost efficiency and patient safety for all surgical procedures performed in the United States.⁹ Studies have revealed a substantial decrease in morbidity and mortality since the development of NSQIP.⁸ However, despite the significant numbers of studies published on ACDF from the NSQIP database, there is a paucity of literature on the effect that NSQIP has had on ACDF outcomes over time.¹⁰⁻¹⁷

The NSQIP database has been fundamental to large-scale, national research. Many studies have specifically analyzed NSQIP to identify factors and related surgical outcomes following ACDF. One of the aims of NSQIP and other national databases is to identify modifiable risk factors that influence rates of readmission and reoperation. When these factors are understood and modified, then there is an opportunity to improve outcomes and rates of readmission in the future. The objective of this study is to determine trends in patient level factors and outcomes, primarily reoperation and readmission following ACDF, since NSQIP has been established in 2006.

MATERIALS

Data Source

The NSQIP database is a nationwide program compiling data on major surgical procedures in both the outpatient and inpatient settings. Patients are selected by billable Current Procedural Terminology (CPT) code and given an *International Classification of Diseases, Ninth Revision* (ICD-9) and *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (ICD-10) code corresponding to the postoperative diagnosis from the operative or pathology reports. Trained surgical clinical reviewers collect data on the perioperative period and up to 30 days after the procedure using a standardized sampling method.¹⁸⁻²⁰ Several variables were added, dropped, or changed in the NSQIP database since its inception. The definitions of ethnicity and race were revised in 2008 to comply with the Centers for Medicare and Medicaid Services and other federal agencies. Data from national participant use files from 2006 to 2016 were compiled and all patients undergoing single or multilevel ACDF were identified. The number of participating sites continues to increase each year; in 2006, a total of 121 health centers reported data, which grew to 680 by 2016. The NSQIP database is publicly available and de-identified, thus Institutional Review Board or informed consent were waived.

Patient Selection

We retrospectively reviewed the NSQIP database from 2006 to 2016 for adult patients aged 18–89 years and queried for 5 primary CPT codes: 22551 (Anterior or Anterolateral Approach Technique Arthrodesis Procedures on the Spine [Vertebral Column] single level), 22552 (Anterior or Anterolateral Approach Technique Arthrodesis Procedures on the Spine [Vertebral Column] additional levels), 22554 (Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace [other than for decompression]), 22856 (ACDF code prior to 2010), and 63075 (ACDF code prior to 2010). The CPT coding for ACDF changed over the study period. In 2010 and the years prior, the CPT code 63075 was used in concert with 22554 for representing anterior discectomy and subsequent fusion. In 2011, these 2 codes were combined into 1 code: 22551 for first fusion and discectomy level (with code 22552 for additional levels).²¹ Only patients with ICD-9 or ICD-10 codes appropriate for ACDF in an elective case were evaluated. Cases were excluded if they were emergent; did not provide pertinent demographic data such as sex, height, or weight; or had disseminated cancer. Furthermore, cases undergoing revision surgery or fusion extending to the thoracic, lumbar, or pelvis were excluded: 22800, 22802, 22804, 22808, 22810, 22849, 22850, and 22855.

Independent Variables

Demographic variables, comorbidities, and perioperative variables were analyzed across time. Demographic variables included age, sex, body mass index (BMI), race, and ethnicity. Comorbidities included smoking, ventilator dependency, history of chronic obstructive pulmonary disease, ascites, diabetes, history of cardiac heart failure, use of hypertensive medications, renal failure, dialysis, wound infection, steroids, recent 10% weight loss, bleeding disorder, dyspnea, functional status before surgery, and sepsis. Perioperative variables collected were inpatient versus outpatient procedure, American Society of

Anesthesiologists (ASA) class, total operation duration, and total length of hospital stay, as well as symptoms of radiculopathy and myelopathy. Radiculopathy and myelopathy were considered present if respective ICD-10 diagnostic codes were explicitly mentioned.

Outcome Variables

The primary outcome variables were reoperation and readmission within 30 days of surgery. The readmission variable was added in 2011, whereas reoperation was available since the inception of NSQIP in 2006. Although readmission was not reported until 2011, we recognize the importance of tracking this variable and describing the trend with the data available, which is a meaningful time period of 5 years. For readmission, ICD-9 and ICD-10 codes were summarized. Secondary outcome variables included medical and surgical complications within 30-days such as surgical-site infections, dehiscence, pneumonia, reintubation, venous thromboembolism events, failure to wean off of the ventilator within 48 hours, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke or cerebrovascular accident, cardiac arrest requiring resuscitation, myocardial infarction, or requiring transfusion.

Statistical Analysis

IBM SPSS Statistics, Version 24 (IBM Corp., Armonk, New York, USA) was used to perform all statistics. Descriptive statistics are given as either n (%) or mean value \pm standard error (SE) where appropriate. Categorical variables were analyzed by the χ^2 test and continuous variables were analyzed using analysis of variance. A time trend analysis was performed using the χ^2 test for trend and ordinary linear regression, for categorical and continuous variables, respectively. Nonparametric tests, including the Kruskal–Wallis H test and Jonckheere–Terpstra test, were implemented for cell counts less than 10 and non-normally distributed data.

RESULTS

Population Characteristics

A total of 36,854 patients met our inclusion criteria for elective ACDF (Figure 1). Overall, 50.2% of patients were female and the mean age was 53.56 [SE: 0.06] years (Table 1).

The total number of ACDF procedures significantly increased even when adjusted for total surgical cases reported to NSQIP since 2006 (Figure 2). Over the 11-year period, there were more female patients ($P < 0.001$) and procedures performed as outpatient surgery, consistently increasing from 2012 to 2016 ($P < 0.001$). Mean age increased from 48.19 [SE: 1.49] in 2006 to 54.08 [SE: 0.12] in 2016 ($P < 0.001$). BMI was statistically significantly ($P < 0.001$) but not clinically relevant (29.4 in 2006 to 30.5 in 2016). Patients reporting symptoms of myelopathy varied significantly across years ($P < 0.001$). Radiculopathy was based on the ICD-10 code and was first recorded in 2014, with only 5 cases (0.10%) documented as having radiculopathy present in 2014, rising to 3,542 (35.70%) cases in 2016.

Baseline comorbidity of patients differed throughout the analyzed time period. The number of patients with diabetes was significantly different across years ($P < 0.001$). The proportion of patients with ASA classes 3 and 4 increased over time ($P < 0.001$). When stratified by inpatient versus outpatient status, the percentage of patients undergoing inpatient ACDF with low ASA classification (1 and 2) decreased from 80% in 2007 and 66% in 2016, as did those with ASA classification scores of 3 and 4 (88% in 2007 to 76% in 2016, respectively). These trends were significant over the study period ($P < 0.05$). In addition, more patients had dyspnea at moderate exertion and at rest ($P < 0.001$) and were on dialysis ($P = 0.005$) between 2006 and 2016. The proportion of smokers within year of operation significantly decreased between 2006 and 2016 ($P < 0.001$). The functional status of patients did not worsen over time ($P = 0.054$).

Patient Outcomes

Readmission risk, first documented in NSQIP in 2011, increased slightly from 1.9% to 3.1% from 2011 and 2016 ($P < 0.001$, Figure 3). By manual entry, the most common readmission causes were pneumonia ($n = 66$, 0.20%), followed by deep surgical-site infection ($n = 29$, 0.10%) and pulmonary embolism ($n = 25$, 0.10%). The most common causes of readmission by ICD-9-CM codes were the following: hematoma complicating a procedure ($n = 42$, 0.10%), dysphagia ($n = 29$, 0.10%), and other acute postoperative pain ($n = 18$, <0.01%). The most common reason for readmission by ICD-10 codes was dysphagia ($n = 24$, 0.10%). The majority of readmission causes were not reported (manually entry $n = 36,103$ [98.0%], ICD-9 $n = 36,553$ [99.2%], and ICD-k $n = 36,659$ [99.5%]).

There were no obvious trends in unplanned reoperations between 2006 and 2016, but the percentage varied over time ($P < 0.001$, Figure 3). The most commonly documented postoperative diagnoses were intervertebral disc disorders ($n = 7850$, 21.30%), cervical spondylosis with myelopathy ($n = 4512$, 12.20%), and spondylosis without myelopathy ($n = 4120$, 11.20%).

When adjusted for sex, age, inpatient versus outpatient status, and BMI, operation time decreased significantly between 2006 (143.3 ± 63.7 minutes; 95% confidence interval [CI] 119.9–166.6) and 2016 (124.5 ± 65.24 minutes, 95% CI 123.3–125.8, $P = 0.009$). Length of stay also differed significantly between 2006 (1.7 ± 1.4 days, 95% CI 1.3–2.3) and 2016 (1.5 ± 2.5 days, 95% CI 1.5–1.6) with no clear trends ($P < 0.001$). There were differences in discharge destination with no discernable trend over time ($P < 0.001$). There was a total of 52 reported deaths within 30 days of operation over the 11 years (Figure 4).

Rates of postoperative complications varied throughout the study period but there were no significant differences in failure to wean, defined as on ventilator greater than 48 hours, pulmonary embolism or deep venous thrombosis requiring therapy, pneumonia, progressive renal insufficiency, or urinary tract infections (see Table 2). In addition, there were no significant differences in rates of superficial, deep, or organ space incisional surgical infections, or wound disruption. Between 2006 and 2016, there was also no significant difference in rates of serious medical complications including systemic infections (Table 2).

DISCUSSION

This is the first study to analyze trends of ACDF surgery in the context of the NSQIP database since its inception in 2006. The total number of ACDF surgeries performed in the United States, even when adjusted for the total surgical volume reported to NSQIP, is increasing, which is consistent with current literature.^{1,4-6} The readmission rates reported in NSQIP have slightly increased over time, and there have been no significant decreases in postoperative complications aside from decreased intraoperative red blood cell transfusions from 2011 to 2016. In contrast to the trend of increasing readmission rates and higher rates of outpatient ACDF procedures identified in this study, based on current literature it might be expected that readmission rates should be decreasing with increased outpatient operations.^{11,22} We hypothesized that the population selected for outpatient procedures would be expected to have fewer medical comorbidities. We did observe an increase frequency of lower ASA classification scores since the inception of NSQIP, but this trend did not translate into fewer 30-day readmissions. The lack of improvement could potentially be confounded by severity of patient disease among participating sites as the proportion of patients with ASA 3 and 4 increased overtime from 2006 to 2016, in addition to increased age, which has been shown to be associated with increased risk of readmission.²³

In terms of patient selection, there has been a tendency not to operate on patients who are active smokers. In this study, the frequency of current smoking status continues to decrease since 2006. There is more evidence that insurance companies will deny financial coverage for patients who smoke,²⁴ but these finding also can be linked to the association of smoking with increased rates of pseudarthrosis and pulmonary complications that likely influence patient selection.^{14,25}

Our findings also demonstrate an increased rate of outpatient ACDF. This trend can be explained by the safety of outpatient ACDF on select patients^{11,22,26} and the adoption of outpatient surgery in many centers in conjunction with the evolution of surgery-centers over the past decade.²⁷ Our study demonstrates a trend toward decreased operative time and length of stay. This may be explained by improvement in efficiency and comfort with the surgical technique by the surgeon and the surgical team. Decreased length of stay can be explained by many potential factors, such as early mobilization, increased social work efficiency in placement, and better postoperative pain control.²⁸⁻³⁰

There is a paucity of data on time trends in patient outcomes from the NSQIP database among patients undergoing elective ACDF surgeries. The NSQIP database, designed to collect and provide data to enhance cost effectiveness and patient safety of surgical procedures, has been shown to effectively improve morbidity and mortality in all surgical procedures at both high-performing and low-performing hospitals over time.⁸⁻³¹ Contrary to these findings, there were no significant improvement trends in surgical outcomes aside from decreased red blood cell transfusion rate over time for patients undergoing ACDF and this may be due to the increase proportion of patients with ASA 3 and 4 undergoing this operation. However, postoperative medical and surgical complications may be underreported in large databases such as NSQIP, especially more minor and indirect surgical

complications, therefore limiting interpretation of morbidity associated with ACDF procedures. Moreover, data elements have evolved substantially over time, with new factors being added and removed annually, and therefore the ability to analyze trends is limited. Many studies have published recommendations on methodologies to improve patient care following ACDFs,¹⁰⁻¹⁷ but further collective evidence is needed to provide clear recommendations on how to improve patient outcomes.

The NSQIP database has a significant amount of valuable data that provides unique, important information on trends and outcomes of increasingly common procedures such as ACDF. It must be emphasized that NSQIP only consists of direct surgical outcomes and does not aim to directly report on clinical or functional results. However, the lack of substantial improvements that can be inferred from the direct surgical outcomes over time, despite this growing data resource, suggests that although many studies have used this database to reveal insights into surgical outcomes, the application of these findings in clinical practice has been limited. Therefore, to improve patient outcomes and fully use available data, we propose regular review and procedure specific updates on outcomes and trends be reported to these national databases. Ideally, there would be standardized method of reporting that could be compared over time and be made easily accessible to clinicians.

Between 2006 and 2016, the morbidity and mortality associated with ACDF procedures recorded in NSQIP has remained exceedingly small and highly varied. It is likely that the proportion of patients experiencing complications following ACDF maybe small and highly heterogenous that the data elements collected may not generate meaningful insights to guide changes in clinical management. More specific neurosurgical quality improvement and outcome databases would be more useful in guiding interventions that lead to improvements in clinical care, such as the Quality Outcomes Database (<https://www.codetechnology.com/n2qod-outcomes-database/>). In addition, the majority of readmission causes were not reported, potentially due to being unknown by those submitting the data, further limiting the ability of NSQIP to identify clinically relevant and applicable information to help reduce 30-day readmissions.

This study has several important limitations such as the heterogeneity in the care, record keeping, and management between sites and surgeons, but these variables were not captured in this database. In addition, our primary outcome, readmission, was first recorded in 2011, limiting inference to time of data collection and was subject to small sample bias. In addition, causes for readmission were not reported in the majority of readmission variables, limiting our ability to infer trends on etiologies. Many other factors, such as radiculopathy, relied only on ICD-10 coding and was a recent addition, further limiting disease specific inference. Additionally, adjusting for important confounders in medically complex patients was not performed in this trend analysis.

CONCLUSIONS

Since the establishment of the NSQIP database, the proportion of ACDF surgery to all other NSQIP procedures has increased, yet we did not identify significant trends in reoperation or postoperative complications, except increased readmission risk. Data elements have changed

significantly. One of the primary purposes of the NSQIP database is to provide data for study to improve patient safety. Future efforts to more effectively translate NSQIP studies on ACDF procedures to clinical practice is warranted.

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Abbreviations and Acronyms

ACDF	Anterior cervical discectomy and fusion
ASA	American Society of Anesthesiologists
BMI	body mass index
CI	Confidence interval
CPT	Current Procedural Terminology
ICD-9	International Classification of Diseases, Ninth Revision
ICD-10	International Statistical Classification of Diseases and Related Health Problems, Tenth Revision
NSQIP	National Surgical Quality Improvement Program
SE	Standard error

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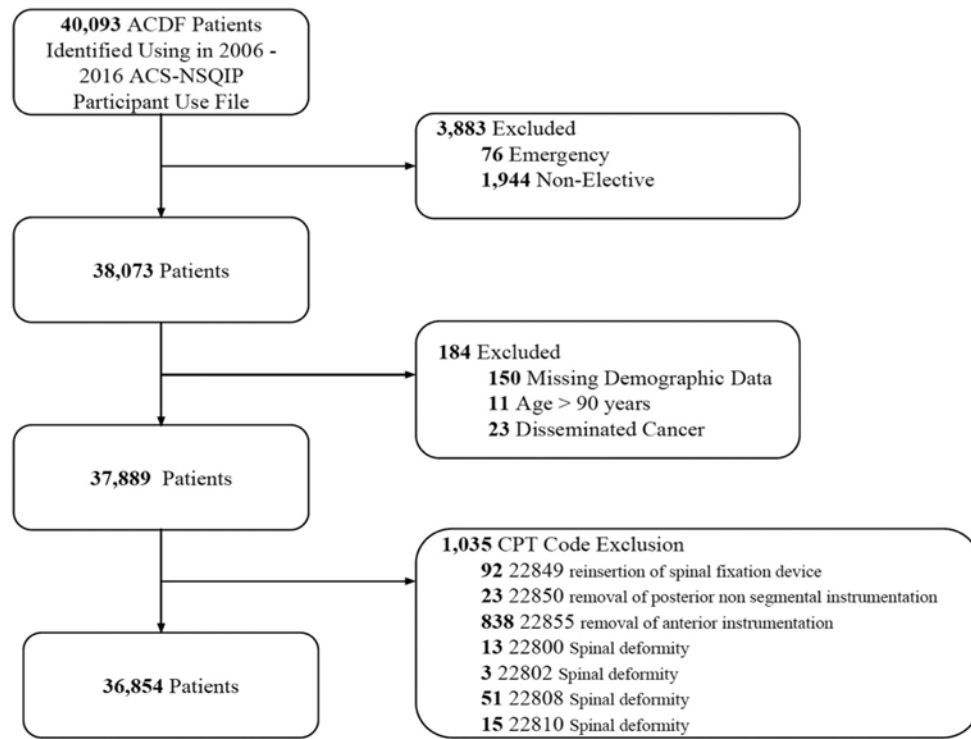


Figure 1. Attrition figure for included patients undergoing ACDF surgery from the 2006 to 2016 ACS-NSQIP database. ACDF, anterior cervical discectomy and fusion; ACS-NSQIP, American College of Surgeons National Surgical Quality Improvement Program database; CPT, Current Procedural Terminology.

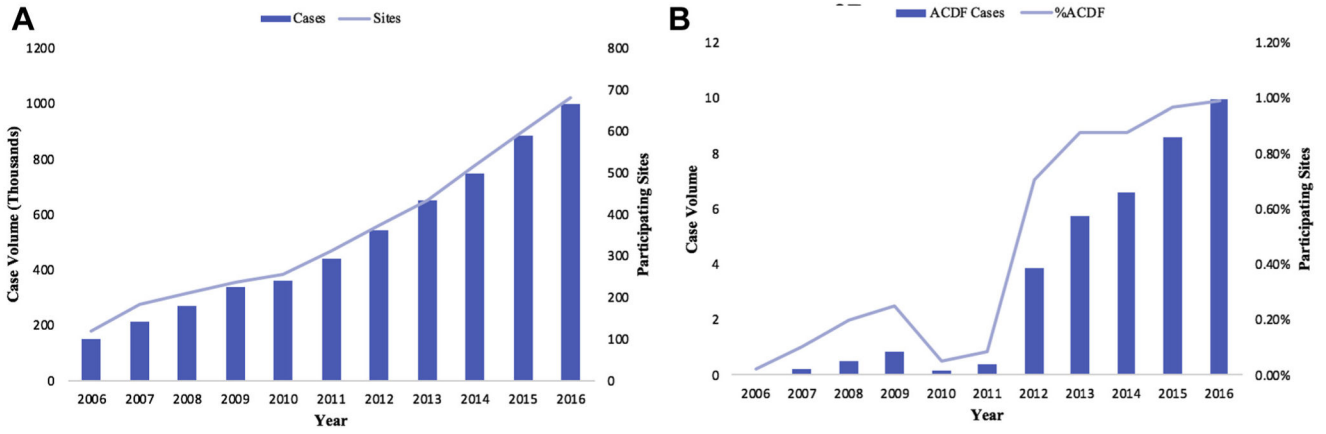


Figure 2. Trends in ACDF procedure volume over time by participating sites from the NSQIP database from 2006 to 2016. **(A)** Sites indicate number of participating health care sites in the ACS-NSQIP database. **(B)** %ACDF indicates percentage of procedures coded as ACDF procedures compared with all procedures in the ACS-NSQIP. ACDF, anterior cervical discectomy and fusion; NSQIP, National Surgical Quality Improvement Program database; ACS, American College of Surgeons.

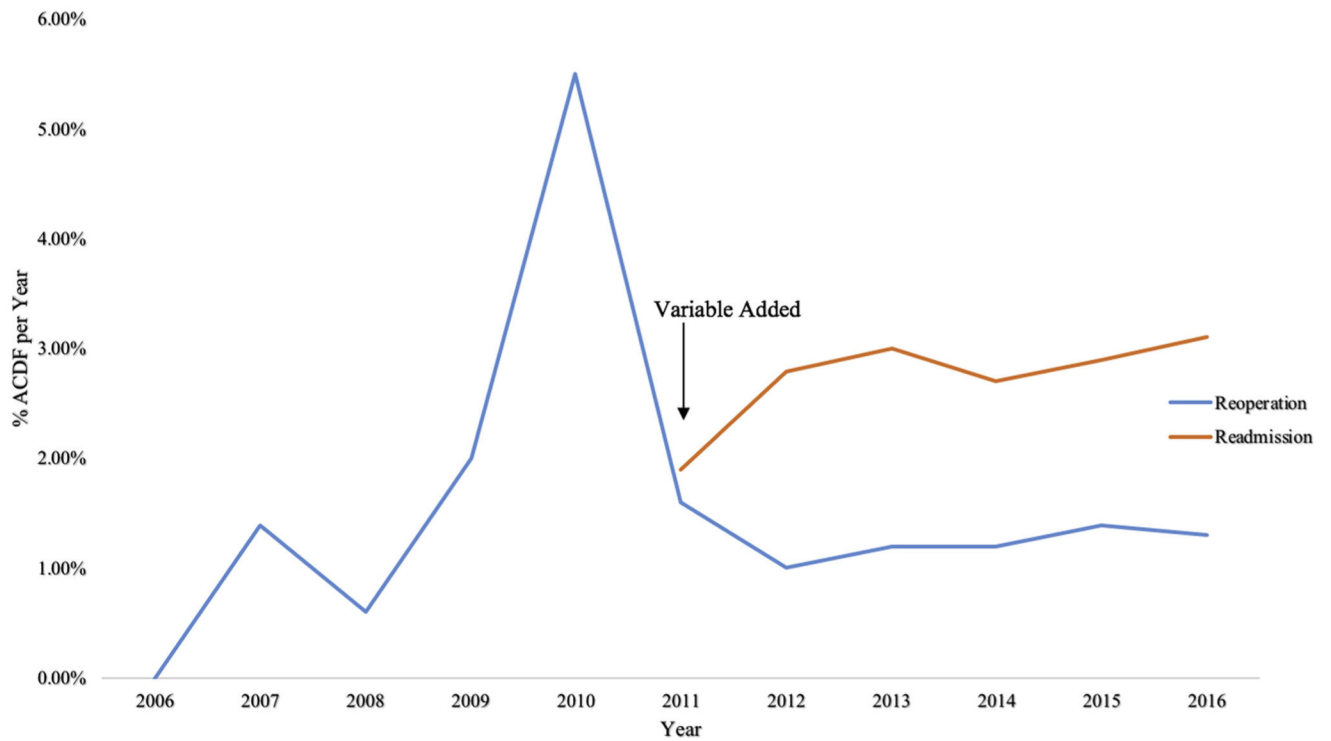


Figure 3.

Time trends in reoperation and readmission following ACDF procedure over time from 2006 to 2016. %ACDF per year indicates the percentage of all NSQIP ACDF operations per year. ACDF, anterior cervical discectomy and fusion; NSQIP, National Surgical Quality Improvement Program database.

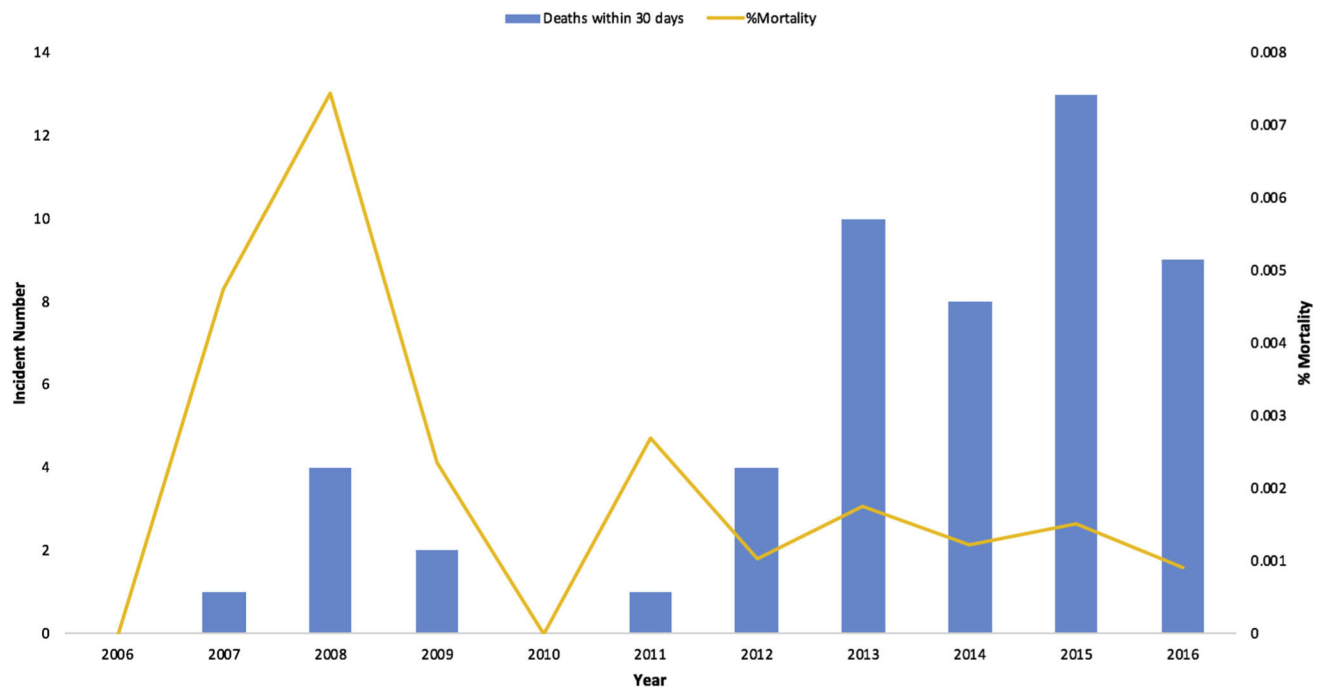


Figure 4. Percent mortality and death within 30 days following ACDF over time. %Mortality indicates the percentage of mortality as reported in NSQIP in individuals undergoing ACDF. ACDF, anterior cervical discectomy and fusion; NSQIP, National Surgical Quality Improvement Program database.

Table 1. Patient Characteristics and Intraoperative Variables in Patients Undergoing ACDF from ACS-NSQIP 2006 to 2016

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	P Value
Total ACDF	31	211	538	848	183	373	3853	5725	6577	8578	9937	
Demographics												
Age	48.2 [1.5]	51.4 [0.8]	52.5 [0.5]	52.1 [0.4]	52.1 [0.9]	52.7 [0.6]	53.3 [0.2]	53.6 [0.2]	53.3 [0.1]	53.7 [0.1]	54.1 [0.1]	<0.001
BMI	29.4 [1.3]	29.6 [0.4]	29.8 [0.3]	30.0 [0.2]	30.3 [0.5]	30.1 [0.4]	30.3 [0.1]	30.1 [0.1]	30.3 [0.1]	30.4 [0.1]	30.5 [0.1]	0.003
Male	14 (45.2%)	88 (41.7%)	250 (46.5%)	417 (49.2%)	90 (49.2%)	195 (57.4%)	1850 (48.4%)	2717 (47.7%)	3289 (50.3%)	4251 (49.9%)	2768 (50.4%)	0.001
Race												<0.001
White	NA	0	395 (73.4%)	679 (80.1%)	135 (73.8%)	268 (10.5%)	3195 (82.9%)	4604 (82.2%)	5338 (81.2%)	6887 (80.3%)	7947 (80.0%)	
Black	NA	1 (0.5%)	54 (10.0%)	67 (7.9%)	28 (15.3%)	56 (15.0%)	357 (9.3%)	493 (8.6%)	615 (9.4%)	878 (10.2%)	991 (10.0%)	
Asian	NA	0	7 (1.3%)	5 (0.6%)	2 (1.1%)	9 (2.4%)	61 (1.6%)	117 (2.0%)	128 (1.9%)	172 (2.0%)	174 (1.8%)	
American Indian/ Alaska Native	NA	0	16 (3.0%)	21 (2.5%)	0	0	7 (0.2%)	35 (0.6%)	64 (1.0%)	82 (1.0%)	59 (0.6%)	
Native Hawaiian/ Pacific Islander	NA	0	0	0	0	1 (0.3%)	13 (0.3%)	18 (0.3%)	35 (0.5%)	29 (0.3%)	38 (0.4%)	
Ethnicity												<0.001
Hispanic	NA	0	32 (5.9%)	35 (4.1%)	9 (4.9%)	21 (5.6%)	170 (4.4%)	239 (4.2%)	316 (4.8%)	417 (4.9%)	465 (4.7%)	
Non-Hispanic	NA	1 (0.5%)	506 (94.1%)	813 (95.9%)	166 (90.7%)	325 (87.1%)	3507 (91.0%)	5183 (90.5%)	5758 (87.5%)	7542 (87.9%)	8583 (86.4%)	
Comorbidities												
Diabetes (with insulin)	1 (3.2%)	8 (3.8%)	15 (2.8%)	35 (4.1%)	14 (7.7%)	27 (7.2%)	161 (4.2%)	269 (4.7%)	354 (5.4%)	439 (5.1%)	539 (5.7%)	<0.001
Current smoker (within 1 year)	18 (58.1%)	82 (38.9%)	183 (34.0%)	280 (33.0%)	53 (29.0%)	114 (30.6%)	1157 (30.0%)	1692 (29.6%)	1831 (27.8%)	2261 (26.4%)	2633 (26.5%)	<0.001
Dyspnea												<0.001
Dyspnea with moderate exertion	8 (25.8%)	11 (5.2%)	33 (6.1%)	38 (4.5%)	17 (9.3%)	15 (4.0%)	235 (6.1%)	302 (5.3%)	289 (4.4%)	379 (4.4%)	421 (4.2%)	
Dyspnea at rest	0	0	3 (0.6%)	1 (0.1%)	0	20 (0.5%)	20 (0.5%)	9 (0.2%)	10 (0.2%)	14 (0.2%)	34 (0.3%)	
Functional status												0.054
Partially dependent	0	10 (4.7%)	10 (1.9%)	21 (2.5%)	5 (2.7%)	10 (2.7%)	58 (1.5%)	63 (1.1%)	72 (1.1%)	93 (1.1%)	129 (1.3%)	

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	P Value
Totally dependent	0	2 (0.9%)	2 (0.4%)	1 (0.1%)	1 (0.5%)	0 (0.0%)	8 (0.2%)	2 (0.0%)	6 (0.1%)	6 (0.1%)	9 (0.1%)	0.052
COPD	2 (6.5%)	4 (1.9%)	16 (3.0%)	24 (2.8%)	6 (3.3%)	10 (2.9%)	129 (3.4%)	253 (4.4%)	282 (4.3%)	337 (3.9%)	410 (4.1%)	0.332
Hypertension requiring medication	12 (38.7%)	84 (39.8%)	226 (42.0%)	358 (42.2%)	78 (42.6%)	157 (42.10%)	1648 (42.8%)	2453 (42.8%)	2847 (43.3%)	3784 (44.1%)	4439 (44.7%)	0.005
On dialysis	0	0	0	0	1 (0.5%)	3 (0.8%)	16 (0.4%)	8 (0.1%)	13 (0.2%)	10 (0.1%)	20 (0.2%)	0.055
Open wound or wound infection	0	0	1 (0.2%)	1 (0.1%)	3 (1.6%)	1 (0.3%)	17 (0.4%)	11 (0.2%)	9 (0.1%)	21 (0.2%)	18 (0.2%)	0.818
Steroid use	1 (3.2%)	9 (4.3%)	11 (2.0%)	26 (3.1%)	4 (2.2%)	20 (5.4%)	119 (3.1%)	166 (2.9%)	183 (2.8%)	274 (3.2%)	274 (3.2%)	0.614
>10% weight loss in <6 months	0	2 (0.9%)	1 (0.2%)	7 (0.8%)	1 (0.5%)	1 (0.3%)	4 (0.1%)	10 (0.2%)	10 (0.2%)	10 (0.1%)	12 (0.1%)	0.766
Bleeding disorders	0	3 (1.4%)	4 (0.7%)	10 (1.2%)	0	5 (1.3%)	29 (0.8%)	51 (0.9%)	64 (1.0%)	84 (1.0%)	111 (1.1%)	0.943
Sepsis	0	0	0	1 (0.1%)	0	0	0	0	0	0	0	<0.001
SIRS	1 (3.2%)	1 (0.5%)	4 (0.7%)	3 (0.4%)	1 (0.5%)	2 (0.5%)	6 (0.2%)	8 (0.1%)	11 (0.2%)	15 (0.2%)	20 (0.2%)	0.943
Sepsis	0	0	0	1 (0.1%)	0	0	0	0	0	0	0	<0.001
Preoperative transfusion RBC	0	0	0	0	1 (0.0%)	0 (0.0%)	1 (0.0%)	0 (0.0%)	1 (0.0%)	2 (0.0%)	0 (0.0%)	<0.001
Inpatient vs. outpatient	0	0	0	0	0	0	0	0	0	0	0	<0.001
Inpatient	22 (71.0%)	175 (82.9%)	460 (85.5%)	719 (84.8%)	154 (84.2%)	323 (86.6%)	2974 (77.2%)	4347 (75.9%)	4916 (74.7%)	6187 (72.1%)	7012 (70.6%)	<0.001
Outpatient	9 (29.0%)	36 (17.1%)	78 (14.5%)	129 (15.2%)	29 (15.8%)	50 (13.4%)	879 (22.8%)	1378 (24.1%)	1661 (25.3%)	2391 (27.9%)	2925 (29.4%)	<0.001
Radiculopathy	0	0	0	0	0	0	0	0	5	837	3543	<0.001
Myelopathy	5 (16.1%)	75 (35.5%)	172 (32.0%)	274 (32.3%)	174 (95.1%)	350 (93.8%)	1111 (28.8%)	1754 (30.6%)	2055 (31.2%)	2454 (28.6%)	2184 (22.0%)	<0.001
ASA class												<0.001
I: no disturbance	0	20 (9.5%)	24 (4.5%)	46 (5.4%)	13 (7.1%)	15 (4.0%)	177 (4.6%)	241 (4.2%)	294 (4.5%)	368 (4.3%)	402 (4.0%)	<0.001
II: mild disturbance	21 (67.7%)	123 (58.3%)	327 (60.8%)	498 (58.7%)	93 (50.8%)	214 (57.4%)	2240 (58.1%)	3339 (58.3%)	3760 (57.2%)	4846 (56.5%)	5308 (53.4%)	<0.001
III: severe disturbance	10 (32.3%)	59 (28.0%)	175 (32.5%)	292 (34.4%)	75 (41.0%)	139 (37.3%)	1366 (35.5%)	2058 (35.9%)	2427 (36.9%)	3231 (37.7%)	4060 (40.9%)	<0.001
IV: life threatening	0	8 (3.8%)	11 (2.0%)	11 (1.3%)	2 (1.1%)	5 (1.3%)	63 (1.6%)	75 (1.3%)	90 (1.4%)	125 (1.5%)	154 (1.5%)	<0.001
Operation time	143.3 [11.4]	150.8 [4.7]	137.5 [3.0]	130.5 [2.2]	133.2 [4.4]	130.8 [3.4]	124.3 [1.1]	122.1 [0.9]	124.3 [0.8]	124.0 [0.7]	124.5 [0.7]	0.003

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	P Value
Hospital variables												
Total hospital length of stay	1.7 [0.3]	2.1 [0.3]	1.9 [0.1]	2.0 [0.1]	1.9 [0.6]	6.1 [2.0]	1.6 [0.1]	1.4 [0.0]	1.6 [0.0]	1.5 [0.0]	1.5 [0.0]	<0.001
Days from operation to discharge	1.6 [0.2]	1.9 [0.2]	1.7 [0.1]	1.8 [0.1]	1.5 [0.6]	2.1 [0.2]	1.6 [0.1]	1.5 [0.0]	1.5 [0.0]	1.5 [0.0]	1.5 [0.0]	<0.001

Data are displayed as n (%) or mean [standard deviation].

ACDF, anterior cervical discectomy and fusion; ACS-NSQIP, American College of Surgeons National Surgical Quality Improvement Program database; BMI, body mass index; NA, not available; COPD, chronic obstructive pulmonary disease; SIRS, systemic inflammatory response syndrome; RBC, red blood cell; ASA, American Society of Anesthesiologists.

Table 2.

Outcomes Following ACDF Procedures from ACS-NSQIP 2006–2016

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	P Value
Unplanned reoperation	0	3 (1.4%)	3 (0.6%)	17 (2.0%)	10 (5.5%)	6 (1.6%)	38 (1.0%)	69 (1.2%)	80 (1.2%)	123 (1.4%)	134 (1.3%)	<0.001
Readmission	NA	NA	NA	NA	NA	0	107 (2.8%)	169 (3.0%)	180 (2.7%)	252 (2.9%)	309 (3.1%)	<0.001
Superficial SSI	0	2 (0.9%)	1 (0.2%)	4 (0.5%)	1 (0.5%)	0	12 (0.3%)	14 (0.2%)	21 (0.3%)	20 (0.2%)	33 (0.3%)	0.623
Deep incisional SSI	0	1 (0.5%)	0	2 (0.2%)	1 (0.5%)	0	4 (0.1%)	8 (0.1%)	9 (0.1%)	12 (0.1%)	14 (0.1%)	0.802
Organ space SSI	0	0	0	0	0	0	0	4 (0.1%)	8 (0.1%)	4 (0.0%)	10 (0.1%)	0.564
Wound disruption	0	0	0	0	0	0	1 (0.0%)	5 (0.1%)	5 (0.1%)	4 (0.0%)	3 (0.0%)	0.896
Pneumonia	0	1 (0.5%)	5 (0.9%)	6 (0.7%)	2 (1.1%)	3 (0.8%)	21 (0.5%)	31 (0.5%)	30 (0.5%)	37 (0.4%)	61 (0.6%)	0.679
Unplanned intubation	0	3 (1.4%)	2 (0.4%)	3 (0.4%)	2 (1.1%)	5 (1.3%)	20 (0.5%)	24 (0.4%)	26 (0.4%)	26 (0.3%)	41 (0.4%)	0.041
Pulmonary embolism	0	0	1 (0.2%)	2 (0.2%)	0	1 (0.3%)	8 (0.2%)	8 (0.1%)	12 (0.2%)	12 (0.1%)	17 (0.2%)	0.993
Deep vein thrombosis requiring therapy	0	0	4 (0.7%)	2 (0.2%)	1 (0.5%)	0	6 (0.2%)	13 (0.2%)	7 (0.1%)	17 (0.2%)	24 (0.2%)	0.146
On ventilator >48 hours	0	1 (0.5%)	4 (0.7%)	4 (0.5%)	1 (0.5%)	4 (1.1%)	9 (0.2%)	15 (0.3%)	14 (0.2%)	22 (0.3%)	23 (0.2%)	0.062
Renal failure	0	1 (0.5%)	0	0	0	0	0	0	4 (0.1%)	6 (0.1%)	1 (0.0%)	0.010
UTI	0	1 (0.5%)	2 (0.4%)	5 (0.6%)	2 (1.1%)	3 (0.8%)	14 (0.4%)	19 (0.3%)	26 (0.4%)	41 (0.5%)	43 (0.4%)	0.800
Stroke/cerebral vascular incident	0	0	1 (0.2%)	2 (0.2%)	0	0	6 (0.2%)	3 (0.1%)	6 (0.1%)	10 (0.1%)	5 (0.1%)	0.582
Cardiac arrest	0	0	1 (0.2%)	1 (0.1%)	0	2 (0.5%)	5 (0.1%)	7 (0.1%)	9 (0.1%)	5 (0.1%)	8 (0.1%)	0.360
Myocardial infarction	0	0	0	1 (0.1%)	0	0	6 (0.2%)	7 (0.1%)	3 (0.0%)	11 (0.1%)	14 (0.1%)	0.845
Transfusion	0	0	0	0	0	4 (1.1%)	17 (0.4%)	29 (0.5%)	12 (0.2%)	14 (0.2%)	14 (0.1%)	<0.001
Sepsis	0	1 (0.5%)	1 (0.2%)	1 (0.1%)	1 (0.5%)	0	7 (0.2%)	9 (0.2%)	15 (0.2%)	10 (0.1%)	17 (0.2%)	0.780
Septic shock	0	0	1 (0.2%)	0	0	1 (0.3%)	0	6 (0.1%)	6 (0.1%)	4 (0.0%)	5 (0.1%)	0.428
Still in hospital >30 days	NA	NA	NA	NA	NA	0	1 (0.0%)	2 (0.0%)	1 (0.0%)	5 (0.1%)	5 (0.1%)	<0.001
Death	0	1 (0.0%)	4 (0.0%)	2 (0.0%)	0	1 (0.0%)	4 (0.0%)	10 (0.0%)	8 (0.0%)	13 (0.0%)	9 (0.0%)	0.017

Renal failure is defined as progressive renal insufficiency/acute renal failure requiring dialysis. Cardiac arrest is defined as intraoperative or postoperative cardiac arrest requiring cardiopulmonary resuscitation. Myocardial infarction is defined as intraoperative or postoperative myocardial infarction. Transfusion is defined as red blood cell transfusion within 72 hours surgery start time.

ACDF, anterior cervical discectomy and fusion; ACS-NSQIP, American College of Surgeons National Surgical Quality Improvement Program database; NA, not available; SSI, surgical-site infection; UTI, urinary tract infection.