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# Anesthesia Duration as an Independent Risk Factor for Early Postoperative Complications in Adults Undergoing Elective ACDF

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## Abstract

**Study Design:** Retrospective study.

**Objective:** To determine the presence of any potential associations between anesthesia time with postoperative outcome and complications following elective anterior cervical discectomy and fusion (ACDF).

**Methods:** Patients who underwent elective ACDF were identified in the American College of Surgeons National Quality Improvement Program database. Patient demographics, medical comorbidities, and perioperative and postoperative complications up to 30 days were analyzed by univariate and multivariate analysis.

**Results:** A total of 3801 patients undergoing elective ACDF were identified. Patients were subdivided into quintiles of anesthesia time: Group 1, 48 to 129 minutes (n = 761, 20%); Group 2, 129 to 156 minutes (n = 760, 20%); Group 3, 156 to 190 minutes (n = 760, 20%); Group 4, 190 to 245 minutes (n = 760, 20%); and Group 5, 245 to 1025 minutes (n = 760, 20%). Univariate analysis showed significantly higher rates of any complication ($P < .0001$), pulmonary complication ($P < .0001$), intra-/postoperative blood transfusions ($P < .0001$), sepsis ($P = .017$), wound complications ($P = .002$), total length of stay >5 days ($P < .0001$), and return to operating room ($P = .006$) in the highest quintile compared to those of other groups. Multivariate regression analysis revealed that prolonged anesthesia was an independent factor for increased odds of overall complications (odds ratio [OR] = 2.71, $P = .012$), venous thromboembolism (OR = 2.69, $P = .011$), and return to the operating room (OR = 2.92, $P = .004$). The 2 groups with the longest anesthesia durations (quintiles 4 and 5) had increased total length of stay more than 5 days (for quintile 4, OR = 3.10, $P = .0004$; for quintile 5, OR = 3.61, $P < .0001$).

**Conclusion:** Prolonged anesthesia duration is associated with increased odds of complication, venous thromboembolism, increased length of stay, and return to the operating room.

## Keywords

ACDF, NSQIP, complications, outcomes, anesthesia, duration

## Introduction

Anterior cervical discectomy and fusion (ACDF) is a commonly performed procedure with excellent and reliable outcomes, fast recovery, and reasonable morbidity rates compared with posterior approaches.[1-3] The number of ACDF procedures performed in the United States has increased almost 8-fold from 1990 to 2004,[4] accounting for the majority of outpatient cervical spine surgeries (68%) compared with posterior

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decompression (21%).[1] In the burgeoning era of rising health care costs and greater scrutiny over surgical outcomes, there has been increasing emphasis on understanding the risk factors and possible predictors to optimize perioperative planning and management.

Across various surgical disciplines, many studies have demonstrated consistently that operative duration is a component of surgical risk.[5-8] Longer operative times have been shown to correlate with postoperative surgical and medical morbidity and mortality as well as hospital stay. In recent national database investigation, Kim et al[6] performed a retrospective cohort analysis of 1 432 855 patients and showed that patients undergoing the longest procedures experienced a 1.27-fold increase in the odds of developing venous thromboembolism (VTE). However, anesthesia time is one parameter that has not been well studied or incorporated into current risk stratification models.

Several studies have hypothesized and reported associations between prolonged anesthesia time with complications including postoperative nausea and vomiting,[9] thromboembolism,[6,10,11] postoperative infection,[12,13] core hypothermia,[14] cardiopulmonary complications,[15,16] and mortality.[17,18] However, few studies have specifically assessed possible associations between anesthesia duration with postoperative complications in the orthopedic or spinal surgery. Given the ageing population and high prevalence of cervical spine degeneration, ACDF is likely to remain as a mainstay surgical treatment for such patients. As such, understanding the relationship between anesthesia duration and postoperative complications following ACDF may be valuable for optimizing perioperative planning, surgical technique, and cost containment.

We sought to address this limitation in the evidence by analyzing data form the American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP), with the goal of elucidating any potential associations between anesthesia time with postoperative outcome and complications following elective ACDF.

## Materials and Methods

### Data Source

The ACS-NSQIP database, a prospectively maintained registry with more than 700 participating academic and private centers, was the data source utilized for the present study. With data cumulative of more than 200 variables relating to patient demographics, clinical characteristics, complications, and short-term (30 days) longitudinal follow-up for various surgical procedures, the ACS-NSQIP permits monitoring and quantification of clinical outcomes, and defining quality metrics across all surgical specialties. The average interrater reliability disagreement rate for participating sites from all audits till date is estimated at 2%. Further information on ACS-NSQIP can be accessed at http://www.acsnsqip.org.

### Patient Selection and Data Collection

Data from the ACS-NSQIP database covering years 2005 to 2012 was used in the present analysis. Current Procedural Terminology (CPT) codes were used to identify elective ACDF procedures (CPT: 22551, 22554, 63075 [CPT code for ACDF prior to 2011]). Only patients aged $\geq$18 years were included in the analysis. Exclusion criteria included patients who underwent spinal deformity surgery, underweight (body mass index [BMI] < 18.5 kg/m$^2$), dependent on ventilator, disseminated cancer, radiotherapy for malignancy, pregnancy, tumors of the central nervous system, chemotherapy, emergency operations, preoperative sepsis, acute renal failure, nonelective cases (variable available only for 2011-2012), combined approaches, posterior approach (CPT: 22600), and patients with missing data (missing preoperative or anesthesia time).

### Explanatory and Control Variables

Recorded patient characteristics included baseline demographics, comorbidities, operative variables, intraoperative complications, and postoperative complications. Patient demographics included age, gender, race (white, black, Hispanic, other), BMI, American Society of Anesthesiologists (ASA) class, inpatient or outpatient status, diabetes, smoker, alcohol use >2 drinks/day in 2 weeks before admission, dyspnea (at rest, on moderate exertion, or none), and functional dependence prior to surgery (independent, partially dependent, or totally dependent). Comorbidities and operative variables included pulmonary comorbidities, cardiac morbidities, peripheral vascular disease, dialysis, impaired sensorium, neuromuscular injury, strokes, corticosteroid use, recent weight loss, bleeding disorders, and level of fusion (single vs multilevel). ACDF patients reported in the database showed undergoing general anesthesia rather than local or other types of anesthesia. The total anesthesia time was recorded from the time when the anesthesia started to the time when anesthesia administration ended. Patients were subdivided equally into quintile cohorts based on general anesthesia time: Group 1 (n = 761, 48-129 minutes); Group 2 (n = 760, 129-156 minutes); Group 3 (n = 760, 156-190 minutes); Group 4 (n = 760, 190-245 minutes); and Group 5 (n = 760, 245-1025 minutes). This method of dividing patients has previously been described in other ACS-NSQIP studies evaluating anesthesia duration and postoperative complications.

A cardiac comorbidity was defined as a history of congestive heart failure (within 30 days before admission), myocardial infarction (within 6 months before admission), percutaneous coronary intervention, cardiac surgery, angina (within 1 month before admission), or use of hypertensive medication. A pulmonary comorbidity was defined as history of severe chronic obstructive pulmonary disease, or current pneumonia. Peripheral vascular disease was defined as a history of revascularization or amputation for peripheral vascular conditions, and rest pain. Smoking history (current smoker within 1 year) and chronic steroid use (regular use within 30 days before admission) were also assessed.

**Table 1.** Comparison of Mean Operative Time and Mean Anesthesia Time by Anesthesia Cohort.

| | | Total Anesthesia Time (Minutes) | | Total Operative Time (Minutes) | |
|---|---|---|---|---|---|
| Anesthesia Cohort | N | Mean | SD | Mean | SD |
| 1 (48-129 minutes) | 761 | 108.07 | 14.95 | 64.45 | 14.65 |
| 2 (129-156 minutes) | 760 | 142.67 | 8.15 | 91.24 | 28.29 |
| 3 (156-190 minutes) | 760 | 172.26 | 9.53 | 112.54 | 18.15 |
| 4 (290-245 minutes) | 760 | 214.87 | 15.89 | 144.72 | 24.16 |
| 5 (245-1025 minutes) | 760 | 324.55 | 88.31 | 230.01 | 77.16 |
| All | | 192.5 | 85.31 | 128.6 | 69.55 |

### *Outcomes*

The primary study outcome was any 30-day postoperative complication following elective ACDF in adults. Complication parameters assessed included any complication, death, pulmonary complications (pneumonia, intubation, ventilator requirement), renal complications (acute renal failure, progressive renal insufficiency), central nervous system complications (strokes and coma), peripheral vascular disease, cardiac complications (myocardial infarction, cardiac arrest), intraoperative/postoperative blood transfusions, VTE, urinary tract infections, sepsis/septic shock, wound complications (superficial and deep surgical site infections, wound dehiscence, organ space surgical site infections). Operative outcomes included graft/flap failure, intraoperative/postoperative blood transfusions, return to operating room (for any surgical procedure), unplanned reoperations (related to initial procedure, data only from 2011-2012), and unplanned readmissions (related to initial procedure, data only from 2011-2012). Univariate and multivariate analysis was used to determine whether anesthetic duration was associated with 30-day postoperative complications.

### *Statistical Analysis*

Descriptive and comparative statistics of demographics, comorbidities, operative details, and postoperative complications were analyzed for all patients. In the univariate analysis, categorical variables were assessed using Pearson's $\chi^2$ or Fisher's exact test where appropriate. Continuous variables were examined using 1-way ANOVA test. Variables with a $P < .2$ in the univariate analysis were carried forward into the multivariate analysis. This specific selection criterion was used to consider as many potential risk factors as possible without compromising the validity of regression models. Multivariate logistic regression analysis was used to determine independent risk factors for 30-day complication rates following elective ACDF. A $P$ value <.05 was considered significant. The overall model was assessed using the $C$ statistic, which is the area under the receiver operating characteristic curve. SAS software (Version 9.3, SAS Institute Inc, Cary, NC) was used for all statistical analyses.

## Results

From the ACS-NSQIP database, 3801 adults undergoing elective ACDF were identified. Patients were subdivided into quintiles of anesthesia time: Group 1, 48 to 129 minutes ($n = 761$, $\mu = 108.07$, $SD = 14.95$); Group 2, 129 to 156 minutes ($n = 760$, $\mu = 142.67$, $SD = 8.15$); Group 3, 156 to 190 minutes ($n = 760$, $\mu = 172.26$, $SD = 9.53$); Group 4, 190 to 245 minutes ($n = 760$, $\mu = 214.87$, $SD = 15.89$); and Group 5, 245 to 1025 minutes ($n = 760$, $\mu = 324.55$, $SD = 88.31$; Table 1). In terms of baseline characteristics, there were significant differences in terms of the distribution of females ($P < .0001$), racial distribution ($P < .0001$), age ($P < .0001$), ASA class $\geq 3$ ($P < .0001$), inpatient versus outpatient ($P < .0001$), diabetes ($P = .008$), alcohol use ($P = .011$), and functional status prior to surgery ($P = .0003$; Table 2). Patients in the highest quintile of anesthesia time were generally more likely to be male, older, ASA class $\geq 3$, be an inpatient, have diabetes, drink alcohol, and be functionally dependent, in comparison to patients with anesthesia time in the lowest quintile. No significant differences between the quintiles were found in terms of obesity class, smoking, or dyspnea.

In terms of comorbidities, the highest quintile for anesthesia time was associated with the greatest proportion of cardiac comorbidities (50.13%), neuromuscular injury (5.26%), recent weight loss (1.05%), and multilevel fusions (20%) in comparison to Group 1 (lowest quintile). No significant differences between the 5 subgroups were found in terms of peripheral vascular disease, dialysis, impaired sensorium, stroke, steroid use, or bleeding disorders. It was significant to note that greater than 84% of all cases were a single-level ACDF versus 16% of cases that were multilevel fusion (>2 vertebral bodies fusion), which was also present in each of the anesthesia time groups (Table 3).

Univariate analysis of complications and outcomes following ACDF according to anesthesia group is summarized in Table 4. Significantly higher rates of any complication ($P < .0001$), pulmonary complication ($P < .0001$), intra-/postoperative blood transfusions ($P < .0001$), sepsis ($P = .017$), wound complications ($P = .002$), total length of stay (LOS) >5 days ($P < .0001$), and return to operating room ($P = .006$) was found in the highest quintile compared to the other groups. No significant differences were found in terms of deaths, renal and central nervous system complications, peripheral vascular disease, cardiac complications, VTE, urinary tract infections, graft failure, unplanned reoperations, or readmissions.

**Table 2.** Demographics and Clinical Characteristics of Adults Undergoing ACDF by Anesthesia Cohort.

| | Anesthesia Time | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Group 1, n (%) | Group 2, n (%) | Group 3, n (%) | Group 4, n (%) | Group 5, n (%) | *P* Value |
| Features (%) | 3801 (100) | 761 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | |
| Gender | | | | | | | |
| Female | 49.91% | 58.08% | 53.55% | 49.61% | 47.63% | 40.66% | <.0001 |
| Male | 50.09% | 41.92% | 46.45% | 50.39% | 52.37% | 59.34% | |
| Race | | | | | | | |
| White | 73.48% | 78.45% | 72.76% | 73.29% | 72.24% | 70.66% | <.0001 |
| Black | 10.02% | 5.65% | 9.34% | 9.61% | 10.79% | 14.74% | |
| Hispanic | 5.34% | 2.50% | 5.66% | 7.24% | 6.84% | 4.47% | |
| Other | 11.15% | 13.40% | 12.24% | 9.87% | 10.13% | 10.13% | |
| Age group (years) | | | | | | | |
| <50 | 44.65% | 47.44% | 48.55% | 47.11% | 42.76% | 37.37% | <.0001 |
| 51-60 | 30.99% | 28.65% | 29.08% | 31.45% | 32.50% | 33.29% | |
| 61-70 | 17.00% | 15.77% | 14.61% | 14.87% | 17.24% | 22.50% | |
| 71-80 | 6.10% | 6.70% | 6.45% | 5.00% | 6.45% | 5.92% | |
| >80 | 1.26% | 1.45% | 1.32% | 1.58% | 1.05% | 0.92% | |
| Obese class | | | | | | | |
| Nonobese (<29.9 kg/m$^2$) | 54.91% | 57.29% | 53.29% | 55.13% | 55.00% | 53.82% | .438 |
| Obese I (30-34.9 kg/m$^2$) | 26.26% | 25.36% | 27.63% | 26.05% | 25.00% | 27.24% | |
| Obese II (35-39.9 kg/m$^2$) | 11.34% | 10.78% | 13.16% | 10.26% | 11.32% | 11.18% | |
| Obese III ($\geq$40 kg/m$^2$) | 7.50% | 6.57% | 5.92% | 8.55% | 8.68% | 7.76% | |
| ASA classification | | | | | | | |
| 1 to 2 | 62.98% | 70.30% | 68.68% | 62.89% | 59.47% | 53.55% | <.0001 |
| 3 to 4 | 37.02% | 29.70% | 31.32% | 37.11% | 40.53% | 46.45% | |
| Surgical setting | | | | | | | |
| Inpatient | 80.27% | 70.57% | 76.45% | 79.21% | 85.26% | 89.87% | <.0001 |
| Outpatient | 19.73% | 29.43% | 23.55% | 20.79% | 14.74% | 10.13% | |
| Diabetes | 14.60% | 13.27% | 13.42% | 12.11% | 16.45% | 17.76% | .008 |
| Smoke | 33.62% | 33.38% | 34.08% | 36.84% | 30.79% | 33.03% | .166 |
| Alcohol | 3.21% | 1.97% | 2.11% | 3.29% | 4.47% | 4.21% | .011 |
| Dyspnea | | | | | | | |
| At rest | 0.39% | 0.53% | 0.26% | 0.39% | 0.39% | 0.39% | .996 |
| Moderate exertion | 6.45% | 6.44% | 6.05% | 6.18% | 6.84% | 6.71% | |
| No dyspnea | 93.16% | 93.04% | 93.68% | 93.42% | 92.76% | 92.89% | |
| Functional status prior to surgery | | | | | | | |
| Independent | 97.34% | 99.08% | 97.11% | 98.42% | 96.45% | 95.66% | .0003 |
| Partially dependent | 2.34% | 0.39% | 2.63% | 1.45% | 3.29% | 3.95% | |
| Totally dependent | 0.32% | 0.53% | 0.26% | 0.13% | 0.26% | 0.39% | |

Abbreviations: ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists.

Multivariate analysis was conducted to determine independent associations with postoperative outcomes and complications (Table 5). In comparison to the lowest quintile group, patients in the highest group of anesthesia duration (>245 minutes) had statistically significant increased risk of overall complications (odds ratio [OR] = 2.71, 95% confidence interval [CI] = 1.33-5.53, $P = .012$), VTE (OR = 2.69, 95% CI = 0.71-10.2, $P = .011$), and return to the operating room (OR = 2.92, 95% CI = 1.24-6.88, $P = .004$). The 2 groups with the longest anesthesia durations (quintiles 4 and 5) had increased total LOS more than 5 days (for quintile 4, OR = 3.10, 95% CI = 1.70-5.64, $P = .0004$; for quintile 5, OR = 3.61, 95% CI = 1.93-6.73, $P < .0001$). There was no statistically significant effect of increased anesthesia time on blood transfusions or wound complications.

## Discussion

Over the past years, advances in surgical techniques and anesthesia care have translated to safe and effective outcomes for patients.[19,20] Given the continual need to improve current techniques, as well as the increasing economic burden of health care, there has been an increasing emphasis in identifying risk factors for perioperative complications to help optimize preoperative planning, risk stratification, and cost containment.

Traditionally, operative duration has been associated with postoperative morbidity and mortality for a variety of general surgical, vascular, orthopedic, and other procedures.[7,21-24] In the setting of spine surgery, Kim et al[25] analyzed 4588 patients from the ACS-NSQIP database who underwent single-level lumbar fusion and showed that increased operative time was associated with stepwise increase in risk of overall

**Table 3.** Comorbidities of Adults Undergoing ACDF by Anesthesia Group.

| | Anesthesia Time | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Group 1, n (%) | Group 2, n (%) | Group 3, n (%) | Group 4, n (%) | Group 5, n (%) | *P* Value |
| Comorbidities | 3801 (100) | 761 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | |
| Pulmonary comorbidity | 3.47% | 3.02% | 3.03% | 3.29% | 3.68% | 4.34% | .591 |
| Cardiac comorbidity | 44.59% | 40.47% | 42.76% | 43.16% | 46.45% | 50.13% | .002 |
| Peripheral vascular disease | 0.84% | 0.26% | 1.05% | 1.05% | 1.32% | 0.53% | .146 |
| Dialysis | 0.29% | 0.13% | 0.26% | 0.26% | 0.26% | 0.53% | .701 |
| Impaired sensorium | 0.13% | 0.00% | 0.13% | 0.13% | 0.13% | 0.26% | .735 |
| Neuromuscular injury | 4.58% | 1.71% | 4.47% | 4.21% | 7.24% | 5.26% | <.0001 |
| Stroke | 2.16% | 1.71% | 2.11% | 1.97% | 2.37% | 2.63% | .767 |
| Steroid use | 2.87% | 2.63% | 2.63% | 3.55% | 1.84% | 3.68% | .179 |
| Recent weight loss | 0.34% | 0.13% | 0.00% | 0.39% | 0.13% | 1.05% | .003 |
| Bleeding disorder | 1.00% | 0.79% | 0.79% | 1.45% | 0.79% | 1.18% | .588 |
| Level of fusion | | | | | | | |
| Single | 84.58% | 91.85% | 85.66% | 83.68% | 81.71% | 80.00% | <.0001 |
| Multilevel | 15.42% | 8.15% | 14.34% | 16.32% | 18.29% | 20.00% | |

Abbreviation: ACDF, anterior cervical discectomy and fusion.

**Table 4.** Univariate Analysis of Complications and Outcomes After ACDF by Anesthesia Group.

| | Anesthesia Time | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Group 1, n (%) | Group 2, n (%) | Group 3, n (%) | Group 4, n (%) | Group 5, n (%) | *P* Value |
| Complication | 3801 (100) | 761 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | 760 (20.0) | |
| Any complication | 3.21% | 1.58% | 2.50% | 2.63% | 3.03% | 6.32% | <.0001 |
| Death | 0.26% | 0.00% | 0.26% | 0.39% | 0.13% | 0.53% | .286 |
| Pulmonary complication | 1.37% | 0.26% | 0.79% | 0.66% | 1.58% | 3.55% | <.0001 |
| Renal complication | 0.05% | 0.00% | 0.13% | 0.13% | 0.00% | 0.00% | .557 |
| CNS complication | 0.16% | 0.13% | 0.00% | 0.26% | 0.13% | 0.26% | .674 |
| Peripheral vascular disease | 0.13% | 0.00% | 0.26% | 0.13% | 0.13% | 0.13% | .735 |
| Cardiac complication | 0.21% | 0.00% | 0.39% | 0.13% | 0.00% | 0.53% | .082 |
| Intra-/postoperative blood transfusion | 0.47% | 0.13% | 0.13% | 0.13% | 0.39% | 1.58% | <.0001 |
| Venous thromboembolism | 0.47% | 0.39% | 0.13% | 0.26% | 0.53% | 1.05% | .086 |
| Urinary tract infection | 0.58% | 0.26% | 0.92% | 0.53% | 0.26% | 0.92% | .217 |
| Sepsis | 0.13% | 0.00% | 0.13% | 0.00% | 0.00% | 0.53% | .017 |
| Wound complication | 0.79% | 0.66% | 0.00% | 0.79% | 0.66% | 1.84% | .002 |
| Graft failure | 0.03% | 0.00% | 0.00% | 0.13% | 0.00% | 0.00% | .406 |
| Total length of stay >5 days | 5.63% | 2.10% | 3.03% | 3.68% | 7.37% | 11.97% | <.0001 |
| Return to OR (for any surgical procedure) | 1.87% | 0.92% | 1.45% | 1.71% | 1.84% | 3.42% | .006 |
| Unplanned reoperation (related to initial procedure) | 0.55% | 0.39% | 0.39% | 0.79% | 0.39% | 0.79% | .477 |
| Unplanned readmission (related to initial procedure) | 1.32% | 0.66% | 1.45% | 1.05% | 1.58% | 1.84% | .128 |

Abbreviations: ACDF, anterior cervical discectomy and fusion; CNS, central nervous system; OR, operating room.

complications, medical complications, surgical complications, and transfusions. Additionally, the type of operation as well as operative length is expected to be indirectly related with anesthesia induction and maintenance times, as it dictates the need for invasive monitoring, special patient positioning, and extent of antiseptic preparation.[20] However, current evidence for the surgical literature assessing anesthesia duration and its influence on intraoperative and postoperative complications remains poor, particularly in the spinal and orthopedic literature.

To address this limitation in the current literature, we sought to assess the influence of anesthesia duration for ACDF, a commonly performed cervical spine surgery. Our analysis of a large national database demonstrated that for patients undergoing ACDF, increased anesthesia duration was significantly associated with postoperative complications, specifically pulmonary complications, intraoperative/postoperative blood transfusions, return to operating room, and LOS >5 days. Following adjustment for confounders, a significant independent association was found for overall complications, VTE, return to

**Table 5.** Multivariate Logistic Regression of 30-Day Outcomes After ACDF by Anesthesia Cohorts.

| | Any Complications | | | | Pulmonary Complication | | | |
|---|---|---|---|---|---|---|---|---|
| Anesthesia Groups (Minutes) | OR | 95% CI | | *P* Value | OR | 95% CI | | *P* Value |
| 1 (48-129) | Reference | | | | Reference | | | |
| 2 (129-156) | 1.556 | 0.746 | 3.246 | .774 | 2.746 | 0.545 | 13.84 | .982 |
| 3 (156-190) | 1.613 | 0.778 | 3.345 | .905 | 2.26 | 0.431 | 11.852 | .620 |
| 4 (290-245) | 1.815 | 0.891 | 3.698 | .635 | 5.621 | 1.242 | 25.448 | .023 |
| 5 (245-1025) | 2.711 | 1.33 | 5.526 | .012 | 4.675 | 0.968 | 22.568 | .140 |
| | Intra-/Postoperative Blood Transfusion | | | | VTE | | | |
| Anestdesia Groups (Minutes) | OR | 95% CI | | *P* Value | OR | 95% CI | | *P* Value |
| 1 (48-129) | Reference | | | | Reference | | | |
| 2 (129-156) | 0.78 | 0.047 | 12.912 | .696 | 0.333 | 0.035 | 3.207 | .204 |
| 3 (156-190) | 0.855 | 0.052 | 14.122 | .774 | 0.667 | 0.111 | 4.001 | .564 |
| 4 (290-245) | 2.147 | 0.215 | 21.491 | .279 | 1.337 | 0.298 | 5.993 | .493 |
| 5 (245-1025) | 1.132 | 0.083 | 15.494 | .971 | 2.688 | 0.71 | 10.171 | .011 |
| | Wound Complication | | | | Total Length of Stay >5 Days | | | |
| Anestdesia Groups (Minutes) | OR | 95% CI | | *P* Value | OR | 95% CI | | *P* Value |
| 1 (48-129) | Reference | | | | Reference | | | |
| 2 (129-156) | <0.001 | <0.001 | >999.999 | .9414 | 1.162 | 0.586 | 2.302 | .025 |
| 3 (156-190) | 1.203 | 0.366 | 3.959 | .944 | 1.533 | 0.792 | 2.967 | .359 |
| 4 (290-245) | 1.001 | 0.289 | 3.473 | .9488 | 3.101 | 1.704 | 5.643 | .0004 |
| 5 (245-1025) | 2.838 | 1.017 | 7.917 | .9237 | 3.606 | 1.933 | 6.727 | <.0001 |
| | Return to Operating Room | | | | | | | |
| Anestdesia Groups (Minutes) | OR | 95% CI | | *P* Value | | | | |
| 1 (48-129) | Reference | | | | | | | |
| 2 (129-156) | 1.389 | 0.53 | 3.639 | .605 | | | | |
| 3 (156-190) | 1.674 | 0.658 | 4.259 | .861 | | | | |
| 4 (290-245) | 1.547 | 0.61 | 3.924 | .894 | | | | |
| 5 (245-1025) | 2.916 | 1.236 | 6.878 | .0041 | | | | |

Abbreviations: ACDF, anterior cervical discectomy and fusion; OR, odds ratio; CI, confidence interval; VTE, venous thromboembolism.

operating room, and LOS >5 days with increased anesthesia time. These results have multiple implications important for patients, clinicians, and hospital administrators.

Several other studies have echoed these results where prolonged anesthesia duration was found to be a risk factor for various complications. VTE remains a cause of serious postoperative morbidity and mortality across all surgical disciplines, and as such is being used as a quality indicator for future hospital reimbursement.[26,27] Similar to the results of the present study, Clarke-Pearson et al reported general anesthesia duration greater than 3 hours was significantly associated with developing VTE.[15] Similarly, Mlodinow et al reported that increased anesthesia time increased rates of VTE, based on an analysis of ACS-NSQIP plastic and reconstructive surgery.[28] One explanation for this observation is that during anesthesia, supine positioning as well as anesthesia effects can lead to increased venous stasis.[29] Increased venous capacitance and decreased venous return secondary to the vasodilatory effects of anesthesia can precipitate clot formation. As such, longer anesthesia time may predispose patients to an increased risk of VTE.[30,31] Collectively, these studies imply that increased anesthesia duration is a risk factor for postoperative VTE, regardless of the type of elective procedure performed.

Although not observed in the present study for ACDF cases, other studies have highlighted associations between prolonged anesthesia duration and postoperative cardiopulmonary complications. We hypothesized that ACDF could be considered a less intensive surgical intervention compared to major open thoracic and general surgery, with fewer cardiopulmonary complications such that additional risk of longer duration of anesthesia was not observed. Fisher et al[15] performed a systematic review of non–thoracic surgery studies, which demonstrated that duration of anesthesia and postoperative nasogastric tube placement were strongly associated with postoperative pulmonary complications. Shortening anesthesia duration was demonstrated to reduce the risk of prolonged intensive care unit stay for patients with severe chronic obstructive pulmonary disease undergoing non–cardiothoracic surgery.[16] Sinclair et al[9] performed a prospective analysis of 17 638 postoperative outpatients after various surgical procedures. They reported that a 30-minute increase in duration of anesthesia increased the likelihood of postoperative nausea and

vomiting by 59%, with an 11-fold higher odds of postoperative nausea and vomiting associated with general anesthesia compared to other forms of anesthesia.[10] Furthermore, increased anesthesia has also been associated with increased blood loss and requirement for blood transfusion.[19] Kim et al investigated 1305 free flap procedures from the NSQIP and reported that increased anesthesia time correlated with increased postoperative transfusions in free flap patients.[19]

Dysphagia and dysphonia are other common complications that may occur following ACDF, with a reported incidence of up to 69%.[32-34] Possible mechanisms for postoperative dysphagia include recurrent laryngeal nerve injury, esophageal ischemia, reperfusion injury, as well as local soft tissue swelling. One limitation of the ACS-NSQIP database is that it does not capture procedure-specific complications such as dysphagia and dysphonia in the context of ACDF. However, prior studies have suggested that such complications may be significantly associated with operative duration. Rihn et al[35] prospectively investigated 38 patients who underwent either 1-level or 2-level ACDF. The authors reported a significant correlation between operative time and severity of postoperative dysphagia, but no significant associations were found between BMI, gender, location of surgery, and number of surgical levels with risk of postoperative dysphagia. With longer operative and anesthesia duration, the cervical vascular structures especially the laryngeal nerves are under considerable pressure and more likely to be traumatized, resulting in postoperative dysphagia and dysphonia. However, it should be noted that measuring dysphagia objectively remains challenging especially in the outpatient setting. There remains a lack of evidence evaluating the relationship between anesthesia duration and postoperative dysphagia. Future studies should seek to explore any possible associations.

Like other published studies utilizing national databases and registries, the strengths of the NSQIP is constrained by several limitations. Although a wide range of variables have been collected and analyzed, there is no data collected for outcomes such as volume of blood lost or transfused in a procedure, preoperative medications, patient-rated outcome scores, and radiological outcomes. Dysphagia and dysphonia are also important complications associated with ACDF that were not captured by the ACS-NSQIP database. Furthermore, the NSQIP database only collects 30-day outcomes and complication rates and will not capture long-term and late-onset complications. There is no way to differentiate whether ACDF patients had cervical radiculopathy or myelopathy, and outcomes can differ in these 2 patient populations. The levels of surgeon expertise, experience of house staff, and competence of outpatient centers/hospitals have not been accounted for in the analysis. CPT and ICD-9 codes are entered by certified coders, but may still be susceptible to miscoding or underreporting.

The current study does not suggest that lengthy procedures be avoided, but rather that anesthesia and procedure length be taken into account in conjunction with existing risk models and patient-specific factors when considering patient risk stratification for ACDF surgery.

## Conclusions

Analysis of a large national database demonstrated that patients with significantly increased anesthesia duration have increased risk of overall complication rate, VTE, increased LOS, and return to the operating room. These results suggest that anesthesia duration should be taken into account when assessing patient risk for ACDF procedures. Time under anesthesia is a useful and easily measurable addition to the robust risk models already in use in orthopedic and spinal surgery.

### Authors' Note

This study was qualified as exempt by the Mount Sinai Hospital Institutional Review Board.

### Declaration of Conflicting Interests

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