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Impact of Obesity on Anterior Cervical Discectomy and Fusion (ACDF): Postoperative Morbidity and Mortality

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ABSTRACT

AIM: To investigate the impact of obesity on postoperative morbidity and mortality in patients who underwent anterior cervical discectomy and fusion (ACDF).

MATERIAL and METHODS: The American College of Surgeons' National Surgical Quality Improvement Project (NSQIP) files from 2006 to 2019 were queried for all patients who underwent an ACDF. Fisher exact tests were used in analyzing univariate differences in preoperative comorbidities and postoperative morbidity and mortality between patients with and without obesity (BMI ≥30 kg/m^2). Results with a p value <0.05 were considered statistically significant. Multivariable logistic regression models were used in determining the independent impact of obesity on ACDF postoperative morbidity and mortality. A p value <0.017 was required for multivariate statistical significance.

RESULTS: There were 96,882 patients who underwent an ACDF from 2006 to 2019 found. 53.77% had non-obese BMI. Patients had statistically significant differences in most perioperative comorbidities and postoperative outcomes on univariate analysis. On multivariate analysis, patients with obesity has decreased adjusted odds of wound infections (aOR=0.7208, CI 0.574–0.9075, p=0.0053), pulmonary events (aOR=0.7939, CI 0.6903–0.9129, p=0.0012), sepsis (aOR=0.5670, CI 0.4359–0.7374, p=2.32E-05), transfusion requirements (aOR=0.5396, CI 0.4498–0.6473, p=3.04E-11), return to operating room (aOR=0.7537, CI 0.6727–0.8447, p=1.17E-06), and length of stay >10 days (aOR=0.7061, CI 0.6438–0.7744, p=1.49E-13).

CONCLUSION: Obesity is a protective factor toward ACDF postoperative complications. Obesity as a marker of patient selection criteria for ACDF procedures should not be used by spine surgeons.

KEYWORDS: ACDF, Obesity, Spine surgery, Cervical fusion

ABBREVIATIONS: ACDF: Anterior cervical discectomy and fusion, **NSQIP:** National Surgical Quality Improvement Project, **BMI:** Body mass index, **COPD:** Chronic obstructive pulmonary disease, **CHF:** Congestive heart failure, **VTE:** Venous thromboembolic disease, **MACE:** Major adverse cardiac event, **LOS:** Length of stay, **UTI:** Urinary tract infection, **OR:** Operating room

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INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is one of the most common procedures in treating cervical spine pathology, with approximately 132,000 ACDF procedures performed annually in the US and rising (26). In addition, the prevalence of obesity and other comorbidities has more than doubled and continues to increase among patients who undergo ACDF (18,23). Morbidity rates for ACDF procedures range from 13.2 to 19.3%, and people with obesity may be at increased risk as a result of body habitus and comorbidities (5,25,29).

The current literature on ACDF morbidity with respect to obesity as a risk factor is inconsistent and outdated. Some studies, including a more recent database study, have shown obesity to be associated with higher complications (13,14,24,25), although most studies demonstrate no significant impact of obesity on ACDF mortality (1,9,16,20,28,30). Study design, sample size, surgical planning, and changes in population characteristics over time may explain the inconsistency of the impact of obesity has on ACDF outcomes. There are major implications for improved economic and patient outcomes in understanding how obesity relates to ACDF morbidity. A reduction in 90-day complication and readmission rates in persons who underwent surgery-induced weight loss prior to ACDF procedures has been demonstrated (17). Obesity has shown to be a predictive factor for patient discharge to a facility other than home, and a higher body mass index (BMI) has been demonstrated to have a lower cost effectiveness with respect to quality-adjusted life years and a higher cost of admission (3,4,14,32).

Our study queried all available National Surgical Quality Improvement Project (NSQIP) files in determining the impact of obesity on ACDF postoperative morbidity and mortality for the first time in the literature. Our multivariate logistic regression analysis attempted to control for the various preoperative variables in isolating the association of obesity with reported morbidity and mortality markers in the database.

MATERIAL and METHODS

The data was de-identified by the American College of Surgeons, and the study was exempt from our Institutional Review Board (IRB) after a Data Use Agreement was signed on March 8th, 2022. So, an IRB number is not provided for exempt studies such as NSQIP studies which is standard for the USA IRB protocols.

The NSQIP files from 2006 to 2019 were queried for all ACDF procedures by using the following CPT codes: 22554, 22551, and 63075. These CPT codes have been used before the NSQIP studies investigating ACDF outcomes (31). Emergent procedures and procedures in patients under 18 years of age were excluded from the study.

Patients with preoperative obesity were defined as BMI ≥ 30 kg/m^2. Preoperative and postoperative variables for these patients were compared to those patients with a BMI ≤ 30 kg/m^2. The preoperative variables compared included sex, diabetes, smoking status, reported dyspnea, functional status, chronic obstructive pulmonary disease (COPD) history, congestive heart failure (CHF) history, hypertension, acute kidney injury, active dialysis need, pre-sepsis criteria, active disseminated cancer, active wound infection, corticosteroid medication use, weight loss, bleeding disorder, old age, chronic kidney disease defined by eGFR, hypoalbuminemia, leukocytosis, thrombocytopenia, and uremia (Table I). Composite events were created for wound infections (superficial surgical site infection (SSI), deep surgical site wound infection, infection of the organ space, surgical wound dehiscence), pulmonary outcomes (pneumonia, prolonged intubation, need for reintubation), venous thromboembolic disease (VTE) (pulmonary embolism, deep vein thrombosis), major adverse cardiac event (MACE) (cardiac arrest, myocardial infarction, stroke), and renal outcomes (emergent dialysis requirement, acute kidney injury) for postoperative outcomes. 30-day in-hospital mortality, sepsis, urinary tract infection (UTI), requirement for transfusion, return to operating room (OR), and extended length of stay (LOS) > 10 days were also analyzed (Table II).

Statistical Methods

Fisher exact tests were used in analyzing univariate differences between preoperative and postoperative variables for patients with and without obesity, with a p value <0.05 considered to be significant. Using R Studio 4.1.1, preoperative variables with a p value <0.20 were selected for logistic regression modeling. Multivariate logistic regression modeling was used in finding adjusted odds ratios for patients with obesity to have a postoperative outcome as compared to patients without obesity. A Bonferroni-adjusted p value <0.017 was required for adjusted odds ratios to be considered significant (Table III).

RESULTS

The study identified 96,882 patients who received an ACDF from 2006 to 2019, 53.77% of which had a normal BMI. Patients with and without obesity significantly differed on preoperative characteristics and comorbidities on univariate analysis of preoperative comorbidities (Table I), including sex (p=2.81E-09), diabetes (p<2.2e-16), smoking status (p<2.2e-16), dyspnea (p<2.2e-16), CHF (p=2.53E-06), hypertension (p<2.2e-16), dialysis (p=0.0001413), sepsis (p=0.001061), cancer (p<2.2e-16), weight loss (p<2.2e-16), older age (p<2.2e-16), hypoalbuminemia (p=0.000129), leukocytosis (p<2.2e-16), uremia (p=4.17E-07), and kidney function (p<2.2e-16). No significant differences in preoperative independent functional status, COPD, deep wound infection, chronic corticosteroid use, bleeding disorder or thrombocytopenia were found.

On univariate analysis of postoperative morbidity and mortality (Table II), patients without obesity were significantly less likely to have wound infections (p=0.0004627), pulmonary events (p=0.00152), 30-day mortality (p=0.003386), sepsis (p=1.258E-07), transfusion within 72 hours (p=1.78E-15), return to OR (p=5.29E-06), and extended LOS (p<2.2e-16). There were no significant univariable differences found for VTE, MACE, renal events, and UTI.

Table I: Univariate Associations Between Obesity and Pre-Operative Variables. Bolded p Values are <0.05 and Convey Statistical Significance

	BMI<30; n=52,093	BMI≥30; n=44,789	
Pre-op variable	**n (%)**	**n (%)**	**Fisher p-value**
Sex (female)	25,353 (48.66)	22,661 (50.59)	**2.81E-09**
Diabetes	5,524 (10.6)	10,531 (23.5)	**< 2.2e-16**
Smoker	16,212 (31.3)	10,288 (23.0)	**< 2.2e-16**
Dyspnea	2,085 (4.0)	2,889 (6.5)	**< 2.2e-16**
Independent functional status	50,728 (97.4)	43,654 (97.5)	0.3195
COPD	2,307 (4.4)	1,999 (4.5)	0.8025
CHF	118 (0.2)	177 (0.4)	**2.53E-06**
Hypertension	19,740 (37.9)	24,994 (55.8)	**< 2.2e-16**
Dialysis	237 (0.5)	136 (0.3)	**0.0001413**
Sepsis	528 (1.0)	364 (0.8)	**0.001061**
Disseminated Cancer	304 (0.6)	109 (0.2)	**< 2.2e-16**
Superficial wound infection	4 (0.01)	0 (0)	0.1283
Deep wound infection	9 (0.02)	5 (0.01)	0.4386
Corticosteroid use	1,808 (3.5)	1,530 (3.4)	0.6461
Weight loss > 10% of body weight	233 (0.4)	52 (0.1)	**< 2.2e-16**
Bleeding disorder	655 (1.3)	581 (1.3)	0.5855
Age ≥70 years old	6,769 (13.0)	4,316 (9.6)	**< 2.2e-16**
Albumin < 3.4 g/dL	1,297 (2.5)	974 (2.2)	**0.000129**
WBC > 11 cells/L	3,252 (6.2)	3,563 (8.0)	**< 2.2e-16**
Platelets < 150,000 cells/mL	2,084 (4.0)	1,808 (4.0)	0.9738
BUN > 23 mg/dL	3,416 (6.6)	3,387 (7.6)	**4.17E-07**
eGFR<60 ml/min/1.73 m^2	3,438 (6.6)	3,723 (8.3)	**<2.2e-16**

COPD: *Chronic obstructive pulmonary disease,* ***CHF:*** *Congestive heart failure,* ***eGFR:*** *Estimated glomerular filtration rate,* ***BUN:*** *Blood urea nitrogen. Bolded p values convey statistical significance in univariate association between Pre-Operative variables and obesity.*

Table II: Univariate Associations Between Obesity and Post-Operative Variables. Bolded p Values are <0.05 and Convey Statistical Significance

	BMI<30; n=52,093	BMI≥30; n=44,789	
Post-op variable	**n (%)**	**n (%)**	**Fisher p-value**
Wound infection	267 (0.5)	162 (0.4)	**0.0004627**
Pulmonary event	727 (1.4)	522 (1.2)	**0.00152**
VTE	256 (0.5)	247 (0.6)	0.2093
MACE	233 (0.4)	167 (0.4)	0.07852
Renal event	49 (0.1)	44 (0.1)	0.836
Death < 30 days	190 (0.4)	116 (0.3)	**0.003386**
Sepsis	251 (0.5)	122 (0.3)	**1.258E-07**
UTI	361 (0.7)	274 (0.6)	0.1196
Transfusion within 72 hours	545 (1.0)	262 (0.6)	**1.78E-15**
Return to OR	1,078 (2.1)	748 (1.7)	**5.29E-06**
LOS >10 days	1,949 (3.7)	1,207 (2.7)	**< 2.2e-16**

VTE: *Venous thromboembolic disease,* ***MACE:*** *Major adverse cardiac event,* ***LOS:*** *Length of stay,* ***UTI:*** *Urinary tract infection,* ***OR:*** *Adjusted odds ratios. Bolded p Values convey statistical significance in univariate association between Post-Operative variables and obesity.*

Table III: Adjusted Odds Ratios (OR) for Each Outcome Variable by BMI Group with BMI<30 as the Reference Group. Adjusted for Sex, Diabetes, Smoker, Dyspnea, CHF, Hypertension, Dialysis, Sepsis, Disseminated Cancer, Superficial Wound Infection, Weight Loss, Age, WBC, BUN, and eGFR Variables. Bolded p Values are <0.017 and Convey Statistical Significance

Outcome	Adjusted OR (ref = BMI<30)	Lower 95% CI	Upper 95% CI	p-value
Wound infection	0.7208	0.5724	0.9075	**0.0053**
Pulmonary event	0.7939	0.6903	0.9129	**0.0012**
VTE	1.3360	0.9219	1.3938	0.2343
MACE	0.7523	0.5936	0.9534	0.0185
Renal event	0.8650	0.5342	1.4009	0.5554
Death < 30 days	0.7427	0.5555	0.9929	0.0446
Sepsis	0.5670	0.4359	0.7374	**2.32E-05**
UTI	0.8963	0.7409	1.0840	0.2598
Transfusion within 72 hours	0.5396	0.4498	0.6473	**3.04E-11**
Return to OR	0.7537	0.6726	0.8447	**1.17E-06**
LOS >10 days	0.7061	0.6438	0.7744	**1.49E-13**

VTE: *Venous thromboembolic disease,* ***MACE:*** *Major adverse cardiac event,* ***LOS:*** *Length of stay,* ***UTI:*** *Urinary tract infection,* ***OR:*** *Adjusted odds ratios. Bolded p Values convey statistical signficance for increased adjusted odds of Post-Operative complications due to obesity.*

On multivariate analysis of postoperative morbidity and mortality (Table III), patients with obesity had significantly decreased adjusted odds of wound infections (aOR=0.7208, CI 0.574–0.9075, p=0.0053), pulmonary events (aOR=0.7939, CI 0.6903–0.9129, p=0.0012), sepsis (aOR=0.5670, CI 0.4359–0.7374, p=2.32E-05), transfusion requirements (aOR=0.5396, CI 0.4498–0.6473, p=3.04E-11), return to OR (aOR=0.7537, CI 0.6727–0.8447, p=1.17E-06), and extended LOS (aOR=0.7061, CI 0.6438–0.7744, p=1.49E-13). No significant differences were found in VTE, renal events, and UTIs in our logistic regression analysis.

DISCUSSION

Obesity and higher BMI has been shown to increase the risk for peri-operative complications in spine surgery and other orthopedic and neurosurgery sub-specialties. However, although risks of elevated BMI on ACDF surgery have been explored, prior results are mixed (8,11,20,21,23). Thus, the goal of this study is to use a larger sample size and more recent data in exploring the risks of obesity (BMI ≥30 kg/m^2) on 30-day complications following ACDF by using a multi-institutional, national database. This study found that obesity has a protective effect on 30-day complication rates following ACDF, with lower odds of many complications including wound infection, sepsis, and return to OR relative to non-obese (BMI <30 kg/m^2) patients.

These findings of increased BMI patients not having increased surgical risks are consistent with several spine surgery studies. There was no significant difference in LOS, major complications, or infectious complications found between patients with BMI > 30 and those with BMI <30 in a retrospective study using 2005–2010 NSQIP data of 2164 patients undergoing single-level or multi-level ACDF (8). Similarly, no significant differences in risks of any complication, extended LOS, DVT/thrombophlebitis, or return to the OR were found between the obesity classes compared to normal weight patients (BMI 18.5–29.9) in a study of patients of different BMI classes undergoing anterior cervical fusion. Moreover, in an analysis of 51,149 patients undergoing anterior cervical spine surgery (ACDF, anterior cervical corpectomy, and cervical arthroplasty), obese patients (BMI 30.0–39.9 kg/m^2) were found to have significantly lower odds of experiencing any adverse event, a serious adverse event, postoperative infections, and mortality within 30 days of surgery relative to normal weight patients (21). Likewise, in a retrospective review of 277 patients undergoing primary 1- to 2-level ACDF for degenerative spine pathology, there were no significant differences in operative time, length of hospital stay, reoperation rates, complication rates, or intraoperative blood loss found between patients of different BMI classes (20). Additionally, in a retrospective analysis of 100 patients undergoing spinal surgery for degenerative lumbar spine disease, there were no significant differences in surgical time, bleeding amount, surgical complications, SSIs, or reoperation rates between the different BMI groups (BMI <25; BMI 25–30; BMI 30–35; BMI > 35) (22).

This study's findings, however, are not consistent with several cervical and non-cervical spine studies. Obese patients (BMI > 30) were found to be at an increased risk for dysphagia, neurological complications, respiratory complications, hematologic complications, PE, and durotomy compared to non-obese patients (23) in a retrospective study using the NIS database of over 1 million patients undergoing ACDF. Similarly, in a large

study using the California State Inpatient Databases of patients undergoing anterior cervical fusion, morbidly obese patients (BMI ≥40) were found to have significantly higher mean total charges and a greater risk for any complication, DVT/PE, neurological complications, pulmonary complications, renal complications, and wound complications (11). Furthermore, a BMI >35 was found to be an independent risk factor for surgical site infection within 30 days of surgery in a retrospective study of patients undergoing posterior cervical surgery (posterior cervical decompression, posterior cervical fusion, cervical laminoplasty) (27). Moreover, Fatima et al compared patients with BMI <30 to those with BMI >30 undergoing single-stage, multi-level posterior cervical spine fusion and found that those with BMI >30 had significantly higher rates of wound infection and mechanical failure, but there was no difference in rates of delirium, atrial fibrillation, or DVT (6). Additionally, in a retrospective study of 24,196 patients undergoing lumbar spine surgery, patients with BMI between 35 and 39.99 were found to be at an increased risk for DVT and superficial wound infection within 30 days of surgery relative to normal BMI patients (18.5–24.99) (19).

Our study supports the obesity paradox that when controlling for perioperative variables, obesity is not an independent risk factor for postoperative complications and is protective. First described in 2003, obese patients were found to have greater survival in dialysis patients (12). This paradox has since been found in other patient populations (2,7,10,15). One may hypothesize that weight reduction before surgery or malnutrition may confound our findings, but we control for greater than 10% preoperative weight loss or hypoalbuminemia in our multivariable analysis. Our findings support that specifically in patients undergoing ACDF procedures, obesity is not an independent risk factor, and more so protective, of surgical risks. Future studies would benefit from analyzing other independent risk factors of ACDF morbidity and mortality.

This study is not without limitations. The use of a large database is prone to erroneous data entry or data omission; however, owing to the control measures of the ACS-NSQIP database, this likely occurs at too low of a rate to significantly influence our results. Additionally, weight has many systemic effects on patients which could influence surgical risks. However, those could not be evaluated due to the limitations of the database, such as rates of osteoporosis. Our study is specific to ACDFs, and we cannot comment on the impact of obesity on the outcomes of different types of spine surgery. Despite these limitations, this is a study with a large sample size which explores the risk of obesity on perioperative complications following ACDFs.

CONCLUSION

Obesity is independently protective of postoperative wound infections, pulmonary events, sepsis, transfusion requirements, return to OR, and extended LOS in patients undergoing ACDFs. Future studies should investigate the impact of metabolic syndrome and other common risk factors on postoperative ACDF morbidity and mortality, and should also investigate the pathophysiology underpinning obesity's protective effect on ACDF postoperative outcomes.

AUTHORSHIP CONTRIBUTION

Study conception and design: GT, JT, JHS
Data collection: PG, BRL JHS
Analysis and interpretation of results: TC, JHS
Draft manuscript preparation: NCA, GT, JHS
Critical revision of the article: WW, JT, NDA, JHS
Other (study supervision, fundings, materials, etc...): JHS
All authors (GT, PG, TC, NDA, WW, JT, BRL, NCA, JHS) reviewed the results and approved the final version of the manuscript.

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