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Original Article

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Abstract

Objective: To determine the implications of obesity on postoperative adverse events following skull base surgery.

Methods: The 2005-2017 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried for adverse events in skull base surgery cases. Patients were stratified by body mass index (BMI) into normal weight ($18.5 \leq BMI < 25$), overweight ($25 \leq BMI < 30$), and obese ($BMI \geq 30$) cohorts. Logistic regression was used to assess the association of overweight or obese BMI with various 30-day postoperative adverse events.

Results: A total of 2305 patients were included for analysis, of which 732 (31.8%) and 935 (40.6%) were overweight or obese, respectively. The mean age was 53.8 ± 15.3 years and 1214 (52.7%) patients were female. Obese patients were younger ($P = .033$) and possessed higher frailty ($P < .001$) and ASA scores ($P < .001$). Operation times and lengths of hospitalization were not significantly different across patient cohorts (all $P > .05$). On propensity score-adjusted multivariable analysis, only bleeding (OR = 0.42, $P < .001$) and deep vein thrombosis (OR = 6.46, $P = .015$) were significantly associated with obesity. There were no significant differences in rates of readmission, reoperation, or mortality between normal weight and obese patients (all $P > .05$).

Conclusions: Obesity was associated with decreased postoperative bleeding and increased deep vein thromboses. Obese patients were otherwise at no higher risk for medical or surgical complications. Elevated BMI did not confer an increased risk for readmission, reoperation, or death. Thus, patient obesity should not be a major determinant in offering skull base surgery in individuals who would otherwise benefit from treatment.

Keywords

skull base surgery, cranial base, obesity, complications, outcomes

Introduction

Over the past decade, obesity rates in the United States have steadily increased, with the Centers for Disease Control and Prevention reporting approximately 42% of adults as obese in 2018.[1] Obesity is associated with a wide spectrum of medical comorbidities, including coronary heart disease, diabetes mellitus, and restrictive respiratory dysfunction, all of which can reduce patient tolerance to physiologically stressful situations.[2] As a result, surgeons have long considered obesity to be a prognostic indicator of poorer perioperative outcomes and increased mortality.[3] With increasing rates of obesity worldwide, elucidating the relationship between body mass index (BMI) and surgical morbidity and mortality has become an active area of investigation. Consequently, there has been an increase in studies investigating the association between obesity and adverse postoperative events in a number of surgical fields.[4-7] These efforts have revealed that, while obesity may oftentimes introduce greater operative risk, the relationship between BMI and patient outcomes can sometimes be nonlinear and, in certain surgical procedures, even paradoxical.[8,9]

In recent years, experts in otolaryngology and neurosurgery have investigated the influence of various sociodemographic and clinical factors in surgical morbidity and mortality.[10-12] However, there is a paucity of literature that

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Table 1. Current Procedure Terminology (CPT) Codes for Resection of Skull Base Lesions.

CPT Code	Description
61600	Extradural resection or excision of neoplastic, vascular or infectious lesion of base of anterior cranial fossa
61601	Intradural resection or excision of neoplastic, vascular or infectious lesion of base of anterior cranial fossa
61605	Extradural resection or excision of neoplastic, vascular or infectious lesion of infratemporal fossa, parapharyngeal space, petrous apex
61606	Intradural resection or excision of neoplastic, vascular or infectious lesion of infratemporal fossa, parapharyngeal space, petrous apex
61607	Extradural resection or excision of neoplastic, vascular or infectious lesion of parasellar area, cavernous sinus, clivus or midline skull base
61608	Intradural resection or excision of neoplastic, vascular or infectious lesion of parasellar area, cavernous sinus, clivus or midline skull base
61615	Extradural resection or excision of neoplastic, vascular or infectious lesion of base of posterior cranial fossa, jugular foramen, foramen magnum, or C1-C3 vertebral bodies
61616	Intradural resection or excision of neoplastic, vascular or infectious lesion of base of posterior cranial fossa, jugular foramen, foramen magnum, or C1-C3 vertebral bodies

comprehensively evaluates the impact of obesity on postoperative complications following skull base surgery. Uncovering such a relationship is essential to more informed clinical decision making and higher quality preoperative counseling. The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database is a multi-institutional outcomes-based collection of surgical cases that provides a unique opportunity to perform such an investigation. In this study, we utilized the NSQIP database to determine if obesity is an independent predictor of adverse postoperative outcomes within the first 30 days following skull base surgery.

Methods

Study Population

The 2005-2017 ACS-NSQIP database is a nationally verified medical database that reports risk-adjusted patient outcomes, including 30-day morbidity and mortality, of various surgical operations from more than 600 participating hospitals. We queried the data from the Participant Use Data File for patients aged $\geq$18 years who underwent intradural or extradural resection of the skull base. Relevant cases were identified using the Current Procedural Terminology (CPT) codes listed in Table 1. Patients who underwent both intradural and extradural resections or whose procedures involved more than 1 cranial fossa were excluded, as they represented only ~1% of our patient cohort, which was too small of a sample size to perform any meaningful statistical analyses.

Individuals with underweight BMIs ($<$18.5) were also excluded. The remaining patients were stratified by their BMIs into normal weight ($18.5 \leq \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$), and obese ($\text{BMI} \geq 30$) cohorts per World Health Organization (WHO) guidelines.[13]

Study Variables

All variables used in this study were derived from data in the ACS-NSQIP database. Independent covariates included basic patient sociodemographics, American Society of Anesthesiologists (ASA) classification, 5-item modified frailty index (5-mFI), current smoker status, skull base lesion site (anterior, middle, posterior cranial fossa), intradural involvement, length of postoperative hospital stay, and operation time. Each patient's 5-mFI was calculated based on their dependent functional status and history of diabetes mellitus, chronic obstructive pulmonary disease, congestive heart failure, and hypertension requiring medication.[14] Measured outcomes included medical complications, surgical complications, and unplanned readmissions, reoperations, and death. Medical complications consisted of pneumonia, unplanned reintubation, pulmonary embolism (PE), ventilator requirement $>$48 hours, renal insufficiency, acute renal failure, urinary tract infection, cerebrovascular accident, myocardial infarction, deep vein thrombosis (DVT), sepsis, and septic shock. Surgical complications included wound disruption, perioperative bleeding, and superficial (skin, mucosa), deep (muscle, fascia), and organ space layer surgical site infections (SSIs). Clinically significant perioperative bleeding was defined as a patient requiring blood transfusion within 72 hours of operation.

Statistical Analysis

All statistical analyses were performed via R (version 3.6.1; The R Foundation for Statistical Computing) in RStudio (version 1.2.1335). A P-value of $<$.05 was considered statistically significant. One-way Analysis of Variance (ANOVA) and chi-square tests of independence were utilized for continuous and categorical variables,

respectively. Logistic regressions using the maximum likelihood method were performed to obtain odd ratios (ORs) and corresponding 95% confidence intervals (CIs) to evaluate independent relationships between obesity and adverse events. The Firth (penalized likelihood) model was utilized for logistic regressions of patient cohorts exhibiting fewer than 5 positive events.[15] Variables that were found to be significantly associated with specific adverse outcomes were included as covariates in multivariable analyses. To further address confounding factors, propensity score matching was performed to create propensity-matched cohorts that were statistically similar in demographic and clinical variables that were previously found to be significantly different on bivariate analysis. Propensity scores were calculated using logistic regression, and 1-to-1 propensity matching without replacement was performed utilizing the nearest neighbor method. A caliper width equal to 0.02 was used to eliminate ~98% of the bias due to the measured confounders.[16] Postoperative complications in propensity-matched cohorts were assessed using multivariable logistic regression.

Results

Descriptive Statistics

A total of 2456 patients from the 2005 to 2017 ACS-NSQIP database was found to have undergone skull base surgery, of which 151 were omitted per the exclusion criteria. Among the 2305 patients included for analysis, the mean age was 53.8 ± 15.4 years and consisted of 1214 (52.7%) females. Table 2 compares the demographic and clinical characteristics of the 3 BMI-stratified patient cohorts. A total of 732 (31.8%) patients were overweight and 935 (40.6%) were obese. Patients in the obese cohort were more commonly younger (<65 years) than the normal weight group (77.9% vs 73.2%, $P = .033$). Moreover, elevated BMI was more common among African Americans (17.6% obese vs 11.8% overweight vs 8.3% normal weight, $P < .001$). Obese patients also exhibited significantly higher frailty (17.0% vs 7.4%, $P < .001$) and ASA scores (66.1% vs 58.0%, $P < .001$) than normal weight patients. Compared to the obese cohort, the normal weight group consisted of more smokers (22.1% vs 17.6%, $P = .030$) and involved more intradural procedures (44.5% vs 37.8%, $P = .026$). Mean operation times ($P = .949$) and lengths of stay ($P = .558$) were not significantly different across patient cohorts.

Higher rates of medical complications were observed among overweight (11.9%) and obese (11.4%) patients than normal weight individuals (7.1%, $P = .005$). When compared to the normal weight group, obese patients exhibited higher rates of DVT (2.6% vs 0.3%, $P < .001$), PE (1.6% vs 0.5%, $P = .038$), and prolonged ventilator weaning (4.9% vs 2.4%, $P = .010$). While surgical complication rates were not significantly different (13.2% obese vs 16.3% normal weight, $P = .147$), obese patients less frequently experienced postoperative bleeding requiring transfusion compared to normal weight patients (10.4% vs 14.4%, $P = .009$). Rates of unplanned readmission (9.3% vs 10.0%, $P = .753$), reoperation (9.0% vs 9.4%, $P = .694$), and death (1.1% vs 1.3%, $P = .363$) were not significantly different between obese and normal weight patients.

Logistic Regression Analysis

Univariate logistic regression models, in which obesity was the independent variable with respect to specific adverse postoperative outcomes, are presented in Table 3. Although, compared to normal weight patients, obesity increased the risk for unplanned reintubation (OR, 2.237; 95% CI, 1.094-5.044), ventilator requirement >48 hours (OR, 2.149; 95% CI, 1.218-4.012), and DVT (OR, 6.843; 2.223-33.872), it was also associated with decreased postoperative bleeding (OR, 0.687; 95% CI, 0.506-0.932). However, obesity was not significantly associated with unplanned readmission (OR, 0.916; 95% CI, 0.631-1.337), reoperation (OR, 0.948; 95% CI, 0.649-1.396), or death (OR, 0.851; 95% CI, 0.334-2.241).

After accounting for various significant demographic and clinical factors, multivariable logistic regression (Table 4) redemonstrated obesity to be a risk factor for DVTs (OR, 6.060; 95% CI, 1.954-30.101). Moreover, obesity was found to be an independent predictor of decreased bleeding (OR, 0.533; 95% CI, 0.374-0.759). Unplanned readmission (OR, 0.881; 95% CI, 0.605-1.289), reoperation (OR, 0.942; 95% CI, 0.641-1.398), and death (OR, 0.845; 95% CI, 0.331-2.225) continued to exhibit no significant association with obesity. To further elucidate the associations between obesity and DVT or postoperative bleeding, obese patients were stratified into class I (BMI 30-34.9), class II (BMI 35-39.9), and class III (BMI 40+). Multivariable analysis demonstrated class I (OR, 5.547; 95% CI, 1.440-36.364), class II (OR, 8.130; 95% CI, 1.991-54.539), and class III (OR, 9.778; 95% CI, 2.176-68.125) obesity to be associated with increased DVT risk. Furthermore, class I (OR, 0.526; 95% CI, 0.344-0.795), class II (OR, 0.597; 95% CI, 0.356-0.977), and class III (OR, 0.376; 95% CI, 0.183-0.717) obesity were associated with decreased risk for postoperative bleeding.

Propensity Score Matching

To further elucidate the relationship between obesity and the postoperative complications that were found to be significant in the aforementioned logistic regressions, propensity score matching was performed to create normal weight (N = 463) and obese (N = 463) patient cohorts that had no

Table 2. Patient Demographics and Outcomes Stratified by BMI.

Variables	Normal weight (18.5 ≤ BMI < 25, N = 638)	Overweight (25 ≤ BMI < 30, N = 732)	Obese (BMI ≥ 30, N = 935)	*P*-value†
Age, y				
<65	467 (73.2)	534 (73.0)	728 (77.9)	.033*
65+	171 (26.8)	198 (27.0)	207 (22.1)	.033*
Sex				
Male	292 (45.8)	394 (53.8)	405 (43.3)	<.001*
Female	346 (54.2)	338 (46.2)	530 (56.7)	<.001*
Race				
White	465 (82.6)	530 (82.2)	662 (78.0)	.046*
Black	47 (8.3)	76 (11.8)	149 (17.6)	<.001*
Other	51 (9.1)	39 (6.0)	38 (4.5)	.002*
Frailty score				
0-1	588 (92.6)	655 (90.2)	772 (83.0)	<.001*
2-3	47 (7.4)	71 (9.8)	158 (17.0)	<.001*
ASA				
1-2	268 (42.0)	306 (41.9)	317 (33.9)	<.001*
3-4	370 (58.0)	425 (58.1)	618 (66.1)	<.001*
Smoker	141 (22.1)	124 (16.9)	165 (17.6)	.030*
Skull base subsite				
Anterior cranial fossa	156 (24.5)	210 (28.7)	281 (30.1)	.047*
Middle cranial fossa	310 (48.6)	315 (43.0)	432 (46.2)	.116
Posterior cranial fossa	172 (27.0)	207 (28.3)	222 (23.7)	.093
Intradural involvement	284 (44.5)	302 (41.3)	353 (37.8)	.026*
Operation time, min	363.6 ± 203.4	349.6 ± 205.4	372.3 ± 208.4	.949
Length of stay, d	5.8 ± 5.7	5.7 ± 6.4	5.7 ± 6.9	.558
Medical complication	45 (7.1)	87 (11.9)	107 (11.4)	.005*
Pneumonia	13 (2.0)	25 (3.4)	32 (3.4)	.224
Unplanned reintubation	9 (1.4)	19 (2.6)	29 (3.1)	.100
Pulmonary embolism	3 (0.5)	9 (1.2)	15 (1.6)	.120
On ventilator >48 h	15 (2.4)	32 (4.4)	46 (4.9)	.034*
Renal insufficiency	1 (0.2)	0 (0.0)	3 (0.3)	.293
Acute renal failure	1 (0.2)	1 (0.1)	2 (0.2)	.925
Urinary tract infection	8 (1.3)	12 (1.6)	11 (1.2)	.698
Cerebrovascular accident	9 (1.4)	12 (1.6)	22 (2.4)	.343
Myocardial infarction	3 (0.5)	3 (0.4)	3 (0.3)	.892
Deep vein thrombosis	2 (0.3)	15 (2.0)	24 (2.6)	.003*
Sepsis	9 (1.4)	19 (2.6)	17 (1.8)	.266
Septic shock	3 (0.5)	5 (0.7)	4 (0.4)	.756
Surgical complication	104 (16.3)	96 (13.1)	123 (13.2)	.147
Superficial SSI	10 (1.6)	9 (1.2)	13 (1.4)	.867
Deep SSI	5 (0.8)	9 (1.2)	4 (0.4)	.182
Organ space SSI	5 (0.8)	8 (1.1)	11 (1.2)	.742
Bleeding requiring transfusion	92 (14.4)	70 (9.6)	97 (10.4)	.009*
Unplanned readmission	52 (10.0)	52 (8.7)	73 (9.3)	.753
Unplanned reoperation	49 (9.4)	48 (8.0)	71 (9.0)	.694
Death	8 (1.3)	4 (0.5)	10 (1.1)	.363

Note. Not all patients had information for these variables, thus the percentages reflect the number of patients with available data.
Abbreviations: ASA, American Society of Anesthesiologists; BMI, Body Mass Index; SSI, surgical site infection.
†Categorical and continuous variables were analyzed using Chi Square Test of Independence or ANOVA, respectively.
*Statistically significant, $P < .05$.

Table 3. Univariate Logistic Regression of 30-Day Skull Base Surgery Complications in Normal Weight (N = 638), Overweight (N = 732), and Obese (N = 935) Patients.

	Overweight (25 ≤ BMI < 30)		Obese (BMI ≥ 30)	
Adverse event	OR (95% CI)	*P*-Value	OR (95% CI)	*P*-Value
Medical complication	1.777 (1.226-2.609)	.003*	1.703 (1.192-2.471)	.004*
Unplanned reintubation	1.862 (0.859-4.350)	.128	2.237 (1.094-5.044)	.037*
On ventilator >48 h	1.899 (1.036-3.636)	.044*	2.149 (1.218-4.012)	.011*
Deep vein thrombosis†	5.500 (1.696-27.826)	.003*	6.843 (2.223-33.872)	<.001*
Other medical complications	1.594 (1.045-2.470)	.033*	1.568 (1.047-2.393)	.032*
Surgical complication	0.775 (0.574-1.046)	.096	0.778 (0.586-1.033)	.082
Bleeding requiring transfusion	0.628 (0.450-0.872)	.006*	0.687 (0.506-0.932)	.016*
Other surgical complications	1.155 (0.659-2.052)	.617	0.992 (0.574-1.745)	.978
Unplanned readmission	0.857 (0.572-1.284)	.453	0.916 (0.631-1.337)	.644
Unplanned reoperation	0.839 (0.552-1.273)	.408	0.948 (0.649-1.396)	.786
Death	0.437 (0.115-1.380)	.173	0.851 (0.334-2.241)	.736

Note. Normal weight patients were used as the reference for the regression models.
Abbreviations: CI, confidence interval; OR, odd ratio.
†Evaluated using Firth logistic regression due to low event frequency in normal weight patients.
*Statistically significant, $P < .05$.

Table 4. Multivariable Logistic Regression of 30-Day Skull Base Surgery Complications in Normal Weight (N = 638), Overweight (N = 732), and Obese (N = 935) Patients.

	Overweight (25 ≤ BMI < 30)		Obese (BMI ≥ 30)	
Adverse event	OR (95% CI)	*P*-Value	OR (95% CI)	*P*-Value
Medical complication	1.589 (1.056-2.421)	.028*	1.328 (0.893-2.003)	.168
Unplanned reintubation	1.906 (0.876-4.467)	.116	2.032 (0.985-4.613)	.068
On ventilator >48 h	1.432 (0.731-2.905)	.304	1.626 (0.874-3.189)	.138
Deep vein thrombosis†	5.526 (1.701-27.979)	.003*	6.060 (1.954-30.101)	.001*
Other medical complications	1.392 (0.877-2.241)	.166	1.218 (0.780-1.936)	.393
Surgical complication	0.827 (0.591-1.157)	.268	0.665 (0.482-0.919)	.013*
Bleeding requiring transfusion	0.617 (0.421-0.885)	.009*	0.533 (0.374-0.759)	<.001*
Other surgical complications	1.301 (0.730-2.355)	.375	1.113 (0.634-1.990)	.713
Unplanned readmission	0.832 (0.554-1.250)	.374	0.881 (0.605-1.289)	.510
Unplanned reoperation	0.860 (0.562-1.316)	.487	0.942 (0.641-1.398)	.767
Death	0.445 (0.118-1.424)	.189	0.845 (0.331-2.225)	.724

Note. Normal weight patients were used as the reference for the regression models.
Abbreviations: CI, confidence interval; OR, odd ratio.
†Evaluated using Firth logistic regression due to low event frequency in normal weight patients.
*Statistically significant, $P < .05$.

statistical differences in their age, sex, race, frailty score, ASA classification, smoker status, skull base surgery site, or intradural involvement (all $P > .05$). Multivariable logistic regression of propensity-matched cohorts demonstrated an increased likelihood for DVTs (OR, 6.462; 95% CI, 1.739-41.795), but a decreased risk of postoperative bleeding (OR, 0.419, 95% CI, 0.255-0.677) with obesity. There were, however, no significant associations between obesity and unplanned reintubation (OR, 2.291; 95% CI 0.892-6.599) or ventilator requirement >48 hours (OR, 1.918; 95% CI, 0.960-3.992).

Discussion

In this study, we evaluated the influence of patient obesity on adverse postoperative events following skull base surgery. Obesity has been traditionally linked to a number of biochemical and physiologic abnormalities, including hyperglycemia, hypertension, and dyslipidemia, that increase the risk for various medical conditions.[17] This association was similarly observed in our study population, in which significantly more overweight and obese patients possessed high frailty and ASA scores. Additionally, we

found a significantly higher rate of medical complications in high BMI patients compared to normal weight individuals. Studies have found that many obesity-related physiologic disturbances can behave synergistically to induce a prothrombotic and proinflammatory state.[18,19] Through this effect, obesity has also been correlated with a significantly higher risk for developing DVTs and associated thromboembolic events.[20] Moreover, decreased ambulation in obese patients has been found to further increase the risk for DVTs.[21,22] Our analyses were consistent with this phenomenon, as we observed significantly higher rates of DVTs in overweight and obese patients. Furthermore, we found pulmonary embolisms to be more common in obese patients compared to normal weight individuals. Therefore, prophylactic measures per the operating surgeons' institutional guidelines should be considered when treating patients with elevated BMIs. This can be especially challenging in consideration of patients who undergo dural repair following skull base surgery who are often restricted to bedrest in the postoperative period, and early ambulation and mobilization, whenever possible, should be recommended in obese patients.

While our multivariable analyses suggested that the significantly higher rate of medical complications in obese patients was likely primarily driven by increased thrombotic events, the significant associations between obesity and increased unplanned reintubation and prolonged ventilator weaning observed on univariate analyses warrant further investigation. This is particularly important, as other surgical fields have found significant associations between obesity and increased postoperative pulmonary complications.[23-25] This phenomenon is hypothesized to be due to reduced lung and chest wall compliance from overlying fat accumulation in conjunction with the upward diaphragmatic shift from increased peritoneal fat, which collectively act to produce a restrictive respiratory pattern and reduce patient tolerance to the physiological stressors involved in surgery.[26] Moreover, perioperative pulmonary atelectasis induced by intubation and worsened by surgical positioning can be significantly greater in obese individuals, making extubation riskier and considerably more challenging.[27] Furthermore, the presence of a restrictive lung ventilatory defect hinders atelectasis recovery, predisposing patients to other postoperative pulmonary complications, such as hypoxemia, pneumonia, and ventilator-induced lung injury.[28] Although, we noted a higher incidence of pneumonia in overweight and obese patients, the difference in rates was not statistically significant. Since the overall incidence of pneumonia in our study population was small (3%), it is possible that our analysis would have reached statistical significance with a larger sample size. Finally, while obstructive sleep apnea (OSA) was not reported in the NSQIP database, obese patients have been previously found to have a higher association with OSA, which may be correlated with increased pulmonary complications and requires special attention following skull base surgery to prevent pneumocephalus and failure of skull base repair.[11]

Interestingly, we did not find a significant difference in overall surgical complications between patient cohorts. Additionally, overweight and obese patients did not exhibit higher incidences of surgical site infections compared to normal weight individuals. While some investigations have found a relationship between obesity and SSIs,[29,30] others have rejected such an association.[31-33] Certain studies have proposed that obesity imposes a higher risk for SSIs due to increased technical difficulty during surgery, greater tension on the healing wound, impaired tissue penetration of perioperative antibiotics, and prolonged operative times.[34,35] These processes may be less prominent in skull base procedures, where patient adiposity plays a less significant role within the surgical field. This may be reflected in our findings, where similar mean operative times were observed across all 3 patient cohorts. Thus, skull base surgeons should not necessarily consider patient obesity a primary risk factor for surgical complications, particularly those related to wound healing, when providing preoperative counseling.

Further subanalysis of surgical complications revealed the rate of postoperative bleeding to be significantly lower in overweight and obese patients. Moreover, stratification of patients into class I-III obesity continued to demonstrate a negative association between obesity and postoperative bleeding. This finding was surprising, as obese patients are typically hypertensive and more likely to strain to higher pressures during ambulation. Although Wardlow et al[33] similarly reported a decrease in perioperative bleeding in obese patients who underwent endoscopic sinus surgery, this phenomenon is still poorly described in the literature and further investigation is warranted. While the cause of our finding is likely multifactorial, current literature remains equivocal on the primary mechanism underlying this phenomenon. The procoagulant state associated with metabolic syndrome and obesity, which is characterized by elevated levels of tissues factor, Factor VIII, and fibrinogen has been hypothesized to contribute to this process.[18,36] Moreover, decreased perioperative bleeding may be augmented by increased adipocytes, which have been demonstrated to produce plasminogen activator inhibitor-1 and impede fibrinolytic pathways.[37] Additionally, reverse Trendelenburg positioning commonly used to facilitate ventilation in obese patients confers the secondary benefit of reducing mean arterial pressure in the head and venous return from the lower extremities, which can consequently reduce total blood loss and improve hemostasis at the surgical site for head and neck procedures.[38]

Among the 3 patient cohorts, we did not observe any significant differences in their readmission, reoperation, or mortality rates. Additionally, we found no significant

difference in the mean lengths of stay of overweight and obese patients compared to that of normal weight individuals. While several studies have previously established an association between obesity and readmission rates,[39-41] recent population-based investigations have reported readmission following head and neck procedures to be independent of patient BMI.[33,42] Furthermore, reoperation and mortality rates have been determined to be primarily driven by the occurrence of major postoperative medical (eg, pneumonia, myocardial infarction, stroke) and surgical (eg, SSIs, wound dehiscence) complications.[43,44] Prolonged hospitalizations have similarly been linked to major postoperative adverse events.[42,45] Thus, our non-significant associations between obesity and reoperation or mortality may be explained by the lack of significant differences in major complication rates between patient cohorts.

To our knowledge, this study is the first to evaluate the influence of patient obesity on postoperative adverse events following skull base surgery. Here, we found obesity to be associated with an increased risk for DVTs and pulmonary complications but decreased risk for bleeding. Importantly, we determined that elevated BMI was not otherwise linked to major medical or surgical complications, and that obese patients were at no higher risk for readmission, reoperation, or death than normal weight individuals. This information can aid physicians in medical decision-making and enhance counseling for overweight patients in need of surgical treatment. There are, however, limitations to this study, much of which was a consequence of using a large administrative database. Since cases were exclusively collected from NSQIP participant institutions, the data may not be representative of the national population. Moreover, as outcomes reported in the database are restricted to 30 days, we were unable to assess complications that may have manifested later in the recovery period after surgery. Additionally, cerebrospinal fluid (CSF) leaks, which are a known and relatively common complication of skull base surgery, were not reported as an explicit variable in the NSQIP database. However, we anticipate that our analysis of readmissions and reoperations accounted for the CSF leak repairs that may have occurred as a result of primary operations. Finally, our utilization of BMI as a measurement of obesity was limited by its lack of consideration of muscular weight or sex-related differences. Despite these limitations, we believe that the large collective population of the many different institutions and patient demographics represented in our analyses strengthen the integrity and validity of our findings, from which generalizable conclusions may be drawn.

Conclusion

In this study, we evaluated the influence of elevated BMI on postoperative adverse events in adult patients who underwent skull base surgery. Obese BMI was found to independently predict an increased likelihood for DVTs and diminished risk for perioperative bleeding. Overweight patients were otherwise not at an increased risk for major medical or surgical complications. Furthermore, elevated BMI was not associated with prolonged hospitalization or higher rates of readmission, reoperation, or mortality. Therefore, while patient obesity should continue to be considered in presurgical risk assessments, physicians should be wary of discouraging skull base surgery primarily on the basis of obesity to individuals who would otherwise benefit from operative intervention.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: ECK is a consultant for Stryker (Kalamazoo, MI). HRD is a consultant for Novus Therapeutics and has equity in Beyondtinnitus and Cactus Medical.

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