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Obesity and perioperative outcomes in older surgical patients undergoing elective spine and major arthroplasty surgery

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Abstract

Study objective: To determine whether obesity status is associated with perioperative complications, discharge outcomes and hospital length of stay in older surgical patients.

Design: Secondary analysis of five independent study cohorts (N = 1262).

Setting: An academic medical center between 2001 and 2017 in the United States.

Patients: Patients aged 65 years or older who were scheduled to undergo elective spine, knee, or hip surgery with an expected hospital stay of at least 2 days.

Measurements: Body mass index (BMI) was stratified as nonobese (BMI ≤ 30 kg/m^2), obesity class 1 (30 kg/m^2 ≤ BMI < 35 kg/m^2) or obesity class 2–3 (BMI ≥ 35 kg/m^2). Primary outcomes included predefined intraoperative and postoperative complications, hospital length of stay (LOS), and discharge location. Univariate and multivariate logistic regression was performed.

Main results: Obesity status was not associated with intraoperative adverse events. However, obesity class 2–3 significantly increased the risk for postoperative complications (IRR 1.43, 95% CI 1.03–1.95, $P = 0.03$), hospital LOS (IRR 1.13, 95% CI 1.02–1.25, $P = 0.02$) and non-home discharge destination (OR 1.95, 95% CI 1.35–2.81, $P < 0.001$) after accounting for patient related factors and surgery type.

Conclusions: Obesity class 2–3 status has prognostic value in predicting an increased incidence of postoperative complications, increased hospital LOS, and non-home discharge location. These results have important clinical implications for preoperative informed consent and provide areas to target for care improvement for the older obese individual.

Keywords

Obesity; Outcomes; Discharge; Older adult

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Declaration of Competing Interest
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1. Introduction

The obesity epidemic is a global issue with prevalence rates tripling since 1975, now impacting 650 million individuals [1]. Given that 1 in 5 individuals will be ≥65 years of age by 2030 in the United States, and 30% of older adults (≥ 65 years of age) are considered to be obese [2,3], the obese and older surgical patients may present special perioperative challenges. Obesity is associated with comorbidities such as hypertension, type II diabetes mellitus, cerebrovascular and cardiovascular disease [4]. In the United States, more than 33% of all surgeries are performed on individuals aged 65 years or older [5] with the most frequent surgery among this age group being musculoskeletal [6].

The objectives of this study were to determine if obesity status was associated with increased intra- or post-operative adverse events, increased hospital length of stay (LOS), or likelihood of patients being discharged to a non-home destination in older patients undergoing major elective spine and major knee and hip arthroplasty operations. We focused on these three types of elective surgery as they were the most common types of surgery being conducted in our cohorts, and also in general in the older patient population [7].

2. Methods

2.1. Participants

Five independent study cohorts provided data from patients enrolled between 2001 and 2017 at the University of California, San Francisco Medical Center. All five studies were part of a larger research goal to investigate the pathophysiology of postoperative delirium [8–12]. Each study evaluated perioperative risk factors as well as incident delirium. Inclusion criteria for the studies were ≥ 65 years of age, scheduled to undergo elective spine procedure, knee or hip arthroplasty surgery, and had an expected LOS of at least 2 days. Exclusion criteria relating to each specific study were reported in Appendix A. Each study was approved by the Institutional Human Research Protection Program and written informed consent was obtained from all subjects.

2.2. Measurement of preoperative demographics

Preoperative characteristics included general demographics (age, gender, and race), comorbidities, Charlson Comorbidity Index, ASA score, surgical site, and date of surgery. General demographics and medical history were obtained from medical records and preoperative telephone interview. The Charlson Comorbidity Index score was calculated to quantify the severity of comorbid conditions [13]. This score was developed to enable researchers to control for the prognostic impact of other chronic diseases on the outcomes of patients with a specific chronic disease. This index is frequently used in measuring outcomes of the older cohort. American Society of Anesthesiologists Physical Status Classification (ASA Class) was utilized to estimate anesthesia risk and overall health [14]. Surgical site was based on the index surgery from medical records. The date of surgery was divided into two periods: 2001–2008 and 2009–2017.

We categorized patient's obesity status according to the body mass index (weight in kilograms divided by height in meters squared) based on the World Health Organization classification [15]. Patients were divided into three groups: nonobese (BMI < 30 kg/m^2), obesity class 1 (30 kg/m^2 ≤ BMI < 35 kg/m^2) or obesity class 2–3 (BMI ≥ 35 kg/m^2). Weight and height were recorded at the time of surgery. In the case when height was missing, BMI was calculated using height within a year of surgery date.

2.3. Measurement of primary outcomes

The presence of intra- and post-operative adverse events during the hospital stay were determined by abstraction from medical records and interviews with the health care team of the patients within the immediate first 2–3 postoperative days as appropriate using pre-defined criteria as developed in our previous work [16,17]. Intraoperative adverse events included any instance of oxygen desaturation, dysrhythmias, or other adverse events (such as surgical related adverse events). Oxygen desaturation was defined as <95% for greater than 10 consecutive minutes. Dysrhythmias included incidents of atrial fibrillation, atrial flutter, supraventricular tachycardia, ventricular tachycardia or fibrillation, heart block (first, second or third degree) and other tachy-arrhythmias such as sick sinus syndrome. Other minor events included dural tear, deep infection to fascia, small pleural opening, and difficulty with foley placement requiring cystoscopy. Postoperative complications were categorized as cardiovascular, acute renal failure, acute thromboembolic event, acute pulmonary failure, acute infection, acute gastrointestinal event, acute transient ischemic attack or stroke, acute hepatic failure, and other minor events. Cardiovascular events included myocardial infarction, chest pain or electrocardiogram or enzyme change (ECG) ST changes, dysrhythmias, and heart failure. The definition of dysrhythmia is the same as in intraoperative adverse events. We defined postoperative acute renal failure as a new requirement of dialysis or elevated serum creatinine 30% over preoperative baseline. Acute thromboembolic event included deep venous thrombosis and pulmonary embolism. Acute pulmonary failure included incidents of pulmonary edema, tracheal intubation, pneumonia, and new pleural effusion. An acute infection complication required documentation of a positive lab culture. Acute gastrointestinal event included bowel ischemia and perforation, gastrointestinal bleed, cholecystitis, and pancreatitis. Acute stroke was determined clinically if there was a new occurrence of focal neurologic abnormality. Acute hepatic function change was defined as an elevation of postoperative liver enzyme with or without jaundice. LOS was measured by the number of days that the patient spent in the hospital after the index surgery, and discharge location was measured as either home or non-home locations. Non-home locations were further categorized as skilled nursing facility, hospital, or nursing home.

2.4. Statistical analysis

Descriptive statistics were computed for patient demographic and surgical characteristics and each of the study outcomes. To assess the association between obesity status and intraoperative and postoperative complications, we first computed univariable Poisson regression models. The covariates were: age, gender, race, Charlson comorbidity score, ASA class, surgery site, and obesity status. If obesity status was associated with the outcome, we then computed a multivariable Poisson regression model, including all the other covariates to examine the association accounting for effect from other variables. In addition to the covariates above, we examine the effect of improvement over time in intra and post-operative care by grouping surgeries into two periods, 2001–2008 and 2009–2017. We include the year indicator as a covariate in univariate and multivariate analysis to account for potential differences in surgery outcomes between two time periods. Negative binomial regression is chosen for modelling LOS because of its the high variance to mean ratio in our data. To assess the association between obesity status and LOS, we first computed univariable negative binomial models. If obesity status was associated with the outcome, we computed a multivariable negative binomial model with all other covariates. Finally, to assess obesity status on discharge location, we computed univariable logistic regression models, with the same covariates as above. If obesity status was associated with the outcome, we computed a multivariable logistic regression model accounting for all other covariates.

3. Results

3.1. Patient characteristics

The initial study population consisted of 1268 total patients. Six patients were excluded based on missing data, one due to missing BMI, three due to missing all three intraoperative events and two due to missing other postoperative events. The number of surgical patients included in this present report was 1262 (661 spine surgery, 290 knee arthroplasty, and 311 hip arthroplasty). This cohort had a mean age of 75.53 ± 5.9 years. Overall, 801 (64%) patients were nonobese (BMI < 30 kg/m^2), 291 (23%) patients had obesity class 1 (30 kg/m^2 ≤ BMI < 35 kg/m^2), and 170 (13%) had obesity class 2–3 (BMI ≥ 35 kg/m^2). Detailed demographics are shown in Table 1.

3.2. Intraoperative and postoperative outcomes

Univariate analyses of the association of the co-variates and the four outcomes (intraoperative complications, postoperative complications, LOS, and discharge to non-home locations) are shown in Table 2. By univariate analysis, the number of intraoperative adverse events was not associated with obesity status (Table 2). Furthermore, specific intraoperative adverse events were not significantly different between the different weight groups (Table 3). However, obesity class 2–3 was associated with increased risk of postoperative complications in both univariate and multivariate analyses (Tables 2 and 4). The other predictors of postoperative complications included nonwhite race, ASA class ≥3 and spine surgery (Tables 2 and 4). Specific postoperative complications by obesity status were not significant (Table 5). Additional analyses that separated obesity class 2 and obesity class 3 revealed obesity class 3 to have increased risk of postoperative complications (Table 6).

3.3. Length of stay

Obesity class 2–3 was also associated with longer LOS on both univariate analysis (Table 2) and multivariate analysis after accounting for other covariates which included patient factors and surgery type (Table 4). Other predictors of LOS included female gender, higher Charlson Comorbidity Index, higher ASA Class, and spine surgery (Table 4). Patients undergoing surgery post 2009 had shorter LOS (Table 4).

3.4. Non-home discharge location

Additionally, by multivariate analysis, obesity class 2–3 was associated with an increased likelihood of discharge to a non-home location after major surgery even after adjusting for patient related factors and surgery type (Table 4). Other predictors of non-home discharge location by multivariate analysis included patients undergoing surgery post 2009, age, female gender, higher Charlson Comorbidity Index score, higher ASA Class, and hip surgery (Table 4). Both obesity class 2 and obesity class 3, when separated with further analysis, were predictors of non-home discharge destination (Table 6).

4. Discussion

This study examined the role of obesity on perioperative outcomes in older adults with undergoing elective orthopedic surgery. Although there have been studies evaluating the impact of obesity status on operative outcomes, our investigation examines the impact of obesity class 1 and obesity class 2–3 in older adults not only on the occurrence of intra- and post-operative adverse events, but also the impact on LOS and likelihood to be discharged to non-home discharge location. Perioperative care in the older obese adult is under-investigated and is an area needing much deserved research [18]. Our results showed that obesity class 2–3 increases risk for prolonged LOS and discharge to locations other than home among older patients. We also found that obesity class 1 did not increase risk for poor perioperative outcomes, while obesity class 2–3 were associated with all outcomes investigated except for intraoperative adverse events. These results reveal that the association between obesity and patient outcomes is not explained by demographic characteristics, number and severity of co-morbid conditions, risk for surgery, and type of surgery. These findings should be considered when discussing with patients during the preoperative informed consent process. Furthermore, a proactive perioperative care plan [19] of older obese surgical patients should be developed.

The lack of association between obesity status and intraoperative complications may be explained by the elective nature of our cohort where medical optimization was possible. An additional observation is that characteristics such as age, Charlson Comorbidity Index Score, ASA score, and surgical site are not associated with intraoperative complications. At first glance, this may be a surprising observation. However, these observations may be explained by the elective nature of our study patients, improved intraoperative anesthetic care of the older patients with multiple comorbidities to include more extensive intraoperative monitoring, use of vasoactive drugs to maintain hemodynamic stability and to aggressively manage fluid third spacing and blood loss [20,21]. These observations may also be explained by contemporary anesthesia and surgical practices which typically take into consideration the anticipated difficulties of caring for an obese patient and therefore, develop appropriate strategies to mitigate risks for a patient's perioperative care plan [19].

The current investigation found that obesity class 2–3 was significantly associated with more postoperative complications. Among the obesity class 2–3 group, the most common complications were cardiac related (Table 5). Although serious cardiac arrhythmias and conduction abnormalities related to obesity is uncommon, it has been reported that obese patients may develop otherwise idiopathic atrial fibrillation, atrial flutter, and ventricular tachycardia, and even bradyarrhythmia related to sinus node dysfunction [22].

The ASA score was one of the consistent predictors of postoperative complications, hospital LOS and non-home discharge destination. The score quantifies patient health before surgery by summarizing the patient characteristics, including BMI [14]. A comprehensive preoperative evaluation using the ASA classification is essential for patients with obesity undergoing surgery as a predictor for perioperative events [23] such as increased risk of prolonged hospital LOS and increased non-home discharge location [24–26].

4.1. Comparisons with previous studies

Previous studies observed the impact of obesity and postoperative complications in hip, knee and spine surgeries and the results were inconclusive. While some studies reported that there was a relationship between obesity and postoperative complications [27–29], others did not [30]. A direct comparison with these studies is not possible because first, these studies in general studied younger patients (59 ± 14 years) [30], and also different weight groups were compared. It has been shown that older age and obesity in multiple surgery types affect outcomes [31–35]. Second, the obesity paradox has also been observed to provide a lower risk of complications and mortality in overweight and obese older adult patients and more within the extremes of BMI [36–38]. This U- shaped relationship [39] between obesity and perioperative complications seen with the obesity paradox was not present in our cohort of older adults undergoing orthopedic surgeries, principally because we did not have sufficient numbers of persons who were underweight to affect results.

Our results showed that obesity class 2–3 did increase LOS. This observation was similarly seen in studies of patients who underwent hip and spine surgery [40,41]. Prior studies that observed obesity status on LOS provided conflicting findings. While some studies reported that obesity status impacted LOS [29,41–43], some reported no association [44–47]. The reason for this difference is unclear. One potential explanation for the discrepant results is that surgical type has significant association with LOS depending on the speed of recovery and the need for postoperative rehabilitation such as physical therapy prior to the patient being discharged. In fact, we reported that LOS was different between different surgery types in that the LOS for hip and knee surgeries was shorter than that in spine surgery. Because our institutional practice for postoperative analgesia for hip and knee arthroplasties typically included regional analgesia, these techniques may have contributed to better pain management which further promoted more rapid recovery compared to spine surgery where regional analgesia was not possible.

In contrast, our results show that obesity class 2–3 and patient related factors were significant factors for non-home discharge location. This finding is novel as most prior studies did not consider the importance of covariates which may affect discharge destinations. We found that surgeries conducted during the second half of the study, age, female gender, Charlson Comorbidity Index Score, and ASA Class ≥3 were associated with non-home discharge location. Whether obesity increases risk for non-home discharge location was inconclusive in prior studies. While some studies have observed no relationship between obesity status and discharge location [48,49], others have found that obesity status had a role in influencing discharge locations and readmission [45,50–52]. Our study reported only an association, and the exact mechanism as to how obesity status is associated with an increased risk of postoperative discharge to a non-home location needs to be investigated in future studies.

4.2. Potential limitations

This study was performed at a single academic medical center and is applicable only to elective surgery. Whether our results can be generalized to those undergoing emergency surgery or ambulatory surgery cannot be determined from this study. However, the patient characteristics in this study are representative of community dwelling older adults where aging increases the likelihood of having multiple comorbidities [53]. Second, our study included a high proportion of non-obese patients relative to obesity class 2–3. Our cohort did not have enough persons in obesity class 3 (n = 56) and underweight cohort (BMI < 18.5 kg/m^2) (n = 17) to provide robust estimates of these classes on the outcomes. Third, our study spanned a 16-year study period. Changes in medical management and surgical technique may have influenced outcomes. We rectified this potential limitation by stratifying the patients into early vs. late periods and found that the recent cohort had shorter LOS but more likely to be discharged to non-home location. Lastly, we defined obesity strictly by BMI, we did not include the potential effect of sleep disordered breathing or stratify obesity by fat distribution. Prior studies have demonstrated the importance of metabolic syndrome [54] as an important clinical entity that has a potential association with perioperative complications [55]. We did not have measurements on levels of triglycerides, fasting plasma glucose, C-reactive protein, insulin resistance, and low high-density lipoprotein cholesterol needed to identify and therefore could not focus on examining this syndrome directly, which should be a focus of further investigations.

4.3. Summary

In the current investigation of older patients undergoing spine, hip, and knee procedures, we found that obesity status of obesity class 2–3 has prognostic value for predicting increased postoperative complications, LOS, and discharge to a non-home location. When counseling the older patients awaiting major surgery, the focus has been on the impact of coexisting diseases and surgery risk. Our results here suggest that BMI ≥ 35 kg/m^2 should be included as one of the major risks when informed consent is being sought preoperatively. Furthermore, given the increased likelihood of the obese older patients being discharged to a non-home location, postoperative care planning must include a discussion and plan for this possibility.

Future studies should explore factors such as normal weight obesity [56] and factors that are modifiable in the older obese surgical patient such as prehabilitation [57], very low carbohydrate diets [58,59] and exercise programs where possible.

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Sponsor's role

The funding agency had no role in the design and conduct of this study including methods, collection, analysis of the data, and no role with the preparation of this manuscript.

Appendix A

Table A

Exclusion criteria of each study Cohort.

Study	Exclusion criteria
Muhlhofer et al. [12]	• Two stage surgery • Cranial surgery or any surgery that interferes with the placement of the sensors • Cardiac bypass surgery • Surgery in prone position • Allergic to adhesive • Anticipated postoperative intubation • Participating in any other clinical trial
Tang et al. [8]	• Preoperative delirium • History of intraoperative recall • Contraindication to receiving light anesthesia (those with a history of coronary artery disease, heart failure, or substance abuse) • Undergoing surgery that involves the brain
Leung et al. [10]	• Patients who cannot complete the neurocognitive testing including those who will be expected to remain intubated postoperatively • Patients with moderate to severe dementia • Patients who score < 12 on the initial administration of MMSE preoperatively Exclusion criteria for the pilot study: • Coagulopathy precluding the placement of intrathecal catheter • History of spine surgery • History of back pain • Anti-coagulation therapy needed to be continued immediately following surgery (i.e. for history of deep vein thrombosis and pulmonary embolism)
Leung et al. [9]	• Inability to perform neurocognitive tests such as those who were expected to remain intubated after surgery • Cases where the use of nitrous oxide was contraindicated
Leung et al. [11]	• Known sensitivity to gabapentin • Use of preoperative gabapentin, pregabalin, and other antiepileptics • Two staged spinal surgery with more than one surgical procedure within the same hospitalization period • Emergency surgery • Preoperative renal dialysis • Opioid tolerance (i.e having a total daily dose of an opioid at or more than 30 mg morphine equivalent for more than one month within the past year)

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Table 1

Demographics of surgical cohort undergoing elective spine, knee, or hip surgery ($N = 1262$).

Variable	N (%)
Age (Years, Mean ± SD)	75.53 ± 5.90
Gender (Female)	672 (53.25%)
Race (White) (%)	1124 (89.06%)
Comorbidities	
Hypertension	744 (58.95%)
Cancer	358 (28.37%)
Cardiac Related Disease[a]	336 (26.62)
Pulmonary Disease	293 (23.2)
Diabetes Mellitus	162 (12.84%)
Coagulation Disorder[b]	80 (6.34%)
Vascular Disease	79 (6.26%)
Stroke	46 (3.65%)
Renal Disease	39 (3.09%)
Charlson Comorbidity Index (Mean ± SD)	0.71 ± 1.17
ASA Class (≥ 3) (%)	534 (42.31%)
Class 1	13 (1.03%)
Class 2	715 (56.66%)
Class 3	526 (41.68%)
Class 4	8 (0.63%)
Surgery site (%)	
Hip	311 (24.64%)
Knee	290 (22.98%)
Spine	661 (52.38%)
Obesity Status (%)	
Nonobese[c]	801 (63.47%)
Obesity Class 1[d]	291 (23.06%)
Obesity Class 2-3[e]	170 (13.47%)
Surgery Year (2009 and after) (%)	813 (64.42%)

Abbreviations: SD, standard deviation; ASA, American Society of Anesthesiologists Physical Status Classification.

[a] History of valvular heart disease, atrial fibrillation, ischemic heart disease, congestive heart failure, or angina.

[b] History of deep venous thrombosis or pulmonary embolism disorder, Parkinson's disease, and other neurologic disorders.

[c] World Health Organization classification of nonobese: Body Mass Index (BMI) < 30 kg/m^2.

[d] World Health Organization classification of obesity class 1: 30 kg/m^2 ≤ BMI < 35 kg/m^2.

[e] World Health Organization classification of obesity class 2–3: BMI ≥ 35 kg/m^2.

Table 2

Univariable analyses of obesity status and intraoperative and postoperative outcomes, length of stay and discharge destination ($N = 1262$).

		Intraoperative complications			Postoperative complications			Length of stay			Non-home discharge destination		
		Mean ± SD: 0.078 ± 0.079			Mean ± SD: 0.23 ± 0.34			Mean ± SD: 5.02 ± 18.79			% Non-home discharge: 38.83%		
Method		Poisson			Poisson			Negative Binomial			Logistic		
		IRR	95% CI	*P*-value	IRR	95% CI	*P*-value	IRR	95% CI	*P*-value	OR	95% CI	*P*-value
Year (2009 and after)		1.47	[0.96,2.33]	0.09	0.90	[0.71,1.15]	0.40	0.78	[0.73,0.84]	<0.001	1.03	[0.82,1.31]	0.78
Age		1.00	[0.97,1.03]	0.94	1.02	[1.00,1.04]	0.10	1.00	[1.00,1.01]	0.56	1.08	[1.06, 1.1]	<0.001
Gender (Female)		0.97	[0.65,1.44]	0.88	0.96	[0.76,1.21]	0.74	1.19	[1.11, 1.28]	<0.001	1.79	[1.43, 2.26]	<0.001
Race (White)		0.98	[0.55,1.95]	0.96	0.70	[0.51,0.98]	0.03	0.90	[0.80,1.00]	0.05	0.71	[0.49, 1.01]	0.055
Charlson		1.05	[0.89,1.22]	0.51	1.07	[0.98,1.17]	0.13	1.07	[1.04, 1.07]	<0.001	1.21	[1.10, 1.34]	<0.001
ASA Class (≥3)		1.45	[0.98,2.15]	0.07	1.93	[1.52,2.44]	<0.001	1.30	[1.21, 1.39]	<0.001	2.17	[1.73, 2.74]	<0.001
Surgery site													
	Hip[a]												
	Knee	0.89	[0.51,1.52]	0.66	1.19	[0.82,1.73]	0.35	1.03	[0.93, 1.14]	0.62	0.91	[0.66, 1.26]	0.58
	Spine	0.75	[0.47,1.20]	0.22	1.55	[1.15,2.13]	0.005	1.33	[1.23, 1.45]	<0.001	0.64	[0.48, 0.84]	0.001
Obesity Status													
	Nonobese[b]												
	Obesity Class 1[c]	1.17	[0.72,1.84]	0.52	1.23	[0.93,1.62]	0.14	1.05	[0.97, 1.15]	0.22	1.21	[0.91, 1.59]	0.18
	Obesity Class 2-3[d]	1.20	[0.65,2.05]	0.53	1.60	[1.15,2.13]	0.004	1.16	[1.05, 1.29]	0.004	2.05	[1.47, 2.86]	<0.001

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification; IRR, Incident Risk Ratio; CI, Confidence Interval; OR, Odds Ratio; SD, standard deviation.

[a] Reference group

[b] Reference group, World Health Organization classification of nonobese: Body Mass Index (BMI) < 30 kg/m^2.

[c] World Health Organization classification of obesity class 1: 30 kg/m^2 ≤ BMI < 35 kg/m^2.

[d] World Health Organization classification of obesity class 2-3: BMI ≥ 35 kg/m^2.

Table 3

Intraoperative complications among obesity status (N = 1262).

Variable	Nonobese *N* = 801 N(%)	Obesity class 1 *N* = 291	Obesity class 2–3 *N* = 170	*P*-value
Oxygen Desaturation[a]	22 (2.7%)	10 (3.4%)	9 (5.3%)	0.23
Dysrhythmia[b]	17 (2.1%)	8 (2.7%)	4 (2.4%)	0.76[*]
Other Adverse Event[c]	16 (2.0%)	5 (1.7%)	2 (1.2%)	0.55

[a]Oxygen desaturation (<95%) for greater than 10 consecutive minutes.

[b]Include incidents of atrial fibrillation, atrial flutter, supraventricular tachycardia, ventricular tachycardia or fibrillation, heart block (First, second or third degree) and other tachy-arrhythmias such as sick sinus syndrome.

[c]Minor surgical complications such as dural tear.

[*]Test conducted using Fisher's exact test due to small cell counts.

Table 4

Multivariable analyses of obesity status and postoperative complications, length of stay and discharge destination ($N = 1262$).

		Postoperative complication			Length of stay			Non-home discharge destination		
Method		**Poisson**			**Negative binomial**			**Logistic**		
Overall test		**<0.001**			**<0.001**			**<0.001**		
		IRR	**95% CI**	***P*-value**	**IRR**	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Surgery year (2009 and after)		0.91	[0.72,1.17]	0.46	0.76	[0.71,0.81]	<0.001	1.31	[1.01,1.70]	0.04
Age		1.01	[0.99,1.03]	0.24	1.00	[1.00,1.01]	0.68	1.09	[1.06,1.11]	<0.001
Gender(Female)		0.97	[0.76,1.22]	0.78	1.20	[1.12,1.28]	<0.001	2.10	[1.63,2.70]	<0.001
Race(White)		0.71	[0.52,1.01]	0.05	0.93	[0.84,1.03]	0.18	0.81	[0.55,1.20]	0.30
Charlson		0.99	[0.90,1.09]	0.88	1.04	[1.01,1.07]	0.007	1.16	[1.04,1.28]	0.007
ASA Class (≥3)		1.71	[1.33,2.21]	<0.001	1.21	[1.12,1.29]	<0.001	1.88	[1.45,2.45]	<0.001
Surgery site										
	Hip[a]									
	Knee	1.05	[0.72,1.54]	0.78	0.98	[0.89,1.09]	0.75	0.75	[0.52,1.06]	0.10
	Spine	1.46	[1.07,2.00]	0.02	1.34	[1.23,1.46]	<0.001	0.53	[0.40,0.72]	<0.001
Obesity Status										
	Nonobese[b]									
	Obesity Class 1[c]	1.11	[0.83,1.46]	0.48	1.04	[0.96,1.13]	0.32	1.26	[0.93,1.69]	0.13
	Obesity Class 2-3[d]	1.43	[1.03,1.95]	0.03	1.13	[1.02,1.25]	0.02	1.95	[1.35,2.81]	<0.001

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification; IRR, Incident Risk Ratio; CI, Confidence Interval; OR, Odds Ratio.

[a]Reference group.

[b]Reference group, World Health Organization classification of nonobese: Body Mass Index (BMI) < 30 kg/m^2.

[c]World Health Organization classification of obesity class 1: 30 kg/m^2 ≤ BMI < 35 kg/m^2.

[d]World Health Organization classification of obesity class 2-3: BMI ≥ 35 kg/m^2.

Table 5

Postoperative complications among obesity status (N = 1262).

Variable	Nonobese *N* = 801 N(%)	Obesity class 1 *N* = 291	Obesity class 2–3 *N* = 170	*P*-value
Any postoperative complications	113 (14.11%)	60 (20.62%)	40 (23.53%)	0.002
Cardiovascular[a]	57 (7.11%)	19 (6.53%)	15 (8.82%)	0.65
Acute renal failure[b]	9 (1.12%)	5 (1.72%)	6 (3.53%)	0.08 *
Acute Thromboembolic event[c]	7 (0.87%)	5 (1.72%)	4 (2.35%)	0.19 *
Acute pulmonary failure[d]	22 (2.75%)	8 (2.75%)	9 (5.29%)	0.20
Acute infection[e]	16 (2.00%)	6 (2.06%)	4 (2.35%)	0.92 *
Other[f]	49 (6.12%)	28 (9.62%)	16 (9.41%)	0.08
Acute TIA/Stroke	4 (0.50%)	2 (0.69%)	0 (0.00%)	
Acute hepatic failure	1 (0.12%)	0 (0.00%)	0 (0.00%)	
Acute GI Event	4 (0.50%)	5 (1.72%)	0 (0.00%)	
Other adverse event	41 (5.12%)	22 (7.56%)	16 (9.41%)	

Abbreviations: TIA, transient ischemic attack; GI, Gastrointestinal.

[a] Included myocardial infarction, chest pain or electrocardiogram or enzyme change (ECG) ST changes, dysrhythmias, and heart failure. Dysrhythmias included heart block (1,2,3 degree), atrial fibrillation or flutter, supraventricular tachycardia, ventricular tachycardia, or fibrillation, and other tachy- and bradyarrhythmia.

[b] A new requirement of dialysis or elevated serum creatinine 30% over preoperative baseline.

[c] Included deep venous thrombosis and pulmonary embolism.

[d] Included incidents of pulmonary edema, tracheal intubation, pneumonia, and new pleural effusion.

[e] Required documentation of a positive lab culture.

[f] Any complications among Acute Transient Ischemic Attack or Stroke, Acute Hepatic Function Change, Acute Gastrointestinal Event, and other.

[*] Test conducted using Fisher's exact test due to small cell counts.

Table 6

Multivariable analyses of nonobese and obesity class 1, 2, and 3 and postoperative complications, length of stay and discharge destination (N = 1262).

		Postoperative complication			Length of stay			Non-home discharge destination		
Method		**Poisson**			**Negative binomial**			**Logistic**		
Overall test		**<0.001**			**<0.001**			**<0.001**		
		IRR	**95% CI**	***P*-value**	**IRR**	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Surgery year (2009 and after)		0.92	[0.72,1.17]	0.48	0.76	[0.71,0.81]	<0.001	1.31	[1.01,1.71]	0.04
Age		1.01	[0.99,1.03]	0.22	1.00	[1.00,1.01]	0.69	1.09	[1.06,1.11]	<0.001
Gender (Female)		0.95	[0.75,1.21]	0.69	1.20	[1.12,1.28]	<0.001	2.06	[1.61,2.66]	<0.001
Race (White)		0.72	[0.53,1.02]	0.06	0.93	[0.84,1.03]	0.17	0.82	[0.56,1.21]	0.32
Charlson		0.99	[0.90,1.09]	0.91	1.04	[1.01,1.07]	0.007	1.16	[1.04,1.29]	0.006
ASA Class (≥3)		1.69	[1.31,2.18]	<0.001	1.21	[1.12,1.30]	<0.001	1.85	[1.42,2.40]	<0.001
Surgery site										
	Hip[a]									
	Knee	1.05	[0.73,1.54]	0.78	0.98	[0.89,1.09]	0.75	0.74	[0.52,1.05]	0.09
	Spine	1.47	[1.08,2.02]	0.02	1.34	[1.23,1.46]	<0.001	0.54	[0.40,0.73]	<0.001
Obesity Status										
	Nonobese[b]									
	Obesity Class 1[c]	1.11	[0.83,1.46]	0.48	1.04	[0.96,1.13]	0.32	1.26	[0.93,1.70]	0.13
	Obesity Class 2[d]	1.21	[0.80,1.78]	0.34	1.15	[1.02,1.29]	0.02	1.53	[1.00,2.33]	0.05
	Obesity Class 3[e]	1.86	[1.16,2.86]	0.007	1.08	[0.92,1.27]	0.35	3.35	[1.83,6.33]	<0.001

Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification; IRR, Incident Risk Ratio; CI, Confidence Interval; OR, Odds Ratio.

[a]Reference group.

[b]Reference group, World Health Organization classification of nonobese: Body Mass Index (BMI) < 30 kg/m^2.

[c]World Health Organization classification of obesity class 1: 30 kg/m^2 ≤ BMI < 35 kg/m^2.

[d]World Health Organization classification of obesity class 2: 35 kg/m^2 ≤ BMI < 40 kg/m^2.

[e]World Health Organization classification of obesity class 3: BMI ≥ 40.