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Review Article

Effects of Body Mass Index on Postoperative Outcomes and Complications for Patients Undergoing Emergency Abdominal Surgery: A NSQIP Review

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ABSTRACT

Introduction: Body mass index (BMI) is closely related to morbidity and mortality, and emergency general surgery is an independent risk factor for postoperative complications and death. **Study Design:** This was a retrospective analysis of NSQIP data from 2018 evaluating outcomes for patients undergoing urgent or emergent abdominal surgery, based on BMI. We first analyzed the impact of patient demographics and comorbidities, including obesity (BMI ≥30), on multiple postoperative outcomes. We then stratified patients by WHO BMI classification and analyzed the same variables. **Results:** In the first analysis, obesity was found to increase the risk of superficial and deep surgical site infection and decrease the risk of pneumonia. The most prevalent risk factor was open surgery, which increased the risk of most postoperative complications. After stratification, we did not identify the previously described "obesity paradox." We found no protective factors for overweight patients or those with mild obesity. However, patients at the extremes of BMI tended toward worse outcomes, including longer operative times and hospital stays. Furthermore, patients with class II or III obesity were typically at higher risk for organ space infection, pulmonary embolism, return to the operating room, and 30-day mortality. **Conclusion:** Body mass index clearly impacts postoperative outcomes in patients undergoing urgent or emergent abdominal surgery. While the obesity paradox was not identified in this study, outcomes generally fared worse for patients at BMI extremes. The most prevalent risk factor across all BMI classifications, for multiple postoperative complications and outcomes including 30-day mortality, was open vs. laparoscopic surgery.

1. Introduction

Obesity, defined as a body mass index (BMI) of 30 kg/m^2 or greater, is a chronic disease that is increasing in prevalence not only in the United States, but also on a global scale. The prevalence of obesity among American adults was 42.4% in 2018, compared to 34.9% just six years prior [1]. The medical cost of obesity as of 2008 was estimated at $147 billion per year [2]. The National Institutes of Health as well as the World Health Organization use the following BMI cutoffs to classify patients [3]. Underweight: BMI <18.5 kg/m^2, normal weight: BMI 18.5-24.9 kg/m^2, overweight: BMI 25-29.9 kg/m^2, obesity class I: BMI 30-34.9 kg/m^2, obesity class II: BMI 35-39.9 kg/m^2, obesity class III: BMI ≥40 kg/m^2.

As has been established in medicine for years, BMI is closely related to morbidity and mortality, a finding that has been replicated in the literature. According to Calle *et al.* from a 1999 study, BMI of 23-25 kg/m^2 in men and 22-23 kg/m^2 in women was associated with the lowest risk of death from all causes, compared with those with the highest BMIs [4]. Furthermore, overall mortality increases by 30% for every 5-point increase in BMI, according to a prospective study from 2009 [5]. In another study from 2012 where 11,000 patients were followed for 12 years, it was demonstrated that a significantly increased risk of mortality existed for underweight patients and patients with class II obesity. Overweight patients, or those with BMI 25.0-29.9, were actually protected from all-cause mortality.

Similarly, in patients with class I obesity relative risk of mortality was close to 1 [6]. This demonstrates the commonly cited "obesity paradox," or protective effect of obesity in relation to comorbidities and mortality [7]. This has also been evaluated in the surgical population. A 2013 literature review evaluated the obesity paradox in cardiac and non-cardiac surgery patients, noting that patients at the extremes of BMI - both underweight and those with morbid obesity - had the highest

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postoperative morbidity and mortality [7]. A NSQIP study from 2009 evaluating patients undergoing nonbariatric general surgery had similar findings, noting underweight patients and those with morbid obesity had the highest risk of death. Conversely, overweight patients and those with "moderate obesity" had a significantly lower risk of death compared to patients with a normal BMI [8].

Emergency general surgery has been shown to be an independent risk factor for death and postoperative complications. Compared with patients who underwent elective surgery, patients who underwent emergency open general surgery were up to five times more likely to die within 30 days of their operation. They were also more likely to experience major complications [9]. A study from 2021 evaluated 30-day mortality for patients undergoing emergency general surgery, stratified into BMI categories based on the WHO classification system. They found that underweight patients had the highest risk of death, with the paradoxical finding that all classes of obesity were protected against mortality compared to normal BMI [10].

Consequently, the main purpose of this study was to investigate the relationship between BMI and emergency general surgery; specifically, by comparing patients with and without obesity with regard to multiple postoperative complications as well as outcomes such as operative time, length of stay, readmission, and 30-day mortality.

2. Methods

This was a retrospective analysis of NSQIP data from 2018 comparing demographics and outcomes of patients undergoing urgent or emergent abdominal surgery. Patients were included in the study if they were 18 or older and were excluded if they had a planned surgical procedure. Potential risk factors included demographics such as age, sex, BMI, race, and ethnicity; other patient characteristics and comorbidities included steroid use, smoking status, preoperative serum albumin, history of severe chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF) within the past 30 days, diabetes mellitus (DM) on insulin, and hypertension (HTN) on medication; and lastly, surgery modality (i.e., open vs. laparoscopic). Outcomes included superficial and deep surgical site infection (SSI), deep vein thrombosis (DVT), pulmonary embolism (PE), urinary tract infection (UTI), pneumonia, operative time, hospital length of stay, return to the operating room, readmission within 30 days, and mortality within 30 days. Data were analyzed using IBM SPSS Statistics for Windows, Version 27.0. (IBM Corp, Armonk, NY, USA) to create bivariate and multivariate analyses. Two separate analyses were performed. In the initial analysis, obesity (BMI ≥30 kg/m^2) was evaluated as a separate potential risk factor for the various postoperative complications and outcomes listed above. In the second analysis, the same variables were evaluated with patients stratified into the six WHO BMI classes (underweight, normal BMI, overweight, class I obesity, class II obesity, and class III obesity).

3. Results

Current Procedural Terminology (CPT) codes were obtained, encompassing most of the major open and laparoscopic surgeries that are performed in an urgent or emergent setting (Table 1). The most common open cases were partial colectomy with primary anastomosis, Hartmann's procedure, and small bowel resection with anastomosis (frequency 5.4%, 3.1%, and 3.7%, respectively). The most common laparoscopic cases were laparoscopic appendectomy and laparoscopic cholecystectomy (frequency 30.8% and 31.2%, respectively). There were 142,681 patients who met criteria for these CPT codes. Of those, 45,280 were booked as emergencies. Of those, 40,091 had BMI data, with 14,959 patients at BMI ≥30 kg/m^2, and 25,132 at BMI <30 kg/m^2. Demographics for patients with and without obesity are shown in (Table 2). The mean (SD) BMI in the obese category was 36.18 (6.2) kg/m^2 compared to 24.79 (3.3) kg/m^2 in the non-obese category ($p<0.001$). In the obese group, more patients were female (54.2%); in the non-obese group patients were more evenly distributed by sex (female 49.9%). In both groups, most patients were white (obese: 82.9%, non-obese: 81.2), with the next most common race being black or African American (obese: 12.7%, non-obese: 8.9). A higher proportion of patients in the obese group were of hispanic ethnicity (19.2%) vs. 15.5% in the non-obese group (<0.0001).

TABLE 1: Frequency of urgent or emergent general surgical operations and their corresponding CPT codes.

SURGERY MODALITY		
OPEN SURGERY		
Surgery Type	*CPT code*	*Frequency*
Exploratory laparotomy	49000	1.8%
Appendectomy or other appendix related surgeries	44950, 44955, 44960	1.5%
Cholecystectomy	47600	1.3%
Partial colectomy with anastomosis	44140	5.4%
Partial colectomy with colostomy	44141	0.8%
Hartmann's procedure	44143	3.1%
Partial colectomy with resection, with colostomy or ileostomy and creation of mucus fistula	44144	0.7%
Partial colectomy with abdominal and transanal approach	44147	0.1%
Colostomy/cecostomy	44320	0.6%
Small bowel resection with anastomosis	44120	3.7%
Small bowel resection with enterostomy	44125	0.2%
Enterorrhaphy for perforation	44602	0.2%
Gastrorrhaphy, suture of perforated duodenal or gastric ulcer	43840	0.9%
LAPAROSCOPIC SURGERY		

Surgery type	*CPT code*	*Frequency*
Laparoscopic appendectomy	44970	30.8%
Laparoscopic cholecystectomy	47562	32.2%
Laparoscopic cholecystectomy with cholangiogram	47563	7.9%
Laparoscopic colectomy, partial, with anastomosis	44204	8.6%
Laparoscopic colectomy, total, with ileostomy or ileoproctostomy	44210	1.0%
Laparoscopic lysis of adhesions	58660	0.3%

Analysis of descriptive statistics for 21 CPT codes encompassing most of the major general surgical operations performed in the urgent or emergent setting.

TABLE 2: Comparison of patient demographics.

	OBESE	NON-OBESE	p-value
Age, mean (SD)	47.22 (17.3)	46.74 (20.1)	0.017
BMI (kg/m^2)	36.18 (6.2)	24.79 (3.3)	<0.001
Sex	54.2% female 45.8% male	49.9% female 50.1% male	<0.0001
Race	82.9% White 12.7% Black or African American 2.7% Asian 1.1% American Indian/Alaska Native 0.6% Native Hawaiian/Pacific Islander	81.2% White 8.9% Black or African American 8.7% Asian 0.8% American Indian/Alaska Native 0.5% Native Hawaiian/Pacific Islander	<0.0001
Ethnicity, Hispanic	19.1%	15.5%	<0.0001

Evaluation of patient demographics stratified by patients with obesity vs. non-obesity.

The comparison of patient characteristics for patients with and without obesity is shown in (Table 3). Rates of DM, CHF and HTN were significantly higher (all p<0.0001), and current smoking status and steroid use for a chronic condition were significantly lower in patients with obesity (p=0.017 and 0.013, respectively). Rates of COPD were similar in both categories.

TABLE 3: Comparison of patient comorbidities.

	OBESE	NON-OBESE	SIGNIFICANCE (p)
DM with oral agents or insulin	13.6%	6.3%	0.000
Current smoker within 1 year	17.5%	18.4%	0.017
History of severe COPD	3.4%	3.5%	0.375
CHF in 30 days prior to surgery	1.4%	0.9%	0.000
HTN requiring medication	33.1%	23.3%	0.000
Steroid use for chronic condition	3.2%	3.6%	0.013

Evaluation of patient comorbidities stratified by patients with obesity vs. non-obesity.

Logistic regression was then used to determine the relative contribution of risk factors to the postoperative complications and outcomes we investigated (Table 4). In this analysis, obesity (BMI ≥30 kg/m^2) was treated as a separate risk factor and increased risk in only two postoperative outcomes: superficial SSI, odds ratio (OR) 1.344, 95% confidence interval (CI, 1.217-1.486) and deep SSI, OR (CI) 1.980 (1.475-2.66). For pneumonia, it was a protective factor, OR (CI) 0.886 (0.794-0.987). The most prevalent risk factor was open surgery, as it was a statistically significant risk factor for 8 of the 9 outcomes we report below. Odds ratios (CIs) ranged from 2.296 (1.72-3.065) for UTI to 12.215 (8.326-17.921) for deep SSI. Another prevalent risk factor was preoperative serum albumin level, with ORs (CIs) ranging from 1.264 (1.189-1.342) for return to the operating room to 10.417 (3.077-35.714) for readmission within 30 days. These ORs indicate that for every 1 mg/kg decrease in the patient's preoperative albumin, the risk ranged from 1.26-fold for return to the operating room to 10-fold for 30-day readmission (data not shown).

TABLE 4: Risk factors for complications and outcomes after emergency general surgery.

Risk Factor	P value	Odds Ratio	95% CI for OR (lower)	95% CI for OR (upper)
Superficial Surgical Site Infection				
Obesity	0.000	1.344	1.217	1.486
Open surgery	0.000	5.975	5.359	6.661
Smoker	0.000	1.248	1.110	1.406
History of Severe COPD	0.009	1.289	1.065	1.560
Diabetes on insulin	0.001	1.374	1.140	1.656

Black or African American	0.012	0.816	0.696	0.957
Deep Surgical Site Infection				
Obesity	0.000	1.980	1.475	2.660
Open surgery	0.000	12.215	8.326	17.921
Pneumonia				
Obesity	0.029	0.886	0.794	0.987
Open surgery	0.000	3.704	3.265	4.201
Male	0.000	1.309	0.691	0.845
Preoperative serum albumin	0.000	1.582	1.477	1.692
Smoker	0.000	1.385	1.230	1.565
Steroid use for chronic condition	0.019	1.218	1.032	1.437
CHF in 30 days before surgery	0.000	1.587	1.271	1.980
History of severe COPD	0.001	1.786	1.546	2.062
DVT				
Open surgery	0.000	3.937	3.234	4.791
Male	0.017	1.214	1.035	1.422
Preoperative serum albumin	0.000	1.689	1.658	2.058
Steroid use for chronic condition	0.000	1.996	1.592	2.506
Black or African American	0.030	1.274	1.024	1.586
Asian	0.032	0.519	0.284	0.947
Pulmonary Embolism				
Open surgery	0.000	4.989	3.034	8.206
Male	0.023	1.456	1.052	2.012
Preoperative serum albumin	0.001	1.439	1.160	1.786
Steroid use for chronic condition	0.003	1.988	1.273	3.106
Urinary Tract Infection				
Open surgery	0.000	2.296	1.720	3.065
Male	0.000	0.512	0.400	0.950
Preoperative serum albumin	0.001	1.299	1.115	1.513
Steroid use for chronic condition	0.026	1.536	1.052	2.242
Return to the Operating Room				
Open surgery	0.000	3.346	3.030	3.695
Male	0.000	1.280	1.175	1.393
Preoperative serum albumin	0.000	1.264	1.189	1.342
Smoker	0.000	1.238	1.118	1.372
Steroid use for chronic condition	0.000	1.395	1.200	1.621
Readmission within 30 days				
Preoperative serum albumin	0.000	10.417	3.077	35.714
Hispanic Ethnicity	0.000	28.340	7.665	104.786
30-Day Mortality				
Open surgery	0.000	6.405	4.791	8.563
Male	0.013	1.181	1.035	1.346
Preoperative serum albumin	0.000	1.996	1.832	2.169
Steroid use for chronic condition	0.000	1.590	1.321	1.912
CHF in 30 days prior to surgery	0.001	1.558	1.206	2.008
History of severe COPD	0.000	1.429	1.199	1.701

Only statistically significant risk factors are included. Evaluated risk factors include: obesity (vs. non-obesity status), open surgery (vs. laparoscopic), male sex (vs. female), every 1 mg/kg decrease in preoperative serum albumin, current smoker within 1 year (vs. nonsmoker), steroid use for chronic condition (vs. non-steroid user), CHF in 30 days prior to surgery (vs. non-CHF status), history of severe COPD (vs. non-COPD status), black or African American race (vs. white), Asian race (vs. white), and hispanic ethnicity (vs. non-hispanic).

Key: 95% CI for OR = 95% confidence interval for odds ratio.

Of note, several factors were protective against multiple outcomes. In addition to obesity for pneumonia as noted above, men were protected from UTIs, OR (CI) 0.512 (0.4-0.95), patients of black or African American race were protected from superficial SSI, OR (CI) 0.816 (0.696-0.957), and patients of Asian race were protected from DVT, OR (CI) 0.519 (0.284-0.947) (Table 4).

However, black or African American patients were at slightly higher risk for DVT, OR (CI) 1.274 (1.024-1.586). When it comes to factors that increase operative time, patients with obesity had operative times expected to be about 7.5 minutes longer than those without obesity. In addition, open cases, as compared with laparoscopic, were expected to be 46.4 minutes longer. Length of stay for patients with obesity, compared to those without obesity, was expected to be 0.4 days shorter. For patients undergoing open surgery, length of stay was expected to be 6.0 days longer than those undergoing laparoscopic surgery (data not shown).

To further investigate a possible obesity paradox, we conducted a second multivariate analysis, in which patients were stratified by WHO BMI class as follows: underweight, normal BMI, overweight, and classes I, II, and III obesity. We evaluated similar risk factors, with a few additions and exceptions: rather than deep SSI, organ space infection was evaluated; and we added wound dehiscence to the evaluation. Table 5 displays the statistically significant results.

TABLE 5: Risk factors for complications and outcomes after emergency general surgery, stratified based on WHO BMI class.

	BMI Class					
Risk Factor	Underweight	Normal BMI	Overweight	Class I Obesity	Class II Obesity	Class III Obesity
Superficial Surgical Site Infection						
Open Surgery	OR 5.906 (p=0.023)	OR 7.142 (p<0.001)	OR 9.365 (p<0.001)	OR 5.468 (p<0.001)	OR 7.663 (p<0.001)	OR 5.771 (p<0.001)
Serum albumin		OR 0.739 (p=0.008)	OR 0.639 (p<0.001)			
Smoker		OR 1.834 (p=0.001)				
Diabetes on insulin			OR 2.156 (p=0.014)			
Asian		OR 1.745 (p=0.034)	OR 2.132 (p=0.021)			
Black		OR 0.286 (p=0.003)				
Dehiscence						
Open surgery		OR 60.986 (p<0.001)			OR 33.728 (p<0.001)	OR 44.479 (p=0.001)
Serum albumin			OR 2.049 (p<0.001)	OR 1.757 (p=0.003)		
Male sex		OR 1.767 (p=0.025)	OR 1.965 (p=0.020)			
Smoker				OR 3.467 (p<0.001)		
Steroid use			OR 2.183 (p=0.045)	OR 5.417 (p<0.001)		
Severe COPD			OR 2.558 (p=0.013)			
HTN on medication						OR 5.451 (p=0.026)
Organ Space Infection						
Open Surgery		OR 2.731 (p<0.001)	OR 2.961 (p<0.001)	OR 3.793 (p<0.001)	OR 2.657 (p<0.001)	OR 7.004 (p<0.001)
Serum albumin		OR 1.558 (p<0.001)	OR 1.362 (p<0.001)		OR 1.395 (p=0.005)	
Male sex			OR 1.332 (p=0.006)	OR 1.330 (p=0.009)	OR 1.527 (p=0.014)	OR 1.431 (p=0.036)
Smoker		OR 1.364 (p=0.004)		OR 1.721 (p=0.581)		
Steroid use		OR 1.523 (p=0.001)	OR 1.489 (p=0.029)			
Hispanic Ethnicity			OR 0.584 (p=0.002)			

Pneumonia						
Open surgery		OR 6.388 (p<001)	OR 3.023 (p<0.001	OR 5.521 (p<0.001	OR 4.510 (p<0.001	OR 5.221 (p<0.001)
Serum albumin		OR 1.399 (p<0.001)	OR 1.727 (p<0.001)	OR 1.550 (p<0.001)	OR 2.353 (p<0.001)	
Smoker within 1 year					OR 1.802 (p=0.017)	
Steroid use						OR 2.200 (p=0.026)
CHF		OR 2.191 (p=0.00)2				
Severe COPD		OR 1.546 (p=0.010)	OR 1.887 (p=0.001)	OR 2.481 (p<0.001)		
Hispanic Ethnicity					OR 0.260 (p=0.025)	
DVT						
Open surgery		OR 3.645 (p=0.001)	OR 11.914 (p<0.001)	OR 16.025 (p<0.001)	OR 12.261 (p<0.001)	OR 10.969 (p<0.001)
Serum albumin		OR 1.605 (p=0.001)	OR 1.931 (p<0.001)	OR 1.645 (p=0.003)	OR 2.488 (p<0.001)	
Male sex			OR 1.610 p=0.043			
Steroid use		OR 2.268 (p=0.001)	OR 2.501 (p=0.002)			
HTN on medication					OR 0.286 (p=0.003)	
Black						OR 2.339 (p=0.040)
Pulmonary Embolism						
Open surgery		OR 4.852 (p=0.001)	OR 4.168 (p<0.001)		OR 27.368 (p=0.002)	
Serum albumin		OR 1.524 (p=0.027)	OR 2.169 (p<0.001)			
Steroid use		OR 4.975 (p<0.001)				
Black	OR 22.519 (p=0.007)					
Native Hawaiian					OR 18.608 (p=0.017)	
Urinary Tract Infection						
Open surgery		OR 2.118 (p=0.013)		OR 3.631 (p<0.001)		OR 8.030 (p<0.001)
Serum albumin	OR 2.257 (p=0.029)	OR 1.406 (p=0.016)			OR 2.667 (p<0.001)	
Male sex			OR 0.419 (p<0.001)	OR 0.337 (p<0.001)		
Steroid use			OR 3.165 (p<0.001)			
Severe COPD			OR 2.160 (p<0.001)			
Diabetes on Insulin					OR 2.801 (p=0.038)	
Return to the Operating Room						
Open Surgery		OR 3.285 (p<0.001)	OR 2.862 (p<0.001)	OR 4.392 (p<0.001)	OR 5.480 (p<0.001)	OR 11.702 (p<0.001)

Serum albumin	OR 1.567 (p=0.009)	OR 1.290 (p=0.001)	OR 1.403 (p<0.001)		OR 1.538 (p=0.001)	
Smoker		OR 1.389 (p=0.010)				
Steroid use			OR 1.504 (p=0.038)		OR 2.101 (p=0.009)	
CHF	OR 3.789 (p=0.012)				OR 2.096 (p=0.047)	
Severe COPD					OR 1.980 (p<0.015)	
Readmission within 30 days						
No significant risk factors						
30-Day Mortality						
Open surgery		OR 5.165 (p<0.001)	OR 5.353 (p<0.001)	OR 5.616 (p<0.001)	OR 16.639 (p<0.001)	OR 10.688 (p<0.001)
Serum albumin	OR 2.809 (p<0.001)	OR 1.721 (p=0.000)	OR 2.353 (p<0.001)	OR 1.938 (p<0.001)	OR 1.953 (p<0.001)	OR 2.119 (p<0.001)
Steroid use			OR 1.814 (p=0.551)			
CHF				OR 2.852 (p<0.001)		
Severe COPD			OR 1.597 (p=0.012)			OR 2.178 (p=0.008)
HTN on medication		OR 1.352 (p=0.022)			OR 2.702 (p=0.022)	
Hispanic Ethnicity					OR 2.702 (p =0.022)	
Hospital Length of Stay						
Open surgery	8.25 days longer (p<0.001)	5.80 days longer (p<0.001)	5.55 days longer (p<0.001)	5.45 days longer (p<0.001)	5.70 days longer (p<0.001)	6.92 days longer (p<0.001)
Serum albumin	3.38 days longer (p<0.001)	1.85 days longer (p<0.001)	1.86 days longer (p<0.001)	1.70 days longer (p=0.003)	1.09 days longer (p<0.001)	2.04 days longer (p<0.001)
Male sex		0.050 days longer (p<0.001)	0.47 days longer (p<0.001)	0.32 days longer (p=0.010)		
Steroid use		1.627 days longer (p<0.001)	1.11 days longer (p<0.001)	1.04 days longer (p<0.001)		
CHF		2.46 days longer (p<0.001)			3.16 days longer (p<0.001)	3.80 days longer (p<0.001)
Severe COPD		0.92 days longer (p=0.004)			1.20 days longer (p=0.008)	
Black						0.73 days longer (p=0.017)
Operative Time						
Open surgery	44.38 min longer (p<0.001)	43.92 min longer (p<0.001)	45.05 min longer (p<0.001)	47.24 min longer (p<0.001)	49.46 min longer (p<0.001)	58.02 min longer (p<0.001)
Serum albumin	15.44 min longer (p<0.001)	8.52 min shorter (p<0.001)	10.27 min longer (p<0.001)	7.47 min longer (p<0.001)	8.13 min longer (p<0.001)	9.68 min longer (p<0.001)
Male sex			2.30 min longer (p=0.002)	3.67 min longer (p=0.004)		7.56 min longer (p<0.001)

Steroid use		8.28 min longer (p=0.004)	9.99 min longer (p<0.001)	14.07 min longer (p<0.001)		
CHF				21.55 min shorter (p<0.001)		
COPD		11.33 min shorter (p<0.001)	9.25 min shorter (p=0.001)			
Diabetes on insulin	14.66 min shorter (p=0.046)					
Black				5.32 min longer (p=0.008)		

Complications and outcomes evaluated included: superficial SSI, dehiscence, organ space infection, pneumonia, DVT, PE, UTI, return to the operating room, readmission within 30 days, 30-day mortality, hospital length of stay, and operative time. Only statistically significant risk factors are included. Evaluated risk factors include: open surgery (vs. laparoscopic), male sex (vs. female), every 1 mg/kg decrease in preoperative serum albumin, current smoker within 1 year (vs. nonsmoker), steroid use for chronic condition (vs. non-steroid user), CHF in 30 days prior to surgery (vs. non-CHF status), history of severe COPD (vs. non-COPD status), black or African American race (vs. white), Asian race (vs. white), and hispanic ethnicity (vs. non-hispanic).

Similar to the previous analysis, open compared with laparoscopic surgery was a very common risk factor for all postoperative outcomes. Indeed, except for organ space infection and 30-day readmission, it was the risk factor seen among the most BMI groups. Other very common risk factors among the complications included decreased serum albumin, contributing to 11; steroid use contributing to 9; male sex contributing to 6; and smoking contributing to 5.

Protective factors included black or African American race (compared to white) in the normal BMI group for risk of superficial SSI (OR 0.286); hispanic ethnicity in the overweight group for risk of organ space infection (OR 0.584), and in BMI class II for pneumonia (OR 0.260); and HTN on medication in the class II obesity group for risk of DVT (OR 0.286).

Hospital length of stay was at least 5 days longer across all BMI classes for open as compared to laparoscopic surgery, with underweight patients experiencing the greatest increase (8.25 days) and patients with class III obesity following at 6.92 days longer. For the remaining groups, increases ranged from 5.45 to 5.8 days. Similarly, every 1 mg/kg decrease in serum albumin prolonged the hospital LOS in each category, with the greatest increase in the underweight group (3.38 days), followed by 2.04 days in patients with class III obesity (p<0.001 for all LOS increases).

When evaluating operative time, open surgery took longer by at least 43 minutes in all BMI groups compared with laparoscopic, with the longest increase seen in the class III obesity group (58.02 minutes). Decreases in serum albumin lengthened operative times across all BMI classes, with the longest increase seen in the underweight group (15.44 minutes).

4. Discussion

As described earlier, previous studies have commented on the obesity paradox, frequently citing increased risk of morbidity and mortality at the extremes of weight, with concurrent protection for patients who are overweight or have class I obesity [6-8].

4.1. Analysis 1: Obesity as a Separate Risk Factor

When we evaluated obesity as a risk factor for the various postoperative outcomes, we found statistical significance for SSI (both superficial and deep) and pneumonia. In our sample, patients with obesity were twice as likely to experience a deep SSI and were also at increased risk of superficial SSI by a factor of 1.344. A NSQIP study from 2011 evaluated risk of SSI in patients undergoing open abdominal procedures, noting that patients with obesity and morbid obesity were at significantly higher risk for SSI. This effect was seen in clean and clean-contaminated cases, but not contaminated or dirty cases [11].

Regarding pneumonia, patients without obesity were 1.1 times more likely to develop pneumonia postoperatively. While this was statistically significant, it is not considerably clinically significant.

4.2. Analysis 1: Obesity as a Separate Risk Factor, as it Relates to Length of Stay and Operative Time

Patients with obesity also experienced a slightly shorter length of stay by about half a day. A single-center retrospective study evaluating patients undergoing high-risk abdominal emergency surgeries evaluated a similar outcome, finding that patients with obesity had an increased hospital length of stay (21.4 days compared with 18.1 days in non-obese patients), but this did not reach statistical significance (p=0.081) [12]. In our study, despite longer operative time by an average of 7.5 minutes, the presence of obesity did not appear to appreciably affect the incidence of DVT or PE. Furthermore, the presence of obesity did not appear to affect return to the operating room, readmission, or mortality.

4.3. Analysis 2: BMI Stratification - No Paradox, but Worse Outcomes in BMI Extremes

A more thorough evaluation of BMI is seen in the second analysis (Table 5), which stratified patients based on weight class. There were no instances in which a patient in the normal BMI class, overweight group, or class I obesity group was protected from an outcome, while those in the classes of obesity at the extremes were at risk. Stated differently, there were no clear signs of the obesity paradox. However, there were several instances where patients with class II or III obesity were at significantly higher risk for multiple postoperative outcomes, including

patients undergoing open surgery for risk of postoperative organ space infection, UTI, PE, return to the operating room, or 30-day mortality. Patients with a normal BMI undergoing open surgery (vs. laparoscopic) had the lowest 30-day mortality risk of all the BMI groups with an odds ratio of 5.165 ($p<0.001$); however, all BMI groups except the underweight group had a statistically significantly elevated risk. This finding coincides with findings seen by Kassahun *et al.*, in a single-center retrospective study evaluating similar outcomes [12]. They noted that mortality rates for patients undergoing emergency general surgery were lowest in the normal-weight group.

4.4. Analysis 2: BMI Stratification, as it Relates to Length of Stay and Operative Time

For risk factors such as decreases in serum albumin and open surgery, patients at the extremes of BMI (underweight and class III obesity), appeared to require the longest hospital lengths of stay. For operative time, a similar effect was seen, as patients with class III obesity undergoing open surgery required operative times 58 minutes longer than their laparoscopic counterparts, a time period that becomes longer with increasing BMI class. In a retrospective study from 2005, Hawn *et al.*, noted that BMI was directly correlated with operative time for multiple general surgical procedures [13]. With decreases in preoperative serum albumin, underweight patients experienced the longest increase in operative times (15 minutes longer).

4.5. Specific Topics: Open vs. Laparoscopic Surgery

The comparison of open to laparoscopic surgery was very eye-opening as well. In the first analysis, open surgery was the most prevalent risk factor and was significant for all complications and outcomes except readmission within 30 days. When stratified into BMI classes, open surgery was again the most common risk factor, yielding very high odds ratios across multiple BMI classes. For DVT in particular, patients in the normal BMI and overweight classes were at 4-5-fold higher risk, while patients with class II obesity were at 27-fold higher risk. Similarly, Nguyen *et al.*, evaluated risk of DVT after open and laparoscopic surgery over a 5-year period, finding a significantly higher rate of DVT in open cases, but not to this extent (OR 1.8%) [14]. On the contrary, in a retrospective study from 2012, Ferrada, *et al.*, did not find an increased risk for DVT in patients with obesity (defined as BMI >25) undergoing open vs. laparoscopic emergency surgery [15]. Open surgery was associated with a similarly large increase in risk for return to the operating room for patients with class III obesity, as well as risk of 30-day mortality in patients with class II and III obesity. These large increases in odds ratios at the BMI extremes of class II and III obesity are more in line with previously described concepts. In terms of operative time and length of stay, open cases were much longer than laparoscopic cases by 46.4 minutes, and hospital stays were about 6 days longer. It is possible that longer operations and hospital stays may account for the increase in risk of DVT, PE, and other postoperative complications for patients undergoing open vs. laparoscopic surgery. As described above, the effects of open vs. laparoscopic surgery were typically more drastic at the extremes of BMI.

4.6. Specific Topics: Preoperative Serum Albumin

The importance of preoperative serum albumin is underscored by this study. In the first analysis, each 1 mg/kg decrease in preoperative serum albumin increased the risk for almost every complication, except superficial and deep SSI. Likewise, each 1 mg/kg decrease in preoperative serum albumin increased the risk of 30-day readmission by a factor of 10.417.

When stratified by BMI class in the second analysis, as expected, decreasing levels of preoperative serum albumin typically increased the risk of postoperative morbidity. Interestingly, this effect is reversed for superficial surgical site infection, such that decreased preoperative albumin was shown to be protective (normal BMI: OR 0.739, overweight: OR 0.639). As far as we know, this has not been reported in the literature. Indeed, increased albumin is typically considered a protective against infection of all types.

4.7. Specific Topics: Obesity Paradox?

These topics have been studied before in the literature but not to the extent of our investigation. Our first analysis confirmed obesity as a risk factor for multiple postoperative complications. However, since all patients with BMI >30 were grouped together, they spanned six obesity classes. Our study is the first we know of that used stratified BMI classes to yield a more fine-grained picture of risk. In doing so, we did not identify a true obesity paradox. While we noted several instances where patients who were underweight or with class III obesity had increased risk for various postoperative complications or outcomes, there were no instances in which being overweight or in class I or II obesity was protective with concurrent increased risk at extreme BMI.

5. Conclusion

While a true obesity paradox did not exist in this study, the extremes of BMI did predict higher risk for multiple postoperative outcomes and mortality in emergency general surgery. Furthermore, we demonstrated that for multiple postoperative outcomes including surgical site infection, pneumonia, DVT, and 30-day mortality, open surgery increased the risk in almost every single BMI class. Finally, we showed that preoperative serum albumin played a significant role in postoperative complications and outcomes in patients undergoing emergency general surgery, including a large impact on 30-day readmission.

Meeting Presentation

Poster presentation at ACS Clinical Congress, San Diego, CA, October 2022.

Abbreviations

BMI: Body Mass Index
COPD: Chronic Obstructive Pulmonary Disease
CHF: Chronic Heart Failure
DM: Diabetes Mellitus
DVT: Deep Vein Thrombosis

HTN: Hypertension
OR: Odds Ratio
PE: Pulmonary Embolism
SD: Standard Deviation
SSI: Surgical Site Infection
UTI: Urinary Tract Infection

REFERENCES

[1] Craig M Hales, Margaret D Carroll, Cheryl D Fryar, et al. "Prevalence of Obesity and Severe Obesity Among Adults: United States, 2017-2018." *NCHS Data Brief*, no. 360, pp. 1-8, 2020. View at: Publisher Site | PubMed

[2] Eric A Finkelstein, Justin G Trogdon, Joel W Cohen, et al. "Annual Medical Spending Attributable to Obesity: Payer-And Service-Specific Estimates." *Health Aff (Millwood)*, vol. 28, no. 5, pp. w822-w831, 2009. View at: Publisher Site | PubMed

[3] Connor B. Weir, Arif Jan "BMI Classification Percentile And Cut Off Points." *StatPearls*, pp. 1-8, 2022. View at: PubMed

[4] E E Calle, M J Thun, J M Petrelli, et al. "Body-Mass Index and Mortality in a Prospective Cohort of U.S. Adults." *N Engl J Med*, vol. 341, no. 15, pp. 1097-1105, 1999. View at: Publisher Site | PubMed

[5] Gary Whitlock, Sarah Lewington, Paul Sherliker, et al.; "Prospective Studies Collaboration. Body-Mass Index And Cause-Specifc Mortality In 900000 Adults: Collaborative Analyses Of 57 Prospective Studies." *Lancet*, vol. 373, no. 9669, pp. 1083-1096, 2009. View at: Publisher Site | PubMed

[6] Heather M Orpana, Jean-Marie Berthelot, Mark S Kaplan, et al. "BMI and Mortality: Results From a National Longitudinal Study of Canadian Adults." *Obesity (Silver Spring)*, vol. 18, no. 1, pp. 214-218, 2010. View at: Publisher Site | PubMed

[7] Tabita M Valentijn, Wael Galal, Elke K M Tjeertes, et al. "The Obesity Paradox In The Surgical Population." *Surgeon*, vol. 11, no. 3, pp. 169-176, 2013. View at: Publisher Site | PubMed

[8] John T Mullen, Donald W Moorman, Daniel L Davenport "The Obesity Paradox: Body Mass Index And Outcomes In Patients Undergoing Nonbariatric General Surgery." *Ann Surg*, vol. 250, no. 1, pp. 166-172, 2009. View at: Publisher Site | PubMed

[9] Joaquim M Havens, Allan B Peetz, Woo S Do, et al. "The Excess Morbidity And Mortality Of Emergency General Surgery." *J Trauma Acute Care Surg*, vol. 78, no. 2, pp. 306-311, 2015. View at: Publisher Site | PubMed

[10] Sean R Maloney, Caroline E Reinke, Abdelrahman A Nimeri, et al. "The Obesity Paradox in Emergency General Surgery Patients." *Am Surg*, vol. 88, no. 5, pp. 852-858, 2021. View at: Publisher Site | PubMed

[11] Robert D Winfield, Stacey Reese, Kelly Bochicchio, et al. "Obesity and the Risk for Surgical Site Infection in Abdominal Surgery." *Am Surg*, vol. 82, no. 4, pp. 331-336, 2016. View at: Publisher Site | PubMed

[12] Woubet Tefera Kassahun, Matthias Mehdorn, Jonas Babel "The Impact Of Obesity On Surgical Outcomes In Patients Undergoing Emergency Laparotomy For High-Risk Abdominal Emergencies." *BMC Surg*, vol. 22, no. 1, pp. 15, 2022. View at: Publisher Site | PubMed

[13] Mary T Hawn, John Bian, Ruth R Leeth, et al. "Impact of Obesity on Resource Utilization for General Surgical Procedures." *Ann Surg*, vol. 241, no. 5, pp. 821-828, 2005. View at: Publisher Site | PubMed

[14] Ninh T Nguyen, Marcelo W Hinojosa, Christine Fayad, et al. "Laparoscopic Surgery is Associated With a Lower Incidence of Venous Thromboembolism Compard with Open Surgery." *Ann Surg*, vol. 246, no. 6, pp. 1021-1027, 2007. View at: Publisher Site | PubMed

[15] Paula Ferrada, Rahul J Anand, Ajai Malhotra, et al. "Obesity Does Not Increase Mortality After Emergency Surgery." *J Obes*, vol. 2014, pp. 1-3, 2014. View at: Publisher Site | PubMed