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The Obese Colorectal Surgery Patient: Surgical Site Infection and Outcomes

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Abstract

Background: Obese patients undergoing colorectal surgery are at increased risk for adverse outcomes. It remains unclear if these risks can be further defined with more discriminatory stratifications of obesity.

Objective: Understand the association between body mass index (BMI) and 30-day post-operative outcomes, including surgical site infection, among colorectal surgery patients.

Design: Retrospective cohort study

Setting: The 2011–2013 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database

Patients: Elective colorectal surgery in 2011–2013 assessed by ACS-NSQIP

Main Outcome Measures: BMI was categorized into World Health Organization categories. Primary outcome was 30-day post-operative surgical site infection. Secondary outcomes included all ACS-NSQIP assessed 30-day post-operative complications.

Results: Our cohort included 74,891 patients with 4.4% underweight (BMI <18.5), 29% normal weight (BMI 18.5–24.9), 33% overweight (BMI 25–29.9), 19.8% obesity class I (BMI 30–34.9), 8.4% obesity class II (BMI 35–39.9), and 5.5% obesity class III (BMI ≥40). Compared to normal weight patients, obese patients experienced incremental odds of surgical site infection from class I to class III (I: OR 1.5 95%CI 1.4–1.6; II: OR 1.9 95%CI; 1.7–2.0; III: OR 2.1 95%CI 1.9–2.3). Obesity class III patients were most likely to experience wound disruption, sepsis, respiratory or renal complication, and urinary tract infection. Mortality was highest among underweight patients (OR 1.3 95%CI 1.0–1.8) and lowest among overweight (OR 0.8 95%CI 0.6–0.9) and obesity class I patients (OR 0.8 95%CI 0.6–1.0).

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Limitations: Retrospective analysis of ACS-NSQIP hospitals may not represent patients outside of ACS-NSQIP and cannot assign causation or account for interventions to improve surgical outcomes.

Conclusion: Patient risk profiles for adverse post-operative outcomes differ across the World Health Organization BMI categories. Patients with increasing BMI and obesity showed an incremental and independent risk for adverse 30-day post-operative outcomes, especially surgical site infections. Strategies to address obesity pre-operatively should be considered to improve surgical outcomes among this population.

Keywords

Surgical Outcomes; Obesity; Body Mass Index; NSQIP; Colorectal Surgery

INTRODUCTION

More than one-third of the United States' adult population can be classified as overweight or obese.[1] Obesity has been widely identified as an independent risk factor for increased morbidity, leading to poor outcomes including increased mortality following colorectal surgery.[2–7] Patients undergoing colorectal procedures can experience SSI rates ranging from 4–30%[6, 8–11] and on average increase the cost of colectomy by $17,324.[12] SSI events are publicly reported as a quality metric with financial implications for hospitals[3,12–15] urging increased interest to reduce these rates. Comprehensive SSI reduction bundles have been shown to reduce superficial SSI rates from 19.3% to 5.7%[16] or from 5.1% to 1.5%.[8] These SSI reduction bundles are good general guidelines for perioperative care of patients undergoing colorectal surgery, but do not take into consideration patient-level characteristics contributing to increased risk.

Although body mass index (BMI) is a commonly accepted measure of patient mass, there are conflicting definitions of obesity cited in surgical literature. Studies of the relationship between obesity and perioperative outcomes are mixed and not surprising given varying sample sizes with heterogeneous definitions of obesity. Few studies investigate the full spectrum of BMI as defined by the World Health Organization (WHO) with six categories (underweight, normal weight, overweight, or obese I-III).[17]

Since patients undergoing colorectal surgery have high rates of surgical site infections with financial implications for patients, payers, and hospitals, more studies with precise and consistent definitions are needed to understand the relationship between obesity and post-operative outcomes in this population.[13] We hypothesized that increasing BMI, as defined by the WHO, is an independent risk factor for 30-day post-operative surgical site infection and adverse post-operative outcomes among patients undergoing elective colorectal surgery.

MATERIALS AND METHODS

Data source and patient selection

After local Institutional Review Board exemption approval, a non-procedure targeted 2011–2013 American College of Surgeons National Surgical Quality Improvement Program

(ACS-NSQIP) Participant Use Data File was queried for all patients undergoing elective colorectal surgery at 121 hospitals.

Patient body mass indices were stratified into six obesity classifications: Underweight (< 18.5 kg/m^2), Normal Weight (18.5–24.9 kg/m^2), Overweight (25–29.9 kg/m^2), Obesity Class I (30–34.9 kg/m^2), Obesity Class II (35–39.9 kg/m^2), and Obesity Class III (≥ 40 kg/m^2).[17] Patients undergoing Altmeier, proctopexy, retrorectal resections, emergency surgery, or having ACS-NSQIP variables coded as “unknown” or “other” were excluded from analysis.

Perioperative variables

ACS-NSQIP patient-specific variables include age, race, sex, BMI, American Society of Anesthesiology (ASA) class, preoperative albumin, history of diabetes mellitus (insulin and non-insulin dependent), history of smoking within one year, history of dependent functional status, history of >10% weight loss within six months, history of severe chronic obstructive pulmonary disease (COPD), history of hypertension requiring medication, and history of steroid use for chronic condition within 30-days. Procedure-specific variables include procedure type as identified by Current Procedure Terminology (CPT) codes, indication for surgery, ostomy formation, hospital length-of-stay, relative value unit (RVU), and wound classification. All colorectal procedure types performed including approach and ostomy formation were identified using CPT codes (45130, 45110, 45395, 44143, 44206, 44160, 44205, 44145, 44207, 45111, 45112, 45114, 45116, 45120, 45121, 45123, 44146, 45119, 45397, 44208, 44140, 44141, 44147, 44204, 44144, 45126, 45400, 45402, 45550, 45160, 44150, 44210, 44151, 44212, 44155, 44156, 44157, 44158, 44211, 45113).

Outcomes

The primary outcome of interest was 30-day post-operative surgical site infection. Surgical site infection was defined as a superficial surgical site infection, deep incisional surgical site infection, and/or organ/space surgical site infection each described according to ACS-NSQIP Participate Use Data File User Guide definitions.[18] Secondary outcomes include additional 30-day ACS-NSQIP post-operative complications: (1) wound disruption; (2) sepsis (including septic shock); (3) venous thromboembolism (deep venous thrombosis or pulmonary embolism); (4) respiratory complication (pneumonia, unplanned intubation, or ventilator > 48 hours); (5) cardiac event (cardiac arrest requiring chest compression resuscitation or myocardial infarction); (6) renal complication (progressive renal failure or acute renal failure); (7) urinary tract infection; (8) bleeding (requiring greater than 4 units of packed red blood cell transfusion within 72 hours from surgery); (9) readmission; (10) mortality.

Statistical Analysis

Differences between categorical and continuous variables were analyzed using Chi-square and Kruskal-Wallis tests for non-normal data, respectively, with one-way ANOVA for normally distributed continuous data. Significant comparisons were included into a multivariate logistic regression to identify predictors of primary and secondary binary outcomes using normal weight patients (BMI 18.5–24.9 kg/m^2) as the reference group.

Missing data were coded using a missing indicator. Statistical significance was set *a priori* at $p<0.05$. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

Our cohort included 74,891 patients who underwent elective colorectal surgery. Patient and procedure-specific characteristics stratified by BMI classification are shown in Table 1. The overall median BMI was 27.4 kg/m^2 (IQR: 23.8–31.8 kg/m^2) with 3,265 (4.4%) underweight, 21,685 (29%) normal weight, 24,705 (33%) overweight, 14,797 (19.8%) obesity class I, 6,324 (8.4%) obesity class II, and 4,115 (5.5%) obesity class III. The majority of patients (62%) were categorized as normal weight and overweight.

The proportion of patients with an ASA class III, a history of diabetes (both insulin and non-insulin dependent), a history of hypertension requiring medication, and diverticulitis disease increased as BMI increased ($p<0.001$). Underweight patients were more likely to be current smokers (28.5%), undergo surgery for benign disease (28.1%) and inflammatory bowel disease (IBD) (14.4%), have a pre-operative albumin <3 (21.6%), have history of steroid use for a chronic condition (17.3%), have a history of >10% weight loss (17%), have contaminated (12.9%) and dirty/infected (10.6%) wound classifications, have dependent functional status (6.3%), and have longer hospital length-of-stays (median 7, IQR: 5–12) when compared to the other BMI classes ($p<0.001$). Normal weight (29%) patients mostly had an ASA I-II (52.2%) and underwent surgery for benign reasons (19.8%). Overall, obesity class III patients had the highest proportion of black patients (16.2%) with higher ASA class III (68.3%) and IV-V (8.5%), history of hypertension (67.6%) and diabetes mellitus (insulin dependent (13%), non-insulin dependent (20.4%)), dirty/infected wound classifications (8.1%), and underwent surgery for a colorectal malignancy (57.1%, $p<0.001$).

The most common procedures performed overall include partial colectomy (39.8%), low anterior resection (23.1%), and ileocecectomy (18.4%) with an overall laparoscopic rate of 48%. Underweight patients had the highest rates of stoma formation at 38.7% in addition to ileocecectomy (23.5%), total abdominal colectomy (7.1%), Hartmann's resection (6.3%), abdominoperineal resection (5.6%), and pelvic exenteration (0.4%). Obesity class I had the highest rates of low anterior resection (25.2%) while obesity class III patients mainly underwent partial colectomy (43.3%). Underweight and obesity class III patients had the lowest rates of laparoscopic rates ($p<0.001$, Table 1).

Unadjusted 30-day outcomes stratified by BMI class are shown in Table 2. Overall, SSI rates were 11.8% and differed significantly across BMI class with normal weight patients having the lowest rate (9.5%, $p<0.001$). The incidence of SSI increased progressively with BMI class from overweight (11.1%) to all three obesity classifications (I: 12.8%, II: 15.9%, III: 18.3%, $p<0.001$). Overall 30-day mortality was 1.3% with underweight patients having the highest rate at 2.8% followed by obesity class III (1.6%) and normal weight (1.5%) patients ($p<0.001$). Overweight patients and obesity class I-II patients had similar mortality rates (1.1%, 1.0%, and 1.2% respectively). Underweight and obesity class III patients had high rates of sepsis, urinary tract infection, readmission, and mortality, while underweight patients had the highest rates of bleeding (17.6%), readmission (14.2%), respiratory

complications (6.6%), organ space infection (5.9%), and mortality (2.8%, p<0.001). Obesity class III patients showed the highest rates in SSI (18.3%), sepsis (7.7%), urinary tract infections (4.0%), and renal complications (2.6%, p<0.001). Underweight patients showed higher rates of venous thromboembolism (2.4%) followed by obesity class II patients at 2.3% (p<0.001).

After adjusting for all significant patient and procedure-specific differences from Table 1, risk of 30-day post-operative outcomes varied across BMI class compared to normal weight patients (Table 3). The association between increasing BMI and odds of any 30-day surgical site infection remain in a step-wise fashion despite adjustment (Figure 1). Underweight patients had the lowest odds of SSI (OR: 0.98; 95% CI 0.87–1.11), however, the adjusted odds of SSI significantly and progressively increased with increasing BMI class from overweight (OR: 1.28; 95% CI 1.20–1.36) to obesity class III (OR: 2.06; 95% CI 1.87–2.28) with obesity class III having the highest odds. Underweight patients had significant odds of wound disruption (OR: 1.55; 95% CI 1.15–2.09), however, odds of wound disruption increased as BMI class progressively increased. Odds of an organ space infection were highest among overweight (OR: 1.10; 95% CI 1.01–1.21) and obesity class III patients (OR: 1.19; 95% CI 1.01–1.41).

DISCUSSION

To date, this study is the largest national retrospective cohort of patients, stratified by standardized WHO BMI classifications, undergoing elective colorectal surgery for broad indications. Our study shows that having an obese BMI class serves as an independent risk factor for adverse 30-day post-operative outcomes including surgical site infections. Odds of any surgical site infection progressively increase in a step-wise fashion as BMI increases from obesity class I to class III. Overall, obesity class III patients had the highest odds of SSI, wound disruption, sepsis, urinary tract infection, respiratory and renal complications. In addition to SSI, odds of wound disruption, sepsis, venous thromboembolism, and renal complication were associated with increased BMI.

While studies have observed general associations between increasing BMI and SSI among colorectal and general surgery patients,[2–6, 9–12, 19–24] heterogeneity in obesity classifications using unique and non-standardized BMI definitions with varying sample sizes has led to mixed observations of BMI influencing post-operative SSI.[25, 26] The WHO BMI classifications provide class-based risk profiles. Merkow et al. concurred with the lack of colorectal literature classifying BMI according to standardized nomenclature through the 2007 ACS-NSQIP database to understand 30-day outcomes among 3,202 patients from 121 hospitals undergoing colectomy for cancer.[5] Their study supports our findings of increasing BMI class and increased risk of SSI, wound disruption, and renal complications. Further, Mullen et al[22] utilized standardized WHO BMI definitions in their 2005–2006 ACS-NSQIP study investigating 30-day morbidity and mortality among 118,707 non-bariatric general surgery patients. Procedure types included laparoscopic cholecystectomy, partial colectomy, ventral and inguinal hernia repair, and laparoscopic appendectomy. Their data also shows a progressive increase in the likelihood of a wound infection with increasing BMI class despite only including a small proportion of colorectal patients in their analyses.

Data from this study supports associations between BMI and adverse 30-day post-operative outcomes including wound disruption,[5,27–30] pulmonary,[4,31–35] and renal complications,[32] yet did not support significant differences across BMI categories regarding cardiac complications.[5,20,32,36] Regarding mortality, morbidly obese (obesity class III) patients' adjusted odds of mortality were not significantly higher than normal weight patients in our study, a finding inconsistent with some colorectal/general surgery literature.[21,26,36–38] Interestingly, our data showed lower mortality rates among overweight and mildly obese patients, a finding supported in studies among general surgery,[22] critically ill,[43,44] renal failure,[45] and congestive heart failure[46] patients. Underweight patients in our study showed the highest mortality and may be attributed to their underlying disease processes resulting in a higher incidence of >10% weight loss within 6 months of surgery, serum albumin <3, steroid use, and inflammatory bowel disease burden.[40–42] Evidence suggests that overweight and mildly obese patients have nutritional reserves and efficient metabolic states compared to more obese patients that better prepare them for surgical stress.[22] It is likely that those underweight and morbidly obese patients have inefficient metabolic regulation with high inflammatory cascades leading to oxidative stress, immunosuppression, and adverse outcomes.[22, 47] However, this protective effect known as the 'obesity paradox'[22] is challenged with a recent international meta-analysis showing higher all-cause mortality among overweight and obese patients without comorbid disease or tobacco use.[48] Further, a recent national study of 4,385 morbidly obese (BMI > 40) colorectal cancer patients undergoing colectomy had higher perioperative mortality compared to patients with a BMI <30.[39] Again, heterogeneity in observed morbidity and mortality rates may be a result of non-standardized BMI classifications among studies with varying sample sizes and patient populations.

Our data suggests that the patients with increasing BMI class have incremental odds of many adverse post-operative 30-day outcomes. The pathophysiology of obesity is complex, but surgical site infections and wound complications may be higher among obese patients as a result of decreased oxygen tension and impaired antibiotic penetration/concentration at the wound surface combined with an overall pro-inflammatory state and diminished immune system.[49–52] Strategies to reduce SSI among colorectal patients have been achieved through perioperative reduction bundles[8, 16, 53–55] and pre-operative antibiotic bowel preparations.[56–59] However, understanding the influence of multi-dimensional, patient-specialized prehabilitation among obese colorectal surgery patients is yet to be fully understood. Prehabilitation provides pre-operative optimization towards 'normal weight' physiology through nutritional assessment and optimization, smoking cessation, poly-pharmacy management, exercise programs to improve functional capacity, and monitored weight management.[60] Prehabilitation could be applied not only to the underweight or frail patient, but also to the obese patient with specific focus on nutritional optimization and monitored weight management goals towards more 'normal' BMI classes and metabolic physiology. For those not able to lose weight in more non-elective cases, perhaps nutritional assessments with protein supplementation could improve outcomes given the anti-inflammatory and immune-modulating properties of whey protein.[61, 62] There is a paucity of literature examining prehabilitation specifically among colorectal surgery patients, especially obese populations.

Our data is limited to a sample of both private and academic hospitals participating in ACS-NSQIP and the colorectal surgery population reported in this study may not be representative of other populations. Data from this study does however support findings similar to other ACS-NSQIP studies, including a large multi-institutional ACS-NSQIP study[22] having similar heterogeneous case-mix suggesting generalizable themes in surgical outcomes by BMI. Observations presented in this study are retrospective in nature and causation cannot be assigned. Further, institutional interventions or strategies aimed at infection reduction or other quality improvement initiatives that may impact post-operative outcomes are not accounted for.

CONCLUSION

BMI class as defined by the World Health Organization is as an independent risk factor for many adverse 30-day post-operative outcomes, specifically SSI among obese patients undergoing colorectal surgery. Comprehensive BMI stratification offers a real-time target for pre-operative risk-reduction strategies aimed at improving outcomes through patient optimization towards ‘normal weight’ physiology. Future studies should explore strategies, such as prehabilitation, not just on the elderly, underweight or frail patient, but the obese patients undergoing colorectal surgery.

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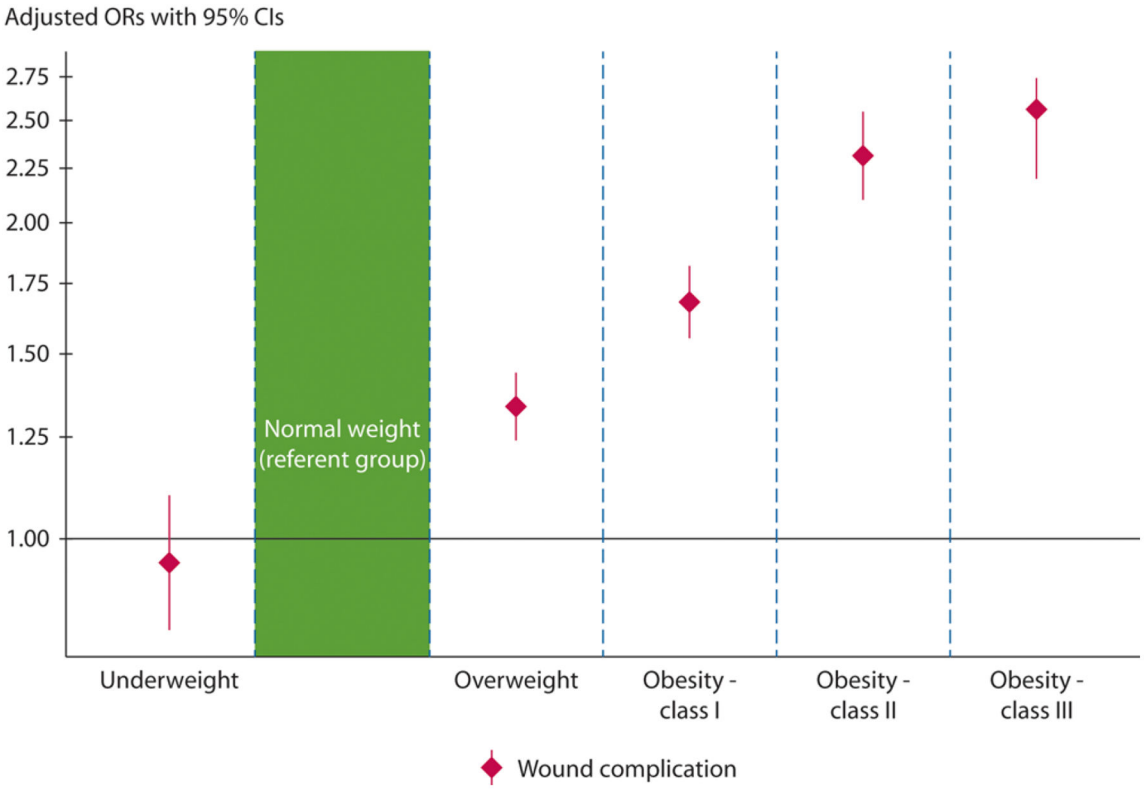

FIGURE 1.
Predicted all-cause surgical site infection by BMI category. Refer to Table 3 for specific ORs and CIs.

TABLE 1.

Patient and procedure-specific demographics stratified by BMI category

Characteristic	Overall, N= 74,891 (100%)	Underweight, N = 3265 (4,4%)	Normal weight, N = 21,685 (29.0%)	Overweight, N = 24,705 (33,0%)	Obesity class I, N = 14,797 (19.8%)	Obesity class II, N = 6324 (8.4%)	Obesity class III, N=4115 (5.5%)
Demographics[a]							
Age, median (IQR), y	62 (52–72)	61 (44–75)	63 (51–751)	63 (53–73)	62 (52–71)	60 (51–69)	59 (50–67)
Sex, men	36,044 (48–1)	1082 (33.1)	9229 (42.6)	13,714 (55.5)	7678 (51.91)	2846 (45.0)	1495 (36.3)
Race							
White	67,073 (89.6)	2868 (87.8)	19,725 (91.0)	22,478 (91.0)	13,085 (88.4)	5468 (86.5)	3449 (83.8)
Black	7818 (10.4)	397 (12.2)	1960 (9.0)	2227 (9.0)	1712 (11.61)	856 (13.5)	666 (16.2)
ASA class							
I-II	36,193 (48.3)	1362 (41.7)	11,323 (52.2)	12,943 (52.4)	7108 (48.0)	2501 (39.5)	956 (23,2)
III	35,131 (46.9)	1663 (50.9)	9346 (43.1)	10,754 (43.5)	7020 (47.4)	3537 (55.9)	2811 (68.3)
IV-V	3567 (4.8)	240 (7.4)	1016 (4.7)	1008 (4.1)	669 (4.5)	286 (4,5)	348 (8.5)
Comorbidities[a]							
Diabetes mellitus							
NIDDM	7498 (10.0)	107 (3.3)	1138 (5.2)	2286 (9.3)	2020 (13,7)	1107 (17.5)	840 (20.4)
IDDM	3637 (4.9)	87 (2.7)	506 (2.3)	957 (3.9)	969 (6.51	581 (9.2)	537 (13.0)
Current smoker	13,124 (17.5)	931 (28.5)	4412 (20,3)	4040 (16,4)	2255 (15,2)	934 (14.8)	552 (13,4)
Dependent functional status	2201 (2.9)	205 (6.3)	753 (3.5)	594 (2.4)	334 (2.3)	157 (2.5)	158 (3.8)
>10% weight loss	3443 (4.6)	556 (17.0)	1521 (7.0)	793 (3.2)	368 (2.5)	125 (2.0)	80 (1.9)
COPD	3918 (5.2)	269 (8.2)	1083 (5.0)	1147 (4.6)	716 (4.8)	384 (6.1)	319 (7.8)
Hypertension	36,833 (49.2)	1020 (31.2)	8240 (38.0)	12,232 (49.5)	8565 (57.9)	3996 (63.2)	2780 (67.6)
Steroid use	6331 (8.5)	564 (17.3)	2352 (10.8)	1825 (7.4)	973 (6.6)	41 3 (6.5)	204 (5.0)
Preoperative laboratory results[a]							
Preoperative albumin							
≥3g/dL	45,653 (61.0)	1792 (54.9)	13,129 (60.5)	15,089(61.1)	9234 (62.4)	3922 (62.0)	2487 (60.4)
<3g/dL	6385 (8.5)	706 (21.6)	2333 (10.8)	1773(7.2)	847 (5.7)	388(6.1)	338 (8.2)
Missing	22,853 (30.5)	767 (23.5)	6223 (28.7)	7843 (31.7)	4716 (31.9)	2014(31.8)	1290 (31.3)
Surgical characteristics[a]							
Surgery indication							
Benign	12,738 (17.0)	916 (28.1)	4285 (19.8)	3853 (15.6)	2133 (14.4)	935 (14.8)	616 (15.0)
Colon and rectal cancer	40,585 (54.2)	1530 (46.9)	11,569 (53.4)	13,660 (55.3)	8046 (54.4)	3429 (54.2)	2351 (57.1)
Diverticulitis	16,282 (21.7)	348 (10.7)	3710 (17.1)	5746 (23.3)	3815 (25.8)	1672 (26.4)	991 (24.1)
IBD	5286 (7.1)	471 (14.4)	2121 (9.8)	1446 (5.9)	803 (5.4)	288 (4.6)	157 (3.8)
Approach							
Open	35,964(52)	1992 (61)	10,583 (48.8)	11,280 (45.7)	6776 (45.8)	3097 (49)	2236 (54.3)
Laparoscopic	38,927 (48)	1273 (39)	11,102 (51.2)	13,425 (54.3)	8021 (54.2)	3227 (51)	1879 (45.7)
Procedure							
Abdominoperineal resection	3079 (4.1)	182 (5.6)	988 (4.6)	1023 (4.1)	522 (3.5)	214 (3.4)	150 (3.6)

Characteristic	Overall, N= 74,891 (100%)	Underweight, N = 3265 (4,4%)	Normal weight, N = 21,685 (29.0%)	Overweight, N = 24,705 (33,0%)	Obesity class I, N = 14,797 (19.8%)	Obesity class II, N = 6324 (8.4%)	Obesity class III, N=4115 (5.5%)
Hartmann	2912 (3.9)	205 (6.3)	909 (4,2)	888 (3.6)	504 (3.4)	228 (3.6)	178 (4,3)
lleocecectomy	13,758 (18.4)	767 (23.5)	4205 (19.4)	4392 (17.8)	2600 (17.6)	1085 (17.2)	709 (17.2)
Low anterior resection	17,293 (23.1)	525 (16.1)	4625 (21.3)	5901 (23.9)	3724 (2S.2)	1550 (24.5)	968 (23.5)
Low anterior resection/DLI	1838 (2.5)	58 (1.8)	632 (2.9)	615 (2.5)	349 (2.4)	117 (1.9)	67 (1.6)
Partial colectomy	29,802 (39.8)	1087 (33.3)	8182 (37.7)	10,022 (40.6)	6048 (40,9)	2682 (42.4)	1781 (43.3)
Pelvic exenteration	142 (0.2)	12 (0.4)	57 (0.3)	45 (0.2)	15 (0.1)	10 (0,2)	3 (0.1)
Total abdominal colectomy	2851 (3.8)	232 (7.1)	954 (4.4)	794 (3.2)	497 (3.4)	228 (3.6)	146 (3.5)
Total abdominal co!ectomy/BI	1 508 (0.7)	36 (1.1)	183 (0.8)	163 (0.7)	78 (0.5)	29 (0.5)	19 (0.5)
Total proctocolectomy/BI	746 (1.0)	55 (1.7)	233 (1.1)	215 (0.9)	130 (0.9)	78 (1.2)	35 (0.9)
TPC/IPAA/DLI	1418 (1.9)	75 (2.3)	509 (2.3)	471 (1.9)	237 (1.6)	78 (1.2)	48 (1.2)
P/IPAA/DL1	544 (0.7)	31 (0.9)	208 (1.0)	176 (0.7)	93 (0.6)	25 (0.4)	11 (0.3)
Stoma formation	20,638 (27.6)	1265 (38.7)	6685 (30.8)	6411 (26.0)	3694 (25.0)	1543 (24.4)	1040 (25.3)
Wound classification							
Clean	923 (1.2)	41 (1.3)	256 (1.2)	304 (1.2)	196 (1.3)	77 (1.2)	49 (1.2)
Clean/contaminated	60,426 (80.7)	2457 (75.3)	17,397 (80.2)	20,110 (81.4)	12,041 (81.4)	5119 (80.9)	3302 (80.2)
Contaminated	8224 (11.0)	421 (12.9)	2458 (11.3)	2624 (10.6)	1588 (10.7)	704 (11.1)	429 (10.4)
Dirty/infected	5318 (7.1)	346 (10.6)	1574 (7.3)	1667 (6.7)	972 (6.6)	424 (6.7)	335 (8.1)
Hospital LOS, median (IQR), d	5 (4–9)	7 (5–12)	5 (4–9)	5 (4–8)	5 (4–8)	6 (4–9)	6 (4–9)

All values are reported as n (%) unless labeled otherwise.

NIDDM = noninsulin-dependent diabetes mellitus; IDDM = insulin-dependent diabetes mellitus; current smoker = current smoker within 1 year preoperative; >10% weight loss = >10% weight loss within 6 months preoperatively; COPD = chronic obstructive pulmonary disease; hypertension = hypertension requiring medication; steroid use = steroids for chronic condition with 30 days preoperatively; DLI = diverting loop ileostomy; 81 = Brooke ileostomy; TPC = total proctocolectomy; P = proctocolectomy; RVU = relative value unit; LOS = length of stay; RVU = relative value unit; IQR = interquartile range.

[a]AII variables have $p < 0.001$

TABLE 2.

Unadjusted 30-day outcomes stratified by BMI category

Characteristic	Overall, N = 74,891 (100%)	Underweight, N = 3265 (4.4%)	Normal weight, N = 21,685 (29.0%)	Overweight, N = 24,705 (33.0%)	Obesity class I, N = 14,797 (19.8%)	Obesity class II, N = 6324 (8.4%)	Obesity class III, N = 4115 (5.5%)	P
Surgical site infection(superficial, deep, organ)	8835 (11.8)	379 (11.6)	2069 (9.5)	2737 (11.1)	1890 (12.8)	1006 (15.9)	754 (18.3)	<0.001
Wound disruption	911 (1.2)	60 (1.8)	201 (0.9)	259 (1.1)	167 (1.1)	127 (2.0)	97 (2.4)	<0.001
Organ space infection	3272 (4.4)	192 (5.9)	914 (4.2)	1053 (4.3)	632 (4.3)	272 (4.3)	209 (5.1)	<0.001
Sepsis	3956 (5.3)	244 (7.5)	1111 (5.1)	1166 (4.7)	741 (5.0)	376 (5.9)	318 (7.7)	<0.001
Venous thromboembolism	1410 (1.9)	79 (2.4)	349 (1.6)	474 (1.9)	282 (1.9)	145 (2.3)	81 (2.0)	<0.001
Respiratory complication	2746 (3.7)	214 (6.6)	792 (3.7)	791 (3.2)	481 (3.3)	247 (3.9)	221 (5.4)	<0.001
Cardiac	697 (0.9)	37 (1.1)	212 (1.0)	222 (0.9)	127 (0.9)	65 (1.0)	34 (0.8)	0.52
Renal complication	927 (1.2)	26 (0.8)	204 (0.9)	288 (1.2)	192 (1.3)	110 (1.7)	107 (2.6)	<0.001
Urinary tract infection	2206 (2.9)	122 (3.7)	657 (3.0)	647 (2.6)	417 (2.8)	199 (3.1)	164 (4.0)	<0.001
Bleeding	8079 (10.8)	576 (17.6)	2654 (12.2)	2408 (9.7)	1347 (9.1)	621 (9.8)	473 (11.5)	<0.001
Readmission	8555 (11.4)	464 (14.2)	2517 (11.6)	2602 (10.5)	1658 (11.2)	757 (12.0)	557 (13.5)	<0.001
Mortality	965 (1.3)	90 (2–8)	328 (1.5)	262 (1.1)	145 (1.0)	76 (1.2)	64 (1.6)	<0.001

All values are reported as n (%). The *p* value notes any statistically significant variation in the specified unadjusted outcome of interest by the 6 BMI classifications.

TABLE 3.

Adjusted 30-day outcomes stratified by BMI category

Characteristic	Underweight OR (95% Cl)	Normal weight OR (95% Cl)	Overweight OR (95% Cl)	Obesity class I OR (95% Cl)	Obesity class II OR (95% Cl)	Obesity class III OR (95% Cl)
Surgical site infection (superficial, deep, organ)	0.98 (0.87–1.11)	Ref	1,28 (1.20–1.36)	1.5 (1.40–1.61]	1.86 (1.71–2.03)	2.06 (1.87–2.28)
Wound disruption	1.55 (1.15–2.09)	Ref	1.22 (1.01–1.47)	1.36 (1.10–1.68)	2.46 (1.95–3.12)	2.67 (2.05–3.47)
Organ space infection	1.09 (0.92–1.29)	Ref	1.10 (1.01–1.21)	1.11 (0.99–1.26)	1.08 (0.93–1.25)	1.19 (1.01–1.41)
Sepsis	1.02 (0.87–1.20)	Ref	1.04 (0.95–1.13)	1.12 (1.01–1.24)	1.29 (1.13–1.47)	1.49 (1.29–1.73)
Venous thromboembolism	1.19 (0.92–1.53)	Ref	1.35 (1.17–1.55)	1.39 (1.18–1.64)	1.68 (1.37–2.06)	1.28 (0.99–1.66)
Respiratory complication	1.29 (1.08–1.53)	Ref	0.99 (0.88–1.10)	1.03 (0.91–1.17)	1.19 (1.01–11.39)	1.38 (1.15–1.64)
Cardiac	0.99 (0.69–1.41)	Ref	0.93 (0.77–1.13)	0.90 (0,71–1.13)	1.08 (0,80–1.45)	0.77 (0.53–1.14)
Renal complication	0.70 (0.46–1.06)	Ref	1.26 (1.05–1.52)	1.34 (1.08–1.65)	1.75 (1.37–2.24)	2.35 (1.81–3.04)
Urinary tract infection	0.97 (0.79–1.19)	Ref	0.99 (0.88–1.11)	1.05 (0.92–1.19)	1,10 (0,93–1,30)	1.22 (1.01–1.47)
Bleeding	1.08 (0.9 7–1.2)	Ref	0.88 (0.82–0.93)	0.81 (0.75–0.87)	0.81 (0.73–0.90)	0.80 (0.71–0.89)
Readmi ssion	1.11 (0.99–1.25)	Ref	0.89 (0.84–0.95)	0.91 (0.84–0.97)	0.88 (0.80–0.97)	0.93 (0.83–1.04)
Mortality	1.34 (1.01–1.79)	Ref	0.75 (0.62–0.92)	0.77 (0.61–0.98)	0.96 (0.70–1.31)	1.01 (0.71–1.44)

Data were adjusted for sex, race, diabetes mellitus, smoking status, functional status, >10% weight loss within 6 months of surgery, history of chronic obstructive pulmonary disease, hypertension requiring medication, steroid use, albumin, procedure type, stoma creation, bowel preparation, surgical approach, ASA classification, indication for surgery, wound classification, BMI, age hospital length of stay, and work relative value unit.

Ref = reference.