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Body Mass Index Significantly Impacts Outcomes of Colorectal Surgery

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There are limited data regarding the association between body mass index (BMI) and colorectal surgery outcomes. We sought to evaluate the effect of BMI on short-term surgical outcomes in colon and rectal surgery patients in the United States. The American College of Surgeons National Surgery Quality Improvement Project database was used to identify all patients who underwent colon or rectal resection from 2005 to 2013. Multivariate regression analysis was used to assess the independent effect of BMI on outcomes. A total of 206,360 patients underwent colorectal resection during the study period. Of these, 3.2 per cent of patients were underweight (BMI < 18.5), 23.8 per cent patients were normal weight (18.5 £ BMI < 25), 26.5 per cent were overweight (25 £ BMI < 30), 25.2 per cent were obese (30 £ BMI < 40), and 5.3 per cent were morbidly obese (BMI ‡ 40). Underweight patients had longer length of stay (confidence interval: 2.70–3.49, P < 0.001) and higher mortality (adjusted odds ratio: 1.45, P < 0.01) compared with patients with a normal BMI. Morbidly obese patients had the highest overall morbidity rate compared with normal BMI patients (adjusted odds ratio: 1.53, confidence interval: 1.42–1.64, P < 0.01). BMI is associated with outcomes in colon and rectal surgery patients. Underweight and morbidly obese patients have a significantly increased risk of postsurgical complications compared with those with normal BMI.

ACCORDING TO THE World Health Organization, more than 1.9 billion adults were overweight in 2014 and over 600 million were obese.1 The obesity epidemic has affected surgical outcomes in many ways. Obesity is a risk factor for surgical complications, including increased intraoperative blood loss, surgical site infections, wound dehiscence, anastomotic leak,2, 3 longer operative times, and increased intraoperative and postoperative complication rates.4–6 Furthermore, obesity is associated with longer lengths of stay, and higher health-care costs.7, 8 Although there has been research documenting an association between increased body mass index (BMI) and poor outcomes after general surgery procedures, there have been no prior nationwide studies on the impact of BMI on colorectal procedures. The purpose of our study was to evaluate the impact of BMI on the 30-day outcomes in colorectal resections using a national database.

Materials and Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database is the first nationally validated, outcomes-based program designed for the purpose of improving surgical quality of care.9 The 2005 to 2013 ACS-NSQIP databases were retrospectively reviewed for all patients undergoing colorectal resections. Adult patients who had colorectal resection, defined by one of the Current Procedural Terminology codes: 44140 to 44160 (open colectomy), 44204 to 44212 (laparoscopic colectomy/ proctectomy),

45110 to 45114 (open proctectomy), and 45395 (laparoscopic abdominoperineal resection) were included in the study. Patients with a diagnosis of inflammatory bowel disease, end-stage renal disease, and disseminated cancer were excluded to avoid potential bias associated with unusually high complication rates in these populations.10, 11

Patients were stratified by BMI and divided into five groups: underweight (18.5 > BMI), normal BMI (18.5 # BMI < 25), overweight (25 # BMI < 30), obese (30 $ BMI > 40), and morbidly obese (BMI $ 40) in line with the BMI classification proposed by the NIH.12 Variables used in the analysis were provided by the NSQIP database and included patient demographics (age, sex, and race), American Society of Anesthesiologists (ASA) score, as well as patient comorbidities [congestive heart failure (CHF), moderate or severe dyspnea, ascites, diabetes mellitus requiring medication, chronic steroid use, history of severe chronic obstructive pulmonary disease (COPD), weight loss more than 10% in last six months, alcohol abuse, smoking status, history of myocardial infarction (MI), preoperative angina, preoperative pneumonia, preoperative acute renal failure, and hypertension requiring medication].

The outcomes evaluated were overall 30-day morbidity and mortality, superficial surgical site infection (SSI), organ space SSI, deep incisional SSI, wound disruption, deep vein thrombosis (DVT), cardiac arrest requiring cardiopulmonary resuscitation, pneumonia, unplanned intubation, ventilator dependency more than 48 hours, urinary tract infection, MI, acute renal failure, and hospital length of stay more than 30 days. Outcomes were evaluated based on the predefined BMI groups. Risk-adjusted analysis was performed to identify associations between BMI and postoperative complications after colorectal surgery.

Statistical analysis was performed with SPSS_ software, Version 22 (SPSS Inc., Chicago, IL). Logistic regression analysis was used to estimate the association between BMI and each outcome, including 30-day mortality and all of the considered postoperative complications. P values less than 0.05 were considered statistically significant. For each outcome, the adjusted odds ratio (AOR) with a 95 per cent confidence interval (CI) was calculated and reported to estimate the relative risk associated with BMI. Adjustments were made for hypertension, diabetes mellitus, dyspnea, preoperative pneumonia, preoperative MI, cardiac angina, emergent admission, ASA score more than 2, steroid use, COPD, weight loss, alcohol abuse, smoke, ascites, CHF, age, sex, and race.

Results

A total of 206,360 cases were analyzed; 6,645 (3.2%) patients were underweight, 49,150 (23.8%) patients had a normal BMI range, 54,712 (26.5%) were overweight, 51,963 (25.2%) were obese, and 10,865 (5.3%) were morbidly obese. Patient demographics and comorbidities by BMI group are listed in Table 1. The mean operation time was increased from 153 ± 97 minutes in underweight patients to 191 ± 104 minutes in morbidly obese patients ($P < 0.05$). The mean length of stay was 9 ± 12, 13 ± 30, 9 ± 10, 9 ± 11, and 11 ± 13 for normal BMI, underweight, overweight, obese, and morbidly obese patients, respectively, ($P < 0.05$). The adjusted mean difference in length of stay between underweight patients and patients with a normal BMI was significant (CI: 2.70–3.49, $P < 0.001$). Also, mortality was higher in the underweight patients' group (AOR: 1.45, $P < 0.01$) compared to patients with a normal BMI (Table 2).

The risk-adjusted analysis for postsurgical complications associated with BMI is reported in Tables 2, 3, 4, and 5 for all the groups. Underweight patients were more likely to have prolonged hospitalization (AOR: 1.29, CI: 1.11–1.51, P 4 0.01), ventilator dependency (AOR: 1.28, CI: 1.11–1.48, P 4 0.01), and urinary tract infection (AOR: 1.27, CI: 1.08–1.51, P 4 0.04) when compared to normal BMI patients after adjustment with comorbid conditions (Table 2).

TABLE 1. *Demographics of Patients Who Underwent Colon and Rectal Resections in the United States, 2005 to 2013*

Patients' Characteristics		Underweight (n = 6,645)	Normal BMI (n = 49,150)	Overweight (n = 54,712)	Obese (n = 51,963)	Morbidly Obese (n = 10,865)
Age	Mean, year	59 ± 19	61 ± 17	62 ± 14	60 ± 13	58 ± 13
	Median, year	62	64	64	62	59
Sex	Female (%)	67.8	59.1	44.6	50.3	63.8
Race	White (%)	74.8	77.9	91.3	79.1	76.4
	African–American (%)	11	8	8.2	10.6	14.7
	Asian (%)	5.1	4.4	2.4	1.1	0.8
	Other (%)	9.2	9.6	9.7	9.1	8.1
Admission	Emergency (%)	23.4	16.7	14.2	13.8	17.7
Other variables	ASA score >2 (%)	98.1	96.1	96.7	98.3	95.5
	Hypertension (%)	34.8	39.1	50.2	60.1	67.1
	Smoke (%)	30.3	21.4	17.2	16.2	15
	Weight loss (%)	21.4	8.9	3.8	2.6	1.9
	Dyspnea (%)	11.4	8.5	8.7	11.7	19.4
	Severe COPD (%)	11.2	6.1	5.3	6.3	9
	Diabetes mellitus (%)	6.2	7.6	13	22.1	33.3
	Alcohol abuse (%)	2.4	2.2	2.3	2	1
	Steroid use (%)	15.3	10.3	7	6.4	6
	Ascites (%)	3.2	2	1.5	1.3	1.5
	CHF (%)	1.7	1.4	1.2	1.5	2.5
	Myocardial infarction (%)	0.7	0.5	0.6	0.6	0.4
	Preoperative angina (%)	0.3	0.4	0.5	0.6	0.6
	Acute renal failure (%)	0.9	0.7	0.8	1	2.1
	Preoperative pneumonia (%)	1.2	0.6	0.5	0.5	0.9

TABLE 2. *Risk-adjusted Outcomes of Underweight* Versus *Normal BMI Colon and Rectal Surgery Patients*

Outcome	Normal BMI 18.5 ≤ BMI <25 (n = 49,150)	Underweight BMI <18.5 (n = 6,645)	AOR; 95 Per Cent CI	*P* Value
30-day mortality	4.4%	8.2%	1.45; 1.24–1.69	<0.01
Overall morbidity	22.8%	29.7%	1.14; 1.05–1.24	0.002
Hospitalization >30 days	3.5%	6.5%	1.29; 1.11–1.51	0.01
Acute renal failure	0.7%	0.9%	1.09; 0.75–1.56	NS
Deep incisional SSI	1.1%	1.7%	1.44; 1.10–1.89	NS
Ventilator dependency	4.8%	8.47%	1.28; 1.11–1.48	0.01
Cardiac arrest	0.9%	1.7%	1.27; 0.94–1.71	NS
DVT	1.6%	2.4%	0.98; 0.76–1.25	NS
Urinary tract infection	3.7%	4.7%	1.27; 1.08–1.51	0.04
Unplanned intubation	3%	5.3%	1.27; 1.07–1.50	0.05
Myocardial infarction	0.8%	0.8%	0.88; 0.58–1.31	NS
Wound disruption	1.3%	2%	0.88; 0.83–1.43	NS
Organ space SSI	4.5%	5.6%	0.98; 0.83–1.16	NS
Superficial SSI	5.6%	4.8%	0.82; 0.70–0.96	0.01

NS, nonsignificant.

TABLE 3. *Risk-adjusted Morbidity and Mortality of Overweight Colon and Rectal Surgery Patients*

Complications	Patients with 18.5 ≤ BMI <25 (49,150)	Patients with 25 ≤ BMI <30 (54,712)	*P* Value	AOR	95 Per Cent CI
Inhospital mortality	4.4%	3.2%	<0.001	0.81	0.73–0.90
Overall morbidity	22.8%	22.4%	0.01	1.05	1.01–1.10
Acute renal failure	0.7%	0.8%	0.10	1.17	0.96–1.42
Deep incisional SSI	1.1%	1.4%	<0.001	1.33	1.14–1.55
Superficial SSI	5.6%	6.9%	<0.001	1.30	1.22–1.40
DVT	1.6%	1.5%	0.97	0.99	0.87–1.14
Ventilator dependency	4.8%	4.3%	0.72	1.01	0.93–1.10
Organ space SSI	4.5%	4.3%	0.20	1.05	0.97–1.15
Myocardial infarction	0.8%	0.7%	0.03	0.79	0.64–0.98
Hospitalization >30 days	3.5%	2.9%	0.08	0.91	0.83–1.01
Wound disruption	680 (1.3%)	842 (1.5%)	0.02	1.18	1.02–1.36
Urinary tract infection	1816 (3.7%)	1694 (3%)	0.01	0.88	0.80–0.97
Cardiac arrest	446 (0.9%)	402 (0.7%)	0.04	0.75	0.62–3.89
Unplanned intubation	1523 (3%)	1423 (2.6%)	0.03	0.89	0.80–0.99

Overweight patients were more likely to have deep incisional SSI (AOR: 1.33, CI: 1.14–1.55, P < 0.001), superficial SSI (AOR: 1.30, CI: 1.22–1.40, P < 0.001), and wound disruption (AOR: 1.18, CI: 1.02–1.36, P 4 0.02) (Table 3). Obese patients were more likely to have deep incisional SSI (AOR: 1.83, CI: 1.57–2.13, P < 0.0001), superficial SSI (AOR: 1.72, CI: 1.60–1.84, P < 0.0001), and wound disruption (AOR: 1.62, CI: 1.41–1.87, P < 0.001) (Table 4). Morbidly obese patients were more likely to have deep incisional SSI (AOR: 2.63, CI: 2.12–3.26, P < 0.0001), superficial SSI (AOR: 2.27, CI: 2.04–2.53, P < 0.0001), and wound disruption (AOR: 2.30, CI: 1.88–2.83, P < 0.0001). Also, morbidly obese patients had the highest overall morbidity rate compared to normal BMI patients (AOR: 1.53, CI: 1.42–1.64, P < 0.01) (Table 5).

Discussion

The number of obese adults continues to increase worldwide. In the United States, more than one-third of adults and one-sixth of young people are obese.1 Previous studies have evaluated the association of BMI and perioperative outcomes in the general surgery population; however, to our knowledge, this is the first study using ACS-NSQIP databases to evaluate the association of BMI on perioperative outcomes after colorectal resections.

Our study identified that increased BMI has a statistically significant association with increased operative time in colorectal procedures. This finding agrees with previous studies that were done on a smaller scale.13 Therefore, it is not surprising that increased BMI was also associated with more wound complications as prolonged operative time has been shown to be a predictor of postoperative wound infections.14–17 Overall morbidity and postsurgical complications were highest in the morbidly obese patients, which is consistent with some published literature,13 however, there are other retrospective studies that dispute this finding.18 Conversely, we found that rates of DVT were lower in the morbidly obese group. Obesity is a well-known risk factor for venous thromboembolism (VTE),34 and although exact reason for the paradoxical decrease in rates of VTE we observed in morbidly obese patients is unknown, it may be a result of aggressive prophylactic anticoagulation in this high-risk population, ideal weight-based dosing of chemoprophylaxis, or preoperative/post discharge administration of chemoprophylaxis.35

TABLE 4. *Risk-adjusted Morbidity and Mortality of Obese Colon and Rectal Surgery Patients*

Complications	Patients with 18.5 ≤ BMI < 25 (49,150)	Patients with 30 ≤ BMI < 40 (51,963)	*P* Value	AOR	95 Per Cent CI
Inhospital mortality	4.4%	3.1%	<0.001	0.78	0.70–0.87
Overall morbidity	22.8%	25.6%	<0.001	1.24	1.18–1.29
Acute renal failure	0.7%	1.2%	<0.001	1.50	1.24–1.82
Deep incisional SSI	0.6%	3%	<0.0001	1.83	1.57–2.13
Wound disruption	1.3%	2%	<0.001	1.62	1.41–1.87
Superficial SSI	5.6%	9%	<0.0001	1.72	1.60–1.84
DVT	1.6%	1.7%	0.17	1.10	0.95–1.26
Ventilator dependency	4.8%	5%	0.04	1.09	1.00–1.20
Urinary tract infection	3.7%	3.5%	0.88	1.00	0.91–1.10
Unplanned intubation	3%	2.6%	0.001	0.82	0.74–0.92
Hospitalization >30 days	3.5%	3.2%	0.26	0.94	0.85–1.04
Myocardial infarction	0.8%	0.6%	0.79	0.81	0.65–1.02
Organ space SSI	24.5%	4.5%	0.11	1.07	0.98–1.18
Cardiac arrest	0.9%	0.7%	<0.001	0.67	0.55–0.83

TABLE 5. *Risk-adjusted Morbidity and Mortality of Extremely Obese Colon and Rectal Surgery Patients*

Complications	Patients with 18.5 ≤ BMI <25 (49,150)	Patients with BMI ≥ 40 (10,865)	*P* Value	AOR	95 Per Cent CI
Inhospital mortality	4.4%	4.6%	0.04	0.77	0.65–0.92
Overall morbidity	22.8%	34.6%	<0.001	1.53	1.42–1.64
Acute renal failure	0.7%	2.3%	<0.001	1.76	1.34–2.30
Deep incisional SSI	1.1%	3.1%	<0.0001	2.63	2.12–3.26
Wound disruption	1.3%	3.1%	<0.0001	2.30	1.88–2.83
Superficial SSI	5.6%	12.6%	<0.001	2.27	2.04–2.53
DVT	1.6%	1.8%	0.90	0.80	0.63–1.03
Ventilator dependency	4.8%	10.5%	<0.0001	1.35	1.18–1.54
Urinary tract infection	3.7%	4.9%	0.001	1.30	1.12–1.51
Unplanned intubation	3%	3.7%	0.10	0.86	0.72–1.03
Hospitalization >30 days	2.9%	5.8%	<0.001	1.32	1.14–1.52
Myocardial infarction	0.8%	0.5%	0.056	0.66	0.43–1.01
Organ space SSI	4.5%	5.4%	0.005	1.23	1.06–1.43
Cardiac arrest	0.9%	1.2%	0.42	0.88	0.64–1.20

Our study demonstrated that, after risk adjustment, underweight patients (BMI < 18) had the highest rates of 30-day mortality and length of stay. These findings reinforce the results of previous smaller studies.19, 20 Underweight patients are often malnourished with significant nutritional deficiencies that can lead to problems with wound healing and anastomotic integrity. 21–24 Furthermore, a patient's low BMI can be a result of disease-related cachexia or overall poor functional status and the inability to care for oneself.26 The negative effects of malnutrition may be particularly pronounced in the elderly where sarcopenia has been shown to be associated with poor outcomes.27, 28 Previous studies have shown improved outcomes in patients who underwent nutritional optimization before they underwent elective surgery.29, 30 Given this information, providers should attempt to nutritionally optimize patients and eliminate any nutritional deficiencies before undergoing elective colorectal surgery.

The mortality rate in our study decreased with increasing BMI, but in patients with a BMI greater than 40, a slight increase in mortality rate was noticed. This finding of decreasing postoperative mortality with increased BMI (excluding BMI > 40) has been previously termed "the obesity paradox" and has been demonstrated in several previous studies.31 The obesity paradox, or reverse epidemiology, suggests that despite the fact that obesity is recognized as a major risk factor in the development of cardiovascular diseases and diabetes, a higher BMI may be associated with a lower mortality and a better outcome in several chronic diseases and health circumstances. One theory to explain this phenomenon is that patients in the nonobese BMI category may actually include those with disease-related weight loss and poor overall

nutrition.32, 33, 36 We attempt to control for this phenomenon by including any weight loss >10 per cent of total body weight within six months of the operation into our regression model. Another theory for this phenomenon is that patients with a nonobese BMI may represent a group of unhealthy or unfit lean patients; and it is these factors that contribute more to their outcomes.37

The main limitation is the retrospective nature of our study that makes firm conclusions difficult. Because this study is not a randomized study, it is subject to selection bias. Coding errors are another concern because discharge data were used for data gathering.25 In addition, although we showed BMI was associated a decreased risk of VTE in morbidly obese patients, information regarding VTE prophylaxis is lacking within the ACS-NSQIP database and, therefore, we are unable to evaluate the type, timing, and dosing of chemoprophylaxis in these patients.

Conclusion

BMI has been previously shown to significantly affect the outcomes of surgery patients and the present study indicates that this association between BMI and surgical outcomes also exists in colon and rectal surgery as well. Underweight and morbidly obese patients have an associated significant increase in postsurgical morbidity and complications compared to those with normal BMI.

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