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Obesity, outcomes and quality of care: body mass index increases the risk of wound-related complications in colon cancer surgery

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Abstract

BACKGROUND: Obese patients may face higher complication rates during surgical treatment of colon cancer. The aim of this study was to measure this effect at a high-volume tertiary care center.

METHODS: All patients with colon cancer treated surgically at a single center from 2004 through 2011 were reviewed. Multivariate regression assessed relationships of complications and stay outcomes with body mass index (BMI) controlling for age, gender, comorbidity score, surgical approach, and history of smoking.

RESULTS: In 1,048 included patients, BMI was a predictor of several complications in both laparoscopic and open procedures. For every increase of BMI by one World Health Organization category, the odds ratios were 1.61 ($P < .001$) for wound infection and 1.54 ($P < .001$) for slow healing. Additionally, right colectomies had an odds ratio of 3.23 ($P = .017$) for wound dehiscence. No further associations with BMI were found.

CONCLUSIONS: BMI was incrementally associated with wound-related complications, illustrating how the proliferation of obesity relates to a growing risk for surgical complications. As the surgical community strives to improve the quality of care, patient-controllable factors will play an increasingly important role in cost containment and quality improvement.

Obesity is still on the rise in the Western world and continues to be a growing challenge for the surgical community. In the United States, the proportion of obese adults has steadily increased over the past 50 years. In 1962, 13.4% of adults were classified as obese,[1] and now, 35.7% of adults in the United States are obese according to the latest data from the Centers for Disease Control and Prevention.[2] Meanwhile, hospitals and surgeons are striving to improve their outcomes and reduce their complication rates. The Surgical Care Improvement Project (SCIP) measures and guidelines, meant to improve the

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quality of care,[3] as well as the National Surgical Quality Improvement Program (NSQIP) surveying are now commonplace.[4,5]

Hospitals and surgeons are judged on their performance. However, obesity, which is a patient-controllable risk factor, is beyond the control of the medical community but plays an important role in surgical outcomes. Obesity is suspected to increase resection difficulty[6] and to be predictive of a complicated postoperative course,[7,8] although this premise has also been disputed.[9–11]

Colon cancer is affected by obesity as an etiologic risk factor,[12–14] but it may also be a potential complicating factor during surgical treatment. The higher prevalence of obesity combined with the abdominal location and the relatively advanced median age of affected patients[15] may be a triad that exacerbates the risk for obesity-related complications during operative management of colon cancer.

More than 100,000 new cases of colon cancer are diagnosed each year in the United States,[15] and surgical resection is indicated for the vast majority of these. Meanwhile, obesity rates are reaching new heights, yet current literature fails to provide unequivocal, reliable evidence on links between obesity and colon cancer surgery complications. Even scarcer is evidence concerning these potential links at centers that have been compliant with SCIP guidelines and are NSQIP implementers.

Body mass index (BMI) is a widely used numeric expression of body habitus using patient weight in relationship to the square of height. It is closely related to percentage body fat and total body fat[16] and is the measure used to define a threshold value for obesity. In this study, therefore, we measured the effect of BMI on operative outcomes and the risk for postoperative complications at a center that has been among the early adopters of NSQIP in the private sector.[17]

Methods

Patients

All patients surgically treated for colonic adenocarcinoma at Massachusetts General Hospital from 2004 through 2011 were included. Data on all cases were gathered from medical records and hospital data repositories as defined by an institutional review board–approved protocol. Patients without known BMIs were the only ones to be excluded from further analysis.

Perioperative BMI was determined using several sources, including the operative anesthesia record, preadmission history and physical examination, preoperative anesthesia examination, and physical examination by the operating surgeon. In case of discrepancies, patient history and outside records were also reviewed to identify the most accurate measurement.

Links were assessed between BMI and outcomes, including duration of surgery, conversion rate, duration of stay, and postoperative complications. Most complications were actively reported because of our center's enrollment in the American College of Surgeons NSQIP throughout the time span of this research. Some complications were further specified in our database for the sake of this research according to their clinical magnitude: Wound infection was any culture-ascertained infection or infectious redness or discharge located at the operative wound severe enough to necessitate targeted attention, including antibiotic treatment. Slow healing included any operative wound that was the independent cause of a longer stay or led to targeted and unplanned clinical attention, not limited to infectious origins. Bowel motility delay was any return of bowel function that took substantially longer than initially expected and necessitated an unplanned intervention, such as the (re)placement of a nasogastric tube or initiation of parenteral nutrition. Fascial dehiscence, bowel obstructions, anastomotic leaks, bowel perforations, and colitis were all empirically established, usually ascertained through imaging or appropriate lab work.

BMI was categorized according to the classification defined by the World Health Organization in 2000[18]: these groups were underweight (<18.5 kg/m^2), normal (18.5 to 24.9 kg/m^2), preobese (25 to 29.9 kg/m^2), and obese grades I (30 to 34.99 kg/m^2), II (35 to 39.99 kg/m^2), and III (>40 kg/m^2). After direct association measures, BMI was also controlled for possible confounders, including baseline characteristics that could influence its link with outcomes. These were age, race, gender, comorbidity scores, and smoking status. Baseline characteristics found to significantly influence BMI were considered in multivariate models. For complications found to be significantly associated with BMI, a further detailed breakdown was made on the basis of resection region (right colectomy, left colectomy, or sigmoid or low anterior), admission type (urgent vs elective), and surgical approach (open vs laparoscopic).

Statistical analysis

Statistical significance was defined as a P value $\leq .05$. Statistical analysis was performed using SPSS version 20.0 (IBM, Armonk, NY). Bivariate Pearson's correlations were measured between BMI and baseline characteristics. Univariate analysis was used to assess the statistical significance of differences between groups using chi-square tests for nominal variables and analysis of variance for continuous numbers. In multivariate analysis, binary logistic regression was used for dichotomous outcomes, while linear regression was used for continuous outcomes. The most appropriate multivariate model in terms of included covariates was selected on the basis of model fit (R^2).

Results

Of the 1,071 patients operated on for colon cancer in the defined time interval, 1,048 had reliable information to

determine BMI. The 23 excluded patients lacked height determination when it was deemed impractical or irrelevant to the patient's care at admission (eg, severe scoliosis, wheelchair bound, emergency protocol). These patients did not differ substantially from the included patients in any aspect.

Baseline characteristics

The baseline characteristics and their correlations with BMI are shown in Table 1. Patient age was inversely correlated with BMI ($r = -.161$, $P < .001$). There was no association with race, while there was a positive correlation with male gender ($r = .118$, $P < .001$). The Charlson comorbidity score was not associated with BMI, while American Society of Anesthesiologists (ASA) score was weakly but significantly correlated ($r = .080$, $P = .01$). BMI was also inversely correlated with a history of smoking ($r = -.092$, $P = .003$), but this was not found for current smoking. Last, there was no association between surgical approach and weight ($P = .088$).

Complications

Overall complication rates are shown in Table 2; wound infection, slow wound healing, and fascial dehiscence were associated with BMI ($P < .001$ for all). Other complications, conversion risk, as well as 30-day reoperation, readmission, and death rates were not related to BMI.

Logistic regression was used to calculate the overall odds ratios (OR) for the measured complications between successive BMI intervals. These are shown in a forest plot in Fig. 1. For every increase in BMI category, the odds of having a wound infection within 30 days postoperatively increased by an OR of 1.61 ($P < .001$), slow healing had an OR of 1.54 ($P < .001$), and fascial dehiscence had an OR of 2.87 ($P = .001$).

These findings were subsequently explored further by reviewing the associations for major resection regions and for emergency and elective surgeries. Table 3 displays these results. Left-sided colectomies were at particular risk for wound infections (OR, 2.15; $P < .001$) and slow healing (OR, 2.16; $P < .001$), whereas fascial dehiscence appeared to be strongly associated with right-sided colectomies (OR, 3.23; $P = .017$). Outcomes were similar in the overall population and the elective-only population. Urgent resections were not significantly associated with the complications, but trends appeared to be comparable. The lack of statistical significance may be the effect of the small sample size, as they accounted for only about 9% of our population.

Multivariate analysis

The 3 complications found to be significantly related to BMI were included in binary multivariate logistic regression accounting for covariates and reviewing the OR for unit of BMI as well as for category increases of BMI. These outcomes are shown in Table 4; variations in OR for specific approaches were largely within the immediate range of the original values. The only clearly added risk factor in open procedures was an increase in OR for fascial

Table 1 Baseline characteristics and their correlation with BMI

Characteristic	Value		
BMI (kg/m^2), mean (range ± SD)	27.6 (14.7–59.5 ± 6.35)		
Underweight (<18.5)	3.4%		
Healthy (18.5–24.9)	34.6%		
Preobese (25.0–29.9)	33.2%		
Class I obesity (30–34.9)	17.1%		
Class II obesity (35–39.9)	6.8%		
Class III obesity (>40)	4.9%		
		BMI correlation	*P*
Age (y), mean (range ± SD)	66.6 (26–97 ± 14)	−.161	<.001
Race (Caucasian)	89.8%	NS	.376
Gender (male)	51.2%	.118	<.001
ASA score, mean (range ± SD)	2.36 (2–4 ± .6)	.080	.010
Charlson Score (range ± SD)	3.19 (2–12 ± 1.7)	NS	.77
Current smoking	12%	NS	.26
History of smoking	40.7%	−.092	.003
Technique		NS	.088
Open	69%		
Laparoscopic	18.4%		
Laparoscopic or hand assisted	12.6%		

ASA = American Society of Anesthesiologists; BMI = body mass index.

Table 2 Complication rates per BMI category

Complication	BMI categories						P
	Underweight (n = 36)	Normal (n = 363)	Preobese (n = 326)	Obese I (n = 179)	Obese II (n = 71)	Obese III (n = 51)	
Conversion, n/n laparoscopic	0/3 (0%)	10/68 (14.7%)	7/69 (10.1%)	6/36 (16.7%)	1/11 (8.3%)	2/5 (40%)	.44
Surgery duration (min)	107 ± 58	136 ± 86	142 ± 85	140 ± 78	129 ± 58	151 ± 77	.22
Wound infection	0 (0%)	12 (3.3%)	22 (6.3%)	21 (11.7%)	12 (16.9%)	7 (11.7%)	<.001
Slow wound healing	0 (0%)	18 (5%)	26 (7.5%)	24 (13.4%)	11 (15.5%)	10 (19.6%)	<.001
Fascial dehiscence	0 (0%)	1 (.3%)	1 (.3%)	2 (1.1%)	0 (0%)	3 (5.9%)	<.001
Bowel motility delay	2 (5.6%)	37 (10.2%)	41 (11.8%)	22 (12.3%)	5 (7%)	3 (5.9%)	.51
Bowel obstruction	0 (0%)	4 (1.1%)	3 (.9%)	3 (1.7%)	1 (1.4%)	0 (0%)	.87
Bowel perforation	0 (0%)	2 (.6%)	2 (.6%)	0 (0%)	0 (0%)	0 (0%)	.86
Colitis	0 (0%)	5 (1.4%)	4 (1.1%)	1 (.6%)	0 (0%)	1 (2%)	.80
Sepsis	1 (2.8%)	6 (1.7%)	3 (.9%)	1 (.6%)	2 (2.8%)	2 (3.9%)	.35
GI bleed	0 (0%)	4 (1.1%)	0 (0%)	2 (1.1%)	0 (0%)	0 (0%)	.34
Anastomotic leak	1 (2.8%)	6 (1.7%)	7 (2%)	2 (1.1%)	3 (4.2%)	1 (2%)	.71
Stay duration (d)	6.33 ± 4.9	6.45 ± 5.3	6.58 ± 5.5	5.65 ± 4.5	5.92 ± 4.1	9.9 ± 18.2	.20
In-stay death	1 (2.8%)	5 (1.4%)	2 (.6%)	1 (.6%)	1 (1.4%)	2 (3.9%)	.30
30-d reoperation	1 (2.8%)	7 (1.9%)	9 (2.6%)	7 (3.9%)	2 (2.8%)	2 (3.9%)	.83
30-d readmission	2 (5.6%)	28 (7.7%)	27 (7.8%)	12 (6.7%)	6 (8.5%)	7 (13.7%)	.69

BMI = body mass index; GI = gastrointestinal.

dehiscence ($P = .009$). In laparoscopic procedures, the OR for wound infection was surprisingly slightly higher than they for open procedures. Slow wound healing was borderline significant ($P = .056$) for continuously approached BMI, while BMI intervals still were significantly associated ($P = .043$). Fascial dehiscence after laparoscopic procedures was not associated with BMI divided over categories ($P = .99$), while still having a relative increase in odds of 1.344 ($P = .045$) for every increase of BMI by 1 unit. All other complications were nonsignificant

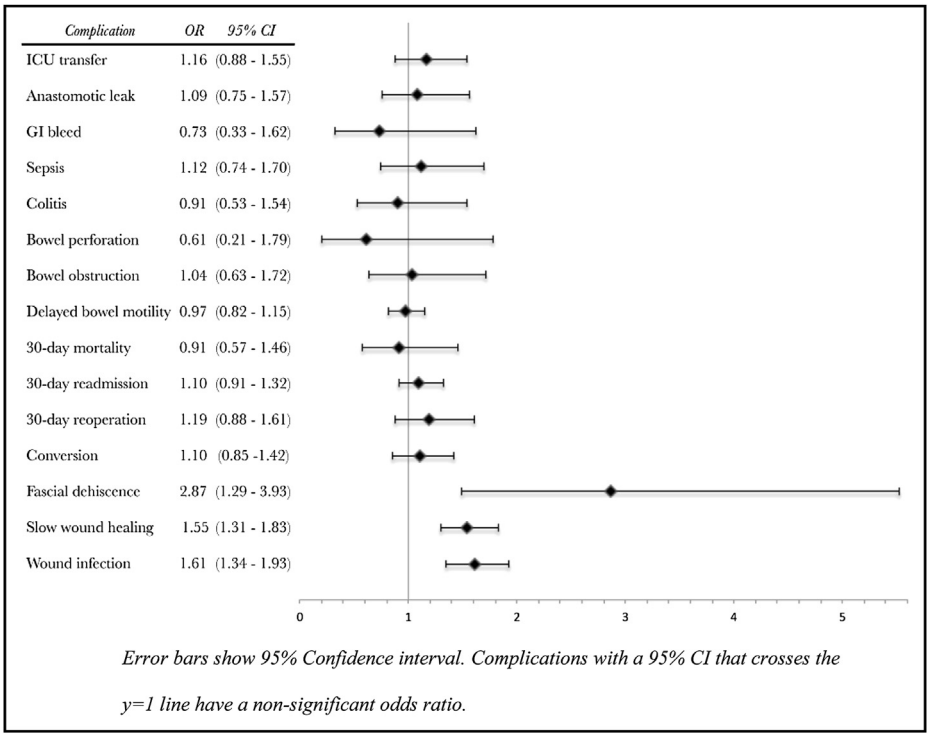

Figure 1 Forest plot displaying the odds ratio between 2 successive World Health Organization BMI categories for all major abdominal complications in the general colon cancer population. Error bars show 95% confidence intervals (CIs). Complications with 95% CIs that cross the $y = 1$ line have nonsignificant odds ratios. GI = gastrointestinal; ICU = intensive care unit.

Table 3 Breakdown of complication rates by region and admission type

	Overall (n = 1,047)		Left (n = 127)		Right (n = 557)		Sigmoid/LAR (n = 238)		Elective (n = 937)		Urgent (n = 97)	
Complication	OR	*P*	OR	*P*	OR	*P*	OR	*P*	OR	*P*	OR	*P*
Wound infection	1.61	<.001	2.15	.001	1.53	.001	1.40	.1	1.61	<.001	NS	.112
Slow wound healing	1.54	<.001	2.16	.001	1.49	.001	1.58	.012	1.57	<.001	NS	.56
Fascial dehiscence	2.87	.001	NS	.99	3.23	.017	NS	.53	2.95	.001	*	*

LAR = low anterior resection; OR = odds ratio.
*No cases with the analyzed complication in this category; regression impossible.

regardless of the set of covariates used and are therefore omitted from Table 4 for legibility purposes.

Comments

The surgical community strives to improve patient care by implementing guidelines that ensure risks and preventable complications are identified, kept at a minimum, and avoided in a systematic way. Over the past 2 decades, a fast growing trend of standardization and benchmarking of quality of care has led to the implementation of increasingly detailed and demanding guidelines in the United States. After the successive introductions of (Veterans Administration) NSQIP in 1994[19] and American College of Surgeons NSQIP in 2004,[5] as well as Surgical Infection Prevention (SIP) in 2002 and SCIP in 2006,[3] these universal standards have provided very successful tools to track and tackle many perioperative issues.

However, it is important to keep in mind that many factors leading to complications are often simply out of the medical community's immediate control. Obesity is one of these patient-controllable factors, and it can be a significant challenge in virtually any medical intervention. Although the link between obesity and difficulties in abdominal surgery is intuitive, both its effects and their magnitude are disputed. Reports on this subject have been conflicting, and it remains to be conclusively established what the risks are in more specific cases. The aim of this study, therefore, was to provide an answer on the role of obesity in the surgical treatment of colon cancer by establishing the relationship between BMI and postoperative complications and outcomes.

The first step was to identify any factors that could influence these relationships. All relevant baseline characteristics were therefore examined. We noted that our BMI distribution was below the national average, which is a finding that matches the differences in state averages as reported by the Centers for Disease Control and Prevention.[20] Because we use methods that are not influenced by the distribution of obesity in the population, this should not be an issue in the interpretation of our findings. We have also noted that BMI had an inverse correlation with age. Even though this was explainable through the physiology of aging,[21] older age is also possibly related to higher risks of complications, so it was important to verify for any potential confounding effect in multivariate analysis. Differences in BMI between genders were statistically significant and match reports that describe a higher median BMI in men in the United States.[2] It was therefore reasonable to account for this difference in multivariate models as well. ASA score differences were likely an expression of the relationship between body habitus and several comorbid diseases that could raise this score. Last, the negative

Table 4 Multivariate models, elective cases only

	BMI categories		BMI continuous	
Complication	*P*	OR	*P*	OR
Wound infection†	<.001	1.60	<.001	1.09
Open only†,‡	<.001	1.57	<.001	1.09
Laparoscopic only	.029	1.87	.025	1.13
Slow wound healing‡	<.001	1.53	<.001	1.08
Open only†,‡	<.001	1.54	<.001	1.08
Laparoscopic only*	.043	1.71	.056	1.10
Fascial dehiscence	.001	2.26	.001	1.14
Open only	.009	3.00	.001	1.19
Laparoscopic only	.99	NS	.045	1.34

Rows show the odds ratio for the listed complication for every single upward step in BMI category (left) or increase of 1 kg/m^2 in BMI (right).
*Outcomes corrected for age.
†Outcomes corrected for gender.
‡Outcomes corrected for history of smoking.

correlation between BMI and former smoking could be explained by coinciding changes in lifestyle, which led both to weight loss and the decision to stop smoking. The subsequently confirmed relationship between former smoking in multivariate models as a predictor of impaired wound healing issues associated with BMI is quite possibly an expression of the known accelerating effect of long-term cigarette smoking on skin aging,[22] which in turn contributes to the impaired healing.

Our analysis demonstrated that increases in BMI do not correlate with many complications and do not significantly contribute to increases in length of stay, surgery duration, conversion, readmission, reoperation, or death rates. They are, however, a clear risk factor for several wound-related complications. Regional breakdown of procedures demonstrated that left-sided resections were at particular risk for wound infections and slow healing and that fascial dehiscence was strongly related to right-sided resections, although there is no apparent explanation for these regional differences. In addition, our multivariate models show that the increases in relative odds of complications were independent of age and comorbidity. Findings were similar after urgent procedures were removed from the sample and regardless of surgical technique used. The findings for laparoscopic resections did, however, have larger *P* values. This is likely to be the result of a smaller sample size, rather than the expression of a weaker association between BMI and the aforementioned complications in laparoscopic cases.

This illustrates a limitation of our study: even with a set of over 1,000 patients, we still had inherent difficulties identifying the analyzed trends in certain subsets, such as certain approaches, procedures, or urgent cases. This also partially impaired the use of multivariate models on those smaller groups. This same issue may make it more difficult to find statistically significant findings for complications that did not occur frequently. However, as illustrated by the fascial dehiscence example, which was highly significantly linked with BMI with only 7 overall occurrences, this does not need to be a limitation except for the inherent difficulty of performing subset analyses for those low-incidence findings.

The findings of this study are an addition to a widely addressed topic. Many reports have described related outcomes, with very different results: some have used national (Veterans Administration) NSQIP data to identify risk factors for postoperative morbidity but did not identify BMI as a risk factor.[23] A previous study performed at our center compared only obese with nonobese patients with colonic adenocarcinoma and was not able to find the association using a smaller sample size.[11] Other studies identified links between BMI and overall complications in surgical colon cancer patients using the NSQIP database, but only for those over 65 years of age,[24] or identified a higher risk for wound infection and dehiscence, but only for morbidly obese patients.[25]

Our extensive analysis of a large consecutive set of patients with colon cancer also enabled us to demonstrate that the relative odds of wound-related complications tended to incrementally increase throughout weight categories. This also means that preobese people are at an increased risk compared with people with healthy BMIs. There is a significant potential for risk reduction to be found in every category above ideal weight. It would have been very interesting to assess if the underweight group was also at higher risk for any of the indexed complications. However, our sample was too small to produce meaningful results. This may be an interesting topic for further research.

Our findings are especially interesting considering that both the SCIP and NSQIP efforts put a strong emphasis on surgical site infections, and our center has been among the early implementers of these guidelines, with the aim of improving surgical outcomes servicewide.[17] This shows that even after significant and successful efforts to achieve reductions in complication rates, factors outside the grasp of the surgical community can influence these outcomes. Last, even though obesity may be outside the realm of the surgeon or the hospital, it should not be ignored and presents significant problems when trying to improve morbidity or mortality rates.

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