Impact of Obesity on Surgical Site Infection in Colon and Rectal Surgery

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ABSTRACT

Obesity affects over 30% of the United States population. Over the past 10 years, there has been increased recognition of the prevalence of obesity and its contribution to worse outcomes among medical and surgical patients. In particular, obesity has been validated as a risk factor for surgical site infection (SSI) among patients undergoing major abdominal surgery with some reports demonstrating an increased risk of SSI as high as sixty percent (60%) among obese patients. For patients undergoing elective colon and rectal surgery, a higher incidence of SSI (up to 45%) has been reported in comparison to outcomes of other surgical procedures. Obesity, as well as numerous other variables, have been implicated as a potential source for this increased incidence. Although the pathophysiology of obesity-related SSI has been suggested (decreased wound oxygen tension, impaired tissue antibiotic penetration, altered immune function, etc.), the true effect of obesity has not been clearly described. The purpose of this review is to examine the growing epidemic of obesity and its specific impact on SSI for both general and colorectal surgical patients. The proposed mechanisms for why obesity increases the risk of SSI will be briefly discussed, as well.

KEYWORDS: Obesity, surgical site infection, colectomy, colorectal surgery

Objectives: On completion of this article, the reader should recognize the growing epidemic of obesity within the United States and its impact on surgical outcomes, in particular surgical site infection. The reader also should recognize potential mechanisms for obesity-related SSI.

In the past 10 years, considerable attention has been directed toward two major public health care concerns. The first public health concern is the growing epidemic of obesity [body mass index (BMI) ≥ 30 kg/m²] among adults and children in the United States. The prevalence of obesity has increased significantly over the past 30 years and obesity currently represents a substantial health problem affecting over 30% of the United

States population.¹ Further consideration to the fact that many non-obese Americans still remain technically overweight (BMI = 25.0 to 29.9 kg/m²) signifies that the majority (>than 60%) of Americans are either overweight or obese, making the United States one of the “fattest” countries in the world. Projections now estimate that 75% of Americans will be overweight or obese by year 2015.^{2,3} The second public health concern is the

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occurrence of patient adverse events and its negative consequences on patient care, patient safety, and health-care costs. As a result of this concern and increased scrutiny over surgical outcomes, various national health care quality initiatives have evolved, including the National Surgical Quality Improvement Program (NSQIP), the Surgical Care Improvement Project (SCIP), and the National Healthcare Safety Network (NHSN). A fundamental purpose of the many health care initiatives, therefore, is to provide both consistent data regarding trends in adverse events and evidence-based measures for quality improvement. Surgical site infection (SSI) and its corresponding risk factors, in particular, have become a primary focus for which quality measures have been implemented to improve surgical outcomes.⁴ Although compliance with quality measures and identification of significant risk factors are at times separate issues, they are not mutually exclusive. Whether or not complete adherence to performance measures is either attainable or affects surgical outcomes is debatable. Still, identification of risk factors for SSI allows for corrective intervention prior to surgery in hopes of improving patient outcomes.⁵⁻⁷

An understanding of the effect of obesity on the incidence of wound infections and other wound complications remains incomplete despite considerable attention to both the growing "epidemic" of obesity and the frequent occurrence of surgical site infection (SSI) after gastrointestinal surgery. Obesity is a well-established risk factor for significant medical co-morbidities, including diabetes, cancer, pulmonary disease, and cardiovascular disease, and it is associated with increased overall mortality.⁸ The assumption that obesity is a risk factor for SSI or other post-operative complications is a logical conclusion. However, these assumptions are frequently based on anecdotal experience and preconceived opinions of patients with excess body weight undergoing elective surgery. Objective evidence implicating obesity as an independent risk factor for the development of post-operative complications after general surgery procedures is not always conclusive. This deficit is ever more present as the impact of obesity specifically on wound complications after elective colon and rectal procedures is investigated; a deficit that potentially has significant consequences on not only patient care, but increasing health-care costs and length of stay, as well.⁹ Therefore, the purpose of this review is to provide an objective assessment of the potential risk obesity imposes on the development of wound complications after elective colon and rectal surgical procedures.

DEFINITION OF OVERWEIGHT AND OBESITY WEIGHT CLASS

A standardized definition of obesity is necessary to provide data that is valid and conveys an accurate risk

assessment between patients and procedures. Perhaps this is easier said than done. Differences in body composition between males and females of the same age, and among people of different ages, inherently affect the ability of standardized measures to accurately assess body fat. This is largely attributed to the inability of body weight to differentiate between lean and fat body mass. The ability to accurately measure true body fat is hindered by racial and ethnic differences, as well.^{10,11} Within the current literature, numerous indices of obesity are described including body weight (BW), body-mass index (BMI), body-fat percentage (BF%), visceral obesity, skin thickness, subcutaneous fat depth, and waist/hip circumference.^{10,12,13} Each has its own advantages and disadvantages in regards to identifying and predicting obesity as a risk factor for SSI and other post-operative adverse events.

Body-mass index and body-fat percentage are the most common obesity indices utilized in the analysis of obesity and its effect on post-operative complications. Optimal BW for a particular physical frame has been suggested through Metropolitan Life Insurance Company height-weight charts, yet this measurement is grossly inadequate for the purpose of evidence-based recommendations. Although body weight is a simple measurement, its usefulness as a predictive variable for the degree of body fat is limited.^{14,15} BW, therefore, has been replaced by BMI and BF%. BMI is calculated as mass (kg) $\div$ height (m).² Currently, both the Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) define "overweight" and "obesity" in adults as BMI equal to 25.0 kg/m² to 29.9 kg/m² and greater than 30 kg/m², respectively. Obesity is further divided into Class I (30 kg/m²–34.9 kg/m²), Class II (35 kg/m²–39.9 kg/m²), and Class III ($\geq$ 40 kg/m²).¹⁶ BMI is routinely used in epidemiologic studies and clinical practice, yet the ability of BMI to adequately estimate true body fat can be affected by age, gender, and ethnicity. Individuals of the same BMI will have differences in body composition (i.e., muscle mass and fat mass), resulting in an over- or underestimation of weight class. Despite this major limitation, BMI is typically reflective of the body composition in the majority of the U.S. population and is best utilized for general recommendations.¹⁷

The definition of obesity by BF% is $>25\%$ for men and $>35\%$ for women. BF% tends to be a more accurate predictor of body fat than BMI even though the correlation between BMI and BF% is relatively good within age-, gender-, and ethnicity-groups. Otherwise, predicting BF% with BMI has wide variability. Whether or not the improved specificity and sensitivity of BF% correlates to improved identification of obesity-related risk is not clear.¹⁸⁻²⁰ The various techniques to measure BF%, including bioelectrical impedance analysis and anthropometric methods, are beyond the scope of this discussion.

PREVALENCE OF OBESITY

Over the past twenty years, there has been a gradual increase in the prevalence of obesity among adult Americans. Although annual percentage increases in the prevalence of obesity are variable and differences in obesity rates exist between racial and ethnic groups, the majority of Americans are either overweight or obese. In 2009, nine states (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and West Virginia) reported an obesity rate greater than 30%; Colorado is the only state with an obesity rate less than 20% according to the CDC's Behavioral Risk Factor Surveillance System (BFRSS).²¹ The National Health and Nutrition Examination Survey (NHANES), a program of the CDC and the National Center for Health Statistics (NCHS), provides national data regarding the prevalence of obesity and the changing trends in health and nutrition status among Americans. NHANES data for 1999–2008 indicates that the age-adjusted prevalence of obesity in the United States for men and women is 32.2% and 35.5%, respectively. Furthermore, the age-adjusted prevalence of both overweight and obese Americans ($\text{BMI} \geq 25.0 \text{ kg/m}^2$), regardless of gender, is reported to be greater than 68%. This is especially true among non-Hispanic black and Mexican American ethnicity groups for which the prevalence of overweight and obesity is greater than 70% and 40%, respectively.²²

DEFINITION OF SURGICAL SITE INFECTION

The term surgical site infection, or SSI, has largely replaced the term “wound infection” to provide a more uniform definition of wound occurrences in the clinical and research setting. In 2005, the National Healthcare Safety Network (NHSN) was established as a division of the CDC to provide prospective data collection, reporting, and analysis of healthcare events that impact both patient and healthcare worker safety. At its origin, NHSN incorporated the former National Nosocomial Infections Surveillance (NNIS) system, a reporting system that followed the incidence of SSI and other hospital-acquired infections (HAIs).²³ Nosocomial infections, risk factors, and populations under surveillance by the CDC have been defined by the NNIS, and the main objective of these definitions has been to provide valid and consistent data points for which comparative data can be generated between healthcare systems and providers. The NNIS-risk index score has originated from this effort, and is still cited today as a clinical predictor of SSI. The data has now allowed the NHSN, which includes the NNIS, to identify patient-related and procedure-related characteristics that contribute to HAIs.²⁴ HAIs are simply defined as any clinical infectious disease acquired during hospitalization that was not present at the time of hospital admission. They occur

in ~6% of all hospitalized patients. Among all HAIs reported, urinary tract infection (33.1%), pneumonia (15.5%), and surgical site infection (14.8%) represent the three most common sites of distribution; as one may expect, SSI is the most common HAI for surgical patients.²⁵ The CDC defines surgical site infections according to one of three categories.

Surgical site infection classification is divided into superficial incisional SSI, deep incisional SSI, and organ/space SSI. Superficial SSI involves the skin and subcutaneous tissue, while deep SSI involves the muscle and fascial layers. Anatomical structures, other than the incision, and/or organs that are affected with the operative procedure are the source of organ/space SSI. Additional criteria in regards to timing of infection, signs and symptoms of SSI, and isolation of organisms required to define SSI are detailed through the CDC's published definitions of nosocomial infections by Horan et al.²⁶ For all three types of SSI, potential risk factors have been analyzed and identified through epidemiologic studies. Although risk factors outside of obesity are beyond the scope of this discussion, independent variables contributing to SSI typically include both operative and patient characteristics, such as lack of antimicrobial prophylaxis, duration of operation, wound class, advanced age, American Society of Anesthesiology (ASA) score, malnutrition, diabetes, and steroid use.²⁷ The NNIS system designed a basic SSI risk index category (scale 0 to 3; 1 point each for $\text{ASA} \geq 3$, operation classified as contaminated or dirty-infected, and/or lengthy duration of operation) to predict the risk of a SSI within a surgical patient surveillance component protocol.^{28,29} Laparoscopy was subsequently incorporated into a modified SSI risk index category (scale -1 to 3; 1 point subtracted for laparoscopy) because of lower SSI rates reported by the NNIS in select operations (cholecystectomy, colon operation, gastric operation, and appendectomy).³⁰ Obesity, as are many other identifiable risk factors for SSI, has not been included in the basic or modified SSI risk index category despite multiple studies demonstrating the influence of outside variables on SSI. To date, the ability of the NNIS-risk index score to predict SSI in elective general and colorectal surgery is variable with or without the inclusion of other identifiable risk factors, such as obesity.^{31,32}

PREVALENCE OF SURGICAL SITE INFECTION

The reported prevalence of SSI is highly variable because of differences in SSI definition, detection, and reporting. The NNIS system data reports SSI rates less than 12% for all operative procedures and NNIS risk-index categories, including colon operations in patients with a high modified risk index (NNIS 2 or 3).³⁰ In contrast, most non-CDC studies report a higher incidence (up to 45%)

and greater variability (3% to 45%) of SSI among general and vascular surgical patients depending on the surveillance method and reporting criteria.³³⁻³⁶ Furthermore, the reported incidence of SSI among colon and rectal procedures typically ranges from 25% to 45% depending partly on the respective institution's experience. Anthony et al reported the overall rate of SSI to be 35% among patients undergoing colon and rectal operations within a single-institution, randomized controlled trial. Despite near-perfect compliance with SCIP guidelines and evidence-based interventions to reduce SSI, the incidence of SSI continued to be as high as 45% in studied patients.³⁷ Blumetti et al described a similar overall incidence of SSI (24.5%; 105 SSIs) for 428 patients undergoing colon and rectal operations. The authors of this 4-year retrospective review identified that procedures for diverticular disease, inflammatory bowel disease, and ostomy reversal incur the highest rates of SSI. Like Anthony et al, Blumetti reported a higher occurrence of superficial SSI (70%) versus deep/organ space SSI (30%).³⁸ Konishi et al demonstrated a statistically significant difference in the incidence of SSI between colon surgery (9.4%) and rectal surgery (18.0%) as a consequence of additional risk factors (i.e., ostomy closure, lack of oral antibiotics preoperative steroids, preoperative radiation) not taken into consideration by the NNIS risk index.³⁹ In summary, the overall incidence of SSI for colon and rectal operations ranges from 5% to 45% in most recent studies despite high variability among institutional and national databases. Of note, a recent survey of members of the American Society of Colon and Rectal Surgeons revealed that 75% of participants considered their own wound infection rate to be less than 10%.⁴⁰

IMPACT OF OBESITY ON SURGICAL SITE INFECTION

The impact of obesity on postoperative complications in patients undergoing elective general surgery has been well reported. Still, study outcomes are at times inconsistent, or at least outcomes do not necessarily validate the preconceived idea that obese patients are constantly at increased risk for postoperative morbidity and mortality. Whether or not the implications of obesity on wound occurrences are applicable specifically to colon and rectal surgery remains in question with a growing number studies examining wound complications in obese patients undergoing colon and rectal procedures. Increasingly, obesity is being identified as a risk factor for wound infection following colon and rectal surgery.⁴¹

GENERAL SURGERY

Most current studies analyzing potential risk factors for SSI will reference weight class as part of the patient

demographics and examine its effect on operative outcomes. According to weight class, Mullen et al reported a statistically significant increase in postoperative surgical site infection and wound dehiscence with increasing classes of obesity among 118,707 patients undergoing non-bariatric general surgery. Although overall postoperative morbidity for overweight, Class I obese, and Class II obese patients was similar to the overall postoperative morbidity of healthy weight patients, the incidence of SSI for overweight and obese individuals ranged from 5.6% to 8.0% versus 4.9% for healthy weight individuals. This represented a significant and gradual increase across all levels of obesity. Interestingly, the unadjusted odds ratio of 30-day mortality for the same patient cohort was significantly lower in overweight and obese patients compared with healthy weight patients.⁴² Comparable results were reported for over 6,000 patients followed prospectively after elective general surgery, as well. Rates of overall postoperative morbidity did not differ between obese and non-obese patients; however, subset analysis of SSI included within a broad category of postoperative complications revealed a statistically significant increase in SSI for obese patients (BMI >30 kg/m²) undergoing open surgery. Within this same study, no difference in the incidence of SSI was found between obese and non-obese patients undergoing laparoscopic surgery.⁴³ Bamgbade et al reported significantly higher superficial and deep SSIs among obese patients (obese, 6.0% v. non-obese, 3.5%) within thirty days of non-cardiac major surgery, as well, even though the frequency of overall complications was not different between weight classes in terms of surgical specialty.⁴⁴ So, while the reported overall post-operative morbidity between non-obese and obese patients may not always be significantly different for elective general surgery, the negative impact of obesity on wound occurrences is apparent.

COLON AND RECTAL SURGERY

In 2000, Benoist et al reported their single-institution experience regarding obesity and surgical outcomes after colon and rectal surgery in 158 obese patients defined by BMI >27 kg/m². Post-operative complications, including SSI and intra-abdominal fluid collection (assumed to be indicative of deep/organ space infection by this author), were compared with 426 nonobese patients undergoing similar procedures. Results of this 8-year retrospective review were divided according to anatomic resection (right colectomy v. left colectomy v. rectal resection), while patients with underlying inflammatory bowel disease were excluded. The differences between obese and nonobese patients varied according to anatomic resection. For patients who underwent right colectomy, no statistically significant difference was demonstrated for abdominal wound infection between

obese and nonobese patients ($n=2$, 8% v. $n=3$, 3%, respectively). Although a trend toward an increased number of obese patients developing post-operative intra-abdominal fluid collections was reported, this difference was not statistically significant. For patients who underwent left colectomy or resection with high colorectal anastomosis, no significant difference was once again demonstrated for abdominal wound infection between both groups (obese; $n=7$, 10% v. nonobese; $n=8$, 6%). Intra-abdominal fluid collections, however, were significantly more common within the obese patient group (10% v. 2%). Abdominal wound infections and anastomotic leaks were significantly more frequent among obese patients after rectal resection, while differences in intra-abdominal fluid collections did not reach statistical significance between patient groups. Overall, authors offered two conclusions regarding the impact of obesity on surgical outcomes. First, the impact of obesity on right or left colectomy is negligible. Second, significantly increased abdominal wound infection and anastomotic leak rates are evident in obese patients after rectal resection, and certain high-risk patients should be considered for defunctioning stoma at the time of surgery.⁴⁵

A single-surgeon experience reported by Smith et al in 2004 reviewed the incidence of superficial and deep SSIs over a 2-year period of elective colon and rectal surgery. Of 176 patients studied, forty-five patients (25.6%) developed a SSI with an equal number of patients diagnosed in the inpatient and outpatient setting. Of these 45 patients with SSI, thirty-one were reported to have a BMI >25 kg/m² (previously defined as “overweight” or “obese” by the WHO). Increasing BMI, in addition to intraoperative hypotension, was found to be a significant risk factor for the development of SSI by multivariate analysis. BMI as an independent predictor of SSI was found have an odds ratio of 2.5 and 3.0 for SSI among overweight and obese patients, respectively.⁴⁶ In consideration of the type of SSI, Blumetti et al identified BMI as an independent risk factor for overall SSI and incisional SSI among 428 patients; BMI, however, was not found to be a predictive risk factor for organ/space infection.³⁸ Comparable results for the negative impact of BMI were not identified in a prior retrospective review of 534 colon resections by Blee et al. Although mean operative time increased significantly with increasing BMI, the incidence of wound infection across normal weight, overweight, and obese individuals showed no statistically significant difference in occurrence despite anatomic resection or type of SSI.⁴⁷

Three recent studies published in 2011 have contributed to the assertion that increasing BMI affects the incidence of SSI. Obesity was attributed to a 60% increase in SSI among 7,020 patients reviewed by Wick et al at Johns Hopkins University School of Medicine.

Obese patients reported a SSI rate of 14.5% versus 9.5% in nonobese patients; this was statistically significant and represented an odds ratio of ~ 1.60 on statistical analysis. The overall rate of SSI was 10.3% for all patients, while open colectomy was associated with an increased risk of SSI when compared with laparoscopy.⁴⁸ Khoury et al further defined the impact of obesity on laparoscopic intestinal resection, including both colorectal and small bowel resection, with a case-matched study between obese and nonobese patients. Obese patients defined by a BMI >30 kg/m² experienced a significantly greater occurrence of wound infection (10.6%, v. 4.8%, $p=0.002$) even though abdominopelvic abscess occurred with similar frequency.⁴⁹ In contrast, random allocation to either an extended or standard treatment arm employing evidence-based interventions to reduce SSI revealed an overall SSI rate of 36% that was not affected by BMI. The extended treatment arm included omission of mechanical bowel preparation, maintenance of perioperative normothermia, maintenance of increased concentration of inspired oxygen, reduction of intraoperative intravenous fluids, and use of wound protector. The standard treatment arm included use of mechanical bowel preparation, intraoperative forced-air warming, maintenance of 30% inspired oxygen concentration, intravenous fluid administration at direction of the anesthesiologist, and no wound edge protection. Among the 211 randomized patients undergoing colorectal procedures, the mean BMI was similar between patients with and without a detected SSI.³⁷

THE PATHOPHYSIOLOGY OF OBESITY-RELATED SSI AND FUTURE AREAS OF RESEARCH

Numerous theories have been suggested regarding the pathophysiology between obesity and the occurrence of surgical site infection, including decreased oxygen tension within surgical wounds, impaired tissue penetration of perioperative antibiotics, prolonged operative times, increased operative blood loss, and obesity-related diminished immune function.^{50–54} For example, Kabon et al effectively demonstrated significantly diminished subcutaneous tissue and wound oxygen tension among obese patients undergoing major abdominal surgery in comparison to nonobese patients. Wound and tissue hypoxia was evident among obese patients at both baseline and after supplemental oxygen administration; oxygen tension levels during the perioperative period in obese patients remained at levels associated with an increased risk of SSI (≤ 40 mmHg).^{50,51} Sakai et al reported an association between increased visceral fat volume and SSI that was partly attributed to an increase in mean operative time and mean operative blood loss.⁵² Furthermore, Toma et al demonstrated a significantly lower tissue concentration of perioperative antibiotics

in obese patients despite a 2-fold higher dose in comparison to normal-weight patients. Adipose tissue concentration of preoperative antibiotics remained below the minimum inhibitory concentration and was suggested as a potential mechanism for increased SSI among obese patients.⁵³ Other proposed mechanisms of obesity-related SSI include altered immune function and metabolic changes contributing to an overall susceptibility to infectious disease among obese individuals.⁵⁴

CONCLUSION

The impact of obesity on surgical outcomes has historically been well recognized and is currently under increased evaluation in consideration of both the growing epidemic of obesity and interest in surgical improvement. Its true effect, however, has been influenced by various factors including prior utilization of nonstandardized definitions of obesity, debate regarding the best method to evaluate body composition, and differences in SSI surveillance among reported studies. Furthermore, the clinical relevance of obesity and the reason why obesity contributes to worse surgical outcomes (poor tissue oxygenation, impaired immune response, etc.) have not been fully elucidated. Although obesity has been identified as a potential risk factor for SSI in elective general surgery, the same level of evidence has not been prepared for patients undergoing elective colorectal surgery. What we do know is that the incidence of SSI is higher in patients undergoing colorectal procedures when compared with other general surgery procedures, and obesity is a very common perioperative variable for which little can be done to change prior to surgery, unlike tobacco use and poor nutrition. Most surgeons would agree that the negative effect of obesity can be assigned across all surgical patients to some degree and recent research has certainly improved the validity that obesity affects the outcome of colon and rectal surgery. Still, despite concerted efforts to find modifiable risk factors for SSI, adherence to evidence-based measures to prevent SSI has not always shown a beneficial impact. Further evidence is warranted to elucidate the obesity-related pathophysiology behind SSI and to confirm the role obesity plays on surgical outcomes, particularly in consideration of inconsistencies demonstrated between obesity and SSI among different anatomic resections and different types of SSI.

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