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Morbidity and mortality after surgery for nonmalignant colorectal polyps

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Abstract

Background & Aims—Despite evidence that most non-malignant colorectal polyps can be managed endoscopically, a substantial proportion of patients with a non-malignant colorectal polyp are still sent to surgery. Risks associated with this surgery are not well characterized. We aimed to describe 30-day post-operative morbidity and mortality and to explore risk factors for adverse events in patients undergoing surgical resection for non-malignant colorectal polyps.

Methods—We analyzed data collected prospectively as part of the National Surgical Quality Improvement Program. Our analysis included 12,732 patients who underwent elective surgery for a non-malignant colorectal polyp from 2011 through 2014. We report adverse events within 30 days of the index surgery. Modified Poisson regression was used to estimate risk ratios and 95% confidence intervals.

Results—Thirty-day mortality was 0.7%. The risk of a major post-operative adverse event was 14%. Within 30 days of resection, 7.8% of patients were readmitted and 3.6% of patients had a second major surgery. The index surgery resulted in a colostomy in 1.8% and ileostomy in 0.4% of patients. Patients who had surgical resection of a non-malignant polyp in the rectum or anal canal compared with the colon had a risk ratio of 1.58 (95% CI, 1.09–2.28) for surgical site infection and 6.51 (95% CI, 4.97–8.52) for ostomy.

Conclusion—Surgery for a non-malignant colorectal polyp is associated with significant morbidity and mortality. A better understanding of the risks and benefits associated with surgical

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management of non-malignant colorectal polyps will better inform discussions regarding the relative merits of management strategies.

Keywords

adverse event; colorectal polyp; ostomy

Introduction

Screening endoscopy (sigmoidoscopy and colonoscopy) with polypectomy reduces the incidence of and mortality from colorectal cancer.[1–4] Most polyps are removed with endoscopic resection, although polyps considered to be complex because of size, location or morphology are commonly resected surgically.[5–7] An estimated 1% of all patients with a non-malignant colorectal polyp will be sent for surgical resection.[8–10] In the United States, 73,000 elective colectomies for colorectal cancer and non-malignant polyps are performed annually.[9] Of these, 32% are performed on patients with non-malignant disease[9] even though most advanced colonic neoplasms can also be safely and effectively removed with endoscopic techniques. Endoscopic assessment of polyp morphology and pit pattern can be effectively used to stratify advanced colonic neoplasia into lesions that are suitable for endoscopic resection and those that are more appropriately referred for surgery.[11, 12]

Despite the frequent use of surgical resection for non-malignant colorectal polyps, the risks of this surgery have not been well described. Surgical resection can be complicated by the need for an ostomy, postoperative infection, wound dehiscence, readmission, reoperation and death. Prior estimates of these risks have included hypothetical models,[13] small numbers of cases,[7, 14, 15] or limited detail on morbidity with no mortality estimates.[9] Understanding the risks associated with surgical resection is necessary to make an informed decision whether to pursue surgery versus endoscopic resection.

To better inform the decision to consider surgical resection, we performed an analysis of patients who had an elective surgery for a non-malignant colorectal polyp using data collected as part of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP). The aims of this study were to describe 30-day morbidity and mortality and to explore risk factors for select adverse events.

Methods

We analyzed data collected prospectively as part of the American College of Surgeons National Surgical Quality Improvement Program. The NSQIP was developed in 1994 and is a validated, national program to measure and improve surgical outcomes. The NSQIP included 315 U.S. hospitals in 2011, 374 hospitals in 2012, 374 hospitals in 2013 and 517 hospitals in 2014. The NSQIP has been described previously.[16–18] In brief, trained surgical clinical reviewers collect data on over 150 predetermined and well-defined variables, including preoperative risk factors, intraoperative variables, and 30-day postoperative outcomes for patients undergoing major surgical procedures. To ensure that the data collected are of high quality, routine inter-rater reliability audits are performed. The

University of North Carolina at Chapel Hill Office of Human Research Ethics determined this study to be exempt from continuing review.

Study Population

We included all patients captured in the NSQIP between 2011 and 2014 over the age of 18 who had an elective colectomy or proctectomy and a postoperative diagnosis of a benign neoplasm of the colon, rectum or anal canal (International Classification Of Diseases, Ninth Revision (ICD-9) code 211.3 or 211.4). The ICD-9-CM codes corresponded to the postoperative diagnosis in the operative report and/or after the return of the pathology report. The NSQIP database captures the indication for surgery with a single postoperative diagnosis. The following Current Procedural Terminology (CPT) codes were included: 44140, 44141, 44143, 44144, 44145, 44146, 44147, 44150, 44151, 44160, 44204, 44205, 44206, 44207, 44208, 44210, 45110, 45111, 45112, 45113, 45119, 45123, 45395, 45397 (Supplemental Tables). We did not include transanal surgery. We included only those patients who underwent elective surgery so as to exclude patients who potentially had suffered iatrogenic colonic perforation. Elective surgery is a variable in the NSQIP defined as any patient brought to the hospital for a scheduled surgery from their home or normal living situation on the day the procedure is performed. This variable excludes any patient transferred from another acute care hospital, emergency department, or clinic or any patient who undergoes an emergent/urgent surgical case.

Patient characteristics before surgery are reported and include age, sex, race, body mass index, current smoking status, co-morbid conditions, medications, functional health status, and American Society of Anesthesiologists (ASA) class. Comorbid conditions included diabetes, hypertension, chronic obstructive pulmonary disease, heart disease and end stage renal disease requiring dialysis. Patients who use non-insulin anti-diabetic agents or insulin were considered to have diabetes. Hypertension was defined as any patient who had a documented history of hypertension in the medical record severe enough to require antihypertensive medications. Heart disease was defined as any patient with a history of congestive heart failure in the 30 days before surgery, history of myocardial infarction 6 months before surgery, previous percutaneous coronary intervention or previous cardiac surgery. The regular administration of oral or parenteral corticosteroid medications or immunosuppressant medications within 30 days before the operative procedures or at the time the patient was being considered as a candidate for surgery was considered chronic steroid and immunosuppressant medication use. Functional health status classified the patients' ability to perform activities of daily living in the 30 days before surgery.

The surgical approach was categorized as laparoscopic or open based on CPT code. A laparoscopic approach included patients with any of the following codes: 44204, 44205, 44206, 44207, 44208, 44210, 45395, 45397. An open surgical approach included those with any of the following codes: 44140, 44141, 44143, 44144, 44145, 44146, 44147, 44150, 44151, 44160, 45110, 45111, 45112, 45113, 45119, 45123.

Adverse events within 30 days of the index surgery are reported and include: ileostomy or colostomy, superficial surgical site infection, deep incisional site infection, abscess, anastomotic leak, wound dehiscence, urinary tract infection, pneumonia, sepsis, septic

shock, renal failure, deep venous thrombosis/thrombophlebitis, pulmonary embolus, stoke/cerebrovascular accident, myocardial infarction, time on ventilator greater then 48 hours, hospitalization greater then 30 days, cardiac arrest, reoperation, readmission and mortality. With the exception of ostomy, these outcomes were chosen because they are the most common adverse events after a surgical procedure and are also considered important indices in quality.[19] Ostomy was included because this is an important outcome from the patient perspective.

An ileostomy was defined as any patient with an ileostomy code (including CPT code 44310). A colostomy was defined as any patient with any of the following CPT codes: 44141, 44143, 44144, 44146, 44188, 44206, 44208, 45110, 45395. Adverse events were stratified by surgical approach.

Statistical Analysis

Means and standard deviations were calculated for continuous variables, medians for skewed distributions of continuous variables, and proportions for categorical data. The risk of having one or more major adverse events per person was calculated and included the following: ostomy, deep incisional site infection, abscess, anastomotic leak, wound dehiscence, pneumonia, sepsis, septic shock, acute renal failure, deep venous thrombosis, pulmonary embolus, stroke/cerebrovascular accident, myocardial infarction, ventilator >48 hours, remaining hospitalized >30 days, cardiac arrest, reoperation, readmission and/or mortality. Modified Poisson regression with robust error variances was used to estimate risk ratios and 95% confidence intervals.[20] Multivariable models were created which generated adjusted risk estimates. The models included all the variables simultaneously. Four separate models were fit to capture the more common adverse events: (1) ostomy, (2) reoperation, (3) readmission, and (4) a composite of deep incisional site infections, abscesses, anastomotic leak and wound dehiscence. The composite outcome was created because these important events were too infrequent to model individually. Exposures known or hypothesized to be associated with these adverse events were included in the model. [21] P-values less than 0.05 were considered statistically significant. The analysis was performed using SAS 9.4 (SAS Institute, Cary, NC).

Results

The present analyses included 12,732 patients who had surgery for a non-malignant colorectal polyp (Table 1). The majority of patients (96%) had surgical resection for a non-malignant polyp of the colon and a small percentage (4%) had a resection for a non-malignant polyp of the rectum or anal canal. A third of patients (35%) were over the age of seventy. Patients had the following comorbid conditions: overweight (36%), obesity (39%), diabetes (19%) or hypertension (57%) and 18% were smokers.

A laparoscopic resection was more common (76%) than an open surgical approach (24%). The average hospital stay was 5 days. The length of stay after a laparoscopic resection (4.8 ± 5.9 days) was shorter compared with an open approach (6.4 ± 5.7 days).

The overall risk of 30-day mortality was 0.7% (Table 2). Postoperative mortality increased with advancing age. Mortality was 0.2% among those ≤49 years old, 0.3% among those 50 to 59 years old, 0.5% among those 60 to 69 years old, 0.8% among those 70 to 79 years old, and 2.8% among those ≥80 years old.

The risk of one or more major post-operative adverse events was 14%. A major post-operative adverse event included ostomy, deep incisional site infection, abscess, anastomotic leak, wound dehiscence, pneumonia, sepsis, septic shock, acute renal failure, deep venous thrombosis, pulmonary embolus, stroke/cerebrovascular accident, myocardial infarction, ventilator >48 hours, remaining hospitalized >30 days, cardiac arrest, reoperation, readmission and/or mortality. Among those with a major adverse event, the average length of hospital stay was 9.1 days compared with 4.5 days for those without a major adverse event (Supplemental Table 1).

Within 30 days of the index surgery, 7.8% of patients were readmitted and 3.6% of patients returned to the operating room for a second major surgical procedure. The index surgery resulted a colostomy in 1.8% and an ileostomy in 0.4% of patients. The risk of deep incisional site infection was 0.7% and abscess or anastomotic leak 2.6%. Wound dehiscence occurred in 0.6% of patients. Other postoperative infections and comorbid adverse events are reported in Table 2.

Smoking, obesity and comorbid cardiopulmonary disease were risk factors for adverse events (Table 3). After adjustments for other risks factors, patients who smoke had an increased risk (RR) of 1.32 (95% CI, 1.14–1.53) for readmission and 1.63 (95% CI, 1.32-2.02) for reoperation compared to nonsmokers. Compared with a normal body mass index, an overweight and obese body mass index was associated with an increased risk of deep incisional site infection, abscess, anastomotic leak or wound dehiscence (overweight: RR 1.47; 95% CI, 1.11–1.96; obese: RR 1.53; 95% CI, 1.15–2.04). Patients with chronic obstructive pulmonary disease and heart disease were at increased risk of readmission, reoperation and surgical site infections (Table 3).

An open surgical approach was associated with an increased risk of adverse events. After adjustments for other risks factors, patients with an open surgery compared with a laparoscopic resection had a RR of 1.60 (95% CI, 1.40–1.82) for readmission, 1.48 (95% CI, 1.22–1.80) for reoperation, 4.73 (95% CI, 3.65–6.12) for ostomy and 1.41 (95% CI, 1.15–1.71) for surgical site infections.

Non-malignant polyps in the rectum were associated with an increased risk of adverse events. A resection for a non-malignant polyp of the rectum or anal canal had a RR of 1.58 (95% CI, 1.09–2.28) for deep incisional site infection, abscess, anastomotic leak or wound dehiscence and 6.51 (95% CI, 4.97–8.52) for ostomy.

Discussion

Using quality improvement data collected from more than 500 hospitals across the United States, we determined the morbidity and mortality associated with surgery for non-malignant colorectal polyps. Before the age of 80, mortality was below 1% (0.2%–0.8%). After the age

of 80, mortality was 3%. Morbidity was common. One in seven patients had at least one major postoperative event. Within thirty days of surgery, 7.8% of patients were readmitted and 3.6% of patients returned to the operating room for a second major surgical procedure. After the index surgery, 2.2% of patients were left with an ostomy.

Mortality in our cohort was generally similar to one study,[15] markedly lower compared with another series, [14] and substantially lower than estimated by scoring systems designed to predict operative mortality.[13] The risk of major morbidity (15%) in our cohort was similar to most prior estimates [9, 15] and lower than 2 small series.[7, 14] In contrast with prior work, our detailed estimates of morbidity and mortality represent hundreds of hospitals and thousands of surgeons across the United States.

As expected, smoking, obesity, and comorbid cardiopulmonary disease were risk factors for adverse events. Differences in surgical approach also affected this risk. An open surgery compared with a laparoscopic resection was associated with an increased risk of readmission, reoperation, surgical site infections and receiving an ostomy. Similar to our results, a traditional open operation compared with laparoscopic resection for colorectal cancer or diverticular disease is associated with an increased risk of adverse events and longer hospital stay.[22–25] Notably, laparoscopic resection is only safer among high-and medium-volume surgeons compared with low-volume surgeons.[26]

Risk of adverse events was site specific. Surgical resection in the rectum was associated with a significant risk of surgical site infections and not surprisingly, stoma formation. Patients with an ostomy often experience substantial impairments in quality of life and ostomy maintenance can be a significant financial burden.[27] An ostomy can be complicated by skin breakdown, hernia formation, stomal stenosis, retraction, bleeding, and prolapse. Ostomy reversal is major surgery and is associated with significant morbidity and mortality.[28, 2930] A proctectomy was performed in 3% of our population. Proctectomy is associated with adverse events not captured by NSQIP included chronic derangements of defecatory, sexual, and urinary function.[31]

Our study has numerous strengths. More than five hundred hospitals across the United States participate in the ACS NSQIP capturing data on hundreds of thousands of patients. The program prospectively collects data on hundreds of variables in a standardized manner and with a system of checks to assure reliability. NSQIP has procedures in place to collect mortality and morbidity data through the 30th day after the principal operative procedure regardless of follow-up at a NSQIP site.

Our study also has limitations. The ACS NSQIP is not representative of all hospitals in the United States. A disproportionate number of academic hospitals participate in the program. Additionally, the ACS NSQIP is a quality improvement program and participation in this program may improve outcomes. As such, we may have underestimated the risk of postoperative morbidity and mortality although our estimates of overall morbidity are almost identical to prior work.[9, 15] Those patients who had an open surgery compared with a laparoscopic operation may be systematically different in ways not captured by variables in NSQIP and this could potentially bias the open approach to greater adverse events. In our

cohort, only a small proportion (4%) of resections were for rectal/anal cancer. A transanal surgical approach to rectal/anal lesions is increasing common and likely accounts for our small numbers. We did not include transanal surgery in our analyses because the risks of this surgery are different then a transabdominal approach. We may have under estimated the prevalence of ileostomy and colostomy in our cohort because three codes (44150, 44210, 45113) are with or without ostomy. These codes represent 3.5% of our cohort. Our cohort does not include patients with a CPT code for total colectomy with proctectomy. This is more extensive surgery commonly performed for inflammatory bowel disease or familial adenomatous polyposis, which may have worse outcomes. The NSQIP database captures the indication for surgery with a single postoperative diagnosis and requires that the appropriate ICD-9-CM code corresponded to the condition noted as the postoperative diagnosis in operative report, and/or after the pathology reports are entered. The accuracy of these codes in NSQIP is unknown and if colorectal cancer was miscoded for a non-malignant polyp there is the potential for misclassification. Furthermore, individuals with endoscopic resection of a malignant polyp may have been reclassified as non-malignant after a negative surgery. Surgery for colon cancer is different (more extensive) than surgery for non-malignant colon polyps, and patients with cancer have a slightly increased risk of adverse events. In a NSQIP cohort of patients with colorectal cancer, the risk of any adverse event was 18.5% and mortality was 1.8%. [32] If patients were captured as non-malignant colorectal polyps but had colorectal cancer we may have overestimated the risk of surgery. Again, it is reassuring that our estimates are similar to prior work.[9, 15] Finally, we had no details on the size, location (beyond rectum versus colon), or morphology of the non-malignant polyps.

Understanding the risks of surgical adverse events becomes especially important given the emerging evidence that many complex non-malignant colorectal neoplasms can be effectively and safely managed with endoscopic resection, including large, laterally spreading tumors. Endoscopic resection has been shown to prevent the need for surgery in 92% of cases (6442 patients) in a systematic review of endoscopic resection of large colorectal polyps.[33] Per polyp, the risk of iatrogenic perforation was 1.5% and post-procedural bleeding was 6.5%.[33] The risk of surgery for an adverse event was 1% and mortality directly due to endoscopic or surgical management was 0.08%.[33] Need for multiple endoscopic procedures and continued surveillance may be considered potential disadvantages to an endoscopic approach, however most patients with advanced polyps will require regular surveillance whether or not they undergo colonic resection. Incomplete resection and/or recurrence are risks associated with endoscopic resection. Recurrence occurred in 14% of cases.[33] Among those with a recurrence, 2% had an invasive colorectal cancer.[33] In another study of 1050 patients with a sessile polyp ≥20 mm or laterally spreading tumor treated with endoscopic mucosal resection, mortality was 0%.[13] In work limited to large sessile serrated adenomas/polyps, there is evidence that endoscopic mucosal resection of these lesions is as effective and safe compared with resection of large conventional adenomas.[34, 35] In the future, as endoscopic submucosal dissection becomes more widely available, it will be important to understand how outcomes for surgical resection compare with this novel approach to resection.[36]

For non-malignant lesions of the rectum, where our data showed significant risk of infection and stoma formation, endoscopic resection allows preservation of the rectum and anal

sphincter and maintenance of continence. Notably, these endoscopic outcomes represent practice at academic centers with high-volume expertise where outcomes are better. In contrast, our surgical resection data includes both community and academic practices. Moreover, we have no way to know which of the non-malignant colorectal polyps in our cohort would have been amenable to endoscopic therapy and can not directly compare outcomes for surgery to endoscopic therapy.

Despite the prevalence of non-malignant colon polyps in the United States, the effect of this diagnosis on patients' lives is unknown. Premalignant diagnoses like Barrett's esophagus are associated with significant psychological distress, decrements in quality of life, increased health care costs and utilization.[37] Similarly, a diagnosis of a non-malignant colorectal polyp may compromise a patient's quality of life. Successful treatment may mitigate these effects. The impact of surgical and endoscopic resection of non-malignant polyps on quality of life is unknown and needs to be addressed.

The total cost of surgical management of non-malignant colorectal polyps is estimated at $16,600 to $19,000 per patient.[38, 39] In contrast, endoscopic resection is significantly more cost-effective compared with surgical resection.[38, 39] The estimated total cost of endoscopic management of a complex colorectal polyp is between $5500 to $6300 per patient.[38, 39]

Although the operative mortality associated with surgical resection is relatively low, the risk of adverse events suggests endoscopic resection may be preferable for managing non-malignant colorectal polyps that do not harbor an overt malignancy. Our work reinforces the recommendation[7, 40, 41] that patients with advanced non-malignant colorectal polyps should be evaluated for resection by an endoscopist skilled in advanced mucosal resection before consideration of referral for surgery.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

ACS	American College of Surgeons
NSQIP	National Surgical Quality Improvement Program

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Table 1

Characteristics of patients in NSQIP undergoing surgery for non-malignant colorectal polyps

	Surgery
Characteristics, n(%)	**n = 12,732**
Age at procedure	
≤49 y	878 (7)
50–59	3,243 (25)
60–69	4,191 (33)
70–79	3,395 (27)
≥80	1,018 (8)
Sex	
Male	6,220 (49)
Female	6,504 (51)
Race	
White	10,020 (79)
Black	1,498 (12)
Other	403 (3)
Unknown/missing	811 (6)
Body mass index	
Underweight (<18.5)	195 (2)
Normal (18.5–25)	3,040 (24)
Overweight (25–30)	4,554 (36)
Obese (>30)	4,893 (39)
Current smoker	2,297 (18)
Comorbid condition	
Diabetes	2,364 (19)
Hypertension	7,227 (57)
Chronic obstructive pulmonary disease	730 (6)
Heart disease	193 (2)
Dialysis dependent	85 (0.7)
Medications	
Chronic steroid use/immunosuppressants	368 (3)
Functional health status before surgery	
Independent	12,522 (99)
Partially dependent	135 (1)
Totally dependent	18 (0.1)
American Society of Anesthesiologists Classification	
Normal healthy patient	430 (3)
Mild systemic disease	6,412 (50)
Severe systemic disease	5,532 (43)

	Surgery
Characteristics, n(%)	**n = 12,732**
Severe systemic disease that is constant threat to life	351 (3)
Surgical Management	
Laparoscopic approach	9,717 (76)
Open approach	3,015 (24)

Table 2

30-Day Adverse Events after Surgery for Non-Malignant Colorectal Polyps Stratified by Surgical Approach

Event, n (%)	Laparoscopic (n =9,717)	Open (n = 3,015)	All Procedures (n = 12,732)
Mortality	46 (0.5)	39 (1.3)	**85 (0.7)**
≥ 1 Major Events *	1,134 (12)	696 (23)	**1,830 (14)**
Readmission	648 (6.7)	347 (11.5)	**995 (7.8)**
Reoperation	308 (3.2)	151 (5.0)	**459 (3.6)**
Colostomy with index surgery	86 (0.9)	144 (4.8)	**230 (1.8)**
Ileostomy with index surgery	13 (0.1)	35 (1.2)	**48 (0.4)**
Surgical site infection			
Superficial	388 (4.0)	212 (7.0)	**600 (4.7)**
Deep	62 (0.6)	25 (0.8)	**87 (0.7)**
Anastomotic leak or Abscess	219 (2.3)	106 (3.5)	**325 (2.6)**
Wound dehiscence	40 (0.4)	35 (1.2)	**75 (0.6)**
Other postoperative infections			
Urinary tract infection	111 (1.1)	68 (2.3)	**179 (1.4)**
Pneumonia	110 (1.1)	64 (2.1)	**174 (1.4)**
Sepsis	154 (1.6)	80 (2.7)	**234 (1.8)**
Septic shock	68 (0.7)	41 (1.4)	**109 (0.9)**
Comorbid adverse events			
Acute renal failure	53 (0.6)	40 (1.3)	**93 (0.7)**
DVT/thrombophlebitis	59 (0.6)	24 (0.8)	**83 (0.7)**
Pulmonary embolism	26 (0.3)	16 (0.5)	**42 (0.3)**
Stroke/CVA	15 (0.2)	6 (0.2)	**21 (0.2)**
Myocardial infarction	34 (0.4)	26 (0.9)	**60 (0.5)**
Ventilator >48 hours	74 (0.8)	46 (1.5)	**120 (0.9)**
Hospitalized >30 days	31 (0.3)	18 (0.6)	**49 (0.4)**
Cardiac arrest	32 (0.3)	21 (0.7)	**53 (0.4)**

* Major adverse events includes any one of the following: ostomy, deep incisional site infection, abscess, wound dehiscence, pneumonia, sepsis, septic shock, acute renal failure, deep venous thrombosis, pulmonary embolus, stroke/cerebrovascular accident, myocardial infarction, ventilator >48 hours, still in hospital >30 days, cardiac arrest, reoperation, readmission and/or mortality

Abbreviations: Deep venous thrombosis (DVT); Cerebrovascular accident (CVA)

Table 3

Risk Factors for Adverse Events

	Readmission	Reoperation	Ostomy	Deep surgical site infection, abscess, anastomotic leak, wound dehiscence
Characteristic	**RR (95% CI)***	**RR (95% CI)***	**RR (95% CI)***	**RR (95% CI)***
Age (ref. ≤59 years)				
60–69	0.85 (0.73, 0.99)	1.06 (0.84, 1.33)	1.16 (0.85, 1.57)	0.91 (0.72, 1.14)
≥70	1.02 (0.88, 1.19)	1.09 (0.85, 1.39)	1.34 (1.03, 1.85)	0.75 (0.58, 0.96)
Sex (ref. male)				
Female	0.85 (0.75, 0.97)	0.62 (0.51, 0.75)	0.74 (0.58, 0.93)	0.83 (0.69, 1.00)
Race (ref. White)				
Black	0.92 (0.76, 1.11)	0.68 (0.47, 0.98)	1.61 (1.17, 2.21)	0.71 (0.50, 1.01)
BMI (ref. 18.5–25)				
Overweight (25–30)	1.07 (0.91, 1.26)	1.03 (0.79, 1.34)	0.79 (0.59, 1.05)	1.47 (1.11, 1.96)
Obese (>30)	1.07 (0.91, 1.28)	1.14 (0.87, 1.49)	0.73 (0.53, 1.00)	1.53 (1.15, 2.04)
Current Smoker (ref. non-smoker)				
Current smoker	1.32 (1.14, 1.53)	1.63 (1.32, 2.02)	1.15 (0.86, 1.54)	1.13 (0.90, 1.43)
Comorbid condition (ref. no disease)				
Diabetes	1.09 (0.93, 1.28)	0.92 (0.73, 1.17)	1.20 (0.89, 1.62)	0.98 (0.77, 1.24)
Hypertension	1.18 (1.03, 1.36)	1.17 (0.95, 1.44)	0.92 (0.70, 1.19)	1.16 (0.93, 1.43)
Chronic obstructive pulmonary disease	1.41 (1.14, 1.75)	1.41 (1.03, 1.91)	0.97 (0.61, 1.55)	1.78 (1.32, 2.40)
Heart disease	1.48 (1.03, 2.12)	1.85 (1.14, 2.99)	0.65 (0.20, 2.09)	1.78 (1.09, 2.93)
Medication (ref. no use)				
Chronic steriod use/Immunosuppressants	1.30 (0.96, 1.76)	1.61 (1.06, 2.45)	0.64 (0.27, 1.52)	1.56 (1.01, 2.40)
Surgical Management (ref. laparoscopic approach)				
Open approach	1.60 (1.40, 1.82)	1.48 (1.22, 1.80)	4.73 (3.65, 6.12)	1.41 (1.15, 1.71)
Location (ref. colon)				
Rectum or anal canal	1.17 (0.89, 1.53)	1.28 (0.86, 1.92)	6.51 (4.97, 8.52)	1.58 (1.09, 2.28)

*RR, adjusted risk ratio, CI, confidence interval, model was multivariable and in addition to the variables above include year of operation, functional health status, body mass index category of underweight, other race, and length of hospital stay; ref. = reference