Predictors and Consequences of Unplanned Conversion to Open During Robotic Colectomy: An ACS-NSQIP Database Analysis

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Abstract

Robotic-assisted surgery has become a desired modality for performing colectomy; however, unplanned conversion to an open procedure may be associated with worse outcomes. The purpose of this study is to examine predictors and consequences of unplanned conversion to open in a large, high fidelity data set. A retrospective analysis of 11 061 robotic colectomies was conducted using the American College of Surgeons - National Surgical Quality Improvement Program (ACS-NSQIP) 2012–2017 database. Predictors of conversion and the effect of conversion on outcomes were analyzed by multivariate logistic regression resulting in risk-adjusted odds ratios of conversion and morbidity/mortality. Overall, 10 372 (93.8%) patients underwent successful robotic colectomy, and 689 (6.2%) had an unplanned conversion. Predictors of conversion included age ≥ 65 years, male gender, obesity, functional status not independent, American Society of Anesthesia (ASA) classification IV-V, non-oncologic indication, emergency case, smoking, recent weight loss, bleeding disorder, and preoperative organ space infection. Conversion is an independent risk factor for mortality, overall morbidity, cardiac morbidity, pulmonary morbidity, renal morbidity, venous thromboembolism morbidity, wound morbidity, sepsis, bleeding, readmission, return to the operating room, and extended length of stay (LOS). Unplanned conversion to open during robotic colectomy is an independent predictor of morbidity and mortality.

Keywords

robotic, unplanned, conversion, predictors, colectomy, colorectal

Abbreviations and Acronyms

ACS = American College of Surgeons
AIC = Akaike Information Criterion
ASA = American Society of Anesthesia
BMI = body mass index
COPD = chronic obstructive pulmonary disease
CHF = congestive heart failure
CI = confidence interval
INR = international normalized ratio
LOS = length of stay
NSQIP = National Surgical Quality Improvement Program
OR = odds ratio
ROLARR = robotic vs laparoscopic resection for rectal cancer trial
SSI = surgical site infection
UTI = urinary tract infection
VTE = venous thromboembolism

Introduction

Colectomy is one of the most common general surgery procedures in the United States.[1,2] Since the introduction of laparoscopic colectomy in 1991,[3,4] many studies have shown equivalent or better postoperative and survival outcomes when compared to open procedures.[2,5,6] Laparoscopy is associated with lower morbidity and mortality and a shorter length of hospital stay when compared to open.[6] There are several reported advantages robotic colectomy has over laparoscopic colectomy, including greater control, precision, ergonomics, three-dimensional visualization, endo-wrist maneuverability, and tremor filtering.[2,5,7,8] Because of these advantages, a robotic approach can aid complex procedures.[9] Robotic surgery utilization is rapidly increasing.[10,11]

Unplanned conversion to open during laparoscopic surgery is associated with worse outcomes, including increased operative blood loss, anastomotic leak rate, reoperation, length of hospital stay, and oncologic outcomes.[4,12,13] Further, unplanned conversion causes increased postsurgical complications, such as intra-abdominal abscess, prolonged ileus, and wound infection.[14] Allaix et al reported tumor-related aspects as the most frequent reason for conversion.[13] Recent literature also suggests similar findings of worse outcomes in unplanned conversion to open during robotic surgery.[15]

The risk factors for unplanned conversion to open are essential information surgeons need to guide their decision-making. The purpose of this study is to examine predictors of unplanned robotic conversion to open. Additionally, the purpose of this study is to compare the influence of unplanned robotic conversion on patient outcomes versus successful robotic completed approaches and planned open approaches.

Materials and Methods

Data Source

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a nationwide quality improvement initiative based on high fidelity, professionally curated data. The ACS-NSQIP database contains over 150 data points regarding patient demographics, indications, preoperative comorbidities, laboratory values, and 30-day outcomes on a procedure level basis. The ACS-NSQIP targeted procedure – colectomy database, first released in 2012, contains an additional set of colectomy-specific data points, such as operative approach and tumor characteristics for colon cancer cases. This study was exempt from Institutional Review Board approval as the data contained no patient identifying information.

Patient Selection

A total of 11 060 colectomies conducted via a robotic approach and 63 300 colectomies conducted via a planned open approach during 2013 and 2017 were included. Robotic cases were defined as cases with a value of "Robotic," "Robotic with open assist," and "Robotic with unplanned conversion to open" for the COL_APPROACH data point found in the targeted procedure database. Planned open cases were defined as cases with a value of "Open (planned)." The COL_APPROACH data point was first reported in the 2012 database, but only 1 robotic case was reported that year; thus, the year 2012 was excluded.

Predictor Variables

Patient demographics, indication/operative conditions, preoperative comorbidities, and laboratory values were analyzed as predictor variables. Demographic variables included persons aged ≥65 years, sex, race (eg, White, Black, and Other), and obesity (body mass index [BMI] ≥35 kg/m^2), functional status (independent or not independent), and American Society of Anesthesiologists (ASA) classification (ASA I-II, ASA III, or ASA IV-V). Indications/operative conditions were categorized by oncologic case (non-oncologic or oncologic), and emergency status (emergency, non-emergency). An oncologic case was any colectomy with an indication of colon cancer or colon polyp. Preoperative comorbidities included in the analysis were congestive heart failure (CHF), hypertension, smoking within the past 1 year, dyspnea within the past 30 days, chronic obstructive pulmonary disease (COPD), dialysis, urinary tract infection (UTI), weight loss > 10% within the past 6 months, disseminated cancer, history of chemotherapy treatment, bleeding disorder, preoperative transfusion (< 72 hours before surgery), non-organ space soft tissue infection (STI) or open wound, organ space STI, preoperative sepsis or septic shock, diabetes, and steroid or immunosuppressive therapy within the past 30 days. Laboratory values analyzed were hypoalbuminemia (albumin < 3.5 g/dL), hyperbilirubinemia (bilirubin > 1.2 mg/dL), elevated creatinine (creatinine > 1.2 mg/dL [male] or 1.1 mg/dL [female]), anemia (hematocrit < 30%), elevated international normalized ratio (INR > 1.4), thrombocytopenia (platelet < 100 000 /mL), and leukocytosis (white blood cell > 11 000/mL). Several other preoperative comorbidities are captured in the ACS-NSQIP database but were excluded from this analysis because of a low number of occurrences. Comorbidities excluded from analysis were ventilator requirement within the past 48 hours, pneumonia, renal failure, ascites, dialysis, and UTI. Wound class was excluded because it is not strictly a preoperative predictor.

Outcome Variables

All outcomes reported in the ACS-NSQIP database are 30-day outcomes; thus, all outcomes analyzed in this study were 30-day outcomes. Outcomes analyzed were mortality, overall morbidity, organ system-specific morbidity (neurologic, cardiac, pulmonary, renal, VTE, and wound), sepsis/septic shock, bleeding requiring transfusion, readmission, return to the operating room, and length of hospital stay (LOS) greater than the median. Overall morbidity was defined as the presence of 1or more major postoperative complication. Neurologic morbidity was defined as 1 or more occurrence of stroke. Cardiac morbidity was defined as 1 or more occurrence of cardiac arrest or myocardial infarction (MI). Pulmonary morbidity was defined as 1 or more occurrence of postoperative pneumonia, ventilator requirement >48 hours post-operation, or reintubation. Renal morbidity was defined as one or more occurrence of renal failure or renal insufficiency. VTE morbidity was defined as 1 or more occurrence of deep vein thrombosis (DVT) or pulmonary embolism (PE). Wound morbidity was defined as one or more occurrence of superficial surgical site infection (SSI), deep SSI, organ space SSI, or wound dehiscence.

Statistical Analysis

Bivariate analysis of the distribution of predictor variables by approach and the distribution outcome variables by approach was conducted using Chi-square tests. Multivariate analysis of outcomes was conducted by multivariate logistic regression using models constructed by forward/backward stepwise minimization of Akaike Information Criterion (AIC), starting with fully saturated models and setting the minimum model to include approach as a predictor regardless of the impact on AIC. This resulted in a risk-adjusted odds ratio (OR) and corresponding 95% confidence interval (95% CI) of the analyzed outcome given the specified approach relative to the specified reference approach. This analysis was conducted for the robotic cohort only to calculate the predictors of unplanned conversion to open and the consequences of unplanned conversion to open. This analysis was performed on the unplanned conversion to open combined with the planned open cohorts to calculate the effect of unplanned conversion to open approach relative to planned open approach on outcomes. Statistical significance was assigned to a P value < .05 for bivariate analysis. For multivariate analysis, statistical significance was assigned to risk-adjusted OR whose 95% CI did not include 1. P values are reported for the multivariate analysis to illustrate the importance of each variable to the final model. Statistical analysis was performed using R version 3.5.1.

ACS-NSQIP Disclosure Statement

Hospitals participating in the ACS-NSQIP are the source of the data used in this study; however, the hospitals have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Results

Predictors of Unplanned Conversion to Open

The predictors of unplanned conversion to open during robotic colectomy are presented in Table 1. The 3 strongest predictors are emergency case (OR, 3.45; 95% CI, 1.31-8.11; *P* = .0070), organ space SSI (OR, 2.27; 95% CI, 1.14-5.77; *P* = .0140), and functional status not independent (OR, 2.26; 95% CI, 1.29-3.75; *P* = .0026). Other patient demographic predictors of unplanned conversion to open are persons aged ≥ 65 years (OR, 1.31; 95% CI, 1.11-1.56; *P* = .0019), male (OR, 1.36; 95% CI, 1.16-1.60;

Table 1. Predictors of Unplanned Conversion To Open During Robotic Colectomy

Preoperative Variable	Bivariate Analysis				Multivariate Analysis	
	All n (%)	Successful n (%)	Converted n (%)	*P* value	Adjusted OR of Conversion (95% CI)	*P* value
Total	11 061 (100.0)	10 372 (93.8)	689 (6.2)	-	-	-
Age ≥ 65 years	4453 (40.26%)	4147 (39.98%)	306 (44.41%)	.0217*	**1.31 (1.11-1.56)**	**.0019***
Male	5561 (50.28%)	5176 (49.90%)	385 (55.88%)	.0024*	**1.36 (1.16-1.60)**	**.0002***
Race						
White	9127 (82.52%)	8569 (82.62%)	558 (80.99%)	.4570	-	-
Black	941 (8.51%)	874 (8.43%)	67 (9.72%)		-	-
Other	993 (8.98%)	929 (8.96%)	64 (9.29%)		-	-
Obese (BMI ≥ 30 kg/m^2)	4341 (39.25%)	4005 (38.61%)	336 (48.77%)	1.26E-07*	**1.60 (1.36-1.88)**	**9.60E-09***
Functional status not independent	114 (1.03%)	95 (0.92%)	19 (2.76%)	3.57E-06*	**2.26 (1.29-3.75)**	**.0026***
ASA Classification I-II	5573 (50.38%)	5272 (50.83%)	301 (43.69%)	1.45E-06*	-	-
ASA Classification III	5212 (47.12%)	4858 (46.84%)	354 (51.38%)		1.10 (0.93-1.31)	.2764
ASA Classification IV-V	276 (2.50%)	242 (2.33%)	34 (4.93%)		**1.73 (1.13-2.60)**	**.0094***
Non-oncologic indication	6995 (63.24%)	6626 (63.88%)	369 (53.56%)	5.19E-08*	**1.68 (1.42-2.00)**	**3.84E-09***
Emergency case	27 (0.24%)	20 (0.19%)	7 (1.02%)	2.24E-05*	**3.45 (1.31-8.11)**	**.0070***
CHF within 30 days	49 (0.44%)	47 (0.45%)	2 (0.29%)	.5330	0.37 (0.06-1.24)	.1765
Hypertension requiring treatment	5316 (48.06%)	4947 (47.70%)	369 (53.56%)	.0029*	-	-
Smoke cigarettes within 1 year	1732 (15.66%)	1591 (15.34%)	141 (20.46%)	.0003*	**1.40 (1.14-1.71)**	**.0011***
Dyspnea within 30 days	568 (5.14%)	524 (5.05%)	44 (6.39%)	.1245	-	-
COPD	426 (3.85%)	383 (3.69%)	43 (6.24%)	.0008*	1.29 (0.90-1.81)	.1454
Dialysis	39 (0.35%)	35 (0.34%)	4 (0.58%)	.2972	-	-
UTI	16 (0.14%)	14 (0.13%)	2 (0.29%)	.2990	-	-
Weight loss > 10% in last 6 months	259 (2.34%)	229 (2.21%)	30 (4.35%)	.0003*	**1.74 (1.14-2.58)**	**.0073***
Disseminated cancer	416 (3.76%)	385 (3.71%)	31 (4.50%)	.2928	-	-
Received chemotherapy	1312 (11.86%)	1234 (11.90%)	78 (11.32%)	.6503	1.24 (0.95-1.60)	.1113
Bleeding disorder	240 (2.17%)	210 (2.02%)	30 (4.35%)	4.82E-05*	**1.81 (1.18-2.67)**	**.0043***
Preoperative transfusion (< 72 hours before surgery)	57 (0.52%)	51 (0.49%)	6 (0.87%)	.1783	-	-
Non organ space STI/Wound	61 (0.55%)	54 (0.52%)	7 (1.02%)	.0891	-	-
Organ Space SSI	38 (0.34%)	30 (0.29%)	8 (1.16%)	.0002*	**2.72 (1.14-5.77)**	**.0140***
Sepsis or septic shock	49 (0.44%)	40 (0.39%)	9 (1.31%)	.0004*	-	-
Diabetes	1716 (15.51%)	1601 (15.44%)	115 (16.69%)	.3782	-	-
Steroid or immunosuppressive therapy within 30 days	532 (4.81%)	484 (4.67%)	48 (6.97%)	.0063*	-	-
Albumin < 3.5 g/dL	1056 (9.55%)	945 (9.11%)	111 (16.11%)	1.41E-09*	**1.54 (1.22-1.92)**	**.0002***
Bilirubin > 1.2 mg/dL	279 (2.52%)	257 (2.48%)	22 (3.19%)	.2463	-	-
Creatinine > 1.2 (M) or > 1.1 (F) mg/dL	1053 (9.52%)	964 (9.29%)	89 (12.92%)	.0017*	-	-
Hematocrit < 30%	477 (4.31%)	436 (4.20%)	41 (5.95%)	.0288*	-	-
INR > 1.4	95 (0.86%)	84 (0.81%)	11 (1.60%)	.0302*	-	-
Platelet < 100,000 /µL	64 (0.58%)	58 (0.56%)	6 (0.87%)	.2963	-	-
WBC > 11,000 /µL	606 (5.48%)	541 (5.22%)	65 (9.43%)	2.46E-06*	**1.53 (1.15-2.01)**	**.0030***

P =.0002), obese (OR, 1.60; 95% CI, 1.36-1.88; P <.0001), and ASA classification IV-V (OR, 1.73; 95% CI, 1.13-2.60; P = .0094). Non-oncologic indication, such as diverticulitis or volvulus, is a predictor of unplanned conversion to open (OR, 1.68; 95% CI, 1.42-2.00; P < .0001). Comorbidities that predict unplanned conversion to open are smoking within 1 year of operation (OR, 1.40; 95% CI, 1.14-1.71; P = .0011), weight loss > 10% within the last 6 months (OR, 1.74; 95% CI, 1.14-2.58; P = .0073), and bleeding disorder (OR, 1.81; 95% CI, 1.18-2.67; P = .0043). Laboratory predictors of unplanned conversion to open were hypoalbuminemia (OR, 1.54; 95% CI, 1.22-1.92; P =. 0002) and leukocytosis (OR, 1.53; 95% CI, 1.15-2.01; P = .0030).

Consequences of Unplanned Conversion to Open

The consequences of unplanned conversion to open are presented in Table 2. Unplanned conversion to open is an independent risk factor for all adverse outcomes analyzed except stroke. Notably, unplanned conversion to open is a strong independent risk factor for mortality (OR, 6.10; 95% CI, 3.16-11.33; P < .0001) and overall morbidity (OR, 3.02; 95% CI, 2.52-3.60; P < .0001).

Outcomes of Unplanned Conversion to Open Approach Versus Planned Open Approach

Comparison of outcomes between unplanned conversion to open approach versus planned open approach is presented in Table 3. Compared to patients undergoing a planned open colectomy, patients who had an unplanned conversion from robotic to open colectomy had a risk-adjusted higher rate of overall morbidity (OR, 1.23; 95% CI, 1.04-1.46; P = .0139), renal failure or insufficiency (OR, 2.00; 95% CI, 1.26-3.03; P = .0018), venous thromboembolism (DVT or PE; OR, 1.69; 95% CI, 1.10-2.48; P = .0115), sepsis or septic shock (OR, 1.40; 95% CI, 1.05-1.84; P = .0177), and bleeding requiring transfusion (OR, 1.38; 95% CI, 1.08-1.74; P = .0092). Compared to patients undergoing a planned open colectomy, patients who had an unplanned conversion from robotic to open colectomy had a risk-adjusted lower rate of length of stay greater than the median of 7 days (OR, 0.82; 95% CI, 0.69-0.97; P = .0204).

Table 2. Consequences of Unplanned Conversion To Open for Patients Undergoing Robotic Colectomy

Morbidity/Mortality	Bivariate Analysis				Multivariate Analysis	
	All	Successful	Converted	*P* value	Adjusted OR of M&M for Patients Converted (95% CI)	*P* value
Total	11 061 (100.0)	10 372 (93.8)	689 (6.2)	-	-	-
Mortality	**51 (0.46%)**	**35 (0.34%)**	**16 (2.32%)**	**9.57E-14***	**6.10 (3.16-11.33)**	**2.36E-08***
Overall morbidity	**1559 (14.09%)**	**1334 (12.86%)**	**225 (32.66%)**	**0.00E00***	**3.02 (2.52-3.60)**	**4.90E-34***
Stroke	14 (0.13%)	12 (0.12%)	2 (0.29%)	.2120	1.86 (0.28-7.03)	.4265
Cardiac (Arrest or MI)	**72 (0.65%)**	**61 (0.59%)**	**11 (1.60%)**	**.0014***	**2.34 (1.15-4.35)**	**.0116***
Pulmonary (Pneumonia, Ventilator > 48 hours, or Reintubation)	**192 (1.74%)**	**151 (1.46%)**	**41 (5.95%)**	**0.00E00***	**3.38 (2.30-4.86)**	**1.81E-10***
Renal failure or insufficiency	**120 (1.08%)**	**98 (0.94%)**	**22 (3.19%)**	**3.46E-08***	**2.99 (1.79-4.78)**	**1.06E-05***
VTE (DVT or PE)	**128 (1.16%)**	**103 (0.99%)**	**25 (3.63%)**	**3.77E-10***	**3.53 (2.21-5.42)**	**3.16E-08***
Wound (Superficial SSI, Deep SSI, Organ Space SSI, or Dehiscence)	**735 (6.64%)**	**622 (6.00%)**	**113 (16.40%)**	**0.00E00***	**2.82 (2.25-3.51)**	**8.56E-20***
Sepsis or septic shock	**291 (2.63%)**	**233 (2.25%)**	**58 (8.42%)**	**0.00E00***	**3.30 (2.37-4.52)**	**4.27E-13***
Bleeding requiring transfusion	**467 (4.22%)**	**379 (3.65%)**	**88 (12.77%)**	**0.00E00***	**3.98 (3.01-5.22)**	**9.14E-23***
Readmission	**992 (8.97%)**	**891 (8.59%)**	**101 (14.66%)**	**6.72E-08***	**1.69 (1.33-2.11)**	**8.28E-06***
Return to operating room	**506 (4.57%)**	**455 (4.39%)**	**51 (7.40%)**	**.0002***	**1.60 (1.17-2.16)**	**.0026***
LOS > Median (4 days)	**3445 (31.15%)**	**2973 (28.66%)**	**472 (68.51%)**	**.00E00***	**5.24 (4.41-6.24)**	**4.19E-78***

Table 3. Outcomes of Unplanned Conversion to Open Approach versus Planned Open Approach						
Morbidity/Mortality	**Bivariate Analysis**				**Multivariate Analysis**	
	All	**Open**	**Converted**	***P* value**	**Adjusted OR of M&M for Patients Converted vs Planned Open (95% CI)**	***P* value**
Total	63 989 (100.0)	63 300 (98.9)	689 (1.1)	-	-	-
Mortality	**3953 (6.18%)**	**3937 (6.22%)**	**16 (2.32%)**	**2.37E-05***	1.56 (0.89-2.55)	.0946
Overall morbidity	**28 385 (44.36%)**	**28 160 (44.49%)**	**225 (32.66%)**	**5.07E-10***	**1.23 (1.04-1.46)**	**.0139***
Stroke	354 (0.55%)	352 (0.56%)	2 (0.29%)	.3495	1.12 (0.18-3.54)	.8713
Cardiac (Arrest or MI)	**1816 (2.84%)**	**1805 (2.85%)**	**11 (1.60%)**	**.0485***	1.26 (0.65-2.20)	.4487
Pulmonary (Pneumonia, Ventilator >48 hours, or Reintubation)	**7904 (12.35%)**	**7863 (12.42%)**	**41 (5.95%)**	**2.83E-07***	1.37 (0.98-1.88)	.0575
Renal failure or insufficiency	1869 (2.92%)	1847 (2.92%)	22 (3.19%)	.6696	**2.00 (1.26-3.03)**	**.0018***
VTE (DVT or PE)	2224 (3.48%)	2199 (3.47%)	25 (3.63%)	.8257	**1.69 (1.10-2.48)**	**.0115***
Wound (Superficial SSI, Deep SSI, Organ Space SSI, or Dehiscence)	10 871 (16.99%)	10 758 (17.00%)	113 (16.40%)	.6793	1.15 (0.93-1.40)	.1939
Sepsis or septic shock	**11 401 (17.82%)**	**11 343 (17.92%)**	**58 (8.42%)**	**9.03E-11***	**1.40 (1.05-1.84)**	**.0177***
Bleeding requiring transfusion	**12 463 (19.48%)**	**12 375 (19.55%)**	**88 (12.77%)**	**7.89E-06***	**1.38 (1.08-1.74)**	**.0092***
Readmission	7935 (12.40%)	7834 (12.38%)	101 (14.66%)	.0706	1.22 (0.98-1.50)	.0710
Return to operating room	4737 (7.40%)	4686 (7.40%)	51 (7.40%)	.9994	1.34 (0.99-1.78)	.0457*
LOS > Median (7 days)	**29 354 (45.87%)**	**29 153 (46.06%)**	**201 (29.17%)**	**0.00E00***	**0.82 (0.69-0.97)**	**.0204***

Discussion

This investigation of a large protocol-driven national database shows that when comparing successful robotic completed surgery to unplanned conversion from robotic to open surgery, much worse outcomes in terms of mortality and 30-day morbidity occur. Significantly higher complications in the unplanned conversion to open group include cardiac, pulmonary, and renal complications, venous thromboembolism, wound infection rate, sepsis or septic shock, bleeding requiring transfusion, readmission, return to the operating room, and length of stay. Other categories of complications showed non-significant differences.

This study shows that when comparing the planned open surgery group to the unplanned conversion to open group, the conversion group had worse outcomes in terms of 30-day morbidity. There was, however, no difference in mortality. Interestingly, the planned open group on univariate analysis had worse outcomes, including mortality, overall morbidity, cardiac arrest, pulmonary complications, sepsis or septic shock, and bleeding requiring transfusion. However, on multivariate analysis, there was no significant difference in mortality, and the unplanned conversion to open group had worse outcomes for overall morbidity, renal complications, VTE, sepsis or septic shock, and bleeding requiring transfusion. These findings may reflect that the planned open group included patients in poor health; when this was accounted for in the multivariate analysis, the unplanned conversion to open group had worse outcomes. In multivariate analysis, only hospital LOS was shorter in the unplanned conversion to open group. The other categories showed non-significant differences.

Studies of colorectal surgery have shown that minimally invasive surgery has similar oncologic outcomes to open surgery for colorectal surgery.[16-20] A recent report by Justiniano et al revealed decreased hospital utilization compared to open surgery,[22] and Huerta et al showed that operating times can become equivalent to laparoscopic times after completing the learning curve (90 cases for robotic novice, 20 cases for robotic expert).[23]

A number of retrospective, prospective cohort, and meta-analyses show that robotic surgery has a lower conversion to open rate with similar or better complication rates compared to laparoscopic and open surgical approaches.[16,18,24-37] Of note, the largest randomized robotic versus laparoscopic trial, the robotic vs laparoscopic resection for rectal cancer (ROLARR) trial, failed to show a difference in unplanned conversion to open between laparoscopic and robotic surgeries.[21] However, later analysis suggested that when correcting for operator experience, the conversion rate in robotic surgery may have been higher due to surgeon inexperience.[38] Additionally, multiple randomized controlled trials demonstrate that robotic surgeries confer decreased risk of converting to open surgeries than the laparoscopic approach.[39,40]

Unplanned conversion to open procedures has been shown to have worse outcomes, including increased hospital length of stay and unplanned readmission associated with decreased overall survival.[18] Complications associated with conversion included ileus, surgical site infection, and postoperative blood transfusion.[41,42]

A study by Lee et al using the same NSQIP data set used in this study over a shorter period corroborates our results that unplanned conversion to open has worse outcomes than robotic completed surgeries.[15] However, they concluded no difference between unplanned robotic converted to open and planned open. Instead, our data suggest that when controlling for patient factors in the multivariate analysis, robotic conversion to open has worse outcomes than planned open in several categories. Lee et al performed a subgroup analysis dividing groups into colon resection and rectal resection and found no significant differences in the colon resection group but significant differences in the rectal resection group.

In a meta-analysis, specific reasons for unplanned conversion included adhesions, bleeding, local tumor invasion, surgeon inexperience, hollow viscus ischemia, bowel perforation, body habitus (body wall obesity, and visceral obesity, narrow pelvis).[35] A number of preoperative factors shown to increase the risk of unplanned conversion to open include moderate-severe adhesions, coronary artery disease, diabetes, increased ASA class, and surgeon inexperience.[43] In this study, predictors of unplanned conversion were split into 3 categories: (1) high case acuity (eg, emergency, organ space infection, non-oncologic indication, leukocytosis), (2) poor baseline health (eg, functional status not independent, recent weight loss, ASA IV-V, hypoalbuminemia, smoking, $\geq$ 65 years), and (3) technical difficulty (eg, bleeding disorder, obesity, being male).

This study has several limitations. Causal inference cannot be made due to the retrospective observational nature of this study and database completeness issues. Significant predictors were not captured in this database, including surgeon and institutional experience, selection bias affecting operative approaches, robotic platform used (Si, Xi), alternative approaches considered/available, type of anastomosis, location of the pathology, variation in intraoperative anatomy (eg, adhesions, previous surgical history), and perioperative medical care (eg, ERAS protocol). Moreover, unmeasured baseline patient characteristics not captured in this data set may have influenced the rate of conversion and patient outcomes. Finally, the relatively small size of the robotic converted to open cohort may magnify the observed effects of conversion but not reflect clinically relevant differences.

In conclusion, other studies show robotic colorectal surgery is a reasonable alternative to laparoscopic and open surgery, especially when operating in the pelvis. The literature shows that robotic surgery has lower rates of unplanned conversion to open and is similar to better outcomes. However, our study shows unplanned robotic conversion to open portends poorer outcomes than robotic completed and planned open surgeries. Therefore, in high-risk patients, careful consideration of surgical approach, and a thorough discussion of the risks and benefits of the surgical approach options, must be held with patients.

Conflict of Interest

None of the authors identify a conflict of interest.

ACS-NSQIP disclaimer statement:
"The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS-NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors."

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