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ORIGINAL ARTICLE

Comparison of Risk Factors for Unplanned Conversion from Laparoscopic and Robotic to Open Colorectal Surgery Using the Michigan Surgical Quality Collaborative (MSQC) Database

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Abstract Robotic colorectal surgery has been shown to have lower rates of unplanned conversion to open surgery when compared to laparoscopic surgery. Risk factors associated with conversion from robotic to open colectomy and comparisons of the risk factors between robotic and laparoscopic approaches have not been previously reported. Patients who underwent elective laparoscopic and robotic colorectal surgeries between July 1, 2012 and April 28, 2015, were identified in the Michigan Surgical Quality Collaborative registry. Candidate covariates were identified, and hierarchical logistic regression models were used to identify risk factors for conversion. There were 4796 cases that met study inclusion criteria. Conversion was required in 18.2 % of laparoscopic and 7.7 % of robotic cases ($p < 0.0001$). Risk factors for conversion in the laparoscopic group included the following: moderate/severe adhesions, obesity, colorectal cancer, hypertension, rectal operations, urgent priority, and tobacco use. Risk factors for conversion in the robotic group included the following: severe adhesions, bleeding disorder, presence of cancer, cirrhosis, and use of statins. Higher surgeon volume was protective in both groups. Conversion rates are lower for robotic than for laparoscopic colorectal surgery with fewer predictors of conversion. Recognition of factors predicting conversion may allow surgeons to choose an operative approach that optimizes the benefits of the available technologies.

Keywords Robotic surgical procedures · Colorectal surgery · Minimally invasive surgery · Conversion to open surgery

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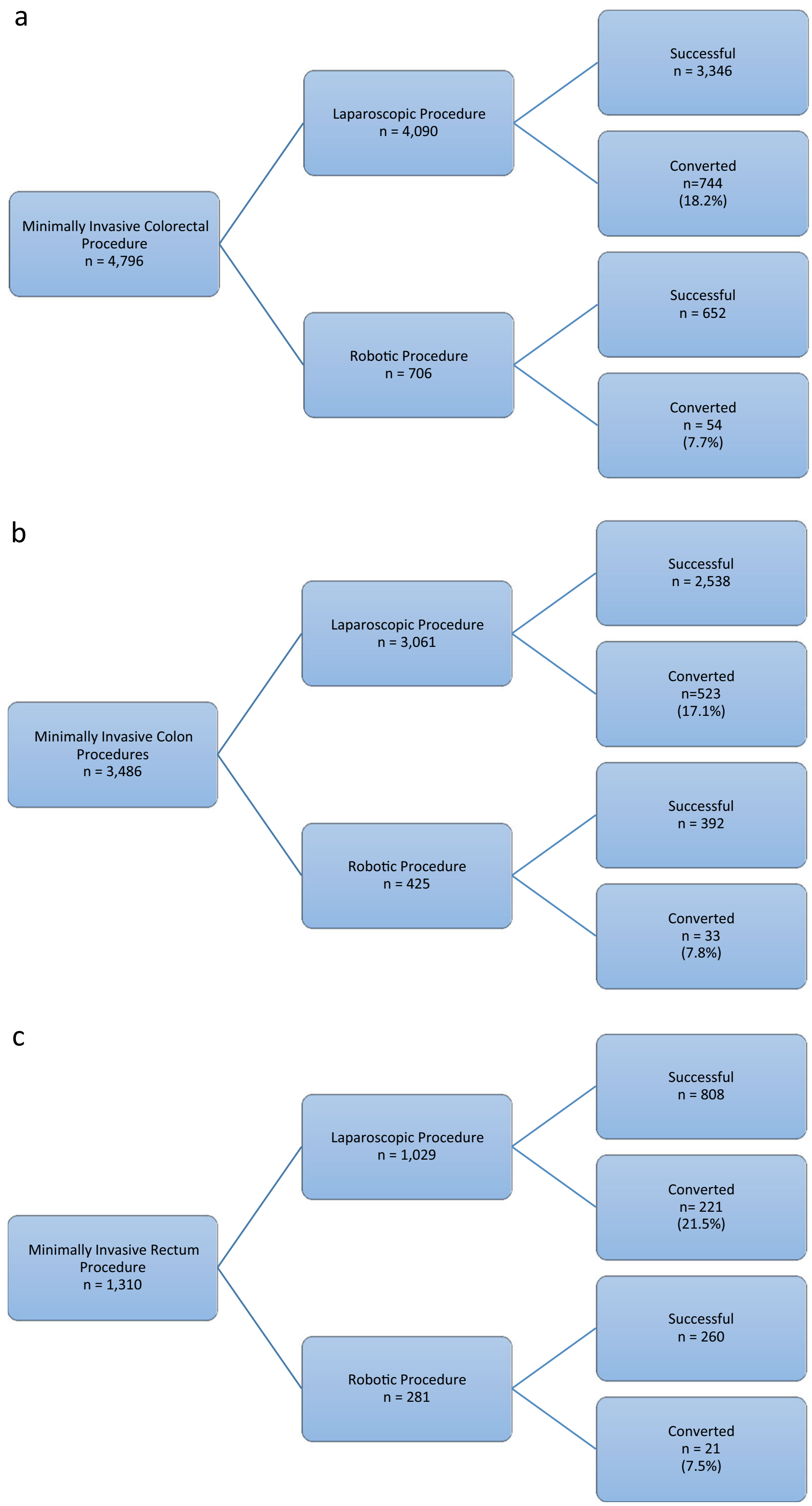
Introduction

Several studies have demonstrated that minimally invasive colorectal operations are safe and oncologically sound.[1–5] Conversion from a laparoscopic to an open procedure has been shown to have worse outcomes with respect to ileus, septic complications, and oncologic margins when compared to those operations that do not require conversion.[6–8]

Previous studies have demonstrated that high body surface area, high body mass index, recent weight loss, smoking, ASA class, tobacco use, chronic obstructive pulmonary disease, ascites, and recent treatment with chemotherapy are all significant risk factors for conversion to an open procedure.[9–11] Tumor-specific factors in those with cancer have also been found to influence the need to convert to an open procedure.[12] These studies

Fig. 1 Treatment of patient cohort. **a** Treatment of entire cohort. **b**. Treatment of colon cohort. **c** Treatment of rectum cohort



are limited by either a small sample size or the methodology by which conversion was defined. There are no studies that identify risk factors for conversion from the robotic to the open approach.

The purpose of this study was to identify risk factors using a large protocol-driven, validated regional database that are associated with unplanned conversion to an open procedure in both laparoscopic and robotic colorectal operations.

Table 1 Comparison of characteristics for 4796 patients with laparoscopic and robotic surgery

Covariate total (*n* = 3337)	Laparoscopic (*n* = 2890)	Robotic (*n* = 447)	*p* value[a]
Age, mean (SD)	62.1 (13.8)	60.9 (13.2)	0.32
Male Gender, *n* (%)	1878 (45.9)	321 (45.5)	0.84
Race, *n* (%)			0.18
Caucasian	3423 (83.7)	601 (85.1)	
African American	460 (11.3)	64 (9.1)	
Other	207 (5.1)	41 (5.8)	
BMI, *n* (%)			0.16
Obese	1540 (37.7)	245 (34.7)	
Overweight	1403 (34.3)	246 (34.8)	
Normal	1047 (25.6)	203 (28.8)	
Underweight or unknown	100 (2.4)	12 (1.7)	
Tobacco use, *n* (%)	952 (23.3)	183 (25.9)	0.14
Alcohol use, *n* (%)	135 (3.3)	19 (2.7)	0.49
ASA class, *n* (%)			<0.0001*
1 and 2	2048 (50.1)	407 (57.7)	
3	1875 (45.8)	287 (40.7)	
4	167 (4.1)	12 (1.7)	
Partially/totally dependent functional status, *n* (%)	123 (3.0)	12 (1.7)	0.06
Diabetes, *n* (%)	777 (19.0)	144 (20.4)	0.34
COPD, *n* (%)	334 (8.2)	63 (8.9)	0.51
Dyspnea, *n* (%)			0.63
Upon moderate exertion	399 (937)	69 (9.8)	
At rest	23 (0.6)	2 (0.3)	
No dyspnea	3668 (89.7)	635 (89.9)	
Ventilator, *n* (%)	3 (0.1)	0 (0.0)	1.00
Sleep apnea, *n* (%)			0.54
Level 1	3585 (87.7)	612 (86.7)	
Level 2	292 (7.1)	50 (7.1)	
Level 3	213 (5.2)	44 (6.2)	
Hypertension requiring meds, *n* (%)	2207 (54.0)	356 (50.4)	0.09
Congestive heart failure, *n* (%)	23 (0.6)	4 (0.6)	1.00
Coronary artery disease, *n* (%)	607 (14.8)	93 (13.2)	0.27
Arrhythmias, *n* (%)	352 (8.6)	60 (8.5)	1.00
Use of beta blocker, *n* (%)	1120 (27.4)	181 (25.6)	0.36
Use of statin, *n* (%)	1443 (35.3)	230 (32.6)	0.17
Peripheral vascular disease, *n* (%)	83 (2.0)	10 (1.4)	0.37
Preop/intraop ascites, *n* (%)	11 (0.3)	0 (0.0)	0.38
Preop/intraop cirrhosis, *n* (%)	18 (0.4)	6 (0.9)	0.15
Preop/intraop cancer, *n* (%)	91 (2.2)	16 (2.3)	0.89
Steroid use (30 days), *n* (%)	200 (4.9)	25 (3.5)	0.12
HIV/AIDS, *n* (%)	12 (0.3)	3 (0.4)	0.47
Weight loss, *n* (%)	111 (2.7)	22 (3.1)	0.54
Deep vein thrombosis, *n* (%)	190 (4.6)	30 (4.3)	0.70
Bleeding disorders, *n* (%)	115 (2.8)	16 (2.3)	0.46
Location of operation, *n* (%)			<0.0001*
Colon	3061 (74.8)	425 (60.2)	
Rectum	1029 (25.2)	281 (39.8)	
Surgical priority urgent, *n* (%)	477 (11.7)	20 (2.8)	<0.0001*
Adhesions, *n* (%)			0.0001*
Severe	563 (13.8)	63 (8.9)	
Moderate	659 (16.1)	95 (13.5)	
None/mild	2868 (70.1)	548 (77.6)	

Table 1 (continued)

Covariate total ($n = 3337$)	Laparoscopic ($n = 2890$)	Robotic ($n = 447$)	p value[a]
Diagnosis, n (%)			0.35
Colorectal cancer	1575 (38.5)	279 (39.5)	
Colorectal adenomas/polyps	691 (16.9)	110 (15.6)	
Diverticular disease and fistulas	1230 (30.1)	228 (32.3)	
Other	594 (14.5)	89 (12.6)	
Hospital sample volume, mean (SD)	127.9 (74.7)	134.9 (73.4)	0.004*
Surgeon sample volume, mean (SD)	34.4 (27.1)	42.5 (26.0)	<0.0001*

BMI body mass index, *ASA* American Society of Anesthesiology, *COPD* chronic obstructive pulmonary disease

*Significant difference, $p < 0.05$

[a] p values based on chi-square /Fisher's exact test or Wilcoxon two-sample test

Materials and Methods

Data Collection

St. Joseph Mercy Health System Institutional Review Board approval was obtained for this study. The Michigan Surgical Quality Collaborative (MSCQ) database was queried to identify patients who underwent colorectal procedures between July 1, 2012 and April 28, 2015. During this study period, the MSCQ database included 62 participating hospitals with 419 participating surgeons. Data was extracted based on Current Procedural Terminology (CPT) codes for abdominal (44140, 44141, 44144, 44151, 44160, 44188, 44204, 44205, 44206, 44210) and pelvic (44145, 44146, 45110, 44207, 44208, 45395, 45400, 45402) colorectal surgeries among MSQC-participating hospitals. Exclusion criteria were the following: age under 18 years, American Society of Anesthesiology (ASA) classification 5 and 6, emergent cases, or those with emergency status unknown.

The primary outcome of interest was rate of conversion from robotic or laparoscopic operation to an open operation. The MSQC database does not separate conventional and hand-assisted laparoscopy with respect to conversion and so the primary outcome reflects these two approaches combined. Secondary outcomes were the significant risk factors for conversion to an open procedure.

Statistical Analysis

Hierarchical logistic regression was utilized to identify preoperative variables that were considered to be significant risk factors for conversion to an open procedure and to control for clustering of outcomes within hospitals and surgeons. Models were fit separately for laparoscopic and robotic operations, identifying risk factors specific to each operative procedure.

Patient variables considered in the modeling process include patient demographics (age, gender, ethnicity), general health factors (BMI, tobacco use, alcohol use, functional health status, ASA classification), comorbidities (diabetes, COPD, dyspnea, ventilator use, sleep apnea, hypertension, congestive heart failure, coronary artery disease, arrhythmias, beta blocker, statin, peripheral vascular disease, ascites, cirrhosis, cancer, chronic steroid use, HIV/AIDS, loss of >10 % body weight, DVT, bleeding disorder) surgery factors (location of operation, surgical priority, presence of adhesions), diagnosis, and hospital and surgeon sampled volume. Surgeon volume is a continuous variable and is defined as a count of the surgeons' volume in our sample during the study period. It is a proxy measure for surgeon experience that is otherwise not captured in MSQC data. Statistical significance was reported when $p < 0.05$. All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC).

MSQC collects the adhesions variable based upon surgeon description in the operative note. Adhesions are defined as: (1) none/mild adhesions (not mentioned or described as "few" or "limited"), (2) moderate adhesions (described as "some", "multiple", or "many"—may require lysis but do not impair ability to do operation) and, (3) severe (described as "severe", "dense", "extensive", "excessive", "significant", or "hostile" and/or taking an hour/60 min or more to lyse or prohibiting planned procedure).

Results

There were 4796 patients that met inclusion criteria for minimally invasive colorectal procedures in this study. Of these patients, 4090 had a laparoscopic operation with an 18.2 % conversion rate to open ($n = 744$). Seven hundred and six (706) patients had a robotic operation with a conversion rate of 7.7 % ($n = 54$). This difference in conversion between the two groups was statistically significant ($p < 0.0001$). When stratified by colon and rectum locations, laparoscopic colon conversion was 17.1 % ($n = 523$), and robotic colon conversion was 7.8 % ($n = 33$), $p < 0.0001$. Laparoscopic rectum

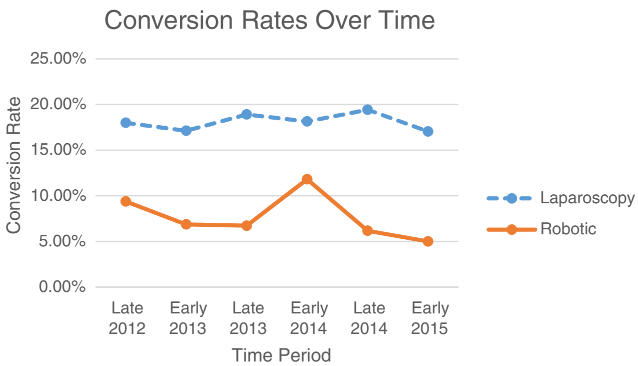


Fig. 2 Trends in conversion rates over time

conversion was 21.5 % ($n = 221$), and robotic rectum conversion was 7.5 % ($n = 21$), $p < 0.0001$ (Fig. 1).

Demographic and clinicopathologic characteristics were compared between the two groups and are described in Table 1. There was a significant difference between the two groups with respect to ASA Class ($p < 0.0001$), and there were significantly more patients of urgent priority in the laparoscopic group (11.7 % vs. 2.8 %, $p < 0.0001$). There was a significant difference between groups with respect to adhesions ($p = 0.0001$).

Examination of conversion rate trends over time revealed no significant differences in conversion rates over the study period for either operative approach. For laparoscopic colorectal procedures, the rate of conversion to an open procedure ranged from 17.05 to 19.42 % ($p = 0.84$). For robotic colorectal procedures, the rate of conversion to an open procedure ranged from 5 to 11.81 % ($p = 0.39$) (Fig. 2).

The risk factors for conversion from a colorectal laparoscopic or robotic approach to an open procedure are depicted in Table 2. Risk factors varied between the two groups. Severe and moderate adhesions were risk factors for conversion for laparoscopy. Moderate adhesions were not a risk factor for conversion with the robotic approach. Obesity was a risk factor for conversion for laparoscopy, but not the robotic platform. Higher surgeon case volume was protective from conversion in both groups. Subgroup analysis of colon and rectal procedures revealed that many of the risk factors remain for laparoscopic colectomy while there are no conversion risk factors for robotic colectomy (Table 3). For rectal resections,

Table 2 Risk factors for conversion to open procedure stratified by laparoscopic procedures and robotic procedures

Laparoscopic procedures ($n = 4090$)			
Effect	Category	Reference category	Odds Ratio (95 % CI)
Adhesions	Moderate	None/mild	2.30 (1.80, 2.94)*
	Severe		8.4 (6.67, 10.64)*
Ascites	Yes	No	5.81 (1.12, 30.3)*
BMI	Underweight or unknown	Normal	1.12 (0.61, 2.05)
	Overweight		1.11 (0.87, 1.42)
	Obese		1.43 (1.12, 1.82)*
Disseminated cancer	Yes	No	1.87 (1.05, 3.33)*
Diagnosis	Colorectal adenomas/polyps	Diverticular disease and fistulas	0.96 (0.69, 1.32)
	Colorectal cancer		1.37 (1.07, 1.74)*
	Other		2.29 (1.72, 3.05)*
Hypertension	Yes	No	1.34 (1.11, 1.63)*
Location	Rectum	Colon	1.41 (1.13, 1.77)*
Priority	Urgent	Elective	2.15 (1.65, 2.80)*
Tobacco use	Yes	No	1.44 (1.16, 1.78)*
Surgeon volume	–		0.98 (0.98, 0.99)*
Robotic procedures ($n = 706$)			
Effect	Category	Reference category	Odds ratio (95 % CI)
Adhesions	Moderate	None/mild	0.83 (0.27, 2.56)
	Severe		3.56 (1.52, 8.33)*
Bleeding disorder	Yes	No	6.25 (1.08, 37.04)*
Disseminated cancer	Yes	No	4.65 (1.02, 21.28)*
Cirrhosis	Yes	No	40 (2.05, 1000)*
Statin	Yes	No	1.98 (1.01, 3.86)*
Surgeon volume	–		0.96 (0.93, 0.98)*

BMI body mass index, *CI* confidence interval

*Significant at the $p < 0.05$ level

Table 3 Risk factors for conversion for laparoscopic and robotic colon procedures

Laparoscopic colon procedures (*n* = 3061)			
Effect	Category	Reference category	Odds ratio (95 % CI)
Adhesions	Moderate	None/mild	2.23 (1.68, 2.97)*
	Severe		8.33 (6.33, 10.99)*
Ascites	Yes	No	7.58 (1.23, 47.62)*
BMI	Underweight or unknown	Normal	1.22 (0.57, 2.62)
	Overweight		1.2 (0.89, 1.61)
	Obese		1.57 (1.18, 2.08)*
Diagnosis	Colorectal adenomas/polyps	Diverticular disease and fistulas	0.96 (0.67, 1.39)
	Colorectal cancer		1.5 (1.11, 2.03)*
	Other		2.46 (1.74, 3.48)*
Priority	Urgent	Elective	2.32 (1.73, 3.11)*
Sex	Male	Female	1.28 (1.02, 1.6)*
Tobacco	Yes	No	1.36 (1.05, 1.75)*
Surgeon volume	–		0.97 (0.96, 0.98)*
Robotic colon procedures (*n* = 425)			
Effect	Category		Odds ratio (95 % CI)
Surgeon volume	–		0.95 (0.91, 0.98)*

BMI body mass index, *CI* confidence interval

*Significant at the $p < 0.05$ level

moderate and severe adhesions remain risk factors for conversion for the laparoscopic approach while only ASA class 3 or 4 is a risk factor for conversion for robotic rectal resections (Table 4).

Discussion

This analysis of a protocol-driven, large regional database composed of hospitals and surgeons with varying levels of minimally invasive expertise showed that risk factors for conversion to open are different for the laparoscopic and robotic approaches. Risk factors for laparoscopic colorectal resection include *obesity*, *moderate adhesions*, *and severe adhesions*. Of these three risk factors, only severe adhesions was a risk factor for conversion with the robotic approach. On subgroup analysis, adhesions remain a risk factor for the laparoscopic, but not the robotic platform. Obesity is a risk factor for conversion during laparoscopic, but not robotic colectomy. ASA Class 3 or 4 is a risk factor for conversion for robotic but not laparoscopic rectal resections.

Conversion rates in the literature for laparoscopic colorectal surgery vary from 0 to 34 % and for robotic surgery from 0 to 15 %.[13–18] Other studies have shown that risk factors for laparoscopic conversion to open are advanced age, high ASA class, high BMI, male gender, history of prior abdominal operation,

Table 4 Risk factors for conversion for robotic and robotic rectal procedures

Laparoscopic rectal procedures (*n* = 1029)			
Effect	Category	Reference category	Odds ratio (95 % CI)
Adhesions	Moderate	None/mild	2.32 (1.46, 3.69)*
	Severe		7.58 (5, 11.49)*
Coronary artery disease	Yes	No	1.98 (1.16, 3.36)*
Diabetes	Yes	No	2.01 (1.28, 3.17)*
Statin	Yes	No	0.63 (0.41, 0.97)*
Hospital volume	–		0.99 (0.98, 1)*
Robotic rectal procedures (*n* = 281)			
Effect	Category	Reference category	Odds ratio (95 % CI)
ASA class	ASA 3	ASA 1 or 2	7.52 (2.06, 27.03)*
	ASA 4		5.81 (0.27, 125)
Hospital volume	–		0.84 (0.75, 0.96)*

ASA American Society of Anesthesiology, *CI* confidence interval advanced neoplasia, low anterior resection for mid and low rectal neoplasms, and complicated diverticulitis.[10–13,19,20] Our study also revealed that adhesions from previous abdominal operations, obesity, and the diagnosis of neoplasia are risk factors for laparoscopic conversion, and severe adhesions are a risk factor for robotic conversion to open. The robotic platform was designed to address the limitations of laparoscopy. It is possible that the enhanced vision, dexterity, and articulated instruments characteristic of the robotic approach may mitigate some of the conversion predictors that characterize laparoscopic colorectal surgery, thereby allowing complex operations in those with obesity and moderate adhesions to be completed with the robotic approach.

Our study is the first to examine risk factors predictive of robotic conversion to open in colorectal surgery. A single-institution study performed at M.D. Anderson Cancer Center demonstrated an 8.7 % conversion rate during gynecologic robotic surgery. Increased BMI and non-white race were found to be significant risk factors for conversion to an open procedure in that study.[21] Similarly, patients with higher BMI had an increased risk of conversion to open during robotic sacrocolpopexy.[22] A single-surgeon study of robotic hepatobiliary surgery suggested that obesity and technical difficulty are associated with conversion, though these factors were not studied in a statistically controlled fashion.[23]

In our study, there were significantly more cases with urgent priority in the laparoscopic group and a difference in ASA Class and adhesions between groups. Though these factors were controlled for in the multivariate analysis, it could account for some of the higher risk for conversion in the laparoscopic group. In contrast, there were significantly more rectal operations in the robotic group, and these operations are more at risk for conversion than the colectomy counterparts.[9,17]

This study has limitations inherent to a database analysis in that it is dependent on coding and data entry accuracy. The strength of this study is the source of the data—a large regional database that is protocol-driven, externally audited, and regularly validated. The database protocol contains strict definitions including the definition of conversion, thereby making conversion more likely to be recorded accurately than it would be in an administrative database.

This is a retrospective study of a prospective database and therefore selection bias is a potential consideration. Case-specific chart review to address specific operative approach choices and reasons for conversion is not possible with this methodology. For this reason, it is not possible to identify those cases that were converted from robotic to laparoscopic (or laparoscopic with hand assistance). Though we presume that this study is composed of surgeons of varying levels of minimally invasive expertise, given the variety of hospitals participating in MSQC, it is not possible to control for level of training with either laparoscopic or robotic approaches. This may be considered another strength of the study; however, in that it includes hospitals and surgeons with different academic and community compositions when compared to studies performed by select surgeons with considerable minimally invasive expertise that may not be generalizable.

Conclusion

This large regional protocol-driven database analysis demonstrates that laparoscopic predictors of conversion to open are different than predictors of conversion for the robotic platform and include moderate adhesions, severe adhesions, and obesity. The predictors of conversion for the robotic approach are fewer and do not include moderate adhesions and obesity. Developing technologies that improve the rates and the subsequent consequences of conversion should remain a priority.

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