UC Irvine
UC Irvine Previously Published Works

Title
Risk factors for conversion of laparoscopic colorectal surgery to open surgery: Does conversion worsen outcome?

Permalink
https://escholarship.org/uc/item/5gj6m63m

Journal
World Journal of Surgery, 39(5)

ISSN
0364-2313

Authors
Masoomi, H
Moghadamyeghaneh, Z
Mills, S
et al.

Publication Date
2015-05-01

DOI
10.1007/s00268-015-2958-z

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Risk Factors for Conversion of Laparoscopic Colorectal Surgery to Open Surgery: Does Conversion Worsen Outcome?

Hossein Masoomi • Zhobin Moghadamyeghaneh •
Steven Mills • Joseph C. Carmichael •
Alessio Pigazzi • Michael J. Stamos

Abstract
Introduction The utilization of laparoscopy in colorectal surgery is increasing. However, conversion to open surgery remains relatively high.
Objective We evaluated (1) conversion rates in laparoscopic colorectal surgery; (2) the outcomes of converted cases compared with successful laparoscopic and open colorectal operations; (3) predictive risk factors of conversion of laparoscopic colorectal surgery to open surgery.
Methods Using the National Inpatient Sample database, we examined the clinical data of patients who underwent colon and rectal resection from 2009 to 2010. Multivariate regression analysis was performed to identify factors predictive for conversion of laparoscopic to open operation.
Results A total of 207,311 patients underwent intended laparoscopic colorectal resection during this period. The conversion rate was 16.6 %. Considering resection type and pathology, the highest conversion rates were observed in proctectomy (31.4 %) and Crohn's disease (20.2 %). Using multivariate regression analysis, Crohn's disease (adjusted odds ratio [AOR], 2.80), prior abdominal surgery (AOR, 2.45), proctectomy (AOR, 2.42), malignant pathology (AOR, 1.90), emergent surgery (AOR, 1.82), obesity (AOR, 1.63), and ulcerative colitis (AOR, 1.60) significantly impacted the risk of conversion. Compared with patients who were successfully completed laparoscopically, converted patients had a significantly higher complication rate (laparoscopic: 23 %; vs. converted: 35.2 % vs. open: 35.3 %), a higher in-hospital mortality rate (laparoscopic: 0.5 %; vs. converted: 0.6 %; vs. open: 1.7 %) and a longer mean hospital stay (laparoscopic: 5.4 days; vs. converted: 8.1 days; vs. open: 8.4 days); however, converted patients had better outcomes compared with the open group.
Conclusions The conversion rate in colorectal surgery was 16.6 %. Converted patients had significantly higher rates of morbidity and mortality compared to successfully completed laparoscopic cases, although lower than open cases. Crohn's disease, prior abdominal surgery, and proctectomy are the strongest predictors for conversion of laparoscopic to open in colorectal operations.

Introduction

Laparoscopic resection of the colon and rectum has gained acceptance as the minimally invasive counterpart of traditional open resections. It was first accepted for benign conditions and later for malignant diseases [1]. Laparoscopic colorectal surgery is associated with less operative trauma, lower morbidity and a shorter hospital stay than open colorectal surgery [2]. However, there might be a selection bias in retrospective studies comparing open versus laparoscopic colorectal surgery as performing laparoscopic colorectal surgery in less comorbid/complicated patients might be a reason for having superior outcomes compared with open approach. Improved accessibility to laparoscopic equipment and better training has led to laparoscopic colorectal resection becoming more widely utilized in the treatment of benign and malignant colorectal disease.

There have been previous concerns raised regarding possible negative outcomes of laparoscopic colorectal surgery such as longer operative time and a high rate of conversion to open surgery. Although conversion to open surgery alone is not a complication; patients who experience conversion may not receive the same benefits as those with completed laparoscopic resections. The impact of converting a laparoscopic procedure on post-operative outcome is unclear. Some authors have reported no difference in outcomes between converted and matched open cases [3–5], whereas others have shown an increase in operating time, hospital stay [6] and, morbidity and mortality for converted compared with laparoscopically completed procedures [7, 8].

Laparoscopic conversion rates in colorectal surgery have been reported as high as 41 % [2–14], although more recent large series report rates of 15–16 % [15, 16]. There are limited large studies in colorectal surgery

evaluating risk factors for conversion. Knowledge of risk factors for conversion may help surgeons to inform patients about the possibility of conversion, and may assist surgeons in identifying strategies to decrease the conversion rate. In this study, we use the Nationwide Inpatient Sample (NIS) database (1) to determine the contemporary prevalence of conversation rate in colorectal surgery (2009–2010) and (2) to identify risk factors associated with higher rate of laparoscopic conversion to open colon and rectal surgery.

Methods and materials

The NIS database is the largest inpatient care database in the United States. Approximately 1,000 hospitals (1,051 hospitals in 2010) contribute data annually to the NIS, resulting in a database of information from nearly eight million hospital stays each year [17]. The NIS is comprised of a nationally representative sample of approximately 20 % of U.S. hospitals, resulting in a sampling frame that comprises approximately 96 % of all hospital discharges in the United States. Data elements within the NIS are drawn from hospital discharge abstracts that allow determination of all procedures performed during a given hospital admission. It also contains discharge information on inpatient hospital stay including patient characteristics, length of stay, specific post-operative morbidity, and observed in-hospital mortality. The NIS database has no information available on complications occurring after discharge. Not all data elements in the NIS are provided by each State data source. These data elements are provided by the NIS because they can be valuable for research purposes, but they should be used cautiously. For example, ethnicity data is missing from a number of states; therefore race-specific estimates may be biased. Approval for use of the NIS patient-level data in this study was obtained from the Human Research Protection (HRP) of the University of California, Irvine Medical Center and the NIS.

Data analysis

Using the NIS database, we analyzed discharge data on patients who underwent elective/emergent laparoscopic or open colon and rectal resection in 2009 and 2010, which have specific laparoscopic International Classification of Disease ninth revision, Clinical Modification (ICD-9 CM) procedure codes. Patients who underwent colon and rectal surgery without resection (e.g., simple ostomy closure, rectopexy) were excluded from this study. We used ICD-9- CM procedure codes and principal diagnosis codes to identify the type of colorectal resection performed and the indication for surgery. To identify laparoscopic colorectal operations which converted to open operations, we used the ICD-9-CM diagnosis code of V64.41. Conversion is defined in NIS aborting laparoscopic procedure and proceeding with open midline approach. Also, we used ICD-9-CM codes of lysis of abdominal adhesions (54.5, 54.51, and 54.59) to identify patients who had previous abdominal surgery. We were unable to differentiate laparoscopic form laparoscopic hand-assisted procedures, or incision length information as there are no ICD-9-CM codes to differentiate these types of laparoscopic procedure or to provide details on extraction incisions. Also, we were unable to differ high versus low anterior resection as there is no ICD-9-CM code available for high anterior resection.

Preoperative factors that were analyzed include patient characteristics (age, sex, and ethnicity), obesity (body mass index of 30 and above), admission type (emergent or elective), pathologic conditions (malignancy, diverticulitis, ulcerative colitis, Crohn’s disease and benign tumor), surgical site (right colon, transverse colon, left colon, sigmoid, and rectum), surgical techniques (laparoscopic versus open), and hospital teaching status. The overall rate of laparoscopic conversion to open colorectal operation and the rate of conversion by surgical site, pathology type and admission type were examined. We also evaluated inpatient post-operative outcomes in laparoscopic, open and converted groups. Evaluated complications were urinary tract infection, pneumonia, respiratory failure, acute kidney injury, myocardial infarction, deep venous thrombosis, pulmonary thromboembolism, ileus (defined as delayed gastrointestinal transit in the post-operative period), wound infection, wound dehiscence, abdominal abscess, and bowel obstruction.

Risk-adjusted analysis was performed to identify independent predictors for conversion of laparoscopic to open colon and rectal surgery. Available important factors which might have impact in laparoscopic conversion to open surgery were evaluated including patient characteristics (gender, age, and race), obesity, procedure type, pathology, admission type (elective versus emergent), prior history of abdominal surgery and

teaching status of hospitals. Female gender, age\65 years, Caucasian, right colectomy, laparoscopic technique, benign tumor pathology, elective admission, no lysis of abdominal adhesions, and nonteaching hospital were used as a reference.

Statistical analysis

Multivariate logistic regression analysis was performed and odds ratio with a 95 % confidence interval were calculated to determine the combined effect of various preoperative factors for conversion of laparoscopic to open colon and rectal operation. All statistical analyses for the NIS database were conducted using SAS version 9.2 (SAS institute, Cary, North Carolina), incorporating recommended discharge and hospital weights. Discharge weight was used to create national estimates for all analyses. Statistical significance was set at P values \0.05 and odds ratios and 95 % confidence intervals.

Table 1 Colorectal resection in the United States, 2009–2010

Characteristics	Frequency (%)
Total #	646,414
Mean Age (year)	61.7 ± 17.4
Age ≥ 65	47.7
Female	53.3
Race	
White	77.7
Black	9.9
Hispanic	7.2
Asian\Islander	1.9
Native American	0.6
Other	2.7
Comorbidity	
Diabetes mellitus	15.3
Hypertension	48.5
Congestive heart failure	6.7
Chronic lung disease	15.4
Chronic kidney disease	6.0
Liver disease	1.9
Peripheral vascular disease	5.0
Alcohol abuse	2.1
Smoker	21.5
Elective admission rate	58.1
In-hospital mortality rate	4.1
Teaching hospitals	49.4
Laparoscopic procedure	27.7

Results

A total of 646,414 patients underwent colon or rectal resection in 2009 and 2010 in the United States. The majority of patients were female (53.3 %) and Caucasian (77.72 %). The mean age was 61.7 with 47.7 % of patients older than 65 years (Table 1). The most prevalent comorbidities were hypertension (48.5 %), smoking

(21.5 %), and chronic lung disease (15.4 %). The most common payer-type was Medicare (46.7 %). Almost half of these operations were performed in teaching hospitals (49.4 %). The majority of procedures were performed electively (58.1 %). The overall rate of laparoscopic approach was 27.7 % (elective surgery: 37.3 % vs. emergent surgery: 14.3 %). The overall rate of lysis of abdominal adhesions was 14.9 % (open procedure: 15.7% vs. laparoscopic procedure: 12.8 %; P\0.01).

The overall rate of conversion of laparoscopic to open colon and rectal surgery was 16.6 %. Table 2 shows rates of conversion of laparoscopic to open colon and rectal surgery in different types of colorectal resection and pathologies. The most common indication for colorectal resection was colorectal malignancy (32.3 %) followed by diverticulitis (20.1 %). The most common procedure type was right colectomy (35.4 %) followed by sigmoid colectomy (27.8 %). Considering procedure type, the highest rate of conversion was observed in proctectomy (31.3 %). Considering pathologic conditions, the highest conversion rate was observed in Crohn's disease patients (20.2 %). Conversion rate was significantly higher in emergent surgeries compared with elective surgeries (25.6 vs. 13.8 %; P\0.01).

Table 3 shows the frequency of conversion rate in different pathology and procedure types. Table 4 shows the comparison of outcomes of elective colorectal resections in open versus laparoscopic versus laparoscopic converted to open. Patients who were converted to open surgery had worse outcomes compared with the laparoscopic group; however, the converted group had better outcomes compared with the open group. As, patients' demographic and surgical details were different in the three evaluated groups; therefore, we used multivariate regression analyses to compare outcomes in three groups. Using multivariate regression analyses (Table 5), converted to open resections independently increased the complication rate (adjusted odds ration [AOR], 1.54) compared to completed laparoscopic resections; however, there was no significant difference in in-hospital mortality rate (AOR, 0.97) between the converted to open patients compared to completed laparoscopically.

Table 2 Frequency of procedure and pathology and conversion rate in colon and rectal surgery

	Frequency of procedure %	Conversion rate %
Procedures		
Right colectomy	35.4	16.4
Transverse colectomy	3.7	20.5
Left colectomy	8.9	19.0
Sigmoid colectomy	27.8	13.7
Total colectomy	4.3	11.3
Proctectomy	14.5	31.3
Other[a]	5.4	15.0
Pathology		
Malignant tumor	32.3	15.8
Diverticulitis	20.1	14.7
Benign tumor	7.9	7.9
Ulcerative colitis	1.8	11.3
Crohn' s disease	2.5	20.2
Other[b]	35.5	27.2
Admission type		
Elective	58.1	13.8
Emergent	41.9	25.6

[a] Included: (1) Open and other multiple segmental resection of large intestine; (2) Other and unspecified partial excision of large intestine

[b] included: bowel injury, obstruction, bleeding, perforation, and bowel ischemia

Table 6 lists the multivariate logistic regression analyses for risk factors for conversion of laparoscopic to open colorectal surgery. Multivariate regression analysis (risk adjusted) showed that for patients' characteristics, factors associated with a higher conversion rate were: male gender (AOR, 1.22), and Native American race (AOR, 1.40). Obesity (AOR, 1.63) also was an independent risk factor of conversion rate. Considering procedure type, proctectomy (AOR, 2.42), transverse colectomy (AOR, 1.33), and left colectomy (AOR, 1.16) independently increased rates of conversion to open surgeries compared with right colectomy. Considering pathologic conditions compared with benign tumor pathology (e.g., polyps), Crohn's disease (AOR, 2.80), malignant pathology (AOR, 1.90), and ulcerative colitis (AOR, 1.60) were independently associated with a higher rate of conversion. Also, lysis of abdominal adhesions (AOR, 2.45), emergent admission (AOR, 1.82), and teaching hospitals (AOR, 1.07) were all associated with higher rates of conversion in this patient population.

Discussion

This report with data from a large number of patients who underwent colon and rectal resection from January 2009 to December 2010 showed an overall conversion rate of 16.6 %. Patients who were converted to open colorectal resection had 1.5 times higher rate of complication. Similar to prior studies [13, 15], we did not find any significant increase in mortality rate in converted patients. Patients who converted to open surgery, stayed approximately 2 days longer compared with patients who were completed laparoscopically (8.3 vs. 6.5 days). Converted patients also had higher total hospital charges compared with non-converted patients.

Table 3 Frequency of conversion rate in different pathology and procedure types

	Right colectomy	Transverse colectomy	Left colectomy	Sigmoid colectomy	Total colectomy	Proctectomy
Malignancy (%)	12.4	20.6	16.9	13.6	14.4	32.7
Diverticulitis (%)	26.5	33.5	20.9	12.7	18.0	30.5
Benign disease (%)	6.8	13.6	11.7	8.1	8.1	34.7
Crohn's disease (%)	20.2	54.6	9.3	22	21.2	7.2
Ulcerative colitis (%)	18.5	–	19.4	31.8	9.0	17.9

Conversion is defined in the NIS database aborting laparoscopic procedure and proceeding with open midline approach. We doubt, however, a possible bias is that some surgeons will code an enlargement of incision just for extraction as a conversion, as the reimbursement for a laparoscopic approach is greater to the surgeon than a converted or open case. Importantly, our study showed that the group of patients who were converted to open had better outcomes compared with the open group (Tables 3, 4). Although general complications (e.g., UTI, pneumonia) were higher in open procedures compared with converted cases; specific complications (e.g., abdominal abscess, bowel obstruction) tended to be higher in converted cases compared with open operations. These increased specific complications might be related to the higher rate of intraoperative complications and longer operative time in converted procedures compared with open procedures [18]. Similarly, Simorov et al. [16] in a large recent study using a national database review of academic medical centers, showed attempted laparoscopic colon resection had better outcomes than open colectomy in the immediate perioperative period. However, Kang et al. [15] and Casillas et al. [3] showed no significant difference in morbidity and mortality between open and converted to open colorectal resections. In contrast, Belizon et al. [19] reported higher complication rates and a longer hospital stay in the converted patients compared to both the laparoscopic and open groups.

Several factors are believed to influence the need to convert a laparoscopic to open colorectal operation. There include (1) patient-related factors (e.g., gender, obesity, previous abdominal surgery),(2) surgeon-related factors (e.g., learning curve, experience, technical ability) (3) procedural factors (e.g., site of resection), and (4) intraoperative difficulties/complications such as poor visualization, equipment malfunction, and bleeding. Generally, surgeon and procedural-related reasons for conversion can be controlled by adequate training and

Table 4 Comparisons of outcomes in open versus laparoscopic versus converted elective colorectal resections

Outcomes	Open	Laparoscopic	Converted	*P* value[a]	*P* value[b]
In-hospital mortality (%)	1.7	0.5	0.6	<0.01	0.01
Complication rate (%)	35.3	23.0	35.2	0.69	<0.01
Urinary tract infection (%)	1.7	1.0	1.4	<0.01	<0.01
Pneumonia (%)	3.1	1.4	1.9	<0.01	<0.01
Respiratory failure (%)	7.1	2.6	3.8	<0.01	<0.01
Acute kidney injury (%)	5.6	2.4	3.3	<0.01	<0.01
Deep vein thrombosis (%)	0.6	0.2	0.3	<0.01	0.41
Pulmonary thromboembolism (%)	0.3	0.1	0.2	<0.01	0.02
Acute myocardial infarction (%)	0.3	0.2	0.3	0.42	0.56
Ileus (%)	16.7	13.2	18.9	<0.01	<0.01
Abdominal abscess/leak (%)	3.8	1.7	4.1	0.03	<0.01
Wound infection (%)	2.3	1.0	2.1	0.23	<0.01
Wound dehiscence (%)	0.5	0.2	0.7	<0.01	<0.01
Bowel obstruction (%)	6.4	4.1	7.5	<0.01	<0.01
Length of hospital stay (days)					
Mean	8.4	5.4	8.1	<0.01	<0.01
Median	6	4	6		
Mode	5	4	5		
Mean total hospital charges ($)					
Mean	65,821	47,729	57,590	<0.01	<0.01
Median	43,089	37,430	45,851		
Mode	20,076	13,955	18,841		

[a] *P* value in comparison between open and converted groups

[b] *P* value in comparison between laparoscopic and converted groups

experience. Patient-related factors remain largely outside the control of the surgeon; there remains a subset of patients who will perhaps never be suitable candidates for laparoscopic colorectal surgery [14].

We identified multiple independent risk factors of conversion in colorectal resection. Certain patient characteristics were found to confer a higher risk for conversion. Our study showed Native American race (AOR, 1.40) as an independent risk factor for laparoscopic conversion to open colectomy. We do not have an explanation, other than to realize this might be affected by hospital type or access to surgeon expertise. Also, male gender (AOR, 1.22) was associated with the higher risk of conversion compared with female gender. Consistent with our study, a male predominance was observed in converted cases in some other studies [8, 14, 20, 21]. The narrow male pelvis is well recognized as a technical challenge in rectal surgery; however, our study showed that male gender is a predictive risk factor of conversion for both colon and rectal resection. This might related to the factor that male patients often have android body habitus and increased intra-abdominal obesity contributing to the technical difficulty of the procedure that may lead to increased complication [22]. Interestingly, advanced age was not associated with a higher risk of conversion as has been shown in other studies [14, 19]. This is in contrast to findings from the early days of laparoscopic surgery wherein advanced age was considered as a relative contraindication for laparoscopic surgery. With experience, it has been demonstrated that patient age should not be a barrier to a laparoscopic approach, and indeed may be an indication for laparoscopy in an effort to reduce post-operative morbidity [22–24]. Not surprisingly, we found that obesity (AOR, 1.63) is an independent risk factor for conversion. Similarly, Pilarsky et al. [25] reported a significantly higher conversion rate for obese patients with a BMI exceeding 30 kg/m2 compared with non-obese patients (39 vs. 13.5 %).

Anatomical location appears to be a useful predictive factor for determining risk of conversion. In our series, the highest rate of conversion was seen in proctectomy patients (31.3 %). Similarly, Marusch et al. [7] in evaluation of 1,678 patients who underwent laparoscopic colorectal resection reported that resections of the rectum were associated with a higher rate of conversion (20.9 vs. 13 %). Further, Tan et al. [21] in evaluation of

Table 5 Risk-adjusted analysis in comparisons of complication rate and mortality in open versus laparoscopic versus converted colorectal resections

Outcomes	Laparoscopic AOR (95 % CI)[a]	Open	Converted to open AOR (95 % CI)
In-hospital mortality	0.37 (0.35–0.39)*	Reference	0.36 (0.32–0.40)*
Complication rate	0.58 (0.57–0.58)*	Reference	0.88 (0.85–0.90)*
Urinary tract infection	0.87 (0.83–0.92)*	Reference	0.91 (0.82–1.01)
Pneumonia	0.57 (0.54–0.59)*	Reference	0.67 (0.62–0.72)*
Respiratory failure	0.41 (0.40–0.42)*	Reference	0.46 (0.43–0.49)*
Acute kidney injury	0.53 (0.51–0.55)*	Reference	0.56 (0.53–0.59)*
Deep vein thrombosis	0.63 (0.58–0.69)	Reference	0.49 (0.41–0.60)*
Pulmonary thromboembolism	0.59 (0.53–0.66)	Reference	0.42 (0.32–0.55)*
Acute myocardial infarction	0.89 (0.79–0.99)	Reference	0.90 (0.71–1.14)
Ileus	0.77 (0.75–0.78)*	Reference	1.20 (1.16–1.24)*
Abdominal abscess/leak	0.51 (0.49–0.53)*	Reference	1.08 (1.01–1.15)*
Wound infection	0.48 (0.46–0.51)*	Reference	0.80 (0.73–0.87)*
Wound dehiscence	0.35 (0.31–0.40)*	Reference	1.21 (1.05–1.39)*
Bowel obstruction	0.61 (0.59–0.62)*	Reference	0.88 (0.84–0.92)*

[a] AOR (95 % CI): adjusted odds ratio (95 % confidence interval)

* $P < 0.05$

a total 365 laparoscopically assisted right hemicolectomy and anterior resections showed laparoscopic anterior resection had a higher rate of open conversion than laparoscopic right hemicolectomy (18.7 vs. 10.4 %; P = 0.02). We found that compared with right colectomy, proctectomy (AOR, 2.42), transverse colectomy (AOR, 1.33), and left colectomy (AOR, 1.16) were independently associated with a higher risk of conversion.

With regard to the indication for operation, our study demonstrated Crohn's disease had the highest rate of conversion among the different types of pathology studied (20.2 %). Schmidt et al. [26], in evaluation of 113 attempted procedures for Crohn's patients in 1993–2000 showed 40 % of procedures converted to open, and they concluded attempted laparoscopic management is safe and effective if there is an appropriate threshold for conversion to an open procedure. It seems that the conversion rate in Crohn's disease patients has been significantly decreased with advancement of laparoscopic bowel resection experience and familiarity of surgeons with laparoscopic techniques but still remains high. Our study showed Crohn's disease (AOR, 2.80), malignant pathology (AOR, 1.90), and ulcerative colitis (AOR, 1.60) were significant risk factors for conversion compared with benign tumors. Interestingly, we did not find diverticulitis to be a risk factor of conversion.

Previous abdominal surgery is one of the important predisposing risk factors for conversion. However, the NIS database does not reveal if the patients had prior abdominal operation. Using lysis of abdominal adhesions as a marker of prior abdominal operation, our study showed that patients who underwent lysis of abdominal adhesions had approximately 2.5 times higher risk of conversion compared with patients without lysis of adhesions. Similarly, Franko et al. [5] in an evaluation of 1,000 laparoscopic colorectal resection showed a higher rate of conversion in patients with prior abdominal surgery (OR 1.9; CI 1.3–2.8;P\0.001) and pelvic surgery (OR 2.2; CI 1.3–3.8; P = 0.004). However, they did not find a history of prior appendectomy or cholecystectomy as a significant risk factor of conversion. Generally, the presence of prior abdominal surgery is not considered an absolute contraindication, but rather a relative contraindication. Nevertheless, even patients with multiple prior abdominal surgeries have a relatively high success rate of laparoscopic colon and rectal resection [15, 27].

Limitations of our study include those inherent in using an immense database for collection of our data. As with any retrospective study using a large database, information regarding patient selection tends to be a limiting factor for the study. Also, we were unable to identify specific reasons for conversions; was it unsafe to proceed with laparoscopic surgery? Were there intra-operative complications? Was there equipment failure? Casillas et al. [3] in an evaluation of 51 converted patients (out of a total 430 patients) showed that specific indications for conversion were technical (41 %), followed by adhesions (33 %), phlegmon or abscess (23 %),

Table 6 Risk-adjusted analysis for conversion of laparoscopic to open colon and rectal surgery

Factors	Adjusted odds ratio (95 % CI[a])	*P* value
Patient-specific factors		
Age group		
<65 years	Reference	Reference
≥65 years	1.01 (0.98–1.03)	0.61
Gender		
Female	Reference	
Male	1.22 (1.19–1.25)	<0.01
Race		
White	Reference	Reference
Black	1.09 (1.04–1.14)	0.99
Hispanic	0.98 (0.94–1.03)	<0.01
Asian	1.06 (0.97–1.16)	0.59
Native American	1.40 (1.19–1.65)	<0.01
Other	1.03 (0.96–1.12)	0.17
Obesity	1.63 (1.57–1.70)	<0.01
Procedures		
Right colectomy	Reference	Reference
Transverse colectomy	1.33 (1.24–1.44)	<0.01
Left colectomy	1.16 (1.11–1.22)	<0.01
Sigmoid colectomy	0.80 (0.77–0.83)	<0.01
Total colectomy	0.68 (0.62–0.75)	<0.01
Proctectomy	2.42 (2.31–2.54)	<0.01
Other	0.74 (0.69–0.80)	<0.01
Pathology		
Benign disease	Reference	Reference
Malignant tumor	1.90 (1.81–2.0)	<0.01
Diverticulitis	2.06 (1.95–2.19)	0.13
Ulcerative colitis	1.60 (1.39–1.84)	<0.01
Crohn's disease	2.88 (2.65–3.19)	<0.01
Other	3.55 (3.37–3.74)	<0.01
Admission type		
Elective	Reference	Reference
Emergent	1.83 (1.77–1.88)	<0.01
Hospital teaching status		
Non-teaching	Reference	Reference
Teaching	1.07 (1.04–1.10)	<0.01
Lysis of adhesion		
Without	Reference	Reference
With	2.45 (2.37–2.53)	<0.01

CI confidence interval

bleeding (6 %), and failure to identify the ureter (6 %). Additionally, we were also unable to identify surgeon-related factors, (e.g., surgeon's experience and training in laparoscopic colorectal resection), which is a significant predictor of conversion. Also, we were unable to evaluate the effect of hospital volume on conversion rate; however, the COLOR trial study showed a significant difference in conversion rate was

observed among low, medium, and high case volume hospitals (24 vs. 24 vs. 9 %; P\0.001) [28]. The NIS database is only limited to inpatient hospital events and does not include post-discharge complications such as 30-day complications, outpatient follow-up, and readmissions. For example, wound infections that occur after discharge would not be captured in this database; therefore, our calculations of wound infection rate underestimate the actual rate. However, we believe that we have captured the conversion rate as it happens in the initial admission. Also, in evaluation of the outcomes, we lack information on perioperative care pathways which can have a significant impact on surgical outcomes. Lastly, we were unable to evaluate the effect on neoadjuvant therapy in conversion rate; however, Rezvani et al. [29] in evaluation of outcomes of laparoscopic resection of rectal carcinoma after neoadjuvant therapy showed a higher conversion rate in neoadjuvant group (37 %) compared with primary surgical group (13 %). Despite the limitations of the study, this is the largest nationwide study evaluating the rate and risk factors of conversion in laparoscopic colorectal surgery.

In conclusion, our study has shown that the rate of conversion in laparoscopic colon and rectal resection is 16.6 %. Converted patients experience a higher complication rate compared with patients who had an operation completed laparoscopically. Considering outcomes on an intention to treat basis, comparing outcomes of all the laparoscopic attempted colorectal surgery against the open colorectal surgery, we find that morbidity and mortality of patients who has an intended laparoscopic colorectal procedure remains lower than open procedures even after controlling comorbidities using multivariate analysis. Also, our study showed that Crohn's disease, prior abdominal surgery, and proctectomy are the most potent risk factors for conversion in laparoscopic colorectal surgery. None of the identified risk factors alone is a contraindication to laparoscopic surgery; however, a combination of these risk factors might be considered as a contraindication to laparoscopic surgery. Surgeons should be aware of these risk factors and may use this information in selection of patients for laparoscopic surgery and counseling high-risk patients about the risk of conversion and expected outcomes. Future prospective research should be directed at creating contraindication criteria (relative vs. absolute) for laparoscopic colorectal surgery that includes patient, procedural and surgeon-related factors.

References

1. Clinical Outcomes of Surgical Therapy Study Group (2004) A comparison of laparoscopically assisted and open colectomy for colon cancer. N Eng J Med 350:2050–2059
2. Rabasova´ M, Martı´nek L (2012) Conversion risk factors in laparoscopic colorectal surgery. Wideochir Inne Tech Malo Inwazyjne 7(4):240–245
3. Casillas S, Delaney CP, Senagore AJ et al (2004) Does conversion of a laparoscopic colectomy adversely affect patient outcome? Dis Colon Rectum 47:1680–1685
4. Laurent C, Leblanc F, Wu¨trich P et al (2009) Laparoscopic versus open surgery for rectal cancer. Long term oncological results. Ann Surg 250:54–61
5. Franko J, Fassler SA, Rezvani M et al (2008) Conversion of laparoscopic colon resection does not affect survival in colon cancer. Surg Endosc 22:2631–2634
6. Gervaz P, Pikarsky A, Utech M et al (2001) Converted laparoscopic colorectal surgery. Surg Endosc 15:827–832
7. Marusch F, Gastinger I, Schneider C et al (2001) Importance of conversion for results obtained with laparoscopic colorectal surgery. Dis Colon Rectum 44:207–214
8. Chan ACY, Poon JT, Fan JK et al (2008) Impact of conversion on the long-term outcome in laparoscopic resection of colorectal cancer. Surg Endosc 22:2625–2630
9. Lacy AM, Garcia-Valdecasas JC, Delgado S et al (1997) Postoperative complications of laparoscopic assisted colectomy. Surg Endosc 11:119–122
10. Guillou PJ, Quirke P, Thorpe H et al (2005) Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomized controlled trial. Lancet 365:1718–1726
11. Larach SW, Patankar SK, Ferrara A et al (1997) Complications of laparoscopic colorectal surgery: analysis and comparison of early vs latter experience. Dis Colon Rectum 40:592–596

12. Marusch F, Gastinger I, Schneider C et al (2001) Experience as a factor influencing the indications for laparoscopic colorectal surgery and the results. Surg Endosc 15:116–120
13. Lu KC, Cone MM, Diggs BS et al (2011) Laparoscopic converted to open colectomy: predictors and outcomes from the Nationwide Inpatient Sample. Am J Surg 201(5):634–639
14. Thorpe H, Jayne DG, Guillou PJ (2008) Patient factors influencing conversion from laparoscopically assisted to open surgery for colorectal cancer. Br J Surg 95(2):199–205
15. Kang CY, Chaudhry OO, Halabi WJ et al (2012) Outcomes of laparoscopic colorectal surgery: data from the Nationwide Inpatient Sample 2009. Am J Surg 204(6):952–957
16. Simorov A, Shaligram A, Shostrom V et al (2012) Laparoscopic colon resection trends in utilization and rate of conversion to open procedure: a national database review of academic medical centers. Ann Surg 256(3):462–468
17. Overview of the Nationwide Inpatient Sample (NIS). http://www.hcup-us.ahrq.gov/nisoverview.jsp. Reviewed on 7 Aug 14
18. Marusch F, Gastinger I, Schneider C et al (2001) Importance of conversion for results obtained with laparoscopic colorectal surgery. Dis Colon Rectum 44:207–214
19. Belizon A, Sardinha CT, Sher ME (2006) Converted laparoscopic colectomy: what are the consequences? Surg Endosc 20(6):947–951
20. Schwandner O, Schiedeck TH, Bruch HP (1999) The role of conversion in laparoscopic colorectal surgery. Do predictive factors exist? Surg Endosc 13:151–156
21. Tan PY, Stephens JH, Rieger NA, Hewett PJ (2008) Laparoscopically assisted colectomy: a study of risk factors and predictors of open conversion. Surg Endosc 22:1708–1714
22. Mason EE, Renquist KE, Jiang D (1992) Perioperative risks and safety of surgery for sever obesity. Am J Clin Nutr 55:573S–576S
23. Sklow B, Read T, Birnbaum E et al (2003) Age and type of procedure influence the choice of patients for laparoscopic colectomy. Surg Endosc 17:923–929
24. Stocchi L, Nelson H, Young-Fadok TM et al (2000) Safety and advantages of laparoscopic versus open colectomy in the elderly: matched-control study. Dis Colon Rectum 43:326–332
25. Pilarsky AJ, Saida Y, Yamaguchi T et al (2002) Is obesity a highrisk factor for laparoscopic colorectal surgery? Surg Endosc 16:855–858
26. Schmid CM, Talamini MA, Kaufman HS, et al (2001) Laparoscopic surgery for Crohn's disease: reasons for conversion. Ann Surg 233(6):733–739
27. Barleben A, Gandhi D, Nguyen XM et al (2009) Is laparoscopic colon surgery appropriate in patients who have had previous abdominal surgery? Am Surg 75(10):1015–1019
28. Kuhry E, Bonjer HJ, Haglind E et al (2005) Impact of hospital case volume on short-term outcome after laparoscopic operation for colonic cancer. Surg Endosc 19(5):687–692
29. Rezvani M, Franko J, Fassler SA, et al (2007) Outcomes in patients treated by laparoscopic resection of rectal carcinoma after neoadjuvant therapy for rectal cancer. JSLS 11(2):204–207