



# Use of laparoscopic colectomy increasing in trauma: comparison of laparoscopic vs. open colectomy

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## Abstract

Laparoscopy accounts for > 70% of general surgical cases. Given the increased use of laparoscopy in emergent colorectal disease, we hypothesized that there would be an increased use of laparoscopic colectomy (LC) in trauma patients. In addition, we hypothesized increased length of stay (LOS) and mortality in trauma patients undergoing open colectomy (OC) vs. LC. This was a retrospective analysis using the National Trauma Data Bank (2008–2015). We included adult patients undergoing LC or OC. A multivariable logistic regression model was used for determining risk of LOS and mortality. We identified 19,788 (96.8%) patients undergoing OC and 644 (3.2%) who underwent LC. There was a 21-fold increased number of patients that underwent LC over the study period ( $p < 0.05$ ), with approximately 119 per 10,000 trauma patients undergoing LC. The most common operation was a laparoscopic right hemicolectomy (27.5%). LC patients had a lower median injury severity score (ISS) (16 vs. 17,  $p < 0.001$ ). There was no difference in LOS ( $p = 0.14$ ) or mortality ( $p = 0.44$ ) between the two groups. This remained true in patients with isolated colorectal injury. The use of LC has increased 21-fold from 2008 to 2015, with laparoscopic right hemicolectomy being the most common procedure performed. There was no difference in LOS, in-hospital complications, or mortality between the two groups. We suggest that LC should be considered in stable adult trauma patients undergoing colectomy. However, future prospective research is needed to help determine which trauma patients may benefit from LC.

**Keywords** Trauma · Colorectal · Colon injury · Laparoscopic colectomy · Open colectomy

## Introduction

The inception of laparoscopic surgery traces back as early as 1901 to pioneers such as Georg Kelling, Dimitri Ott and Hans Christian Jacobaeus [1]. However, its widespread use by general surgeons did not truly begin until the 1980s, after Lukichev and Muhe performed laparoscopic cholecystectomies in humans [2, 3]. While initially used predominantly for elective cases, laparoscopy has since been adopted for urgent/emergent general surgical operations. Laparoscopy is currently used for 72–89% of cholecystectomies [4] and 51–70% of appendectomies [5]. The previous studies on

elective colectomy for colorectal cancer, namely, the COST trial, have demonstrated that elective laparoscopic colectomy (LC) is safe compared to open colectomy (OC), with decreased length of stay and use of parenteral and oral analgesics [6, 7]. More recently, there have been reports on the use of LC in the emergency setting [8, 9]. A National Surgical Quality Improvement Program (NSQIP) study found that utilization of laparoscopy for management of emergent colorectal disease increased from 9.3% in 2012 to 10.9% in 2014 [10].

Previous reports on the use of laparoscopy in trauma have also emerged [11–15]. However, utilization of laparoscopy in trauma has predominantly been for diagnostic purposes [16]. Several authors have demonstrated the safe use of diagnostic laparoscopy to evaluate for possible diaphragmatic injury in patients with left thoracoabdominal stab wounds, as well as the potential for laparoscopic repair [17, 18]. Currently, no trauma organizations [Eastern Association for the Surgery of Trauma (EAST), Western Trauma Association

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(WTA), American Association for the Surgery of Trauma (AAST)] or Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) have any guidelines on the use of LC for trauma.

The application of LC for traumatic injuries using a large database has not yet been examined. Given the increased utilization of laparoscopy in emergent colorectal disease, we hypothesized that there would be an increased use of LC for trauma patients from 2008 to 2015. In addition, we hypothesized increased length of stay (LOS) and mortality in trauma patients undergoing OC compared to LC.

## Methods

A retrospective analysis of the National Trauma Data Bank (NTDB) was performed between January 2008 and December 2015 [19]. All patients  $\geq 18$  years of age were eligible for inclusion. Patients were categorized based on whether they underwent LC or OC, as defined by International Classification of Diseases (ICD) version-9 procedural codes (LC 17.31–17.39, 45.81; OC 45.71–45.79, 45.82–45.83). The primary outcome was the use of LC over the study period. A comparison of trauma patients undergoing LC and OC was performed. Secondary outcomes were LOS and mortality.

Demographic variables collected included age and gender. Pre-hospital comorbidities included end-stage renal disease (ESRD), diabetes, hypertension, cerebrovascular accident (CVA), smoking, congestive heart failure (CHF), and chronic obstructive pulmonary disease (COPD). The injury profile included the injury severity score (ISS), severe grade ( $> 3$ ) for abbreviated injury scale (AIS) by body region, hypotension on arrival (systolic blood pressure  $< 90$  mmHg), and an associated traumatic brain injury (TBI), as well as spine, liver, spleen, stomach, and small bowel injuries. An isolated colorectal injury was indicated in patients with an AIS grade  $< 3$  for head and thorax with no associated liver, spleen, or small bowel injuries. We also identified patients that underwent any other major abdominal operation. This was defined as any repair and/or resection of the liver, spleen, small bowel, or diaphragm, and identified by the appropriate ICD-9 procedural codes listed in Table 5 in Appendix A. In-hospital complications included development of acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), deep vein thrombosis (DVT), pulmonary embolism (PE), superficial infection, urinary tract infection (UTI), myocardial infarction (MI), catheter related blood stream infection (CRBSI), pneumonia and severe sepsis. All variables were coded as present or absent.

Descriptive statistics were performed for all variables. A Student's *t* test was used to compare continuous variables and  $\chi^2$  was used to compare categorical variables for bivariate analysis. Categorical data were reported as percentages,

and continuous data were reported as medians with inter-quartile range or as means with standard deviation.

After identifying the average LOS in the study population, we used a univariable logistic regression model to identify risk for increased LOS in OC vs. LC. We then performed a similar analysis for mortality. Covariates (age  $\geq 65$  and ISS  $\geq 25$ ) known to increase morbidity and mortality in trauma were controlled for using a hierarchical multivariable logistic regression model to identify the adjusted risk for increased LOS and mortality in OC vs. LC [20, 21]. Risk of increased LOS and mortality was reported with an odds ratio (OR) and 95% confidence intervals (CI). The analysis was performed based on the set of patients with complete data for all variables in the model. Differences with  $p < 0.05$  were considered statistically significant. All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 24. (Armonk, NY: IBM Corp).

## Results

In total, 20,428 trauma patients underwent LC or OC between 2008 and 2015. Of these, 19,784 (96.8%) underwent OC, while 644 (3.2%) underwent LC. The use of LC increased 21-fold from 2008 to 2015 ( $p < 0.05$ ), with approximately 119 per 10,000 trauma patients undergoing LC. There was an increased use of LC each year, reaching a high of 210 per 10,000 patients in 2015 (Table 1). The most common type of colectomy in both groups was a right hemicolectomy (OC 31.5%, LC 27.5%,  $p < 0.001$ ). Compared to patients that underwent OC, those that underwent LC were older (mean age, 43.1 vs. 38.1 years,  $p < 0.001$ ) with a lower median ISS (16.0 vs. 17.0,  $p < 0.001$ ) and lower rate of hypotension on arrival (9.9% vs. 14.1%,  $p < 0.05$ ) but higher rate of a blunt mechanism (49.2% vs. 38.4%,  $p < 0.001$ ). LC patients had a higher prevalence of CHF (2.3% vs. 1.3%,

**Table 1** Incidence of adult trauma patients undergoing laparoscopic colectomy by year

Year	Laparoscopic colectomy Frequency	Number in every 10,000 patients
2008	5	10
2009	37	68
2010	58	100
2011	73	115
2012	79	112
2013	111	165
2014	123	175
2015	158	210
Total	644	119

All  $p < 0.05$

$p < 0.05$ ), diabetes (7.5% vs. 5.3%,  $p < 0.05$ ), and hypertension (18.8% vs. 13.8%,  $p < 0.001$ ). LC patients had a higher incidence of TBI (17.1% vs. 13.8%,  $p < 0.05$ ) but lower incidence of stomach (5.3% vs. 9.7%,  $p < 0.001$ ), small bowel (33.5% vs. 46.6%,  $p < 0.001$ ), liver (19.6% vs. 23.0%,  $p < 0.05$ ) and spleen injuries (13.0% vs. 16.9%,  $p < 0.05$ ), as well as a lower rate of severe AIS for the abdomen (10.7% vs. 16.4%,  $p < 0.001$ ) (Table 2).

There were no statistically significant differences between the OC and LC groups in complications and mortality (all  $p > 0.05$ ). Compared to patients that underwent OC, those that underwent LC had a lower rate of other abdominal operations (32.0% vs. 50.2%,  $p < 0.001$ ). The most common other abdominal operation in both groups was small bowel repair (> 80%). LC and OC patients had similar LOS ( $p = 0.82$ ), ICU LOS ( $p = 0.97$ ), and ventilator days ( $p = 0.84$ ) (Table 3).

The mean LOS for the study population was 19.7 days. After adjusting for covariates, there were no differences in risk for increased LOS ( $\geq 20$  days) (OR 1.15, 95% CI 0.96–1.38,  $p = 0.14$ ) or mortality (OR 1.11, 95% CI 0.86–1.42,  $p = 0.44$ ) in patients undergoing OC when compared to LC (Table 4). This analysis remained true on a subgroup analysis of patients with isolated colorectal injury (increased LOS: OR 1.62, 95% CI 0.92–2.86,  $p = 0.10$ ).

## Discussion

This retrospective review of the NTDB, spanning over 7 years, demonstrated that the use of LC in trauma has increased 21-fold from 2008 to 2015. Approximately 119 per 10,000 trauma patients currently undergo LC, with laparoscopic right hemicolectomy being the most common operation performed. Compared to OC, trauma patients undergoing LC are older, have a higher rate of pre-hospital comorbidities, and suffer less severe trauma. There was no difference between OC and LC in terms of LOS, hospital complications, and mortality rate. This remained true for patients with isolated colorectal injury.

Clear indications for the use of laparoscopy to treat emergent colorectal disease have not yet been established [22], but the use of LC in the realm of emergency general surgery has been increasing. Sujatha-Bhaskar et al. found up to 10% of emergent colorectal disease is treated with LC, with obstructions secondary to colorectal cancer being the most common disease treated laparoscopically [10]. With the evolving convergence of trauma and emergency general surgery, acute care surgeons with experience using LC to treat emergent colorectal pathology may be more apt

**Table 2** Demographics of adult trauma patients undergoing open vs. laparoscopic colectomy

Characteristic	Open colectomy ( $n = 19,784$ )	Laparoscopic colectomy ( $n = 644$ )	$p$ value
Age, years, mean (SD)	38.1 (17)	43.1 (19)	< 0.001
Male, $n$ (%)	16,301 (82.7%)	509 (79.0%)	< 0.05
ISS, median (IQR)	17.0 (16)	16.0 (16)	< 0.001
Blunt mechanism, $n$ (%)	7591 (38.4%)	317 (49.2%)	< 0.001
Penetrating mechanism, $n$ (%)	11,683 (59.1%)	305 (47.4%)	< 0.001
Hypotension on arrival (SBP < 90 mmHg), $n$ (%)	2781 (14.1%)	64 (9.9%)	< 0.05
Comorbidities, $n$ (%)			
Congestive heart failure	251 (1.3%)	15 (2.3%)	< 0.05
Smoker	2768 (14.0%)	105 (16.3%)	0.10
End-stage renal disease	88 (0.4%)	3 (0.5%)	0.94
Cerebrovascular accident	130 (0.7%)	10 (1.6%)	< 0.05
Diabetes	1044 (5.3%)	48 (7.5%)	< 0.05
Hypertension	2738 (13.8%)	121 (18.8%)	< 0.001
COPD	926 (4.7%)	26 (4.0%)	0.45
Injuries, $n$ (%)			
Traumatic brain injury	2736 (13.8%)	110 (17.1%)	< 0.05
Spine	4830 (24.4%)	141 (21.9%)	0.14
Stomach	1923 (9.7%)	34 (5.3%)	< 0.001
Small bowel	9225 (46.6%)	216 (33.5%)	< 0.001
Liver	4543 (23.0%)	126 (19.6%)	< 0.05
Spleen	3346 (16.9%)	84 (13.0%)	< 0.05

SD standard deviation, ISS injury severity score, IQR interquartile range, SBP systolic blood pressure, COPD chronic obstructive pulmonary disease

**Table 3** Analysis of clinical outcomes in adult trauma patients undergoing open vs. laparoscopic colectomy

Outcome	Open colectomy (n = 19,784)	Laparoscopic colectomy (n = 644)	p value
LOS, days, mean (SD)	19.8 (21)	18.8 (18)	0.82
ICU, days, mean (SD)	11.7 (14)	11.1 (13)	0.97
Ventilator, days, mean (SD)	9.6 (12)	9.5 (12)	0.84
Other abdominal operation, n (%)	9936 (50.2%)	206 (32.0%)	<0.001
Type of colectomy, n (%)			
Total	467 (2.4%)	74 (11.5%)	<0.001
Cecum	1919 (9.7%)	70 (10.9%)	<0.001
Right	6256 (31.5%)	177 (27.5%)	<0.001
Transverse	3413 (17.2%)	103 (16.0%)	<0.001
Left	2851 (14.4%)	48 (7.5%)	<0.001
Sigmoid	3748 (18.9%)	137 (21.3%)	<0.001
Segmental/other	3564 (18.0%)	70 (10.9%)	<0.001
Complications, n (%)			
Acute kidney injury	1493 (7.5%)	50 (7.8%)	0.84
ARDS	1320 (6.7%)	35 (5.4%)	0.21
Deep vein thrombosis	1040 (5.3%)	43 (6.7%)	0.11
Pulmonary embolism	402 (2.0%)	18 (2.8%)	0.18
Superficial infection	728 (3.7%)	21 (3.3%)	0.58
Urinary tract infection	658 (3.3%)	22 (3.4%)	0.90
Myocardial infarction	147 (0.7%)	3 (0.5%)	0.42
CRBSI	149 (0.8%)	2 (0.3%)	0.20
Pneumonia	2314 (11.7%)	70 (10.9%)	0.52
Severe sepsis	802 (4.1%)	25 (3.9%)	0.83
Mortality, n (%)	2846 (14.5%)	87 (13.5%)	0.48

LOS length of stay, SD standard deviation, ICU intensive care unit, ARDS acute respiratory distress syndrome, CRBSI catheter related blood stream infection

**Table 4** Adjusted\* odds ratio for risk of increased length of stay and mortality in open vs. laparoscopic colectomy in adult trauma patients

Outcome	OR	CI	p value
Increased length of stay	1.15	0.96–1.38	0.14
Mortality	1.11	0.86–1.42	0.44

\*Controlled for age  $\geq 65$  and injury severity score  $\geq 25$

to use LC in the management of colorectal trauma [23]. This may partly explain why the incidence of LC in trauma has increased.

Surgeons trained more recently may favor laparoscopic surgeries. Aquina et al. reviewed a state-wide database and found the use of LC to vary up to 99.8% depending on the surgeon. Although some of the variation can be explained by patient-level factors, the most important determinant was the number of years, since the surgeon completed training [24]. Trauma surgeons have a median age of 47 and are considered the third youngest sub-specialty group of all surgeons [25]. In addition, trauma surgeons just beginning

their career have more advanced laparoscopic training than ever before. The number of LCs done by graduating surgical residents increased from 4.2 in 2004 to 21.6 in 2014 [26]. Future studies should confirm if laparoscopic training during residency/fellowship and if the number of LCs done by the end of training correlate with the increased use of LC in trauma surgery.

Patient selection is important to the success of laparoscopic surgery. Our study found that the mean age of patients undergoing LC was older than those undergoing OC. However, the 5-year difference between groups (38.1 years vs. 43.1 years) is likely not clinically significant as both groups are relatively young, compared to patients seen in emergency general surgery. Some authors have suggested that young patients stand to benefit the most from laparoscopic surgery as they are better able to tolerate the physiologic changes occurring with insufflation and are better able to maintain appropriate cardiac output with compensatory tachycardia [27]. The concern in older patients is that the physiologic demands of pneumoperitoneum, positioning, and longer operative times may contribute to worse outcomes. However, with adequate perioperative cardiac care, there is no

evidence that these factors portend worse outcomes in older patients [28]. Fujii et al. performed a meta-analysis of laparoscopic surgery in over 3200 elderly patients (age  $\geq 65$ ) with colorectal cancer and found that those treated with LC had less estimated blood loss, surgical site infections, bowel obstruction, and ileus [29].

Aside from age, another important factor for patient selection of LC is pre-existing comorbidities. Healthier patients are thought to tolerate the added physiologic demands of laparoscopic surgery [30]. Kim et al. conducted a multi-center observational study on patients undergoing laparoscopic surgery and found patients with no comorbidities had a 9.5% rate of local complications, while those with  $\geq 3$  comorbidities had a 21.6% complication rate [31]. Our findings conflict with these previous reports. Compared to the OC group, the LC group had a *higher* rate of pre-hospital comorbidities including CHF, CVA, diabetes, and hypertension. Despite this, these patients actually had no worse outcomes compared to the OC group. Conversely, it must be noted that LC patients did have a lower median ISS. As such, it appears that LC can be safely accomplished in an overall less severely injured, stable adult trauma population, even with several comorbidities. Future prospective research is needed to confirm precise indications for LC in trauma and help determine which subset of trauma patients will benefit most from LC.

Operative choice may influence the LOS in trauma patients. Although laparoscopic surgery has been shown to decrease hospital LOS in elective colorectal surgery, we were not able to demonstrate this in our study of trauma patients undergoing colectomy [32, 33]. Furthermore, patients with isolated colorectal injury treated with OC did not have an increased LOS, when compared to those managed with LC. The rate of major hospital complications in both groups was similar, which helps explain why the LOS was similar. Enhanced recovery after surgery (ERAS) is a multidisciplinary perioperative pathway aimed at reducing complications and LOS after major colorectal surgery [34]. The implementation of ERAS in non-trauma patients undergoing colorectal surgery has been shown to decrease LOS for both open (from 7 to 6 days) and laparoscopic procedures (from 6 to 4 days) [35]. Similar pathways in trauma patients undergoing LC may be beneficial. However, some patients may have concomitant injuries that may preclude them from being able to start a diet. In our study, the average LOS for both the open and laparoscopic groups was 19.7 days, far higher than the aforementioned elective studies that had improvement utilizing ERAS. We propose that future prospective studies on perioperative pathways, similar to ERAS, should occur using select trauma patients with

isolated colorectal injuries undergoing LC to determine if a subset of trauma patients may benefit from an enhanced recovery pathway.

Our study involves a large national database with multiple participating trauma centers; therefore, a reporting bias is undoubtedly present. In addition, all data fields in the NTDB are subject to input error, and thus, some procedures and diagnoses may be miscoded. Information regarding cost analysis, surgeon age, residency/fellowship training, and experience with LC was missing. Furthermore, there is an inherent selection bias in whom the trauma surgeon felt to be an appropriate candidate for LC. The NTDB only tracks morbidity and mortality as part of the index hospitalization; thus, complications occurring after discharge are not captured. In addition, intraoperative factors such as hemodynamic status, as well as operative time are not available within the NTDB.

The use of LC in trauma patients has increased 21-fold over the past 8 years. Approximately 119 per 10,000 trauma patients undergo LC, with laparoscopic right hemicolectomy being the most common operation performed. Compared to OC, trauma patients undergoing LC are slightly older, have a higher rate of pre-hospital comorbidities, and suffer less severe trauma. No difference was found in terms of LOS, hospital complications, and mortality between the LC and OC groups. This remains true for patients with isolated colorectal injury. We suggest that LC should be considered in stable adult trauma undergoing colectomy, even if the patient has several comorbidities. However, future prospective research is needed to help determine which trauma patients may benefit from LC.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflicts of interest.

**Research involving human participants and/or animals** This research involved humans. However, since this retrospective study was performed using a national database with deidentified patients, risk to participants is minimal.

**Informed consent** There is no consent required.

## Appendix A

See Table 5.

**Table 5** ICD-9 procedure codes for repair of other abdominal surgery

Major surgery	ICD-9-procedure codes
Spleen	41.42–41.45
Liver	50.22–50.23, 50.3–50.4, 50.61–50.69
Small bowel	45.5–45.63, 46.71, 46.73
Diaphragm	53.72

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