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Elective laparoscopic versus open colectomy for diverticulosis: an analysis of ACS-NSQIP database

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Abstract
Background The benefits of laparoscopic (LC) versus open (OC) colectomy for symptomatic colonic diverticulosis as an elective operation remain unclear.
Methods Using the American College of Surgeons-National Surgical Quality Improvement Project (ACS-NSQIP) participant-user file, patients were identified who underwent elective colon resection for symptomatic colonic diverticulosis, between 2005 and 2008. Demographic, clinical, intraoperative variables, and 30-day morbidity and mortality were collected. Logistic regression analysis was performed to determine the association between the surgical approach (LC vs. OC) and risk-adjusted overall mortality, overall morbidity, serious morbidity, and wound complications.
Results A total of 7,629 patients were identified who underwent colon resection for symptomatic diverticulosis. They were subdivided into two groups: OC (3,870 (50.7%)) and LC (3,759 (49.3%)). Patients who underwent OC were significantly older (59.0 vs. 55.7 years, $P < 0.0001$) with more comorbidities compared with those who underwent LC. After risk-adjusted analysis, it was noted that the patients treated with LC were significantly less likely to experience overall morbidity (11.9% vs. 23.2%), serious morbidity (4.6% vs. 10.9%), and wound complications (9.1% vs. 17.5%), but not mortality (0.3% vs. 0.8%). Operative duration was significantly longer with LC (176.64 vs. 166.70 min, $P < 0.0001$), but the length of stay was significantly shorter (4.77 vs. 7.68 days, $P < 0.0001$). Using logistic regression analysis, patients with history of peripheral vascular disease, percutaneous coronary interventions, current steroid use, and hypertension requiring medication were at an increased risk of morbidity and mortality at 30 days. Patients with history of chronic obstructive pulmonary disease and smoking experienced more wound complications at 30 days.
Conclusions In the elective setting for symptomatic diverticulosis, LC seems to be associated with lower 30-day morbidity and complication rates compared with OC.

Keywords Diverticulitis · Diverticulosis · Colorectal · Cancer · Colectomy · Laparoscopic · NSQIP

Diverticulosis is a common disease in western society with an overall incidence of 33% of the population older than aged 45 years and increasing to 66% of the population older than aged 85 years [1]. Ten to twenty-five percent of patients with diverticulosis will develop diverticulitis and up to 1% will require an operation [2]. The reported rates of hospital admission for diverticulitis have increased during the past few years [3]. Despite improvements in medical management and the changes in the indications and timing of the surgery, the need for surgery is still prevalent for patients with recurrent episodes of acute diverticulitis [4–6]. Resection of the colon by an open procedure (OC) is still the "gold standard," but it is feasible to perform a laparoscopic-assisted colon (LC) resection [7–11]. There is increasingly compelling evidence that LC does indeed provide a number of advantages, including shorter hospital stay, reduced postoperative ileus, earlier

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resumption of oral nutritional intake, reduced pain, and improved cosmesis [12–15]. The purpose of this study is to compare 30-day postoperative outcomes between the standard OC and the LC for symptomatic diverticulosis in the elective setting by using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database.

Material and methods

ACS-NSQIP

The ACS-NSQIP is the first nationally validated, risk adjusted, outcomes-based reporting system to measure and improve the quality of surgical care. ACS-NSQIP collects data on 136 variables from 221 participating hospitals. It includes preoperative risk factors, intraoperative variables, and 30-day postoperative morbidity and mortality outcomes for patients undergoing major surgical procedures in both the inpatient and the outpatient setting. These data were collected by a dedicated surgical clinical reviewer (SCR) at the participating site. As part of the program, the SCR receives continuing education and training regarding data definitions and extraction. After the inclusion criteria were met, sampling of the operating room log's first 40 cases within an 8-day cycle performed. This was to ensure that no particular operating room days' block time would bias the weighting of cases and that cases had an equal chance of being selected from each day of the week. There are 46, 8-day cycles in 1 year, and the program requires that data be submitted for 42 of those cycles. The case selection and case mix were monitored by the program weekly to ensure that the sampling was appropriate. Hospitals with high volume were required to submit a minimum of 1,680 cases annually and hospitals with low volume required a minimum of 900 cases per year. All variables included in the ACS-NSQIP dataset were clearly defined in the database user guide. Information was obtained from computerized and/or paper patient medical records, physician office records, and telephone interviews with patients. The patients were then followed after hospital discharge for 30 days postoperatively. To date, the ACS-NSQIP has had a 95% success rate in capturing the 30-day outcomes for all cases in the database. The accuracy and reproducibility of its data have been previously demonstrated [16, 17].

Patients, aged 18 years or older, who had undergone colectomy based on primary current procedural terminology (CPT) codes and had a postoperative diagnosis of colonic diverticulosis based on the international classification of disease diagnosis codes (ICD-9) were identified from the ACS-NSQIP database from 2005 to 2008. Patients who underwent emergency operations were excluded. High-risk patients also were excluded if they had: preoperative ventilator dependence, American Society of Anesthesiology (ASA) class 5, preoperative septic shock, or total dependent functional status. Patients who had diverting ostomy during the procedure or reversal of an ostomy and patients who had complex operations for complications of diverticulitis, including fistulae and abscesses, also were excluded from the study.

Based on the CPT codes, these patients were divided into two groups: laparoscopic colectomy (LC) and open colectomy (OC). Data comparing preoperative variables between the two groups, including patient variables, associated comorbidities, and ASA (American Society of Anesthesiologists) classification, are listed in Table 1. Thirty-day postoperative variables were collected and further categorized into outcomes listed in Table 2 to facilitate the analysis of the data. Data on operative time and length of stay were collected and compared between two groups.

Statistical analysis

Univariate analysis was performed for all preoperative variables listed in Table 1 between both groups. Chi-square and Fisher's t tests were used for the analysis. A forward conditional stepwise binary logistic regression analysis was conducted to find the association between the preoperative variables, including the type of operation, and the postoperative outcomes listed in Table 2. GraphPad (La Jolla, CA) and the Statistical Package for Social Sciences software (SPSS, Inc., Chicago, IL) were used for statistical analysis. $P < 0.05$ was considered statistically significant.

Results

After inclusion and exclusion criteria, a total of 7,629 patients who underwent elective colon resection for symptomatic diverticulosis from 2005 to 2008 were identified. The distribution of procedures was similar with 3,870 patients in the OC group and 3,759 patients in the LC group. In patient factors, the OC group were significantly older (59 years vs. 55.7 yeara, $P < 0.0001$), female in gender, and with high body mass index (BMI; 28.88 vs. 28.51, $P = 0.0166$; Table 1). When comparing the two groups' preoperative variables, the OC group had a significantly higher incidence of almost all comorbidities except the history of myocardial infarction (Table 1). The OC group also was more likely to be in a higher ASA class (Table 1).

Including all patients, the overall 30-day morbidity in this study was 18.47% (1,343 patients) and 30-day mortality

Table 1 Patient factors

	OC (n = 3,870)	%	LC (n = 3,759)	%	P value
Mean age (year)	59.03	NA	55.72	NA	0.0001
Male	1786	46	1835	48.8	0.021
Female	2084	54	1924	51.2	0.021
BMI	28.88	NA	28.51	NA	0.0166
IDDM	107	2.76	42	1.12	0.0001
NIDDM	297	7.67	195	5.19	0.0001
Smoking	999	25.81	728	19.37	0.0001
Alcoholic	166	4.29	121	3.22	0.016
COPD	195	5.04	74	1.97	0.0001
Ascites	38	0.98	4	0.11	0.0001
CHF	22	0.57	3	0.08	0.0001
MI	14	0.36	5	0.13	0.064
PCI	197	5.09	129	3.43	0.0003
Cardiac surgery	171	4.42	77	2.05	0.0001
Angina	17	0.44	4	0.11	0.007
Hypertension	1952	50.44	1486	39.53	0.0001
PVD	32	0.83	16	0.43	0.03
Dialysis	24	0.62	2	0.05	0.0001
Hemiplegia	20	0.52	7	0.19	0.019
TIA	94	2.43	60	1.60	0.011
CVA with deficit	58	1.50	24	0.64	0.0001
CVA without deficit	62	1.60	31	0.82	0.002
Steroid use	162	4.19	63	1.68	0.0001
Wt loss >10%	175	4.52	74	1.97	0.0001
Bleeding disorder	146	3.77	55	1.46	0.0001
Blood transfusion >4U	14	0.36	0	0	0.0001
ASA classification					
I	150	3.88	266	7.08	0.0001
II	2203	56.93	2701	71.85	0.0001
III	1399	36.15	764	20.32	0.0001
IV	117	3.02	27	0.72	0.0001

OC open colectomy; *LC* laparoscopic colectomy; *BMI* body mass index; *IDDM* insulin-dependent diabetes mellitus; *NIDDM* noninsulin-dependent diabetes mellitus; *Smoking* current smoker within 1 year; *Alcoholic* >2 drinks in 2 weeks before admission; *COPD* history of chronic obstructive pulmonary disease; *CHF* congestive heart failure in 30 days before surgery; *MI* history of MI 6 months before surgery; *PCI* history of previous percutaneous coronary intervention; *Cardiac surgery* history of previous cardiac surgery; *Angina* history of angina 1 month before surgery; *Hypertension* hypertension requiring medication; *PVD* history of revascularization or amputation or peripheral vascular disease; *Dialysis* currently on dialysis; *TIA* history of transient ischemic attacks; *CVA with deficit* stroke with neurologic deficit; *CVA without deficit* stroke with no neurologic deficit; *Steroid use* steroid use for chronic condition; *Wt loss >10%* more than 10% loss body weight in past 6 months; *Bleeding disorder* patient at risk for excessive bleeding due to deficiency of blood clotting elements; *Blood transfusion >4U* transfusion of >4 units of packed red blood cells in 72 h before surgery; *ASA* American Society of Anesthesiologists

was 0.59% (43 patients). When comparing the two groups, the 30-day mortality rate was significantly higher in the OC group ($P = 0.002$). The OC group also had a higher incidence of 30-day overall morbidity ($P < 0.0001$), serious morbidity ($P < 0.0001$), and wound complications ($P < 0.0001$; Table 3). Operative time was significantly high in the LC group by approximately 10 min (176.7 vs. 166.65 min, $P < 0.0001$). The hospital length of stay was significantly low (4.77 vs. 7.81 days, $P < 0.0001$) in the LC group (Table 4).

Risk-adjusted results

Due to high incidence of preoperative comorbidities in the OC group that might account for adverse postoperative

Table 2 Classification of outcomes

Serious morbidity	Organ space SSI, wound dehiscence, bleeding requiring transfusion, ventilator dependence >48 hr, sepsis or septic shock, cardiac arrest, MI, PE, CVA, and progressive or acute renal insufficiency
Overall morbidity	Serious morbidity and/or superficial SSI, deep SSI, pneumonia, unplanned intubation, peripheral neurologic deficit, UTI, and DVT
Wound complications	Superficial, deep, organ space SSI
Mortality	Death

SSI surgical site infection, *MI* myocardial infarction, *PE* pulmonary embolism, *CVA* cerebrovascular accident, *UTI* urinary tract infection, *DVT* deep vein thrombosis

Table 3 30-day outcomes

	OC (n = 3,870)	%	LC (n = 3,759)	%	P value
Mortality	32	0.83	11	0.29	0.002
Overall morbidity	897	23.18	446	11.16	0.0001
Serious morbidity	422	10.9	174	4.63	0.0001
Wound complications	679	17.55	343	9.12	0.0001

OC open colectomy, *LC* laparoscopic colectomy

Table 4 Operative time and length of stay

	LC (n = 3,759)	OC (n = 3,870)	P value
Operative time (min)	176.7	166.6	0.0001
Length of stay (days)	4.77	7.81	0.0001

OC open colectomy, *LC* laparoscopic colectomy

Table 5 Risk-adjusted analysis

Outcome	Variable	P value	Odds ratio	95% CI
Mortality	History of PVD	0.011	5.69	1.5–21.524
Overall morbidity	Open procedure	0.001	1.88	1.651–2.141
	Smoking	0.02	1.19	1.027–1.368
	Hypertension	0.034	1.16	1.011–1.320
	History of CVA	0.004	2.23	1.283–3.869
Serious morbidity	Female sex	0.011	1.27	1.056–1.52
	Open procedure	0.001	1.72	1.410–2.084
	Smoking	0.004	1.34	1.096–1.636
	Alcoholism	0.024	1.55	1.061–2.264
	Steroid use	0.009	1.67	1.135–2.454
Wound complications	Open procedure	0.001	1.95	1.685–2.248
	Smoking	0.006	1.25	1.065–1.455
	COPD	0.01	1.53	1.108–2.108
	History of CVA	0.021	2.015	1.11–3.657

PVD peripheral vascular disease, *CVA* cerebrovascular accident with neurological deficit, *COPD* chronic obstructive pulmonary disease, *CI* confidence interval

outcomes, a multivariate risk adjusted analysis was performed using a stepwise binary logistic regression (Table 5) to find the actual association between the type of procedure and postoperative outcomes. After multivariate analysis, OC was associated with a higher incidence of 30-day overall morbidity ($P = 0.001$; odds ratio (OR), 1.88), serious morbidity ($P = 0.001$; OR, 1.72), and wound complications ($P = 0.001$; OR, 1.95), but it was not associated with a higher 30-day mortality. Additional preoperative factors that were significantly associated with specific postoperative outcomes are listed in Table 5.

Discussion

Since its introduction in early 1990s, laparoscopic colon resection has gained popularity for both benign and malignant conditions. There are several retrospective studies and few randomized studies published in the literature, concluding that laparoscopic colon resection for symptomatic diverticulosis in the elective setting is associated with less, early postoperative morbidity [7, 8, 10–15, 18, 21–24]. The majority of these studies are with small sample size, except for few studies on large patient databases. During recent years, the ACS-NSQIP database has proven to be one of the best patient databases available to study the patient outcomes for surgical procedures [17]. In this study, we used this database to compare the outcomes of laparoscopic and open colectomy for symptomatic diverticulosis in the elective setting.

Contrary to most of the previously published literature [18, 23], the ACS-NSQIP database has almost similar distribution of patients undergoing both LC and OC for symptomatic diverticulosis. However, the reason for the choice of operation is unavailable from this database. Masoomi et al. [23], in their study on National Inpatient database showed the upward trend of LC in the management of symptomatic diverticulosis. Weber et al. [24]

concluded that high-volume surgeons and hospitals are more likely to perform laparoscopic surgery for the management of diverticulosis. Based on these studies, we can hypothesize that the equal distribution of procedures in our study may be because of the upward trend of the laparoscopic procedures in recent years and increased access to the laparoscopic procedures in the hospitals that are included in the ACS-NSQIP database.

Similar to previous studies [18, 19], our data also showed that the patients in OC group are associated with more preoperative comorbidity. The Sigma trial [19], a randomized, controlled study comparing elective laparoscopic vs. open colectomy for colonic diverticulosis, concluded that the laparoscopic procedure is associated with lower complication rates; however, upon further analysis only the major complications are significantly lower in the laparoscopic group. Siddiqui et al. [20], in their meta-analysis also showed that there is significant difference in overall morbidity with low rates in laparoscopic group, but this finding was not consistent when they divided the complications into different categories. In both studies, despite the difference in morbidity, there was no significant difference in mortality rates. Contrary to the above, Masoomi et al. [21], in their National Inpatient Sample database study, showed that the in-hospital mortality rates are four times higher with OC after risk-adjusted analysis. In their study, morbidity also is significantly high with OC compared with LC. However, in their study, even though they had a large patient sample (125,734 patients), 88.3% of them underwent OC. Conversely, our study had almost equal distribution of LC and OC and our study collected 30-day mortality rate, not the in-patient mortality rate. In our study, before risk adjustment, we noticed that there is significantly high incidence of 30-day mortality, morbidity, and wound complications in the OC group. But after logistic regression analysis for risk adjustment, we noticed that the type of procedure (LC or OC) is not associated with high 30-day mortality, but it is associated with high incidence of 30-day overall morbidity and also serious morbidity by almost twofold in the OC group. Our study also showed that OC is associated with significantly high rates of wound complications within the 30-day period. ACS-NSQIP database records only the events in the 30-day postoperative period or until discharge. The events that occurred beyond the 30-day period for discharged patients were not part of this database and also in our study. From our study, it is clearly evident that LC, at least, may have advantages during the early postoperative period because of the low incidence of complications.

One of the main reported advantages of laparoscopic procedures is early postoperative recovery and shorter length of stay (LOS). Previously few studies [18, 22, 24] showed that LC for diverticulitis is associated with shorter LOS by 2–4 days. In favor of these findings, our study also showed that the LC is associated with low LOS by more than 3 days. This shorter LOS is probably due to the low rates of early complications reported in our study. Similar to the reports in previous studies, our study also showed that LC is associated with significantly high operative time. Even though the difference was only approximately 10 min, it may still add to the higher cost of the laparoscopic procedure. However, with lower complication rates and lower length of stay, overall laparoscopic procedure may be cost effective. Because cost is not a part of this database, it was not possible to support this hypothesis conclusively.

Like any other large database-based studies, our study has several limitations. The ACS-NSQIP data provide only short-term outcomes that occur within 30 days after the procedure. Important long-term outcomes, after 30 days, such as readmission, reoperation, recurrence, morbidity, and mortality, were not assessed in our study. The present study measured only the variables available in the ACS-NSQIP database. Many important variables, specifically related to colorectal procedures but not listed in the ACS-NSQIP database, were not included in this study. These include history of previous operations, actual reason for the procedure choice, conversion to open surgery, specific events related to colorectal operations, such as ureteral injury, type of anastomosis, postoperative variables, such as pain scores, ileus, return to work, and so forth. Measures of clinical efficacy, including quality of life, patient satisfaction, and recurrence of symptoms, also were not assessed in the present study. Also, the conclusions from our study were determined from data submitted from hospitals participating in the ACS-NSQIP and might not be a statistically valid nationally representative sample.

In conclusion, laparoscopic colectomy for symptomatic diverticulosis in elective setting may have several advantages over the standard open colectomy, especially in the early postoperative period, with low incidence of complications. These findings support the safety of this laparoscopic procedure and should be considered as a preferred choice depending on the availability and expertise. Despite the merits of ACS-NSQIP database, because of the limitations stated earlier, a large, prospective, randomized study should be conducted to confirm these findings.

Disclosures Venkata R. Kakarla, Steven J. Nurkin, Saurab Sharma, Dan E. Ruiz, and Howard Tiszenkel have no conflicts of interest or financial ties to disclose.

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