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Laparoscopic versus Open Hartmann's Procedure for the Emergency Treatment of Diverticulitis: A Propensity-Matched Analysis

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Abstract

Background—A laparoscopic approach has been proposed to reduce the high morbidity and mortality associated with the Hartmann's procedure for the emergency treatment of diverticulitis.

Objective—The objective of our study was to determine whether a laparoscopic Hartmann's procedure reduces early morbidity or mortality for patients undergoing an emergency operation for diverticulitis.

Design—This is a comparative effectiveness study. A subset of the entire American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) patient sample matched on propensity for undergoing their procedure with the laparoscopic approach were used to compare postoperative outcomes between laparoscopic and open groups.

Setting—This study uses data from the ACS NSQIP Participant User Files from 2005 through 2009.

Patients—All patients who underwent an emergency laparoscopic or open partial colectomy with end colostomy for colonic diverticulitis were reviewed.

Main Outcome Measures—The main outcome measures were 30-day mortality and morbidity.

Results—1,186 patients undergoing emergency partial colectomy with end colostomy for diverticulitis were included in the analysis. Among the entire cohort, the laparoscopic group had fewer overall complications (26% vs. 41.7%, $p=0.008$) and shorter mean length of hospitalization (8.9 vs. 11.6 days, $p=0.0008$). Operative times were not significantly different between groups.

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When controlling for potential confounders, a laparoscopic approach was not associated with a decrease in morbidity or mortality. As compared to a propensity-match cohort, the laparoscopic approach did not reduce postoperative morbidity or mortality.

Limitations—This study is limited by its retrospective nature and the absence of pertinent variables such as postoperative pain indices, time for return of bowel function, and rates of readmission.

Conclusions—A laparoscopic approach to the Hartmann's procedure for the emergency treatment of complicated diverticulitis does not significantly decrease postoperative morbidity or mortality as compared to the open technique.

Introduction

The traditional strategy for treating complicated diverticulitis in the emergency setting has been a two-stage approach comprised of an initial sigmoid resection and end colostomy (Hartmann's procedure) followed by a second surgery to restore intestinal continuity.¹ Due to the high complication and mortality rates associated with this approach,²⁻⁶ the addition of laparoscopy to the Hartmann's procedure has been proposed to reduce the incidence of postoperative complications and expedite recovery.^{7,8}

During elective surgery for diverticulitis, a laparoscopic approach has been shown in multiple studies to have several perioperative advantages over open surgery including shorter length of hospitalization, quicker return of bowel function, fewer infectious complications, and decreased postoperative pain.⁹⁻²⁵ Whether these advantages observed after elective laparoscopic surgery for diverticulitis will extend to emergency surgery for patients with complicated diverticulitis is currently unknown. The objective of this study was to test whether a laparoscopic approach to the Hartmann's procedure was associated with decreased postoperative morbidity and mortality by performing a propensity-matched comparative analysis of laparoscopic and open approaches using data from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP).

Methods

The American College of Surgeons National Surgical Quality Improvement Program Participant User Files for 2005 through 2009 were used for this analysis. Patients were included for analysis if they met all three of the following criteria: (1) primary Current Procedure Terminology code for laparoscopic or open partial colectomy with end colostomy (CPT 44206 or 44143), (2) emergency procedure, and (3) postoperative diagnosis of colonic diverticulitis with or without mention of hemorrhage (International Classification of Diseases 9th Edition codes 562.11 or 562.13).

The primary predictor variable for our analysis was surgical approach for the index procedure (laparoscopic or open). Definitions of other predictor variables definitions are given in the NSQIP participant user guide.²⁶ The primary outcome variables were 30-day postoperative mortality and overall 30-day postoperative morbidity. Specific definitions of secondary outcome variables are also given in the NSQIP participant user guide.²⁶ Three

variables had missing data (BMI - 116 patients, Resident Participation - 10 patients, and ASA Classification - 1 patient). Since there was not a significant difference in the percentage of laparoscopic patients (85.7%) versus open patients (90.9%, $p=0.15$) that had missing data for BMI, we assumed patients were missing BMI data at random and therefore excluded these patients from our multivariate regression models.

Comparisons of preoperative and intraoperative variables for patients undergoing laparoscopic versus open surgery were made using Pearson's chi square tests for categorical variables and Mann-Whitney rank sum tests for continuous variables. Comparisons of the primary and secondary outcomes for the two groups were made in the same manner. For each primary outcome variable, (30-day postoperative mortality and morbidity), all potential preoperative and intraoperative variables were then considered for inclusion in a forward stepwise multivariate logistic regression model, using a p value of < 0.01 as the entry criterion. As the primary predictor of interest, surgical approach (open versus laparoscopic) was forced as a variable into both of these regression models.

In recognition that there was likely a non-random selection bias for treating patients with complicated diverticulitis using an open versus laparoscopic approach, we also conducted a separate analysis using of a subset of the entire NSQIP patient sample matched on propensity for undergoing their procedure with the laparoscopic approach in order to minimize this selection bias. For this analysis, a nonparsimonious logistic regression model was created in order to estimate the likelihood of undergoing the index colectomy procedure laparoscopically, with all of the aforementioned preoperative and intraoperative variables being included as potential confounders in this model. Intraoperative procedure characteristics were specifically included in the model, even those these variables cannot be known preoperative, because they may reflect in part the technical difficulty of a given procedure. A propensity score for laparoscopic approach ranging from 0 to 1 was then calculated for each patient using the logit coefficients for the predictors of laparoscopic approach from the above multivariate logistic regression model. These propensity scores were then used to create two groups of patients matched on their propensity for having undergone laparoscopic surgery using a caliper matching algorithm with a caliper distance of 0.005 and controls being used only once in the matching procedure. Comparison of the preoperative and intraoperative characteristics of the matched cohort of patients was then performed using McNemar's chi-square tests for categorical variables and Wilcoxon signed rank tests for continuous variables. Primary and secondary outcome measures between the matched cohorts were compared in a similar manner. All statistical tests were two tailed with a significance level considered to be $p<0.05$. All statistical analyses were performed using Stata Version 11.0 (College Station, TX). The statistical methods are summarized in Figure 1.

Results

A total of 1,186 patients undergoing emergency partial colectomy with end colostomy for diverticulitis were included in the analysis, with 1,116 (94%) and 70 (6%) patients treated with an open and laparoscopic approach respectively. The pre- and intraoperative characteristics of patients included for analysis are summarized in Table 1. As compared to

patients treated with open surgery, patients treated laparoscopically had an overall lower operative risk as demonstrated by lower American Society of Anesthesia (ASA) physical status classification (54.3% vs. 66.9% having ASA ≥ 3 , $p=0.03$). Fewer patients in laparoscopic cohort presented with systemic inflammatory response syndrome (SIRS), sepsis, or shock (58.6% vs. 69.5%), although this difference did not reach statistical significance ($p=0.06$). While operative time did not differ between procedures (132 ± 65 vs. 124 ± 52 minutes, $p=0.72$), a laparoscopic approach to the Hartmann's procedure were associated with fewer dirty wounds (68.6% vs. 80.6%, $p=0.02$) and had less resident participation (47.1% vs. 64.2%, $p=0.004$). Univariate associations of preoperative and intraoperative variables with 30-day postoperative mortality and morbidity are given in Table 2.

For all patients in the included NSQIP sample, a laparoscopic approach to partial colectomy and end colostomy was associated with a lower overall complication rate [25.7% ($n=18$) vs. 41.7% ($n=486$), $p=0.008$] and similar postoperative mortality [4.3% ($n=3$) vs. 7.1% ($n=83$), $p=0.37$]. Specifically, laparoscopic procedures had a significantly decreased likelihood of prolonged postoperative ventilation [4.3% ($n=3$) vs. 15.7% ($n=183$), $p=0.01$] and median (25-75%) length of hospitalization [6 (5-11) vs. 8.5 (6-13) days, $p=0.0008$]. Major cardiovascular complications were similar between groups, as was the rate of organ space infections [4.3% ($n=3$) vs. 4.9% ($n=57$), $p=0.82$] (Table 3).

Stepwise multivariate logistic regression was performed to determine variables associated with 30-day postoperative death and postoperative morbidity, and the results of these analyses are summarized in Tables 4-5. Despite being associated with decreased perioperative morbidity on univariate analysis, a laparoscopic approach to the Hartmann's procedure was not associated overall morbidity or 30-day mortality when controlling for potentially confounding pre- and intra-operative variables.

To address potential selection bias in the laparoscopic cohort, a separate analysis using of a subset of the entire NSQIP patient sample matched on propensity for undergoing their procedure with the laparoscopic approach was performed. A final propensity-match subset included 67 patients in both open and laparoscopic groups, with their preoperative and intraoperative characteristics summarized in Table 6. Univariate associations of preoperative and intraoperative variables with 30-day postoperative mortality and morbidity using the propensity matched cohort are given in Table 7. On repeat analysis of outcomes using these propensity matched cohorts, no statistically significant differences between open and laparoscopic groups were demonstrated, including postoperative morbidity and mortality (Table 8).

Discussion

In hopes of decreasing the morbidity of the Hartmann's procedure itself and temper its criticism, a laparoscopic approach to the procedure has emerged but has yet to be validated against the standard open approach.^{7,8} The primary objective of this study was to determine whether the addition of laparoscopy to the Hartmann's procedure would decrease postoperative morbidity and mortality for treatment of complicated diverticulitis. On

univariate analyses of the entire study cohort, the laparoscopic group had a significantly decreased overall complication rate and a shorter hospitalization, which was consistent with previous studies comparing laparoscopic and open approaches in elective surgery for diverticulitis.⁹⁻²⁵ However, on both multivariate and case-controlled analyses, the laparoscopic group was not associated with a decrease in either postoperative morbidity or mortality.

Although the Hartmann's procedure has for many years been considered the traditional conservative treatment for such complications,¹ it is associated with significant perioperative morbidity (up to 50%) and mortality (15-25%).²⁻⁶ Such perioperative morbidity and mortality is likely multifactorial and associated with other patient variables such as patient physiologic status, surgeon experience, and patient comorbidities. To account for patient variables thought to be associated with poor outcomes not available in the NSQIP database and to minimize selection bias, we also performed a propensity-matched analysis. No statistically significant advantages of laparoscopic over open technique including mortality, overall morbidity, and length of hospital stay were demonstrated between propensity-match cohorts.

The results of this study seem to imply whatever advantages garnered from a minimally invasive approach to the Hartmann's procedure may be abrogated by the end results (i.e. systemic toxicity) of the disease process itself. Thus, in the acute setting of perforated diverticulitis when purulent and or feculent peritonitis may be present, a laparoscopic sigmoid resection with end colostomy may not provide any appreciable advantage over the open approach in terms of postoperative morbidity or mortality. These results are in contrast to those of previous studies which have reported laparoscopic sigmoid resection for the *elective* treatment of complicated diverticulitis to decrease postoperative morbidity and length of hospitalization.⁹⁻²⁵ Given that a laparoscopic approach seems to only provide a benefit to the patient in the elective setting, the optimal emergency treatment for perforated or complicated diverticulitis may be one that could temporize the resultant peritonitis and systemic toxicity until a sigmoid resection could be performed electively. One such strategy may be to treat acute perforations of diverticulitis with a laparoscopic peritoneal lavage and drainage procedure.²⁷ Advocates of this approach report laparoscopic peritoneal lavage and drainage combined with intravenous antibiotics can effectively treat the acute peritonitis and systemic toxicity of perforated diverticulitis such that a later sigmoid resection and primary anastomosis can be performed on an elective basis. Thus, with this approach, patients might be spared the high morbidity and requisite temporary ostomy of the classic two-stage approach.²⁸⁻³² Whether such an approach is an effective alternative to primary sigmoid resection with or without colostomy for perforated diverticulitis is currently under investigation in an ongoing randomized, prospective trial.²

As it is comprised of a large national dataset encompassing a contemporary time frame (2005-2009), NSQIP provides a unique and powerful tool for evaluating 30-day outcomes after major surgical procedures. However, the NSQIP database has several inherent limitations which should be taken into consideration when interpreting studies using its data.³³ First of all, it is reliant on CPT coding for describing procedure type, which can be variable among providers. In the case of this study, CPT coding did not allow us to

discriminate potential confounding variations of either the open or laparoscopic Hartmann's procedure. Specifically, it is unclear whether a patients in this study could have been started laparoscopically but converted to open, were explored using a lower midline or full laparotomy incision, or required a splenic flexure mobilization. Second, NSQIP does not provide pertinent information regarding the extent or severity of diverticular disease (i.e. Hinchey classification) or complexity of the specific Hartmann's procedure. However, we used the total work relative value units associated with the index operation (which is comprised of the individual WRVUs associated with each CPT code) in attempt to account for procedure complexity.³⁴⁻³⁶ Third, we do not know the exact indication for the emergency operation in the patients included in our analysis (for example, free perforation vs. contained perforation vs. obstruction). Despite the lack of information regarding the specific indication for surgery, some of the covariates in our analysis should allow adjustment for the end result of these specific indications (e.g. signs of septic shock or dirty/contaminated incisional wound classification). Fourth, laparoscopic surgery in other settings has demonstrated other advantages over open surgery that could not be detected using NSQIP data.⁹⁻²⁵ For instance, pertinent variables for this study not recorded in the NSQIP database include postoperative pain indices, time for return of bowel function, and rates of readmission. Therefore, we are unable to say with authority that the laparoscopic approach does not reduce rates of postoperative morbidity and mortality. However, the results of the propensity-matched analysis would suggest that if there were undetected benefits, they are likely not as pronounced as for elective surgery. Finally, while this study constitutes the largest comparison to date; the relatively small number of patients does subject our analysis to type II error.

Despite these limitations, we conclude from our analysis that the laparoscopic Hartmann's procedure offers no clear advantages over the open technique for the management of complicated diverticulitis in the emergency setting. As the realm of minimally-invasive surgery continues to grow, it will become important to identify which procedures are truly enhanced with such techniques. Using a prospective database encompassing more than 250 participating hospitals, we found that laparoscopic partial colectomy with end colostomy for emergency treatment of diverticulitis can be performed efficiently with similar operative times as standard open techniques. However, when compared to a propensity-matched cohort, laparoscopic Hartmann's procedure did not confer any advantages over open surgery in terms of mortality, overall morbidity, or length of hospitalization.

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FIGURE 1.

Summary of statistical methods. NSQIP = National Surgical Quality Improvement Program.

Table 1

Preoperative and Intraoperative Characteristics of Patients Undergoing Emergent Partial Colectomy and End Ileostomy For Diverticulitis Using Entire NSQIP Sample.

Preoperative or Intraoperative Variable		All Patients in NSQIP Sample		
		Open Procedure	Laparoscopic Procedure	P Value
Age in years (mean ± SD)		62.9 ± 14.8	59.0 ± 16.4	0.04
Gender	Female (n=621)	594 (95.7%)	27 (4.4%)	0.04
	Male (n=615)	572 (93.0%)	43 (7.0%)	
Body Mass Index in kg/m ² (mean ± SD) (116 missing values)		29.3 ± 7.3	29.6 ± 5.7	0.78
ASA Class 3 (1 missing value)	No (n=418)	386 (92.3%)	32 (7.7%)	0.03
	Yes (n=817)	779 (95.4%)	38 (4.7%)	
Diabetes Mellitus	No (n=1,071)	1,011 (94.4%)	60 (5.6%)	0.81
	Yes (n=165)	155 (93.9%)	10 (6.1%)	
Tobacco Use	No (n=934)	877 (93.9%)	57 (6.1%)	0.24
	Yes (n=302)	289 (95.7%)	13 (4.3%)	
Frequent Ethanol Use	No (n=1,160)	1,094 (94.3%)	66 (5.7%)	0.88
	Yes (n=76)	72 (95%)	4 (5%)	
Dyspnea	No (n=1,047)	985 (94.1%)	62 (5.9%)	0.36
	Yes (n=189)	181 (95.8%)	8 (4.2%)	
Functional Status	Independent (n=1,173)	1,105 (94.2%)	68 (5.8%)	0.38
	Non-Independent (n=63)	61 (97%)	2 (3%)	
Preop Ventilator	No (n=1,205)	1,135 (94.2%)	70 (5.8%)	0.17
	Yes (n=31)	31 (100%)	0 (0%)	
COPD	No (n=1,095)	1,031 (94.2%)	64 (5.8%)	0.44
	Yes (n=141)	135 (95.7%)	6 (4.3%)	
Preop Pneumonia	No (n=1,217)	1,147 (94.3%)	70 (5.7%)	0.28
	Yes (n=19)	19 (100%)	0 (0%)	
Ascites	No (n=1,164)	1,096 (94.2%)	68 (5.8%)	0.28
	Yes (n=72)	70 (97%)	2 (3%)	
Congestive Heart Failure	No (n=1,205)	1,136 (94.3%)	69 (5.7%)	0.55
	Yes (n=31)	30 (97%)	1 (3%)	
Coronary Artery Disease	No (n=1,064)	1,000 (94.0%)	64 (6.0%)	0.18
	Yes (n=172)	166 (96.5%)	6 (3.5%)	
Peripheral Vascular Disease	No (n=1,215)	1,146 (94.3%)	69 (5.7%)	0.86
	Yes (n=21)	20 (95%)	1 (5%)	
Hypertension	No (n=541)	504 (93.2%)	37 (6.8%)	0.12
	Yes (n=695)	662 (95.3%)	33 (4.8%)	
Renal Disease	No (n=1,183)	1,113 (94.1%)	70 (5.9%)	0.07
	Yes (n=53)	53 (100%)	0 (0%)	
Neurologic Disorder		No (n=1,092)	64 (5.9%)	0.41

Preoperative or Intraoperative Variable		All Patients in NSQIP Sample		
		Open Procedure	Laparoscopic Procedure	P Value
	Yes (n=144)	138 (95.8%)	6 (4.2%)	
Disseminated Cancer	No (n=1,195)	1,126 (94.2%)	69 (5.8%)	0.36
	Yes (n=41)	40 (98%)	1 (2%)	
Preop Infected Wound	No (n=1,205)	1,135 (94.2%)	70 (5.8%)	0.17
	Yes (n=31)	31 (100%)	0 (0%)	
Chronic Steroids	No (n=1,031)	972 (94.3%)	59 (5.7%)	0.84
	Yes (n=205)	194 (94.6%)	11 (5.4%)	
Weight Loss	No (n=1,197)	1,128 (94.2%)	69 (5.8%)	0.4
	Yes (n=39)	38 (97%)	1 (3%)	
Bleeding Disorder	No (n=1,073)	1,014 (94.5%)	59 (5.5%)	0.52
	Yes (n=163)	152 (93.3%)	11 (6.8%)	
Preoperative Transfusion	No (n=1,228)	1,158 (94.3%)	70 (5.7%)	0.49
	Yes (n=8)	8 (100%)	0 (0%)	
Chemotherapy	No (n=1,193)	1,124 (94.2%)	69 (5.8%)	0.34
	Yes (n=43)	42 (98%)	1 (2%)	
Radiotherapy	No (n=1,215)	1,146 (94.3%)	69 (5.7%)	0.86
	Yes (n=21)	20 (95%)	1 (5%)	
Preop SIRS, Sepsis, or Septic Shock	No (n=385)	356 (92.5%)	29 (7.5%)	0.06
	Yes (n=851)	810 (95.2%)	41 (4.8%)	
Dirty/Infected Incisional Wound	No (n=248)	226 (91.1%)	22 (8.9%)	0.02
	Yes (n=988)	940 (95.1%)	48 (4.9%)	
Operative time in minutes (mean $\pm$ SD)		124 $\pm$ 52	132 $\pm$ 65	0.72
Intraoperative Transfusion	No (n=1,085)	1,020 (94.0%)	65 (6.0%)	0.18
	Yes (n=151)	146 (96.7%)	5 (3.3%)	
Resident Participation (10 missing values)	No (n=454)	417 (91.9%)	37 (8.2%)	0.002
	Yes (n=772)	742 (96.1%)	30 (3.9%)	
Total WRVUs		37.9 $\pm$ 13.7	38.0 $\pm$ 11.6	0.13

Table 2

Univariate Association of Preoperative and Intraoperative Variables With 30-Day Postoperative Mortality and Morbidity.

Preoperative or Intraoperative Variable		30-Day Postoperative Outcomes			
		Mortality		Morbidity	P Value
Surgical Approach	Open (n=1,166)	83 (7.1%)	0.37	486 (41.7%)	0.008
	Laparoscopic (n=70)	3 (4%)		18 (26%)	
Age in years (mean $\pm$ SD)		1.08 *	<0.001	1.02 *	<0.001
Gender	Female (n=621)	52 (8.4%)	0.05	257 (41.4%)	0.66
	Male (n=615)	34 (5.5%)		247 (40.2%)	
Body Mass Index in kg/m ² (mean $\pm$ SD) (116 missing values)		0.94	0.002	1.01	0.23
ASA Class 3 (1 missing value)	No (n=418)	0 (0%)	<0.001	109 (26.1%)	<0.001
	Yes (n=817)	86 (10.5%)		395 (48.4%)	
Diabetes Mellitus	No (n=1,071)	67 (6.3%)	0.01	416 (38.8%)	<0.001
	Yes (n=165)	19 (11.5%)		88 (53.3%)	
Tobacco Use	No (n=934)	72 (7.7%)	0.07	381 (40.8%)	0.98
	Yes (n=302)	14 (4.6%)		123 (40.7%)	
Frequent Ethanol Use	No (n=1,160)	83 (7.2%)	0.29	468 (40.3%)	0.23
	Yes (n=76)	3 (4%)		36 (47%)	
Dyspnea	No (n=1,047)	44 (4.2%)	<0.001	393 (37.5%)	<0.001
	Yes (n=189)	42 (22.2%)		111 (58.7%)	
Functional Status	Independent (n=1,173)	68 (5.8%)	<0.001	458 (39.1%)	<0.001
	Non-Independent (n=63)	18 (29%)		46 (73%)	
Preop Ventilator	No (n=1,205)	74 (6.1%)	<0.001	477 (39.6%)	<0.001
	Yes (n=31)	12 (39%)		27 (87%)	
COPD	No (n=1,095)	56 (5.1%)	<0.001	415 (37.9%)	<0.001
	Yes (n=141)	30 (21.3%)		89 (63.1%)	
Preop Pneumonia	No (n=1,217)	79 (6.5%)	<0.001	491 (40.4%)	0.01
	Yes (n=19)	7 (37%)		13 (68.4%)	
Ascites	No (n=1,164)	71 (6.1%)	<0.001	466 (40.0%)	0.03
	Yes (n=72)	15 (21%)		38 (53%)	
Congestive Heart Failure	No (n=1,205)	76 (6.3%)	<0.001	483 (40.1%)	0.002
	Yes (n=31)	10 (32%)		21 (68%)	
Coronary Artery Disease	No (n=1,064)	64 (6.0%)	0.001	415 (39.0%)	0.002
	Yes (n=172)	22 (12.8%)		89 (51.7%)	
Peripheral Vascular Disease	No (n=1,215)	85 (7.0%)	0.69	493 (40.6%)	0.28
	Yes (n=21)	1 (5%)		11 (52%)	
Hypertension	No (n=541)	23 (4.3%)	0.001	182 (33.6%)	<0.001
	Yes (n=695)	63 (9.1%)		322 (46.3%)	

Preoperative or Intraoperative Variable		30-Day Postoperative Outcomes			
		Mortality		Morbidity	P Value
Renal Disease	No (n=1,183)	73 (6.2%)	<0.001	464 (39.2%)	<0.001
	Yes (n=53)	13 (25%)		40 (76%)	
Neurologic Disorder	No (n=1,092)	59 (5.4%)	<0.001	424 (38.8%)	<0.001
	Yes (n=144)	27 (18.8%)		80 (55.6%)	
Disseminated Cancer	No (n=1,195)	73 (6.1%)	<0.001	480 (40.2%)	0.02
	Yes (n=41)	13 (32%)		24 (59%)	
Preop Infected Wound	No (n=1,205)	80 (6.6%)	0.006	483 (40.1%)	0.002
	Yes (n=31)	6 (19%)		21 (68%)	
Chronic Steroids	No (n=1,031)	48 (4.7%)	<0.001	394 (38.2%)	<0.001
	Yes (n=205)	38 (18.5%)		110 (53.7%)	
Weight Loss	No (n=1,197)	77 (6.4%)	<0.001	487 (40.7%)	0.72
	Yes (n=39)	9 (23.1%)		17 (44%)	
Bleeding Disorder	No (n=1,073)	61 (5.7%)	<0.001	414 (38.6%)	<0.001
	Yes (n=163)	25 (15.3%)		90 (55.2%)	
Preoperative Transfusion	No (n=1,228)	85 (6.9%)	0.54	497 (40.5%)	0.007
	Yes (n=8)	1 (13%)		7 (88%)	
Chemotherapy	No (n=1,193)	77 (6.5%)	<0.001	481 (40.3%)	0.08
	Yes (n=43)	9 (21%)		23 (53%)	
Radiotherapy	No (n=1,215)	83 (6.8%)	0.18	493 (40.6%)	0.28
	Yes (n=21)	3 (14%)		11 (52%)	
Preop SIRS, Sepsis, or Septic Shock	No (n=385)	23 (6.0%)	0.36	120 (31.2%)	<0.001
	Yes (n=851)	63 (7.4%)		384 (45.1%)	
Dirty/Infected Incisional Wound	No (n=248)	17 (6.9%)	0.94	85 (34.3%)	0.02
	Yes (n=988)	69 (7.0%)		419 (42.4%)	
Operative time in minutes (mean $\pm$ SD)		0.99 [*]	0.99	1.002 [*]	0.02
Intraoperative Transfusion	No (n=1,085)	53 (4.9%)	<0.001	403 (37.1%)	<0.001
	Yes (n=151)	33 (21.9%)		10 (66.9%)	
Resident Participation (10 missing values)	No (n=454)	34 (7.5%)	0.56	171 (37.7%)	0.08
	Yes (n=772)	51 (6.6%)		330 (42.8%)	
Total WRVUs		1.01 [*]	0.23	1.01 [*]	0.01

* Represents increase in odds of incurring outcome for each unit increase in value of continuous variable.

Table 3

Outcomes for Patients Undergoing Emergent Partial Colectomy and End Colostomy For Diverticulitis Using Entire NSQIP Sample.

Outcome Measure	All Patients in NSQIP Sample		
	Open Procedure (n=1,166)	Laparoscopic Procedure (n=70)	P Value
30-Day Postoperative Death	83 (7.1%)	3 (4%)	0.37
Overall Complication Rate	486 (41.7%)	18 (26%)	0.008
Specific Complications:			
Superficial Surgical Site Infection	125 (10.7%)	3 (5%)	0.09
Deep Surgical Site Infection	35 (3.0%)	1 (1%)	0.45
Organ/Space Surgical Site Infection	57 (4.9%)	3 (4%)	0.82
Wound Dehiscence	48 (4.1%)	0 (0%)	0.08
Pneumonia	104 (8.9%)	3 (4%)	0.18
Unplanned Reintubation	78 (6.7%)	3 (4%)	0.43
Pulmonary Embolism	15 (1.3%)	1 (1%)	0.92
Prolonged Ventilatory Support	183 (15.7%)	3 (4%)	0.01
Progressive Renal Insufficiency	13 (1.1%)	0 (0%)	0.37
Acute Renal Failure	21 (1.8%)	1 (1%)	0.82
Urinary Tract Infection	28 (2.4%)	5 (7%)	0.02
Stroke	10 (0.9%)	1 (1%)	0.62
Coma > 24 hours	3 (0.3%)	0 (0%)	0.67
Peripheral Nerve Injury ⁶¹ (9.8%)	2 (0.2%)	0 (0%)	0.73
Cardiac Arrest	15 (1.3%)	0 (0%)	0.34
Myocardial Infarction	14 (1.2%)	0 (0%)	0.36
Bleeding within 72 hours	10 (0.9%)	2 (3%)	0.1
Graft/Prosthetic Failure	0 (0%)	0 (0%)	-
Deep Venous Thrombosis	25 (2.1%)	2 (3%)	0.69
Sepsis	76 (6.5%)	1 (1%)	0.09
Septic Shock	105 (9.0%)	3 (4%)	0.17
Return to Operating Room	105 (9.0%)	9 (13%)	0.28
Median (IQR) and Mean Length of Postoperative Hospital Stay	8.5 (6-13)	6 (5-11)	0.0008

Table 4

Preoperative/Intraoperative Variables Significantly Associated with 30-Day Postoperative Death After Emergency Partial Colectomy and End Colostomy for Diverticulitis Using Entire NSQIP Sample.

Variable	Adjusted Odds Ratio *	95% Confidence Interval	P Value
Laparoscopic Approach	0.84	0.21-3.23	0.79
Dyspnea	3.60	2.09-6.22	<0.001
Age	1.08	1.05-1.11	<0.001
Disseminated Cancer	6.62	2.73-16.1	<0.001
Intraoperative Transfusion	2.82	1.58-5.01	<0.001
Ascites	3.81	1.75-8.31	0.001
Chronic Steroid Use	2.49	1.43-4.35	0.001

**Laparoscopic versus Open Approach forced into model because primary predictor variable of interest C-index = 0.85

* Risk Adjustment using multivariate logistic regression with forward stepwise selection of all available preoperative and intraoperative variables (entry criterion $p < 0.01$); All patients who died postoperative had an ASA Classification 3, therefore this variable was dropped from the regression model due to estimability

Table 5

Preoperative/Intraoperative Variables Significantly Associated with Postoperative Morbidity After Emergency Partial Colectomy and End Colostomy for Diverticulitis Using Entire NSQIP Sample.

Variable	Adjusted Odds Ratio *	95% Confidence Interval	P Value
Laparoscopic Approach **	0.62	0.33-1.15	0.13
ASA Classification 3	2.03	1.53-2.71	<0.001
Intraoperative Transfusion	2.53	1.69-3.79	<0.001
Preoperative SIRS/Sepsis/Septic Shock	1.70	1.28-2.25	<0.001
Preoperative Dyspnea	1.70	1.19-2.44	0.004
Preoperative Ventilator	4.42	1.46-13.4	0.009

* Risk Adjustment using multivariate logistic regression with forward stepwise selection of all available preoperative and intraoperative variables (entry criterion $p < 0.01$)

** Laparoscopic versus Open Approach forced into model because primary predictor variable of interest c-index = 0.68

Table 6

Preoperative and Intraoperative Characteristics of Patients Undergoing Emergent Partial Colectomy and End Ileostomy For Diverticulitis Using Propensity-Matched Cohorts.

Preoperative or Intraoperative Variable		All Patients in NSQIP Sample		
		Open Procedure	Laparoscopic Procedure	P Value
Age in years (mean $\pm$ SD)		59.4 $\pm$ 13.5	58.5 $\pm$ 16.3	0.63
Gender	Female (n=53)	27 (51%)	26 (49%)	1.0
	Male (n=81)	40 (49%)	41 (51%)	
Body Mass Index in kg/m ² (mean $\pm$ SD)		26.7 $\pm$ 6.5	27.6 $\pm$ 7.8	0.56
ASA Class 3	No (n=59)	27 (46%)	32 (54%)	0.47
	Yes (n=75)	40 (53%)	35 (47%)	
Diabetes Mellitus	No (n=113)	56 (49.6%)	57 (50.4%)	1.0
	Yes (n=21)	11 (52%)	10 (48%)	
Tobacco Use	No (n=109)	55 (50%)	54 (50%)	1.0
	Yes (n=25)	12 (48%)	13 (52%)	
Frequent Ethanol Use	No (n=127)	64 (50.4%)	63 (49.6%)	1.0
	Yes (n=7)	3 (43%)	4 (57%)	
Dyspnea	No (n=117)	57 (48.7%)	60 (51.3%)	0.61
	Yes (n=17)	10 (59%)	7 (41%)	
Functional Status	Independent (n=131)	65 (49.6%)	66 (50.4%)	1.0
	Non-Independent (n=3)	2 (67%)	1 (33%)	
Preop Ventilator	No (n=134)	67 (50%)	67 (50%)	1.0
	Yes (n=0)	0 (0%)	0 (0%)	
COPD	No (n=122)	60 (49.2%)	62 (50.8%)	0.77
	Yes (n=12)	7 (58%)	5 (42%)	
Preop Pneumonia	No (n=133)	66 (49.6%)	67 (50.4%)	1.0
	Yes (n=1)	1 (100%)	0 (0%)	
Ascites	No (n=130)	65 (50.0%)	65 (50.0%)	1.0
	Yes (n=4)	2 (50%)	2 (50%)	
Congestive Heart Failure	No (n=132)	66 (50.0%)	66 (50.0%)	1.0
	Yes (n=2)	1 (50%)	1 (50%)	
Coronary Artery Disease	No (n=121)	59 (48.8%)	62 (51.2%)	0.58
	Yes (n=13)	8 (62%)	5 (38%)	
Peripheral Vascular Disease	No (n=131)	65 (49.6%)	66 (50.4%)	1.0
	Yes (n=3)	2 (67%)	1 (33%)	
Hypertension	No (n=74)	37 (50.0%)	37 (50.0%)	1.0
	Yes (n=60)	30 (50%)	30 (50%)	
Renal Disease	No (n=134)	67 (50.0%)	67 (50.0%)	1.0
	Yes (n=0)	0 (0%)	0 (0%)	
Neurologic Disorder	No (n=124)	62 (50.0%)	62 (50.0%)	1.0

Preoperative or Intraoperative Variable		All Patients in NSQIP Sample		
		Open Procedure	Laparoscopic Procedure	P Value
	Yes (n=10)	5 (50%)	5 (50%)	
Disseminated Cancer	No (n=132)	66 (50.0%)	66 (50.0%)	1.0
	Yes (n=2)	1 (50%)	1 (50%)	
Preop Infected Wound	No (n=134)	67 (50%)	67 (50%)	1.0
	Yes (n=0)	0 (0%)	0 (0%)	
Chronic Steroids	No (n=115)	58 (50.4%)	57 (49.6%)	1.0
	Yes (n=19)	9 (47%)	10 (53%)	
Weight Loss	No (n=131)	65 (49.6%)	66 (50.4%)	1.0
	Yes (n=3)	2 (67%)	1 (33%)	
Bleeding Disorder	No (n=112)	55 (49.1%)	57 (50.9%)	0.81
	Yes (n=22)	12 (55%)	10 (45%)	
Preoperative Transfusion	No (n=134)	67 (50.0%)	67 (50.0%)	1.0
	Yes (n=0)	0 (0%)	0 (0%)	
Chemotherapy	No (n=133)	67 (50.4%)	66 (49.6%)	1.0
	Yes (n=1)	0 (0%)	1 (100%)	
Radiotherapy	No (n=132)	66 (50.0%)	66 (50.0%)	1.0
	Yes (n=2)	1 (50%)	1 (50%)	
Preop SIRS, Sepsis, or Septic Shock	No (n=54)	27 (50%)	27 (50%)	1.0
	Yes (n=80)	40 (50%)	40 (50%)	
Dirty/Infected Incisional Wound	No (n=38)	38 (47%)	20 (53%)	0.83
	Yes (n=96)	49 (51%)	47 (49%)	
Operative time in minutes (mean $\pm$ SD)		138 $\pm$ 62	132 $\pm$ 64	0.63
Intraoperative Transfusion	No (n=124)	61 (49.2%)	63 (50.8%)	0.75
	Yes (n=10)	6 (60%)	4 (40%)	
Resident Participation (10 missing values)	No (n=64)	30 (47%)	34 (53%)	0.57
	Yes (n=67)	37 (55%)	30 (45%)	
Total WRVUs		38.5 $\pm$ 14.9	38.1 $\pm$ 11.8	0.99

Table 7

Univariate Association of Preoperative and Intraoperative Variables With 30-Day Postoperative Mortality and Morbidity Using Propensity-Matched Cohorts.

Preoperative or Intraoperative Variable		30-Day Postoperative Outcomes			
		Mortality		Morbidity	P Value
Surgical Approach	Open (n=67)	3 (4%)	0.65	20 (30%)	0.56
	Laparoscopic (n=67)	2 (3%)		17 (25%)	
Age in years (mean ± SD)		1.08 *	0.05	1.02 *	0.12
Gender	Male (n=81)	3 (4%)	0.98	23 (28%)	0.80
	Female (n=53)	2 (4%)		14 (26%)	
Body Mass Index in kg/m ² (mean ± SD)		0.85	0.10	1.01	0.84
ASA Class 3	No (n=59)	0 (0%)	0.04	13 (22%)	0.20
	Yes (n=75)	6 (7%)		24 (32%)	
Diabetes Mellitus	No (n=113)	2 (1.8%)	0.005	29 (25.7%)	0.24
	Yes (n=21)	3 (14%)		8 (38%)	
Tobacco Use	No (n=109)	4 (4%)	0.94	30 (27.5%)	0.96
	Yes (n=25)	1 (4%)		7 (28%)	
Frequent Ethanol Use	No (n=127)	5 (3.9%)	0.59	34 (26.8%)	0.35
	Yes (n=7)	0 (0%)		3 (43%)	
Dyspnea	No (n=117)	0 (0%)	<0.001	31 (26.5%)	0.45
	Yes (n=17)	5 (29%)		6 (35%)	
Functional Status	Independent (n=131)	5 (3.8%)	0.73	37 (28.2%)	0.28
	Non-Independent (n=3)	0 (0%)		0 (0%)	
Preop Ventilator	No (n=134)	5 (3.7%)	-	37 (27.6%)	-
	Yes (n=0)	-		-	
COPD	No (n=122)	2 (1.6%)	<0.001	33 (27.1%)	0.64
	Yes (n=12)	3 (25%)		4 (33%)	
Preop Pneumonia	No (n=133)	5 (3.8%)	0.84	36 (27.1%)	0.10
	Yes (n=1)	0 (0%)		1 (100%)	
Ascites	No (n=130)	5 (3.9%)	0.69	37 (28.5%)	0.21
	No (n=4)	0 (0%)		0 (0%)	
Congestive Heart Failure	No (n=132)	4 (3.0%)	0.001	36 (27.3%)	0.48
	Yes (n=2)	1 (50%)		1 (50%)	
Coronary Artery Disease	No (n=121)	5 (4.1%)	0.46	35 (28.9%)	0.30
	Yes (n=13)	0 (0%)		2 (15%)	
Peripheral Vascular Disease	No (n=131)	5 (3.8%)	0.73	36 (27.5%)	0.82
	Yes (n=3)	0 (0%)		1 (33%)	
Hypertension	No (n=74)	2 (3%)	0.49	17 (23%)	0.18
	Yes (n=60)	3 (5%)		20 (33%)	

Preoperative or Intraoperative Variable		30-Day Postoperative Outcomes			
		Mortality		Morbidity	P Value
Renal Disease	No (n=134)	5 (3.7%)	-	37 (27.6%)	-
	Yes (n=0)	-		-	
Neurologic Disorder	No (n=124)	4 (3.2%)	0.28	32 (25.8%)	0.10
	Yes (n=10)	1 (10%)		5 (50%)	
Disseminated Cancer	No (n=132)	5 (3.8%)	0.78	37 (28.0%)	0.38
	No (n=2)	0 (0%)		0 (0%)	
Preop Infected Wound	No (n=134)	5 (3.7%)	-	37 (27.6%)	-
	Yes (n=0)	-		-	
Chronic Steroids	No (n=115)	2 (1.7%)	0.003	29 (25.2%)	0.13
	Yes (n=19)	3 (16%)		8 (42%)	
Weight Loss	No (n=131)	3 (2.3%)	<0.001	37 (28.2%)	0.28
	Yes (n=3)	2 (67%)		0 (0%)	
Bleeding Disorder	No (n=112)	2 (1.8%)	0.007	29 (25.9%)	0.32
	Yes (n=22)	3 (14%)		8 (37%)	
Preoperative Transfusion	No (n=134)	5 (3.7%)	-	37 (27.6%)	-
	Yes (n=0)	-		-	
Chemotherapy	No (n=133)	4 (3.0%)	<0.001	36 (27.1%)	0.10
	Yes (n=1)	1 (100%)		1 (100%)	
Radiotherapy	No (n=132)	5 (3.8%)	0.78	35 (26.5%)	0.02
	Yes (n=2)	0 (0%)		2 (100%)	
Preop SIRS, Sepsis, or Septic Shock	No (n=54)	2 (4%)	0.99	16 (30%)	0.67
	Yes (n=80)	3 (4%)		21 (26%)	
Dirty/Infected Incisional Wound	No (n=38)	2 (5%)	0.56	11 (29%)	0.83
	Yes (n=96)	3 (3%)		26 (27%)	
Operative time in minutes (mean $\pm$ SD)		1.00 *	0.50	1.00 *	0.47
Intraoperative Transfusion	No (n=124)	3 (2.4%)	0.005	33 (26.6%)	0.36
	Yes (n=10)	2 (20%)		4 (40%)	
Resident Participation	No (n=64)	2 (3%)	0.69	17 (27%)	0.68
	Yes (n=67)	3 (4%)		20 (30%)	
Total WRVUs		1.00 *	0.90	1.01 *	0.65

* Represents increase in odds of incurring outcome for each unit increase in value of continuous variable.

Table 8

Outcomes for Patients Undergoing Emergent Partial Colectomy and End Colostomy For Diverticulitis Using Propensity-Matched Cohorts.

Outcome Measure	All Patients in NSQIP Sample		
	Open Procedure (n = 67)	Laparoscopic Procedure (n = 67)	P Value
30-Day Postoperative Death	3 (4.5%)	2 (3.0%)	1.0
Overall Complication Rate	20 (30.0%)	17 (25.4%)	0.68
Specific Complications:			
Superficial Surgical Site Infection	11 (16.4%)	3 (4.5%)	0.06
Deep Surgical Site Infection	1 (1.5%)	1 (1.5%)	1.0
Organ/Space Surgical Site Infection	2 (3.0%)	3 (4.5%)	1.0
Wound Dehiscence	2 (3.0%)	0 (0%)	0.5
Pneumonia	0 (0%)	3 (4.5%)	0.25
Unplanned Reintubation	1 (1.5%)	3 (4.5%)	0.63
Pulmonary Embolism	0 (0%)	1 (1.5%)	1.0
Prolonged Ventilatory Support	4 (6.0%)	2 (3.0%)	0.69
Progressive Renal Insufficiency	2 (3.0%)	0 (0%)	0.5
Acute Renal Failure	0 (0%)	1 (1.5%)	1.0
Urinary Tract Infection	2 (3.0%)	4 (6.0%)	0.69
Stroke	1 (1.5%)	1 (1.5%)	1.0
Coma > 24 hours	0 (0%)	0 (0%)	1.0
Peripheral Nerve Injury	0 (0%)	0 (0%)	1.0
Cardiac Arrest	0 (0%)	0 (0%)	1.0
Myocardial Infarction	0 (0%)	0 (0%)	1.0
Bleeding within 72 hours	0 (0%)	1 (1.5%)	1.0
Graft/Prosthetic Failure	0 (0%)	0 (0%)	1.0
Deep Venous Thrombosis	0 (0%)	2 (3.0%)	0.5
Sepsis	4 (6.0%)	1 (1.5%)	0.38
Septic Shock	4 (6.0%)	3 (4.5%)	1.0
Return to Operating Room	3 (4.5%)	8 (11.9%)	0.18
Median (IQR) and Mean Length of Postoperative Hospital Stay	8 (6-11)	6 (5-11)	0.53