Surgical Endoscopy (2019) 33:764–772
https://doi.org/10.1007/s00464-018-6341-7

A comparison of short-term outcomes between laparoscopic and open emergent repair of perforated peptic ulcers

Daniel L. Davenport[1] · Walker R. Ueland[2] · Shyanie Kumar[3] · Margaret Plymale[1,4] · Andrew C. Bernard[1,4] · J. Scott Roth[1,4]

Received: 11 April 2018 / Accepted: 6 July 2018 / Published online: 11 July 2018

Abstract

Background We compared 30-day outcomes in patients undergoing emergent open and laparoscopic repair of perforated peptic ulcers in a large multicenter cohort.

Methods Prospectively obtained data in the American College of Surgeons National Surgical Quality Improvement Program public use files from 2010 to 2016 were reviewed. Perioperative risks and outcomes were compared in unmatched and propensity-matched groups using parametric/non-parametric statistical tests as appropriate.

Results A total of 4210 procedures were identified 345 (8.2%) laparoscopic and 3865 (91.8%) open. Laparoscopic repairs increased from 4.5% of 2010 cases to 11.4% of 2016 cases ($p < .001$). Open repair patients had more acute presentation including higher rates of ASA class, hypoalbuminemia, preoperative septic shock, dyspnea, and mechanical ventilation (all $p < .01$). Laparoscopic operations were longer than open procedures ($p < .001$). Mortality (8.5 vs. 3.5%), median length of stay (7 vs. 5 days), transfusion rates (13.7 vs. 7.0%), renal failure (3.7 vs. 1.2%), and respiratory failure (15.5 vs. 5.2%) were all worse in the unmatched open group (all $p < .01$). Propensity matching resulted in 342 laparoscopic and 626 open cases of similar ulcer type, demographics, ASA class, preoperative SIRS/sepsis, hypoalbuminemia, and wound class. Mortality was similar between matched groups (5.0 vs. 3.5%, $p = .331$). Median length of stay was longer in the open group (6 vs. 5 days, $p < .001$), which also had higher rates of prolonged ventilation/reintubation (9.6 vs. 5.3%, $p = .019$) and abdominal wall wound occurrences (6.2 vs. 2.3%, $p = .042$). Return to the operating room and 30-day readmissions did not differ between the matched groups.

Conclusions Emergent laparoscopic repair of perforated peptic ulcer is increasingly being performed, is safe relative to open repair (in patients without preoperative septic shock), and confers a modest benefit in terms of length of stay, respiratory, and abdominal wall wound complications.

Keywords Perforated peptic ulcer · Outcomes · Laparoscopic repair · Open repair

Peptic ulcer disease (PUD) affects six million Americans every year [1]. In Kentucky alone, this disease contributes to 57 per 100,000 hospitalizations [2]. The etiology of PUD is multifactorial: H. pylori, NSAIDs, alcohol use, smoking, chronic stress, and older age are major contributing risk factors [3, 4]. With improved understanding of contributing factors and targeted medical therapies, the rates of PUD hospitalizations have decreased by half over the last three decades [5–7]. Common complications of PUD include bleeding, perforation, and obstruction. On average, 2–14% of peptic ulcers result in perforation [8], most commonly occurring in females over the age of 60 and chronic NSAID, alcohol or tobacco users. While bleeding is the most frequent complication of PUD, perforation carries a higher rate of surgical intervention and an associated mortality rate of 10–40% [7]. Historically, duodenal perforation was more prevalent;

✉ Daniel L. Davenport
daniel.davenport@uky.edu

[1] Department of Surgery, University of Kentucky, 800 Rose Street, MN274, Lexington, KY 40536-0298, USA

[2] College of Medicine, University of Kentucky, Lexington, KY, USA

[3] General Surgery Residency Program, University of Kentucky, Lexington, KY, USA

[4] Division of General Surgery, University of Kentucky, Lexington, KY, USA

however, due to the aforementioned risk factors, perforated gastric ulcers are more common today [8].

Several risk factors increase perioperative mortality in PPU patients. The main clinical scoring system used to predict morbidity and mortality in PPU patients is the Boey score. It is typically used in conjunction with the Mannheim Peritonitis Index for improved comparison of the severity of physiologic derangement. The Boey score is the most disease-specific and takes into consideration major medical illness, preoperative shock, and duration of perforation longer than 24 h before surgery [9]. A Boey score of 2 or greater indicates mortality of > 30%. Two recently published studies examining prognostic factors discovered that preoperative hypoalbuminemia and increasing age were also important risk factors for predicting mortality in PPU [10, 11]. Hypoalbuminemia is often associated with underlying disease, cancer, or chronic disease, while increasing age may correlate with greater postoperative complications and morbidities [10].

The operative management for perforated peptic ulcer (PPU) includes control of intraperitoneal contamination, closure and/or buttress of perforation, and distal feeding tube placement. The choice of surgical technique, laparoscopy vs. laparotomy, varies depending on the patient's preop clinical status, surgeon expertise/preference, and location of defect. It has been widely reported that open abdominal surgery increases postoperative pain and is associated with higher morbidity (ventral incisional hernia rate, surgical site infection, postoperative respiratory compromise) as compared to laparoscopic surgery. Some studies have shown laparoscopy to lessen these postoperative variables and are associated with fewer complications (i.e., surgical site infection, length of stay) than open repair [12, 13]. Still, others point to laparotomy as the better treatment, especially for repairing ulcers larger than 9 mm [14, 15]. A recent meta-analysis of randomized clinical trials comparing laparotomy to laparoscopic repair found no difference in morbidity or mortality between the two procedures [16]. Thus, current evidence remains inconclusive for favoring one surgical procedure over the other. More research is needed to determine the long-term efficaciousness of each technique.

The purpose of our study was to compare short-term outcomes of laparoscopic and laparotomy techniques in PPU repair using the American College of Surgeons' National Surgical Quality Improvement Program (ACS NSQIP) public use files.

Methods

This study was a retrospective review of the adult ACS NSQIP national public use files from 2010 to 2015. The ACS NSQIP collects data for patients aged 18 years and older undergoing major surgical procedures at over 600 medical centers in the United States and abroad. Admissions for traumatic injury are excluded. The ongoing prospective protocol includes over 135 variables, including demographic and preoperative clinical risk factors, intraoperative variables, and 30-day postoperative morbidity and mortality outcomes. Data are collected in a standardized fashion according to strict clinical definitions by reviewers who undergo annual interrater reliability testing. 30-day follow-up data are obtained from the medical record and through patient contact. Sites are audited for compliance with clinical definitions. This study was designated non-human-subjects research by the University of Kentucky Institutional Review Board and waived from further review.

Emergent repairs of perforated peptic ulcers were selected from the dataset using Current Procedural Terminology (CPT™) codes, emergent case designations, and International Classification of Diseases versions 9 and 10 (ICD-9™ or ICD-10™) codes. The CPT™ code 43659, "Unlisted laparoscopic procedure stomach," was used to identify laparoscopic repair given that there is as-yet no specific CPT™ code for this procedure. CPT™ code 43840 identified the open repairs. Diagnoses of perforated gastric, duodenal, peptic, and gastrojejunal ulcers were selected using the ICD-9™ or ICD-10™ codes shown in the "Appendix." Ulcer size was not available in the dataset. Procedures with complex secondary resections other than the ulcer repair were excluded by CPT codes. Superficial surgical site infection (SSI), deep SSI, and wound dehiscence outcomes were combined into an abdominal wall wound occurrence outcome, while organ/space SSI, sepsis, and septic shock were combined into an intra-abdominal infection outcome.

Patient preoperative, intraoperative, and postoperative variables were compared between initially unmatched groups using Mann–Whitney, Fisher's Exact, Chi-square, and t-tests as appropriate. Significance was set at $p < .01$. Laparoscopic cases were then matched with two open cases of similar clinical profile using propensity score matching (randomly within a caliper of 0.2). The clinical variables used in the propensity match included ulcer type (gastric, duodenal, gastrojejunal, or peptic), age in years, sex, minority race, body mass index group (underweight, normal, overweight, obese), preoperative sepsis (none, SIRS, sepsis, or septic shock), CDC wound class, ASA Class (grouped: I–II, III, IV–V), albumin < 3 g/dL, BUN > 40 mg/dL, creatinine > 1.2 mg/dL, and sodium < 135 mmol/L. Significance was set at $p < .05$ for the matched cohort comparisons given the pseudo-randomization of the propensity score matching.

Results

Unmatched cases

A total of 4210 repairs, 345 (8.2%) laparoscopic, and 33,865 (91.8%) open, were identified. Patients were 48.7% female, 30.8% minority race, with mean age of 59.0 years (SD 17.7). The proportion of laparoscopic repairs increased significantly from 4.5% in 2010 to 11.4% in 2016 (Fig. 1, Chi-square test for linear trend $p < .001$). Duodenal repair was disproportionately performed via an open approach, while gastrojejunal repair was disproportionately performed laparoscopically; gastric and peptic ulcers were similarly represented in both groups (Table 1, Chi-square $p < .001$). Open repair patients had higher rates of clinical factors indicating increased acuity including ASA class, preoperative septic shock, dyspnea, and mechanical ventilation (Table 1, all $p < .01$). The average duration of the operation was 19 min higher ($p < .001$) in the laparoscopic group, and the percent transferred from another healthcare facility was higher as well (Table 1, laparoscopic 27.2%, open 20.3%, $p = .004$). Open procedures more often required transfusion (13.7 vs. 7.0%, $p < .001$). Preoperative variables that did not differ significantly between groups included functional status, diabetes, smoking status, treatment with anti-hypertensives, and history of CHF.

Outcomes are compared between the unmatched groups in Table 2. Length of stay, mortality, renal failure/insufficiency, and respiratory outcomes are all worse in the open group. While wound dehiscence was higher in the open group, surgical site infection was not.

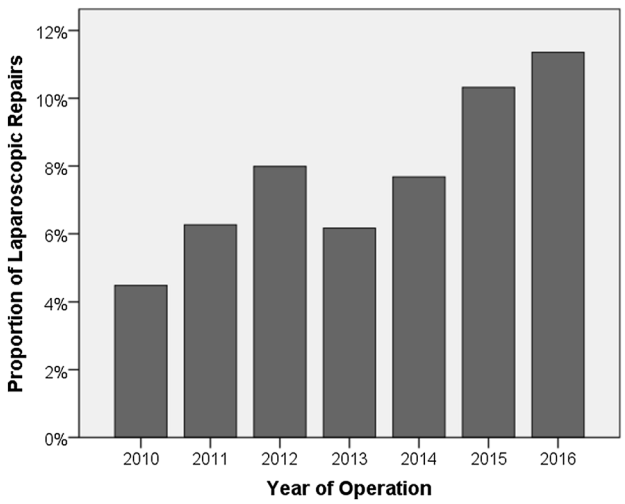

Fig. 1 The percentage of emergent repairs of perforated peptic ulcers performed laparoscopically increased from 4.5% in 2010 to 11.4% in 2016 in the ACS NSQIP national public use files (test for linear trend $p < .001$)

Propensity-matched groups

After matching 342 laparoscopic cases with 626 open cases, the two groups had similar ulcer type, age, sex, race, ASA class, preoperative sepsis, hypoalbuminemia, wound class, and several laboratory variables (Table 3). The matched sample excluded a significant portion of the open cases with preoperative septic shock given the relative rarity in the laparoscopic group. Operative duration remained 19 min longer ($p < .001$) in the laparoscopic group. Length of stay was 1 day longer in the open group, and prolonged ventilation/reintubation occurred about twice as often (Table 4, open 9.6% vs. laparoscopic 5.3%). Abdominal wall wound occurrences were reduced in the laparoscopic group (laparoscopic 2.3% vs. open 6.7%, $p = .042$) while no difference was observed in intra-abdominal infection not present at the time of surgery (laparoscopic 5.6% vs. open 4.3%, $p = .430$). Although significantly different in the overall dataset, after propensity matching there was no difference in 30-day all-cause mortality, re-operation rate, and readmission rate between the two groups.

Discussion

Historically, PPU repair has been done most frequently via exploratory laparotomy. In 1992, Lagoo et al. proposed that laparoscopy should be routinely considered in the management of perforated duodenal ulcer [17]. For the following 20 years, open surgery remained the primary approach for multiple reasons: surgeon inexperience with laparoscopy, acute care surgeon preference to do open operations, and inadequate evidence attesting safety of laparoscopic repair. Within the last two decades, we have seen rapid application of laparoscopic surgery for elective procedures such as cholecystectomy, appendectomy, anti-reflux, and hernia repair. The literature demonstrates minimally invasive surgery provides significant benefit over open operation with decreased hospital length of stay, time to return of bowel function, and postoperative pain, among other variables. These outcomes directly lead to decreased cost and increased patient satisfaction. The present study demonstrates that within the United States ACS NSQIP population, the proportion of laparoscopic PPU repairs has nearly tripled from 4.5% in 2010 to 11.4% in 2016 ($p < .001$). These results indicate that more surgeons are utilizing laparoscopic approach to repair PPUs. This can be attributed to generally decreased morbidity associated with laparoscopic surgery and increased study data pertaining to safety and efficacy of the technique. Several trials performed within the last 5 years have assessed the feasibility and outcomes of laparoscopic repair of PPU [12, 13, 17–20]. Institutions across the globe have published their outcomes data regarding emergent laparoscopic PPU

Table 1 Pre- and intraoperative characteristics that differed between patients undergoing emergent laparoscopic and open repair of perforated peptic ulcers

Variable	Laparoscopic	Open	*p* Value
No. of cases	345	3865	
Ulcer type/location based on diagnosis code, *n* (%)			< .001
Gastric	148 (42.9%)	1673 (43.3%)	
Duodenal	84 (24.3%)	1889 (48.9%)	
Gastrojejunal	104 (30.1%)	183 (4.7%)	
Peptic	9 (2.6%)	120 (3.1%)	
Age, mean year ± SD	54 ± 18	60 ± 18	< .001
Female, *n* (%)	222 (64.3%)	1828 (47.3%)	< .001
Minority race, *n* (%)	74 (21.4%)	1223 (31.6%)	< .001
ASA class, *n* (%)			< .001
I–II	135 (39.1%)	1094 (28.3%)	
III	165 (47.8%)	1689 (43.7%)	
IV–V	45 (13.0%)	1082 (28.0%)	
Body mass index, kg/m^2, *n* (%)			< .001
≤ 18.5, underweight	11 (3.2%)	227 (5.9%)	
18.6–25.0, normal	141 (40.9%)	1949 (50.4%)	
25.1–30.0, overweight	97 (28.1%)	838 (21.7%)	
> 30, obese	96 (27.8%)	851 (22.0%)	
Preoperative SIRS/sepsis, *n* (%)			< .001
SIRS	37 (10.7%)	515 (13.3%)	
Sepsis	117 (33.9%)	1322 (34.2%)	
Septic shock	6 (1.7%)	369 (9.5%)	
Dyspnea, *n* (%)	15 (4.3%)	323 (8.4%)	.006
Preop mechanical ventilation, *n* (%)	1 (0.3%)	136 (3.5%)	.003
BUN > 40 mg/dL, *n* (%)	17 (5.3%)	507 (13.5%)	< .001
Albumin < 3 g/dL, *n* (%)	37 (10.7%)	680 (17.6%)	.001
Creatinine > 1.2 mg/dL, *n* (%)	62 (18.0%)	1274 (33.0%)	< .001
Sodium < 135 mmol/L, *n* (%)	57 (16.5%)	1021 (26.4%)	< .001
Transferred from other healthcare facility, *n* (%)	94 (27.2%)	785 (20.3%)	.004
Operative duration, mean min ± SD	90 ± 53	72 ± 46	< .001
Wound class, *n* (%)			.080
1-Clean	4 (1.2%)	87 (2.3%)	
2-Clean/contaminated	39 (11.3%)	450 (11.6%)	
3-Contaminated	43 (12.5%)	648 (16.8%)	
4-Dirty/infected	259 (75.0%)	2680 (69.3%)	
Transfusion w/in 72 h or during operation, *n* (%)	24 (7.0%)	531 (13.7%)	< .001

repair and have shown it to be a safe and effective operation with reduced surgical site infection, postoperative complications, and hospital length of stay [13, 18–20]. Additionally, a recent meta-analysis of five randomized controlled trials examined laparoscopic vs. open repair of PPU (549 patients). They demonstrated that laparoscopic outcomes were comparable to open surgery in regard to re-operation and mortality, while laparoscopic repair was associated with significant reduction in surgical site infection, faster time to diet and less postoperative pain [21]. Our study affirms a few of these associations, as the propensity matched cohort demonstrated a statistically significant reduction in hospital length of stay, postoperative mechanical ventilation, superficial/fascial wound occurrences, and unplanned intubations for the laparoscopic group. This finding is very important in that reduction in these unfavorable postoperative outcomes have potential for cost savings. Further studies are needed to quantify and validate this benefit.

Patient selection: laparoscopic or open approach

As previously discussed, while the number of laparoscopic PPU repairs have increased, open repair remains the most common. As more research affirms laparoscopy as a safe and effective approach, developing criteria for patient selection for either technique is vital. In our retrospective review,

Table 2 30-day outcomes in patients undergoing emergent laparoscopic and open repair of perforated peptic ulcers

Variable	Laparoscopic	Open	*p* Value
No. of cases	345	3865	
All-cause mortality, *n* (%)	12 (3.5%)	329 (8.5%)	< .001
Median length of stay, day (IQR)	5 (4–7)	7 (5–11)	< .001
Abdominal wall wound occurrence, *n* (%)	8 (2.3%)	259 (6.7%)	.001
Superficial SSI, *n* (%)	6 (1.7%)	144 (3.7%)	.067
Deep SSI, *n* (%)	2 (0.6%)	53 (1.4%)	.319
Wound dehiscence, *n* (%)	0 (0.0%)	76 (2.0%)	.002
Intra-abdominal infection not present at time of surgery, *n* (%)	19 (5.5%)	260 (6.7%)	.430
Organ/space SSI, *n* (%)	28 (8.1%)	278 (7.2%)	.516
Not present at time of surgery	6 (1.7%)	57 (1.5%)	.643
Sepsis, *n* (%)	54 (15.7%)	524 (13.6%)	.288
Not present at time of surgery	6 (1.7%)	74 (1.9%)	1.000
Septic shock, *n* (%)	18 (5.2%)	448 (11.6%)	< .001
Not present at time of surgery	9 (2.6%)	150 (3.9%)	.301
Pneumonia, *n* (%)	11 (3.2%)	349 (9.0%)	< .001
Mechanical ventilation > 48 h or unplanned intubation, *n* (%)	18 (5.2%)	598 (15.5%)	< .001
UTI, *n* (%)	6 (1.7%)	76 (2.0%)	1.000
Renal failure or insufficiency, *n* (%)	4 (1.2%)	144 (3.7%)	.009
Cardiac arrest, acute myocardial infarction, or stroke w/deficit, *n* (%)	9 (2.6%)	162 (4.2%)	.198
Treated DVT or pulmonary embolism, *n* (%)	8 (2.3%)	113 (2.9%)	.616
Any re-operation, *n* (%)	22 (6.4%)	252 (6.5%)	1.000
Any readmission, *n* (%) (*N* = 298, 3035)[a]	24 (8.1%)	237 (7.8%)	.822

IQR interquartile range, *SSI* surgical site infection, *UTI* urinary tract infection, *DVT* deep venous thrombosis

[a]NSQIP started tracking readmissions in 2012, so the readmission data are from 2012 to 2016

there is an association between patients who underwent open surgery and statistically significant higher rates of clinical factors indicating increased acuity. We define "high acuity" as ASA 4 or greater, preoperative respiratory failure or septic shock. For the "high acuity" population, clinical decision to pursue open repair could be attributed to our finding of significantly shorter operative time (19 min, $p < .001$), or improved exposure, mobilization, and intraperitoneal lavage. Additionally, in the hemodynamically unstable or shock patient developing the lethal triad of hypothermia, increased coagulability, and instability, the damage control strategy may be utilized, which is supported by several emergency surgery practice management committees [22, 23]. Meanwhile, in our propensity matched cohort, the majority of the high acuity patients were filtered out, thus the matched cohort represented lower acuity patients. A majority of patients were either SIRS or sepsis, with only 3% in septic shock as compared to 9% in the unmatched group, ASA 3 or less. Interestingly, there was no statistical difference in ASA criteria, mortality, or 30-day readmission or re-operation rates between the two approaches in the matched group. This could suggest that laparoscopic repair is still underutilized in the lower acuity population. More studies are required to validate this idea.

While there is a definite role for open and laparoscopic approach to perforated ulcer repair, careful evaluation of all perioperative characteristics and preoperative clinical status will determine which technique is best. Although open surgery is currently the more frequent option, a strong argument can be made that for selected patients, laparoscopy is a safe alternative.

Limitations

This study has several limitations associated with it being a retrospective review of archival registry data. Patients have unknown treatment bias that may be confounding the results. We have attempted to mitigate this limitation with pseudo-randomized propensity matching using the clinical and perioperative variables available in the dataset. The number of cases is very large for this patient population and they come from numerous sites and surgical practices, also helping to mitigate the treatment bias. However, we are unable to specify type of surgeon (general, minimally invasive, bariatric, etc.)

Additionally, coding is an obvious issue with the laparoscopic procedure. Although we do have precise diagnosis coding for perforated gastric, duodenal, and gastrojejunal

Table 3 Pre- and intraoperative characteristics of a propensity-matched sample of patients undergoing emergent laparoscopic and open repair of perforated peptic ulcers

Variable	Laparoscopic	Open	*p* Value
No. of cases	342	626	
Ulcer type/location, *n* (%)			.308
Gastric	146 (42.7%)	288 (46.0%)	
Duodenal	84 (24.6%)	167 (26.7%)	
Gastrojejunal	104 (30.4%)	155 (24.8%)	
Peptic	8 (2.3%)	16 (2.6%)	
Age, mean year ± SD	54.0 ± 18.3	53.9 ± 17.1	.922
Female, *n* (%)	219 (64.0%)	391 (62.5%)	.676
Minority race, *n* (%)	74 (21.6%)	142 (22.7%)	.747
ASA class, *n* (%)			.656
I–II	132 (38.6%)	235 (37.5%)	
III	165 (48.2%)	295 (47.1%)	
IV–V	45 (13.2%)	96 (15.3%)	
Body mass index, kg/m^2, *n* (%)			.984
≤ 18.4	11 (3.2%)	21 (3.4%)	
18.5–24.9	141 (41.2%)	264 (42.2%)	
25.0–29.9	95 (27.8%)	167 (26.7%)	
30.0+	95 (27.8%)	174 (27.8%)	
Preoperative SIRS/sepsis, *n* (%)			.263
SIRS	37 (10.8%)	78 (12.5%)	
Sepsis	116 (33.9%)	228 (36.4%)	
Septic shock	6 (1.8%)	20 (3.2%)	
Dyspnea, *n* (%)	15 (4.4%)	40 (6.4%)	.245
Preop mechanical ventilation, *n* (%)	1 (0.3%)	11 (1.8%)	.066
BUN > 40 mg/dL, *n* (%)	17 (5.0%)	41 (6.5%)	.396
Albumin < 3 g/dL, *n* (%)	37 (10.2%)	68 (12.6%)	.382
Creatinine > 1.2 mg/dL, *n* (%)	62 (18.1%)	137 (21.9%)	.183
Sodium < 135 mmol/L, *n* (%)	57 (16.7%)	115 (18.4%)	.539
Transferred from other healthcare facility, *n* (%)	94 (27.5%)	160 (25.6%)	.541
Operative duration, mean min ± SD	90 ± 53	71 ± 34	< .001
Wound class, *n* (%)			.845
1-Clean	4 (1.2%)	7 (1.1%)	
2-Clean/contaminated	39 (11.4%)	83 (13.3%)	
3-Contaminated	43 (12.6%)	82 (13.1%)	
4-Dirty/infected	256 (74.9%)	454 (72.5%)	
Transfusion w/in 72 h of or during operation, *n* (%)	24 (7.0%)	58 (9.3%)	.277

ulcers, some coders have used the term "peptic ulcer" which encompasses both gastric and duodenal ulcer by definition. Also, ulcer size was not available.

As with any procedure, there is risk of conversion from laparoscopic to open. Due to lack of NSQIP tracking conversion and no specific CPT code, we are unable to identify the conversion rate. However, an analysis of laparoscopic repair performed by Teoh et al., demonstrated that higher risk patients (hemodynamic instability, ulcer > 1 cm, and ASA grade > 3) had statistically significant higher rate of conversion from laparoscopy to open surgery [24]. In future studies, conversion needs to be captured to better delineate complexity of performed cases.

Conclusion

In conclusion, we have shown in a contemporary, large multicenter cohort of patients that emergent laparoscopic repair of perforated peptic ulcer is increasingly being performed, is safe relative to open repair (in patients without preoperative septic shock), and confers a modest benefit in terms of length of stay and respiratory complications.

Compliance with ethical standards

Disclosure Dr. Bernard has a consulting relationship with Atos Bio for clinical trial data adjudication and does expert witness case review

Table 4 30-day outcomes in a propensity-matched sample of patients undergoing emergent laparoscopic and open repair of perforated peptic ulcers

Variable	Laparoscopic	Open	*p* Value
No. of cases	342	626	
Median length of stay, days (IQR)	5 (4–7)	6 (5–9)	< .001
All-cause mortality, *n* (%)	12 (3.5%)	31 (5.0%)	.331
Abdominal wall wound occurrence, *n* (%)	8 (2.3%)	39 (6.2%)	.042
Superficial SSI, *n* (%)	6 (1.8%)	24 (3.8%)	.082
Deep SSI, *n* (%)	2 (0.6%)	8 (1.3%)	.508
Wound dehiscence, *n* (%)	0 (0.0%)	8 (1.3%)	.056
Intra-abdominal infection not present at time of surgery, *n* (%)	19 (5.6%)	27 (4.3%)	.430
Organ/space SSI, *n* (%)	28 (8.2%)	38 (6.1%)	.231
Not present at time of surgery	6 (1.8%)	4 (0.6%)	.179
Sepsis, *n* (%)	54 (15.8%)	81 (12.9%)	.244
Not present at time of surgery	6 (1.8%)	9 (1.4%)	.787
Septic shock, *n* (%)	18 (5.3%)	42 (6.7%)	.406
Not present at time of surgery	9 (2.6%)	16 (2.6%)	.000
Pneumonia, *n* (%)	11 (3.2%)	37 (5.9%)	.087
Mechanical ventilation > 48 h or unplanned intubation, *n* (%)	18 (5.3%)	60 (9.6%)	.019
UTI, *n* (%)	6 (1.8%)	10 (1.6%)	1.000
Renal failure or insufficiency, *n* (%)	4 (1.2%)	16 (2.6%)	.165
Cardiac arrest, acute myocardial infarction, or stroke w/deficit, *n* (%)	9 (2.6%)	20 (3.2%)	.697
Treated DVT or pulmonary embolism, *n* (%)	8 (2.3%)	20 (3.2%)	.549
Any re-operation, *n* (%)	22 (6.4%)	27 (4.3%)	.168
Any readmission, *n* (%) [*N* = 295,495][a]	24 (8.1%)	41 (8.3%)	1.000

IQR interquartile range, *SSI* surgical site infection, *UTI* urinary tract infection, *DVT* deep venous thrombosis

[a]NSQIP started tracking readmissions in 2012, so the readmission data are from 2012 to 2016

and provides testimony in medical malpractice cases. Dr. Bernard is the President of the Eastern Association for the Surgery of Trauma and receives free travel for association-related meetings and events. Dr. Roth has a consulting relationship with Bard, Allergan, and Miromatrix. He is a participant on a speaking bureau for Bard and Miromatrix. He has some stock ownership in Miromatrix. He receives research funding from Bard. Drs. Plymale, Davenport and Kumar and Mr. Ueland have no conflicts of interest or financial interests to disclose.

Appendix

ICD-9™ codes used to identify perforated peptic ulcers:

531.1-Acute Gastric Ulcer With Perforation
531.10-Acute Gastric Ulcer With Perforation Without Obstruction
531.11-Acute Gastric Ulcer With Perforation With Obstruction
531.2-Acute Gastric Ulcer With Hemorrhage And Perforation
531.20-Acute Gastric Ulcer With Hemorrhage And Perforation Without Obstruction
531.21-Acute Gastric Ulcer With Hemorrhage And Perforation With Obstruction
531.5-Chronic Or Unspecified Gastric Ulcer With Perforation
531.50-Chronic Or Unspecified Gastric Ulcer With Perforation Without Obstruction
531.51-Chronic Or Unspecified Gastric Ulcer With Perforation With Obstruction
531.6-Chronic Or Unspecified Gastric Ulcer With Hemorrhage And Perforation
531.60-Chronic Or Unspecified Gastric Ulcer With Hemorrhage And Perforation Without Obstruction
531.60-Chronic Or Unspecified Gastric Ulcer With Hemorrhage And Perforation With Obstruction
532.1-Acute Duodenal Ulcer With Perforation
532.10-Acute Duodenal Ulcer With Perforation Without Obstruction
532.11-Acute Duodenal Ulcer With Perforation With Obstruction
532.2-Acute Duodenal Ulcer With Hemorrhage And Perforation
532.20-Acute Duodenal Ulcer With Hemorrhage And Perforation Without Obstruction
532.21-Acute Duodenal Ulcer With Hemorrhage And Perforation With Obstruction

532.5-Chronic Or Unspecified Duodenal Ulcer With Perforation
532.50-Chronic Or Unspecified Duodenal Ulcer With Perforation Without Obstruction
532.51-Chronic Or Unspecified Duodenal Ulcer With Perforation With Obstruction
532.6-Chronic Or Unspecified Duodenal Ulcer With Hemorrhage And Perforation
532.60-Chronic Or Unspecified Duodenal Ulcer With Hemorrhage And Perforation Without Obstruction
532.61-Chronic Or Unspecified Duodenal Ulcer With Hemorrhage And Perforation With Obstruction
533.1-Acute Peptic Ulcer Of Unspecified Site With Perforation
533.10-Acute Peptic Ulcer Of Unspecified Site With Perforation Without Obstruction
533.11-Acute Peptic Ulcer Of Unspecified Site With Perforation With Obstruction
533.2-Acute Peptic Ulcer Of Unspecified Site With Hemorrhage And Perforation
533.20-Acute Peptic Ulcer Of Unspecified Site With Hemorrhage And Perforation Without Obstruction
533.21-Acute Peptic Ulcer Of Unspecified Site With Hemorrhage And Perforation With Obstruction
533.5-Chronic Or Unspecified Peptic Ulcer Of Unspecified Site With Perforation
533.50-Chronic Or Unspecified Peptic Ulcer Of Unspecified Site With Perforation Without Obstruction
533.51-Chronic Or Unspecified Peptic Ulcer Of Unspecified Site With Perforation With Obstruction
534.1-Acute Gastrojejunal Ulcer With Perforation
534.10-Acute Gastrojejunal Ulcer With Perforation Without Obstruction
534.11-Acute Gastrojejunal Ulcer With Perforation With Obstruction
534.2-Acute Gastrojejunal Ulcer With Hemorrhage And Perforation
534.20-Acute Gastrojejunal Ulcer With Hemorrhage And Perforation Without Obstruction
534.21-Acute Gastrojejunal Ulcer With Hemorrhage And Perforation With Obstruction
534.5-Chronic Or Unspecified Gastrojejunal Ulcer With Perforation
534.50-Chronic Or Unspecified Gastrojejunal Ulcer With Perforation Without Obstruction
534.51-Chronic Or Unspecified Gastrojejunal Ulcer With Perforation With Obstruction
534.6-Chronic Or Unspecified Gastrojejunal Ulcer With Hemorrhage And Perforation
534.60-Chronic Or Unspecified Gastrojejunal Ulcer With Hemorrhage And Perforation Without Obstruction
534.61-Chronic Or Unspecified Gastrojejunal Ulcer With Hemorrhage And Perforation With Obstruction

ICD-10™ codes used to identify perforated peptic ulcers:

K25.1-Acute gastric ulcer with perforation
K25.2-Acute gastric ulcer with both hemorrhage and perforation
K25.5-Chronic or unspecified gastric ulcer with perforation
K25.6-Chronic or unspecified gastric ulcer with both hemorrhage and perforation
K26.1-Acute duodenal ulcer with perforation
K26.2-Acute duodenal ulcer with both hemorrhage and perforation
K26.5-Chronic or unspecified duodenal ulcer with perforation
K26.6-Chronic or unspecified duodenal ulcer with both hemorrhage and perforation
K27.1-Acute peptic ulcer, site unspecified, with perforation
K27.2-Acute peptic ulcer, site unspecified, with both hemorrhage and perforation
K27.5-Chronic or unspecified peptic ulcer, site unspecified, with perforation
K27.6- Chronic or unspecified peptic ulcer, site unspecified, with both hemorrhage and perforation
K28.1-Acute gastrojejunal ulcer with perforation
K28.2- Acute gastrojejunal ulcer with perforation, with both hemorrhage and perforation
K28.5-Chronic or unspecified gastrojejunal ulcer with perforation
K28.6-Chronic or unspecified gastrojejunal ulcer, with both hemorrhage and perforation

References

1. Sandler RS, Everhart JE, Donowitz M, Adams E, Cronin K, Goodman C, Gemmen E, Shah S, Avdic A, Rubin R (2002) The burden of selected digestive diseases in the United States. Gastroenterology 122:1500–1511
2. Epperson J (2006) Immunization and infectious diseases. In: Robeson S, Owens L (eds) Kentucky Cabinet for Health and Family Services 2010 Mid-decade Review, Frankfort, pp 324–342
3. Peterson WL (1991) *Helicobacter pylori* and peptic ulcer disease. New Engl J Med 324:1043–1048
4. Wakayama T, Ishizaki Y, Mitsusada M, Takahashi S, Wada T, Fukushima Y, Hattori H, Okuyama T, Funatsu H (1994) Risk factors influencing the short-term results of gastroduodenal perforation. Surg Today 24:681–687
5. Wallace JL (2008) Prostaglandins, NSAIDs, and gastric mucosal protection: why doesn't the stomach digest itself? Physiol Rev 88:1547–1565
6. Huang JQ, Sridhar S, Hunt RH (2002) Role of Helicobacter pylori infection and non-steroidal anti- inflammatory drugs in peptic-ulcer disease: a meta-analysis. Lancet 359:14–22

7. Wang YR, Richter JE, Dempsey DT (2010) Trends and outcomes of hospitalizations for peptic ulcer disease in the United States, 1993 to 2006. Ann Surg 251:51–58
8. Lee CW, Sarosi GA (2011) Emergency ulcer surgery. Surg Clin North Am 91:1001–1013. https://doi.org/10.1016/j.suc.2011.06.008
9. Boey J, Wong J, Ong GB (1982) A prospective study of operative risk factors in perforated duodenal ulcers. Ann Surg 195:265–269
10. Thorson K, Soreide JA, Soreide K (2014) What is the best predictor of mortality in perforated peptic ulcer disease? A population-based, multivariable regression analysis including three clinical scoring systems. J Gastrointest Surg 18:1261–1268
11. Unver M, Firat O, Unalp OV, Uguz A, Gumus T, Sezer TO, Öztürk Ş, Yoldaş T, Ersin S, Güler A (2015) Prognostic factors in peptic ulcer perforations: a retrospective 14-year study. Int Surg 100:942–948
12. Bertleff MJ, Lange JF (2010) Laparoscopic correction of perforated peptic ulcer: first choice? A review of literature. Surg Endosc 24:1231–1239
13. Sanabria A, Morales CH, Villegas M (2005) Laparoscopic repair for perforated peptic ulcer disease. Cochrane Database Syst Rev 4:CD004778
14. Di Saverio S, Bassi M, Smeireri N, Masetti M, Ferrara F, Fabbri C, Ansaloni L, Ghersi S, Serenari M, Coccolini F, Naidoo N, Sartelli M, Tugnoli G, Catena F, Cennamo V, Jovine E (2014) Diagnosis and treatment of perforated or bleeding peptic ulcers: 2013 WSES position paper. World J Emerg Surg 9:45
15. Lau WY, Leung KL, Zhu XL, Lam YH, Chung SC, Li AK (1995) Laparoscopic repair of perforated peptic ulcer. Br J Surg 82:814–816
16. Antoniou SA, Antoniou GA, Koch OO, Pointner R, Granderath FA (2013) Meta-analysis of laparoscopic versus open repair of perforated peptic ulcer. JSLS 17:14–22
17. Lagoo S, McMahon RL, Kakihara M, Pappas TN, Eubanks S (2002) The sixth decision regarding perforated duodenal ulcer. JSLS 6:359–368
18. Muller MK, Wrann S, Widmer J, Klasen J, Weber M, Hahnloser D (2016) Perforated peptic ulcer repair: factors predicting conversion in laparoscopy and postoperative septic complication. World J Surg 40:2186–2193
19. Bertleff MJ, Halm JA, Bemelman WA, van der Ham AC, van der Harst E, Oei HI, Smulders JF, Steyerberg EW, Lange JF (2009) Randomized clinical trial of laparoscopic versus open repair of the perforated peptic ulcer: the LAMA trial. World J Surg 33:1368–1373
20. Siu WT, Leong BK, Law BK, Chau CH, Li AC, Fung KH, Tai YP, Li MK (2002) Laparoscopic repair for perforated ulcer. A randomized controlled trial. Ann Surg 235:313–319
21. Tan S, Wu G, Zhuang Q, Xi Q, Meng Q, Jiang Y, Han Y, Yu C (2016) Laparoscopic versus open repair for perforated peptic ulcer: a meta analysis of randomized controlled trials. Int J Surg 33:124–132
22. Varcus F, Paun I, Duta C, Dobrescu A, Frandes M, Tarta C (2018) Laparoscopic repair of perforated peptic ulcer. Minerva Chir 73:188–193
23. Lee JC, Peitzman AB (2006) Damage control laparotomy. Curr Opin Crit Care 12:346–350
24. Teoh AY, Chiu PW, Kok AS, Wong SK (2015) The selective use of laparoscopic repair is safe in high-risk patients suffering from perforated peptic ulcer. World J Surg 39:740–745