Emergency surgery for acute diverticulitis: Which operation? A National Surgical Quality Improvement Program study

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BACKGROUND: The optimal surgical management of acute diverticulitis is still a controversial and unresolved issue. While the Hartmann's procedure (') is the most commonly performed operation, primary anastomosis (PA), with or without proximal diversion, has also been used with increasing frequency.

METHODS: This is a National Surgical Quality Improvement Program database study including all patients requiring emergency surgery for acute diverticulitis. Three operative approaches were analyzed: HP, colectomy with PA, and colectomy with PA with proximal diversion (PAPD). Mortality and postoperative outcomes were compared between the three groups using a logistical regression model.

RESULTS: There were 1,314 patients who required emergent operation for acute diverticulitis, 75.4% underwent HP, 21.7% underwent PA, and 2.9% underwent PAPD. Thirty-day mortality was 7.3%, 4.6%, and 1.6% for HP, PA, and PAPD respectively (p = 0.163), while surgical site infections occurred in 19.7%, 17.9%, and 13.2%, respectively (p = 0.59). After multivariable analysis adjusting for age, alcohol consumption, comorbidities, steroid use, preoperative laboratory values, hemorrhage at admission and laparoscopic surgery, the adjusted odds ratio for 30-day mortality comparing PA with HP was 0.77 (95% confidence interval [CI], 0.38–1.56; p = 0.465), 0.47 (95% CI, 0.06–3.74; p = 0.479) comparing PAPD with HP, and 1.62 (95% CI, 0.19–13.78; p = 0.658) comparing PA with PAPD. In addition, the three groups did not have significantly different adjusted odds ratio for the development of surgical infectious complications, acute kidney injury, cardiovascular incidents, or venous thromboembolism after surgery.

CONCLUSION: Resection and PA in patients undergoing an emergency operation for acute diverticulitis is a safe alternative to the HP, with no significant difference in mortality or postoperative surgical site infections. (*J Trauma Acute Care Surg*. 2013;74: 1385–1391.

LEVEL OF EVIDENCE: Therapeutic study, level IV.

KEY WORDS: Acute diverticulitis; Hartmann's procedure; primary anastomosis; primary anastomosis; proximal diversion.

Acute diverticulitis is a common acute surgical problem in the Western world. An estimated 30% of the population older than 60 years is affected with diverticular disease, and as many as 25% of these people will go on to develop acute diverticulitis.[1–3] In the United States, the age-adjusted admission rate for acute diverticulitis has increased by 26% from 120,500 hospital admissions in 1998 to 151,900 admissions in 2005. The largest increase in hospital admission has been in patients younger than 45 years.[4,5]

Patients with contained perforation (Hinchey Stages I and II) can often be managed with intravenously administered antibiotics with or without percutaneous drainage of the abscess, depending on abscess size. Those with free perforation resulting in either purulent or fecal peritonitis (Hinchey Stages III and IV) require surgery.[1,6,7] The original three-stage operative approach to diverticulitis with perforation (initial diversion, resection of diseased colon, and subsequent anastomosis) is no longer recommended and by the 1980s; the Hartmann's procedure (HP) became the operation of choice in the management of complicated diverticulitis requiring an emergency operation.[6,7] However, in the late 1990s, the concept of resection and primary anastomosis (PA) with or without proximal diversion (PAPD) was introduced and has since become a common procedure.[6–8]

The purpose of this study was to compare postoperative outcomes with the three common techniques (HP, PA, and PAPD) used in the emergency management of acute diverticulitis using the American College of Surgeons' (ACS) National Surgical Quality Improvement Program (NSQIP) database.

PATIENTS AND METHODS

This is a study using the ACS NSQIP database. Established in 2004, the NSQIP database collects data from a growing number of hospitals in the United States, with more than 300 participating in 2011. The NSQIP database is capable of documenting outcomes up to 30 days in 95% of the cases entered into the database. The ACS provides training and ongoing education and conducts audits to ensure data reliability.

International Classification of Diseases—9th Rev. codes were used to identify all patients with diverticulitis (562.11, diverticulitis of colon without hemorrhage; 562.13, diverticulitis of colon with hemorrhage). Only cases coded as emergent were included, and elective cases were excluded. The study population was further divided into three groups based on surgical management using current procedural terminology (CPT) codes: colectomy partial with end colostomy and closure of distal segment (HP), colectomy with PA and colectomy with PA and proximal diversion (PAPD) (Table 1). CPT code 44141 (colectomy partial with skin level cecostomy or colostomy) was excluded because the Hartmann-type procedure has its own CPT code, and an anastomosis is not included in the definition of the CPT code; therefore, it does not necessarily define HP, PA, or PAPD.

TABLE 1. CPT Codes

HP	44143: Colectomy partial with end colostomy and closure of distal segment (Hartmann-type procedure)
	44206: Laparoscopy surgical; colectomy partial with end colostomy and closure of distal segment (Hartmann-type procedure)
PA	44140: Colectomy, partial with anastomosis
	44145: Colectomy with coloproctostomy (low pelvic anastomosis)
	44204: Laparoscopy surgical; colectomy, partial with anastomosis
	44207: Laparoscopy surgical; colectomy partial with anastomosis with coloproctostomy
PAPD	44146: Colectomy partial with coloproctostomy (low pelvic anastomosis) with colostomy
	44208: Laparoscopy surgical; colectomy partial with anastomosis with coloproctostomy; with colostomy

The preoperative characteristics of the three groups were compared using the following variables: age, sex, a history of smoking, alcohol consumption, a history of comorbidities (cardiovascular incidents [CVIs], hypertension, cerebrovascular accidents [CVAs], steroid use, chemotherapy, and radiotherapy of malignancy), level of practitioner performing the operation (attending or resident), septic status at admission (systemic inflammatory response syndrome or septic shock), preoperative laboratory values (white blood cell [WBC] count, hematocrit, and abnormal creatinine level [>1.5 mg/dL]), presence of hemorrhage at admission, and the surgical technique (laparoscopy vs. open surgery). Body mass index (BMI) was used to classify patients as overweight (BMI, 25–29.9 kg/m^2) and obese (BMI $\geq$ 30 kg/m^2).

The outcomes measured included the development of complications including surgical site infections (SSIs), systemic infectious complications (SICs), CVIs, and acute kidney injury (AKI), hospital length of stay (LOS), and mortality.

The preoperative characteristics of the three study groups were compared using Pearson's χ^2 or Fisher's exact test as appropriate for categorical variables, and Student's *t* test or Mann-Whitney U-test for continuous variables. Mortality, SSIs, SICs, postoperative AKI, and postoperative CVIs were reported using Pearson's χ^2.

To compare the safety and efficacy of the three different surgical techniques (HP, PA, and PAPD), a multivariate analysis for each outcome was performed adjusting for covariables that differed between the three groups both statistically and clinically.

TABLE 2. Epidemiology and Clinical Characteristics of Patients Undergoing Emergency Surgery

	Overall (n = 1,314)	HP (n = 991)	PA (n = 285)	PAPD (n = 38)	*p*
Demographics					
Age	62.5 ± 15.2	62.9 ± 15.2	60.7 ± 15.1	64.3 ± 15.4	0.086
Sex (male)	49.4 (649)	49.6 (492)	48.1 (137)	52.6 (20)	0.825
BMI	26.9 ± 1.0	26.8 ± 1.0	27.5 ± 8.8	26.1 ± 8.1	0.502
Overweight	30.7 (403)	30.4 (301)	30.2 (86)	42.1 (16)	0.300
Obese	34.7 (456)	35.0 (347)	34.7 (99)	26.3 (10)	0.543
Social history					
Tobacco	24.3 (319)	24.6 (244)	23.9 (68)	18.4 (7)	0.670
Alcohol	5.9 (77)	5.8 (57)	5.3 (15)	13.2 (5)	0.144
Comorbidities					
Diabetes mellitus	11.9 (156)	12.6 (125)	10.5 (30)	2.6 (1)	0.128
HxCVI	14.5 (191)	15.6 (155)	11.9 (34)	5.3 (2)	0.076
Hypertension	53.0 (697)	54.6 (541)	49.5 (141)	39.5 (15)	0.074
CVA	9.9 (130)	9.6 (95)	11.9 (34)	2.6 (1)	0.159
Renal failure	4.3 (57)	4.8 (48)	2.5 (7)	5.3 (2)	0.210
Steroid use	13.6 (179)	15.7 (156)	7.0 (20)	7.9 (3)	<0.001
Chemotherapy for malignancy	2.7 (35)	3.1 (31)	1.1 (3)	2.6 (1)	0.159
Radiotherapy for malignancy	1.7 (22)	2.0 (20)	0.7 (2)	0.0 (0)	0.224
Septic status at admission					
SIRS	44.7 (588)	46.2 (458)	38.6 (110)	52.6 (20)	0.045
Septic shock	4.9 (65)	5.4 (54)	2.8 (8)	7.9 (3)	0.135
Operative wound classification					
Contaminated	11.4 (150)	9.8 (97)	16.5 (47)	15.8 (6)	0.005
Infected	73.7 (969)	78.6 (779)	56.8 (162)	73.7 (28)	<0.001
Preoperative laboratory values					
WBC	13.7 ± 6.3	14.0 ± 6.4	12.8 ± 6.1	12.4 ± 6.3	0.006
Hematocrit	38.3 ± 6.2	38.3 ± 6.2	38.3 ± 6.2	38.7 ± 6.6	0.925
Abnormal creatinine (>1.5 mg/dL)	16.1 (211)	18.1 (179)	10.2 (29)	7.9 (3)	0.002
Hemorrhage at admission	4.9 (64)	3.9 (39)	7.7 (22)	7.9 (3)	0.022
Laparoscopic operation	6.3 (83)	4.3 (43)	13.3 (38)	5.3 (2)	<0.001
Resident operating	33.1 (435)	32.2 (319)	36.1 (103)	34.2 (13)	0.453

HxCVI, history of cardiovascular incident; SIRS, systemic inflammatory response syndrome.

Owing to the multiple comparisons, statistical significance was set at $p < 0.01$. The type of operative management (HP, PA, and PAPD) was entered into the logistic regression model as an ordinal variable. Adjusted odds ratios (AORs) with 95% confidence intervals and adjusted *p* values were derived from the logistic regressions.

To examine the impact of BMI on development of SSIs, BMI was categorized into four groups as follows: underweight (BMI ≤ 18.5 kg/m^2), normal weight (BMI, 18.6–24.9 kg/m^2), overweight (BMI, 25–29.9 kg/m^2), and obese (BMI ≥ 30 kg/m^2). The incidence of SSIs for each BMI group was assessed.

RESULTS

During the study period (2005–2008), 1,334,886 surgical patients were entered in the ACS NSQIP database. Of these, 1,314 required an emergent operation for acute diverticulitis. A total of 991 patients (75.4%) were managed with the HP, 285 (21.7%) had a colectomy with PA, and 38 (2.9%) had colectomy with PA and proximal diverting colostomy or ileostomy. There were no changing trends in how acute diverticulitis was operatively managed during the 4-year study period. The rates of HP and PA were the same throughout each year.

Baseline characteristics of each group are shown in Table 2. There were no significant differences between the three groups in age, BMI, social history, preoperative septic status, preoperative WBC count, hematocrit, abnormal creatinine level, and most comorbidities. Those who underwent HP (15.7%) were more likely to have a history of steroid use at admission compared with PA (7%) and PAPD (7.9%) ($p < 0.001$). Patients who underwent HP (78.6%) and PAPD (73.7%) were more likely to have an infected wound at operation compared with PA (56.8%) ($p < 0.001$). The PA group (13.3%) was more likely to have a laparoscopic procedure compared with HP (4.3%) and PAPD (5.3%) ($p < 0.001$). No patients in the database underwent laparoscopic lavage and drainage only as the primary surgical management of their diverticulitis.

Unadjusted outcomes between the three procedures are shown in Table 3. There were no significant differences in 30-day mortality or the development of SSIs. SICs were less common in the PA group compared with HP (14.0% vs. 20.7%) and PAPD (14.0% vs. 23.7%), but these differences did not reach statistical significance (Table 3). Similarly, AKI, CVI, and deep venous thrombosis/thrombophlebitis after surgery did not differ significantly among the three groups (Table 3). Pulmonary embolism was more likely to occur after HP (14%) compared with PA (4%), but not significantly so. No pulmonary embolisms occurred in the PAPD group. The hospital LOS was significantly longer in the PAPD group (14 days) and HP group (13.1 days) compared with the PA group (11.8 days) ($p = 0.008$) (Table 3).

There were 65 cases admitted with septic shock, 54 of which underwent HP, 8 underwent PA, and 3 underwent PAPD. The mortalities in HP and PA group were 33.3% and 12.5%, respectively ($p = 0.489$). The SSIs were 22.2% and 25.0% ($p = 0.639$) and the SICs 37.0% and 25.0%, respectively ($p = 0.800$).

When development of SSIs was stratified according to different BMI groups, patients with normal weight had the lowest incidence. Patients classified as overweight or obese were significantly more likely to develop SSIs. Underweight patients were more likely to develop SSI, but this difference did not reach significance (Fig. 1).

After a multivariate analysis (adjusting for age, diabetes, alcohol consumption, history of comorbidities [CVI, CVA, hypertension requiring medication], steroid use, infected wound, preoperative laboratory values [WBC and creatinine], presence of hemorrhage at admission and laparoscopic surgery), no

TABLE 3. Unadjusted Outcomes According to the Type of Emergency Operation

	Overall (n = 1,314)	HP (n = 991)	PA (285)	PAPD (n = 38)	*p*
30-d mortality	6.5 (86)	7.3 (72)	4.6 (13)	2.6 (1)	0.163
SSIs	16.1 (251)	19.7 (195)	17.9 (51)	13.2 (5)	0.509
Superficial wound infection	9.5 (125)	10.1 (100)	8.1 (23)	5.3 (2)	0.392
Deep incisional infection	3.0 (39)	2.8 (28)	3.9 (11)	0.0 (0)	0.364
Abscess	5.0 (66)	5.2 (52)	4.6 (13)	2.6 (1)	0.709
Wound dehiscence	4.0 (53)	4.0 (40)	3.5 (10)	7.9 (3)	0.435
SICs	19.3 (254)	20.7 (205)	14.0 (40)	23.7 (9)	0.034
Pneumonia	7.2 (94)	7.9 (78)	4.2 (12)	10.5 (4)	0.077
UTI	2.8 (37)	2.8 (28)	2.8 (8)	2.6 (1)	0.997
Sepsis	7.8 (102)	7.9 (78)	8.1 (23)	2.6 (1)	0.484
Septic shock	8.7 (114)	9.2 (91)	6.3 (18)	13.2 (5)	0.193
AKI	3.1 (41)	3.1 (31)	3.5 (10)	0.0 (0)	0.505
CVI	5.6 (73)	5.7 (56)	4.9 (14)	7.9 (3)	0.727
Pulmonary embolism	1.4 (18)	1.4 (14)	1.4 (4)	0.0 (0)	0.762
DVT/Thrombophlebitis	2.6 (34)	2.6 (26)	2.1 (6)	5.3 (2)	0.510
Hospital LOS	12.9 ± 9.0	13.1 ± 9.0	11.8 ± 8.0	14.0 ± 10.0	0.008

DVT, deep venous thrombosis; SIC, surgical infectious complication; UTI, urinary tract infection.

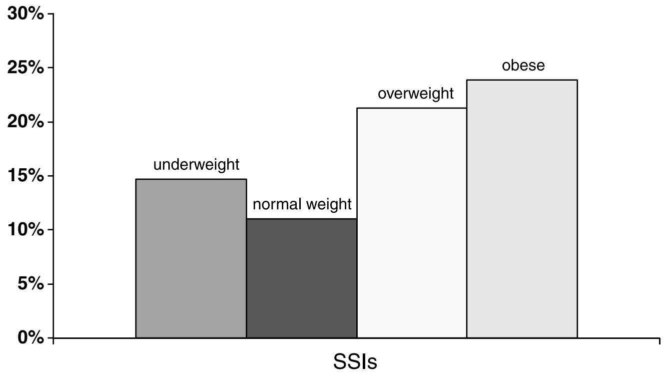

Figure 1. Impact of BMI on the development of SSIs. Underweight to normal weight, $p = 0.271$; normal weight to overweight: $p < 0.001$; overweight to obese, $p = 0.371$, Impact of BMI on development of SSIs (AOR [95% CI], 1.34 [1.15–1.56]; adjusted $p < 0.001$).

significant difference was found in the AOR for 30-day mortality between the three surgical techniques used to manage patients presenting with acute diverticulitis. In addition, the three groups did not have significantly different AOR for the development of SSIs, surgical infectious complications, AKI, CVIs, or venous thromboembolism after surgery (Table 4).

DISCUSSION

The optimal surgical management of acute diverticulitis is still a controversial and unresolved issue. While the HP has become the standard of care in the emergency operative management of acute diverticulitis, the morbidity and mortality of the HP can be as high as 24.2% and 18.8%, respectively.[8] In addition, 10% of patients will have stoma complications after HP and in up to 27% of patients, the stoma will be permanent.[8,9] The postoperative complications after Hartmann's reversal can range from 4.9% to 25%, with an anastomotic leak rate of 4.3%.[8,9] In addition, Vermeulen et al.[10] found that long-term quality of life was worse after the HP compared with PA, with the presence of a permanent stoma being the primary factor that related to poor quality of life in patients surveyed. Because of the potential stoma-related complications, poor quality of life, risk of permanent colostomy, and the complications associated with reversal, avoidance of the HP in the management of acute diverticulitis is a desirable goal.

Last updated in 2006, the American Society of Colon and Rectal Surgeons practice parameters for sigmoid diverticulitis recommend urgent sigmoid colectomy for patients with diffuse peritonitis, but "the precise role and relative safety of PA … remains unsettled."[1] A systematic literature review of 569 patients from 50 studies found that PA for diverticular peritonitis may be safe compared with HP.[8] In a multicenter study of 200 consecutive patients presenting with perforated diverticulitis from the Netherlands, 70% of patients underwent an HP, while 30% were managed by PA. There was no significant difference in mortality comparing HP with PA but a twofold increase in complications after HP compared with PA.[11] In our study of the ACS NSQIP database, 1,314 patients underwent emergency surgery for acute diverticulitis, the majority of which underwent the Hartmann's procedure (75.4%), with nearly 300 patients receiving a resection and PA (21.7%). When HP was compared with PA in a multivariate analysis correcting for multiple factors, there was no significant difference in mortality, SSI, surgical infectious complications, venous thromboembolism, CVI, and AKI (Table 4). There was a trend toward a higher mortality in the HP group (7.3% vs. 4.6%), but this did not reach significance (Table 3). In this analysis of the ACS NSQIP database, resection and PA in patients undergoing an emergency operation for acute diverticulitis showed no difference in mortality or postoperative complications compared with the HP.

TABLE 4. Adjusted Outcomes of the Three Operative Approaches in Acute Diverticulitis

	PA vs. HP		PAPD vs. HP		PA vs. PAPD	
	AOR (95% CI)	Adjusted *p*	AOR (95% CI)	Adjusted *p*	AOR (95% CI)	Adjusted *p*
30-d mortality	0.77 (0.38–1.56)	0.465	0.47 (0.06–3.74)	0.479	1.62 (0.19–13.78)	0.658
SSIs	0.94 (0.66–1.34)	0.727	0.67 (0.25–1.74)	0.406	1.41 (0.52–3.83)	0.499
Superficial wound infection	0.82 (0.50–1.33)	0.414	0.50 (0.12–2.13)	0.348	1.63 (0.37–7.28)	0.522
Deep incisional infection	1.43 (0.67–3.06)	0.355	<0.01 (<0.001–15.23)	0.998	<0.01 (<0.001–5.9E7)	0.998
Abscess	0.98 (0.52–1.88)	0.961	0.58 (0.08–4.34)	0.591	1.71 (0.21–13.70)	0.613
Wound dehiscence	0.81 (0.37–1.74)	0.580	2.15 (0.61–7.55)	0.232	0.37 (0.09–1.51)	0.168
SICs	0.72 (0.49–1.06)	0.098	1.38 (0.63–3.01)	0.424	0.52 (0.22–1.21)	0.130
Pneumonia	0.56 (0.29–1.09)	0.086	1.74 (0.58–5.17)	0.320	0.32 (0.10–1.10)	0.070
UTI	0.95 (0.40–2.24)	0.898	0.77 (0.10–6.17)	0.809	1.22 (0.14–10.61)	0.856
Sepsis	1.14 (0.68–1.91)	0.615	0.34 (0.05–2.53)	0.292	3.36 (0.44–25.98)	0.245
Septic shock	0.87 (0.50–1.51)	0.615	1.70 (0.62–4.65)	0.299	0.51 (0.17–1.52)	0.227
AKI	1.69 (0.75–3.78)	0.204	<0.01 (<0.001–15.23)	0.998	<0.01 (<0.001–3.1E7)	0.998
CVI	0.91 (0.46–1.81)	0.788	2.07 (0.58–7.42)	0.264	0.44 (0.11–1.74)	0.242
Pulmonary embolism	0.90 (0.27–2.93)	0.856	<0.01 (<0.001–12.89)	0.998	0.01 (<0.001–1.9E7)	0.998
DVT/Thrombophlebitis	1.01 (0.39–2.64)	0.980	3.20 (0.69–14.96)	0.139	0.32 (0.06–1.72)	0.182

Adjusting for factors with a $p < 0.01$ (steroid use, contaminated or infected operative wound, WBC, creatinine > 1.5 mg/dL, and laparoscopic surgery), age, alcohol consumption, history of comorbidities (diabetes, CVI, CVA, hypertension requiring medication), and presence of hemorrhage at admission.

DVT, deep venous thrombosis; SIC, surgical infectious complication; UTI, urinary tract infection.

The role of proximal diversion after resection and PA for acute diverticulitis is not clear. The associated complications after diverting ileostomy or colostomy are less frequent when compared with an end colostomy. The rates of wound infection and anastomotic leak are less, and diverting ostomies are more likely to be reversed.[8,9] In the present study, there were only 38 patients who underwent PAPD with mortality rate of 2.6% versus 7.3% compared with HP. In the PAPD group, there was a trend toward fewer SSIs (13.2% vs. 19.7%), more SICs (23.7% vs. 20.7%), and more CVIs (7.9% vs. 5.7%) when compared with the HP (Table 3), but these differences did not reach significance. When comparing the adjusted outcomes of PAPD with HP, there was no difference in mortality or other postoperative complications (Table 4). When comparing PA with PAPD, there was a trend toward higher mortality (AOR, 1.62), SSIs (AOR, 1.41), and postoperative sepsis (AOR, 3.36), but these differences were not significant (Table 4). While there seems to be a trend toward improved mortality and no significant difference in postoperative outcomes in the PAPD group compared with the HP group, given the small number of patients in this study, it is difficult to draw definitive conclusions. A recent analysis of 2,018 patients in the ACS NSQIP database comparing PAPD (340) with HP (1,678) in the management of diverticulitis found no difference in mortality or morbidity between the two approaches. The authors did find a twofold increase in mortality after PAPD compared with HP when only dirty/infected cases were considered. It is difficult to interpret their results for several reasons. First, patients with the diagnosis of diverticulosis were included in their analysis. Second, their definition of PAPD used the CPT code 44140 (colectomy, partial with anastomosis), not CPT codes 44146 (colectomy, partial with coloproctostomy with colostomy) or 44208 (laparoscopy surgical, colectomy partial with anastomosis with coloproctostomy, with colostomy) (Table 1) further confounding their results.[12] Recently, Oberkofler et al.[13] performed the only randomized clinical trial comparing PA with diverting ileostomy to the HP. Sixty-two patients with purulent or fecal peritonitis (Hinchey Stages III and IV) in four centers were randomized to PAPD or HP. The overall outcomes for the initial resection and subsequent stoma takedowns were not significantly different, but there was trend toward a higher mortality (13% vs. 9%) but lower overall morbidity (67% vs. 75%) in the HP group. Those with a PAPD had a significantly higher stoma reversal rate compared with HP (90% vs. 57%, $p = 0.005$).

Only 83 of the patients in this cohort underwent laparoscopic surgery; 43 underwent laparoscopic HP, 38 laparoscopic resection and PA, and 2 had a laparoscopic resection with PAPD (Table 2). No patients in the ACS NSQIP database were identified that underwent laparoscopic peritoneal lavage as the sole surgical management of acute diverticulitis. During the 4-year study period, there was no increasing trend toward the use of the laparoscopic approach in the surgical management of complicated diverticulitis.

The optimal surgical management of critically ill patients admitted in septic shock is not clear. There were only 65 such patients in this study, and no meaningful outcome analysis could be performed. The major beneficial role of damage control in trauma is well established. However, there are no studies addressing this issue in this selected group of unstable patients.

The impact of BMI on SSI after surgery for acute diverticulitis was also evaluated (Fig. 1). In this analysis of the ACS NSQIP database, patients who were overweight or obese were significantly more likely to develop a postoperative SSI. In patients undergoing major intra-abdominal cancer surgery, Mullen et al.[14] found that BMI of greater than 30.1 kg/m^2 was an independent risk factor for overall morbidity primarily from wound infections. The increased risk of SSI in obesity is thought to be secondary to technical difficulty during the operation, altered wound physiology, and impaired wound healing.[15] Underweight patients in this study tended to have more SSIs as well. Mullen et al. did not find that being underweight (BMI < 18.5 kg/m^2) was associated with additional morbidity but, when adjusted for other factors, did increase the risk of death after surgery by more than fivefold.[14] In a prospective analysis of various elective surgical patients, Waisbren et al.[15] found a nonlinear relationship between BMI and SSI. Obese patients as defined by BMI (30.1–45 kg/m^2) did not have an increased risk of SSI when compared with patients with a normal BMI, but when percent body fat was used to define obesity, there was a fivefold increased risk of SSI after elective surgery. More study is needed to determine the precise impact of BMI in postoperative outcomes and SSIs in patients with complicated diverticulitis.

In conclusion, our analysis of the ACS NSQIP database shows that the Hartman's procedure is the most common operation used in NSQIP participating hospitals in the United States for the emergent operative management of acute diverticulitis. There was no difference in postoperative outcomes comparing three different operative strategies (HP, PA, and PAPD). Resection and PA can be performed safely in acute diverticulitis with no difference in postoperative morbidity or 30-day mortality when compared with the Hartmann's procedure. Given the risk of permanent colostomy, known stoma related complications, and the additional morbidity and mortality associated with subsequent Hartmann's reversal, resection and PA with or without proximal diversion should be considered over the HP in the emergent surgical management of acute diverticulitis.

AUTHORSHIP

E.K., M.T., D.S., and D.D. performed the literature search. D.D. and A.S. provided the study design. E.K., D.S., and D.S. performed the data collection. E.K., D.S., D.D., and P.T. performed the data analysis. D.D., K.I., P.T., and A.S. performed the data interpretation. E.K., D.S., D.D., A.S., K.I. wrote the article. A.S., P.T., and K.I. provided the critical revision.

REFERENCES

1. Rafferty J, Shellito P, Hyman N, Buie WD. Practice parameters for sigmoid diverticulitis. *Dis Colon Rectum*. 2006;49:939–944.
2. Heise CP. Epidemiology and pathogenesis of diverticular diseases. *J Gastrointest Surg*. 2008;12:1309–1311.
3. Parks TG. Natural history of diverticular of the colon. A review 521 cases. *BMJ*. 1969;4:639–642.
4. Etzioni DA, Mack TM, Beart RW, Kaiser AM. Diverticulitis in the United States: 1998–2005. Changing patterns of disease and treatment. *Ann Surg*. 2009;249:210–217.
5. Nguyen GC, Sam J, Anand N. Epidemiological trends and geographic variation in hospital admissions for diverticulitis in the United States. *World J Gastroenterol*. 2008;17:1600–1605.

6. Vermeulen J, Lange JF. Treatment of perforated diverticulitis with generalized peritonitis: past, present and future. *World J Surg*. 2010;34:587–593.
7. Biondo S, Borao JL, Millan M, Kreisler E, Jaurrieta E. Current status of the treatment of acute colonic diverticulitis: a systematic review. *Colorectal Dis*. 2012;14:e1–e11.
8. Salem L, Flum DR. Primary anastomosis or Hartmann's procedure for patients with diverticular peritonitis? A systematic review. *Dis Colon Rectum*. 2004;47:1953–1964.
9. Constantinides VA, Heriot A, Remzi F, et al. Operative strategies for diverticular peritonitis. A decision analysis between primary resection and anastomosis versus Hartmann's procedures. *Ann Surg*. 2007;245:94–105.
10. Vermeulen J, Gosselink MP, Busschbach J, Lange JF. Avoiding or reversing Hartmann's procedure provides improved quality of live after perforated diverticulitis. *J Gastrointest Surg*. 2010;14:651–657.
11. Vermeulen J, Akkersdijk GP, Gossenlink MP. Outcomes after emergency surgery for acute perforated diverticulitis in 200 cases. *Dig Surg*. 2007;24:361–366.
12. Gawlick U, Nirula R. Resection and primary anastomosis with proximal diversion instead of Hartmann's: evolving management of diverticulitis using NSQIP data. *J Trauma Acute Care Surg*. 2012;72:807–814. Erratum *J Trauma Acute Care Surg*. 2012;73:534.
13. Oberkofler CE, Rickenbacher A, Raptis DA, et al. A multicenter randomized clinical trial of primary anastomosis or Hartmann's procedure for perforated left colonic diverticulitis with purulent or fecal peritonitis. *Ann Surg*. 2012;256:819–827.
14. Mullen JT, Davenport DL, Hutter MM, et al. Impact of body mass index on perioperative outcomes in patients undergoing major intra-abdominal cancer surgery. *Ann Surg Oncol*. 2008;15:2164–2172.
15. Waisbren E, Rosen H, Bader AM, et al. Percent body fat and prediction of surgical site infection. *J Am Coll Surg*. 2010;210:381–389.

Presentations and outcomes in patients with traumatic diaphragmatic injury: A 15-year experience

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BACKGROUND: Traumatic diaphragmatic injury (TDI) is usually associated with multiple injuries. We aimed to evaluate the patterns, associated injuries, and predictors of in-hospital mortality of patients with TDI.

METHODS: The trauma registry from a Primary Adult Resource Center for Trauma was queried for patients admitted with a TDI from January 1995 to December 2009. Patient characteristics, mechanism of injury, associated injuries, management, and outcomes were analyzed. We compared morbidity and mortality in left and right diaphragmatic injuries (LDI and RDI, respectively).

RESULTS: Of the 773 patients, 650 were male (84%), with a mean (SD) age of 33 (15). Mechanism of injury was penetrating in 561 (73%) and blunt in 212 (27%) patients. LDI, RDI, and bilateral injuries were 57%, 40%, and 3%, respectively. The majority of cases were managed by exploratory laparotomy and direct suture repair. LDI was associated with higher rates of splenic, gastric, and pancreatic injuries and prolonged hospital stay in comparison with RDI. In comparison with LDI, RDI was associated with higher rates of deaths (26% vs. 17%, $p = 0.003$). Overall, mortality in TDI was 21%. Age (odds ratio [OR], 1.02, $p = 0.008$), Injury Severity Score (ISS) (OR, 1.09, $p = 0.001$), associated cardiac injury (OR, 2.8, $p = 0.005$), left diaphragmatic injury (OR, 0.53, $p = 0.005$), and operative interventions (OR, 0.32, $p = 0.001$) were independent predictors for mortality.

CONCLUSION: This largest single institution study on TDI in the literature confirms that LDI are more commonly diagnosed than RDI. Exploratory laparotomy is the most common procedure performed for these injuries. Young age and operative interventions are associated with favorable outcome, whereas high ISS, RDI, and associated cardiac injury are independent predictors for mortality. (*J Trauma Acute Care Surg*. 2013;74: 1392–1398. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiological study, level III.

KEY WORDS: Traumatic diaphragmatic injury; associated injuries; mortality; complications.

Traumatic diaphragmatic injuries (TDI) are relatively uncommon and are usually caused by severe blunt or penetrating trauma of the thoracoabdominal region.[1,2] Diaphragmatic ruptures are usually found in combination with other injuries.[1,2] The overall incidence of TDI varies from 0.8% to 8%, and the incidence of blunt and penetrating trauma differs geographically. A recent report of TDI showed penetrating trauma was the leading cause (65%) of TDI and blunt trauma, representing 35% of all diaphragmatic injuries.[3] Lopez et al.[3] also reported that 64.5% of the patients had left-sided injuries (LDIs) and 35.5% had right-sided injuries (RDIs). This predominance of LDI is possibly caused by the protective effect of the liver on the right side of the diaphragm. Delay in diagnosis is associated with higher morbidity and mortality rates (9–35.7%).[3–5]

Low sensitivity and specificity of routine imaging techniques was attributed to the missed or delayed diagnosis and management of TDI.[6] The range of overlooked diaphragmatic injuries varied from 12% to 66% in patients undergoing conventional management.[7] These missed injuries may remain occult for longer duration and present later with severe complications such as strangulation of intra-abdominal organs and diaphragmatic herniation, leading to higher rates of morbidity and mortality.[8] The present study was designed to evaluate the patterns of injury, incidence of associated injuries, predictors of in-hospital mortality, and early management in patients with TDI, reviewed during a period of 15 years from a single center.

PATIENTS AND METHODS

The trauma registry from R Adams Cowley Shock Trauma Center, a Primary Adult Resource Center for Trauma, was queried for patients admitted with TDI from January 1995 to December 2009. Information regarding demographic characteristics, mechanism of injury (MOI), associated injuries, management, and postoperative outcomes were reviewed. TDI characteristics, length of stay, complications and mortality, as well as method and approach of repair were analyzed. The diagnosis of acutely injured diaphragm was based on the clinical, radiological

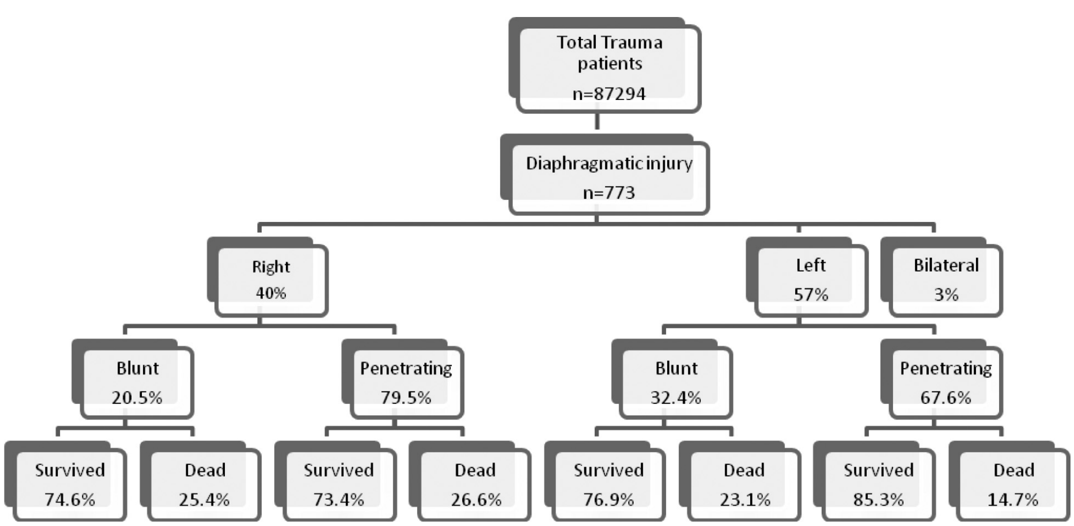

Figure 1. Overview of total trauma patients according to site and MOI.

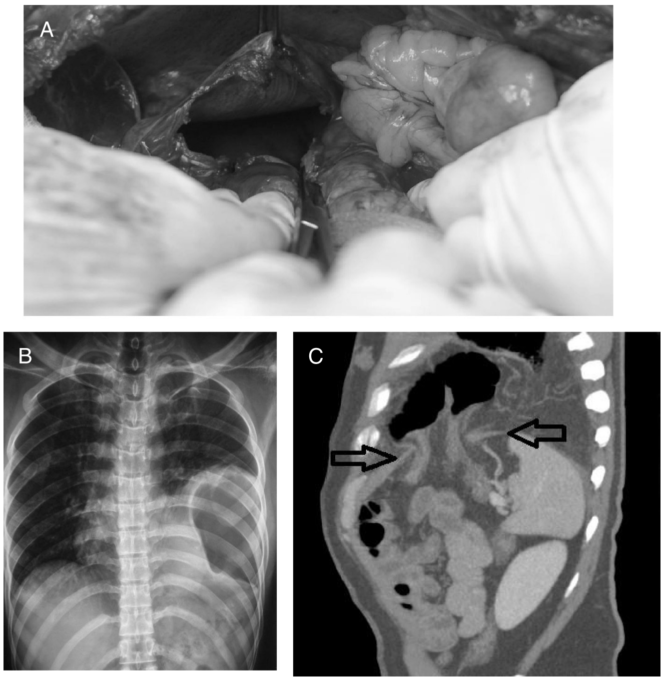

Figure 2. Example of radiological and operative findings in patient with left traumatic diaphragmatic rupture.

(x-ray and computed tomographic [CT] scan of the chest) and operative findings. The data are presented as mean (SD) or total (percentage) as appropriate. Baseline demographic characteristics, presentation, management, and outcomes were also compared between patients having left and right TDIs using the Student's *t* test for continuous variables and Pearson χ^2 test for categorical variables. Furthermore, clinical findings, management, and outcomes were also analyzed according to the site (left vs. right) and mechanism (blunt vs. penetrating) of diaphragmatic injury. Two-tailed *p* value less than or equal to 0.05 was considered statistically significant. The multivariate logistic regression analysis was performed for the predictors of mortality after adjusting the potential covariates that showed significant difference among the univariate analysis. Odds ratio (OR), 95% confidence interval (CI), and corresponding *p* values were analyzed by logistic regression analysis and adjusted accordingly. A subanalysis was performed comparing the demographics and clinical profiles for patients surviving TDI versus those who died. Data were analyzed using the Statistical Package for the Social Sciences version 18 (SPSS Inc., Chicago, IL).

RESULTS

Of the 773 patients with TDI, 650 (84%) were male, and 123 (16%) were female, with age range 20 years to 60 years (mean, 33 years). MOI was penetrating in 561 (73%) and blunt in 212 (27%) patients. Rupture of the diaphragm was left sided in 57%, right sided in 40%, and bilateral in 3% of the patients (Fig. 1 summarizes the study design and outcome). Accompanying injuries in other organs included injury of the lung (77%), liver (52%), spleen (32%), bowel (21%), and stomach (19%) as well as rib fracture (33%). Hemothorax was seen in 54% and pneumothorax in 48%. Two cases sustained traumatic aortic disruption requiring aortic graft. Figure 2 shows an example of the diagnostic tools used in the study (radiological and operative findings of TDI).

The majority of the TDI cases were primarily managed by emergency intervention (77%) including exploratory laparotomy (94%) and thoracotomy (6%). In comparison with patients who underwent emergency intervention, patients without

TABLE 1. Clinical Findings, Management, and Outcomes by Site and Mechanism of Diaphragmatic Injury

	Right-Sided TDI (RDI)*			Left-Sided TDI (LDI)*		
	Blunt	**Penetrating**	***p***	**Blunt**	**Penetrating**	***p***
Age, mean (SD), y	42 (21)	29 (11)	0.001	41 (18)	30 (12)	0.001
Male	70	91	0.001	64	91	0.001
Associated injury						
Lung contusion, %	82.5	77.5	0.38	88	69	0.001
Spleen, %	32	5	0.001	57	41	0.002
Rib fracture, %	54	28	0.001	60	19	0.001
Liver, %	59	80	0.001	34	34	0.97
Bowel, %	21	18	0.69	19	23	0.28
Kidney, %	16	18	0.68	13	19	0.11
Stomach, %	0	9	0.02	5	36	0.001
Cardiac, %	9.5	11	0.75	4.2	9	0.07
Pneumothorax	52	45	0.30	62	43	0.001
Hemothorax, %	52	62	0.19	46	51	0.32
Death, %	25	27	0.84	23	15	0.03
Operative procedure						
Exploratory laparotomy, %	78	92	0.006	97	96	0.78
Thoracotomy, %	22	8	3	4		
Length of hospitalization**	14 (5–21)	6 (1–11)	0.001	12 (5–22)	7 (4–15)	0.001

*3% are bilateral diaphragmatic injury (see text).
**Median (interquartile range).

TABLE 2. Clinical Profiles of Patients Who Survived Diaphragmatic Injury

	Alive (n = 611)	Dead (n = 162)	*p*
Sex			
Male	83.3	87.0	0.26
Diaphragm injury			
Left	59.6	47.8	0.007
Right	36.9	50.3	
Bilateral	3.4	1.9	
Type of injury			
Blunt	26.6	30.4	0.34
Penetrating	73.4	69.6	
Associated injury			
Head	13.1	26.7	0.001
Lung	75	82.6	0.04
Ribs	32.4	36.6	0.30
Spleen	35.3	19.9	0.001
Liver	49.2	62.1	0.003
Bowel	19.9	25.5	0.12
Kidney	17.8	14.9	0.38
Stomach	19.1	16.8	0.49
Cardiac	3.3	21.1	0.001
Pericardium	2.5	13.7	0.001
Pancreas	7.2	8.1	0.70
Pneumothorax	51.6	35.4	0.001
Hemothorax	51.8	60.2	0.05
Operative intervention			
Exploratory laparotomy	77.8	47.2	0.001
Thoracotomy	3.3	9.9	

emergency intervention had higher rate of head injury (25% vs. 13%), cardiac injury (11% vs. 6%), greater mean Injury Severity Score (ISS) (43% vs. 34%), and mortality (38% vs. 15.5%).

The supplemental table (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/A247) shows the MOI, clinical findings, management, and outcomes in RDI versus LDI. LDI was associated with prolonged hospital stay, higher rates of splenic, gastric, and pancreatic injuries compared with RDI. In contrast, RDI had significantly higher rates of liver and cardiac injuries, hemothorax, and mortality (26% vs. 17%, $p = 0.003$). The mean (SD) ISS was comparable among the two groups (29 [16] vs. 28 [15]; $p = 0.33$). Rate of exploratory laparotomy was higher in LDI, whereas thoracotomy was observed more frequently in RDI ($p = 0.001$).

Table 1 demonstrates the clinical findings, management, and outcomes in each side of diaphragm based on the MOI. Among RDI, young age, male sex, liver and gastric injuries, and rate of exploratory laparotomy were more frequently reported in penetrating injuries, whereas blunt injuries were significantly associated with advanced age, splenic injuries, rib fracture, and increased hospital length of stay.

Among LDI, blunt injuries had higher association with advanced age, lung and splenic injuries, rib fracture, pneumothorax, increased hospital length of stay, and mortality.

Mortality

Overall mortality was 21% among TDI patients. In blunt trauma, the mortality was comparable between RDI and LDI (25% vs. 23%, $p = 0.72$); however, in penetrating trauma, the mortality was higher in those with RDI (27% vs. 15%, $p = 0.001$). Table 2 shows clinical profiles of patients who survived diaphragmatic injury versus those who died. Patients who died had higher rate of RDI and associated injuries of the head, lung, liver, and heart. Multivariate logistic regression analysis showed that age (OR, 1.02; 95% CI, 1.01–1.04; $p = 0.008$), mean ISS (OR, 1.09; 95% CI, 1.08–1.12; $p = 0.001$), and associated cardiac injury (OR, 2.83; 95% CI, 1.38–5.82; $p = 0.005$) were independent predictors for mortality, whereas left versus right diaphragmatic injury (OR, 0.53; 95% CI, 0.34–0.83; $p = 0.005$) and operative interventions (OR, 0.32; 95% CI, 0.2–0.53; $p = 0.001$) were independent predictors of survival (Table 3).

DISCUSSION

Diaphragmatic injuries are infrequent and difficult to report owing to a significant number of missed or delayed diagnoses and prehospital deaths.[9] This is a large single-institution report on characteristics, injury profile, management, and outcome of TDI patients, reviewed for a period of 15 years. This study gives us a chance for contemporary analysis of the etiology, MOI, treatment, and outcome in patients with TDI from a primary adult resource center for trauma. The frequency of blunt and penetrating TDI varies depending on the geographic distribution and socioeconomic factors. Table 4 shows a review of literature for injury characteristics and outcome in TDI patients.[3,5,10–26]

In the present study, the majority of our patients with TDI had experienced penetrating trauma (73%) compared with blunt trauma (27%), which is similar to the recent report from Hanna et al.[21] A retrospective review of 15 years data from a Level 1 trauma center also reported penetrating trauma (61%) to be the leading cause of TDI compared with blunt trauma (39%).[19] In contrast, other studies have reported higher incidence of TDI with blunt trauma as compared with penetrating injuries.[12,17,20,25]

These differences in MOI are caused by variation in demography and sociocultural conditions of our study population, which was mainly composed of males of the younger age group. Penetrating injuries in terms of gunshot and stab wounds were the most common cause of TDI in the current report followed by blunt trauma; this was consistent with other previously reported studies.[3,11,19–21] Other studies have

TABLE 3. Multivariate Logistic Regression Analysis for the Predictors of Mortality

Variables	OR	95% CI	*p*
Age	1.02	1.01–1.04	0.008
ISS	1.09	1.08–1.12	0.001
MOI*	1.52	0.87–2.68	0.144
Cardiac injury	2.83	1.38–5.82	0.005
Diaphragm injury**	0.53	0.34–0.83	0.005
Head injury	1.24	0.7–2.19	0.469
Operative interventions†	0.32	0.2–0.53	0.001

*Blunt versus penetrating.
**Left versus right.
†Operated versus none.

TABLE 4. Review of Literature for Injury Characteristics and Outcome in Patients With TDI

References	Duration, y	Age, y	MOI*	Site of Injury**	Mortality, %
Guner et al.[10]	8	46	8 (8/0)	0/8/0	0
Dirican et al.[11]	10	33	48 (15/33)	35/10/3	15
Hwang et al.[12]	8	42	40 (32/8)	36/4/0	17.5
Kuo et al.[13]	9	43	43 (43/0)	24/14/5	9.3
Beigi et al.[14]	4	32	34 (22/12)	22/11/1	14.7
Gwely[15]	10	15–30	44 (44/0)	30/12/0	13.2
Hsee et al.[16]	10	N/A	28 (28/0)	17/10/1	25
Lopez et al.[3]	20	33	124 (44/80)	80/44/0	9
Kishore et al.[17]	5	35	27 (22/5)	23/4/0	11
Al-Refaie et al.[18]	13	36	46 (46/0)	34/12/0	4.3
Tan et al.[5]	7	38	14 (14/0)	9/5/0	35.7
Lewis et al.[19]	13.5	35	254 (99/155)	129/78/9	32
Peer et al.[20]	10	33	29 (24/5)	23/6/0	13.8
Hanna et al.[21]	13	34 (16–79)	105 (39/66)	—	18
Filiz et al.[22]	4	23	13 (6/7)	13/0/0	0
Ozgüç et al., 2007[23]	11	38	51 (26/25)	40/10/1	19.6
Lunca et al.[24]	10	34	61 (15/46)	45/15/1	14.7
Esme et al. [25]	6	35	14 (11/3)	10/4	7
William et al.[26]	22	31	731 (79/652)	(460/263/8)	23
Present series	15	32	773 (212/561)	(441/309/23)	21

*Total number of patients according to MOI (blunt/penetrating).
**Left/right/bilateral.

reported higher incidence of left-sided (60–90%) than right sided TDI (10–36%).[3,11,12,19] Notably, bilateral TDIs are occasionally reported.[14,16]

The present study also showed greater frequency of LDIs after blunt trauma. The frequent blunt LDIs are believed to be caused by less development of the diaphragm at its posterolateral portion, which is the weakest point. A thoracoabdominal pressure gradient develops, resulting in a rupture at the left diaphragm, usually after high-impact blunt trauma such as motor vehicle crash or fall from height.[11] However, the incidence of penetrating trauma is comparable among both sides, which coincides with earlier reports.[19,27,28] The diagnosis of acute TDI remains a challenge because chances of missing small diaphragmatic tears with other associated injuries are high and needs high index of suspicion for diagnosis.[29] In contrast, delayed diagnosis may cause serious complications, leading to increased mortality.[12] The classic clinical signs and symptoms of TDI are not consistently present, and none are specific for diaphragmatic rupture, which can be missed because of more significant associated injuries (90%).[21,22,30] Therefore, a high index of suspicion is required for diagnosis of TDI with related MOI in the trauma setting.

Several investigative modalities are available for the diagnosis of TDI.[31] However, chest x-ray and CT scan are widely used for the routine diagnosis. The diagnosis by initial plain chest x-ray of an acute diaphragmatic tear after trauma has been reported in only 20% to 34% of the cases.[26,30,32,33] The sensitivity of diagnosis may be increased by repeat chest radiographs.

Assessment of diaphragmatic injury by CT examination is more reliable with high sensitivity (33–83%) and specificity (76–100%).[34] Ultrasound examination for trauma patients is useful in detecting large diaphragmatic herniation but insensitive for diagnosing small rupture after penetrating trauma. Current advances in magnetic resonance imaging technique facilitate better visualization of diaphragmatic aberrations, but this technique is not feasible for hemodynamically unstable patients in emergency settings.[35] Minimally invasive techniques found utility in early diagnosis and treatment of TDIs in hemodynamically stable patients.[19,21,36]

The primary attention in the management of the acute phase of TDI should be directed toward the life-threatening injuries. Following stabilization of the patient, a thorough assessment of the patient should be performed, looking for additional injuries.[36] The next question for the surgeon will be which cavity should be entered and whether conventional open approach or minimally invasive approach be used? In most cases, this depends on the patient's hemodynamic stability and the surgeon's preference and skills. In general, there is no superiority of one cavity approach over the other in the management of hemodynamically stable patients, unless the associated injuries mandate a specific approach. Whatever the operative approach for repairing TDI, the main two principles of operative intervention are complete reduction of herniated viscus back to the abdominal cavity and water-tight closure of the diaphragmatic defect. Direct suturing with interrupted or running sutures using nonabsorbable sutures should be adequate. In the present study, the majority of the cases were managed by exploratory laparotomy and direct suture repair. Surgical repair of the diaphragm is important even for small ruptures because spontaneous healing does not occur and eventually may lead to herniation and strangulation.[11] Surgical management can be performed via laparotomy or thoracotomy or through a combination of these procedures.[11] Minimally invasive surgery found utility in the management of TDIs for both diagnosis and therapeutic intervention and as in open surgery may be applied using thoracoscopic approach or laparoscopic approach.[36]

The overall mortality of TDI patients was 21% in our study, which is similar to the earlier published studies from the United States.[26,37,38] In addition, the mortality rate was significantly higher in our patients who had RDI compared with LDI (p = 0.003). In correlation with MOI, the mortality was comparable between RDI and LDI (p = 0.72) after blunt injury; however, in penetrating injury, the mortality was almost twofold greater in those with RDI in comparison with LDI (p = 0.001).

The present series observed age, high ISS, RDI, associated cardiac injury, and need for exploratory laparotomy to be the independent predictors of mortality by multivariate logistic regression analysis. Earlier studies also projected similar results on mortality with slight variations. Lewis et al.[19] found increased age and high ISS as the factors associated with the risk of mortality among patients with TDI. Hanna et al.[21] also reported ISS and head injury to be the independent predictors of mortality. Other studies have reported high ISS, hemorrhagic shock at admission, and hemodynamic status were the determinants of outcome.[11,37] In a large retrospective review of TDI patients, ISS, blood transfusion, blunt trauma, and pancreatic injury were the major predictors of mortality.[26]

Limitation of the Study

The retrospective nature of the study is one limitation. Details of delayed intervention and follow-up are not elaborated, and the exact reasons for immediate nonoperative intervention are lacking. Moreover, data for spine, pelvic, or limb injuries are not available. Lastly, the modalities of diagnosis do not show what percentage of injuries were apparent at admission chest x-ray, CT scan, and intraoperatively.

CONCLUSION

This largest single-institution study in the literature confirms that LDI are more commonly diagnosed than RDI. Exploratory laparotomy is the most common procedure performed for the management of these injuries. Young age and operative interventions are associated with favorable outcome, whereas high ISS, RDI, and associated cardiac injury are independent predictors for mortality. The present series projected a latest insight of the patterns of injury mechanism, associated injuries, and predictors of mortality, which might be helpful for patient outcome and better understanding of traumatic diaphragmatic injury.

AUTHORSHIP

A.M.Z. was involved in the study design, data collection, and writing of the article. A.E.-M. was involved in the data analysis and interpretation, drafting, and article review. H.A.-T. was involved in the data analysis and interpretation, drafting and article review. T.M.S. was involved in the study design, data interpretation, and review article. W.C.C. was involved in the study design, data interpretation, and article review. All authors read and approved the article.

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The study has been approved by institutional review board of University of Maryland, Baltimore, Maryland (HP-00045564).

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Kole KL. Traumatic diaphragmatic injuries. *Trauma Q*. 2002;15:109–120.
2. Arsensio JA, Demetriades D, Rodriguez A. Injury to the diaphragm. In: Mattox KL, Feliciano DV, Moore EE, eds. *Trauma*. 4th ed. New York, NY: McGraw-Hill; 2000:603–632.
3. Lopez PP, Arango J, Gallup TM, et al. Diaphragmatic injuries: what has changed over a 20-year period? *Am Surg*. 2010;76:512–516.
4. Chughtai T, Ali S, Sharkey P, et al. Update on managing diaphragmatic rupture in blunt trauma: a review of 208 consecutive cases. *Can J Surg*. 2009;52:177–181.
5. Tan KK, Yan ZY, Vijayan A, Chiu MT. Management of diaphragmatic rupture from blunt trauma. *Singapore Med J*. 2009;50:1150–1153.
6. Mintz Y, Easter DW, Izhar U, et al. Minimally invasive procedures for diagnosis of traumatic right diaphragmatic tears: a method for correct diagnosis in selected patients. *Am Surg*. 2007;73:388–392.
7. Guth AA, Pachter HL, Kim U. Pitfalls in the diagnosis of blunt diaphragmatic injury. *Am J Surg*. 1995;170:5–9.
8. Degiannis E, Levy RD, Sofianos C, et al. Diaphragmatic herniation after penetrating trauma. *Br J Surg*. 1996;83:88–91.
9. Al-Mashat F, Sibiany A, Kensarah A, Eibany K. Delayed presentation of traumatic diaphragmatic rupture. *Indian J Chest Dis Allied Sci*. 2002; 44:121–124.
10. Guner A, Ozkan OF, Bekar Y, et al. Management of delayed presentation of a right-side traumatic diaphragmatic rupture. *World J Surg*. 2012;36: 260–265.
11. Dirican A, Yilmaz M, Unal B, et al. Acute traumatic diaphragmatic ruptures: a retrospective study of 48 cases. *Surg Today*. 2011;41:1352–1356.
12. Hwang SW, Kim HY, Byun JH. Management of patients with traumatic rupture of the diaphragm. *Korean J Thorac Cardiovasc Surg*. 2011; 44:348–354..
13. Kuo IM, Liao CH, Hsin MC, et al. Blunt diaphragmatic rupture—a rare but challenging entity in thoracoabdominal trauma. *Am J Emerg Med*. 2012;30:919–924.
14. Beigi AA, Masoudpour H, Sehhat S, Khademi EF. Prognostic factors and outcome of traumatic diaphragmatic rupture. *Ulus Travma Acil Cerrahi Derg*. 2010;16:215–219.
15. Gwely NN. Outcome of blunt diaphragmatic rupture. Analysis of 44 cases. *Asian Cardiovasc Thorac Ann*. 2010;18:240–243.
16. Hsee L, Wigg L, Civil I. Diagnosis of blunt traumatic ruptured diaphragm: is it still a difficult problem? *ANZ J Surg*. 2010;80:166–168.
17. Kishore GS, Gupta V, Doley RP, et al. Traumatic diaphragmatic hernia: tertiary centre experience. *Hernia*. 2010;14:159–164.
18. Al-Refaie RE, Awad E, Mokbel EM. Blunt traumatic diaphragmatic rupture: a retrospective observational study of 46 patients. *Interact Cardiovasc Thorac Surg*. 2009;9:45–49.
19. Lewis JD, Starnes SL, Pandalai PK, et al. Traumatic diaphragmatic injury: experience from a level I trauma center. *Surgery*. 2009;146:578–583; discussion 583–584.
20. Peer SM, Devaraddeppa PM, Buggi S. Traumatic diaphragmatic hernia—our experience. *Int J Surg*. 2009;7:547–549.
21. Hanna WC, Ferri LE, Fata P, et al. The current status of traumatic diaphragmatic injury: lessons learned from 105 patients over 13 years. *Ann Thorac Surg*. 2008;85:1044–1048.
22. Filiza AI, Kurta Y, Sucullua I, et al. Traumatic diaphragmatic rupture: an experience of 13 cases. *East J Med*. 2008;13:25–29.
23. Ozgüç H, Akköse S, Sen G, et al. Factors affecting mortality and morbidity after traumatic diaphragmatic injury. *Surg Today*. 2007;37:1042–1046.
24. Lunca S, Romedea NS, Moroşanu C. Traumatic rupture of the diaphragm: diagnostic considerations, prognostic factors, outcomes. *Rev Med Chir Soc Med Nat Iasi*. 2007;111:416–422.

25. Esme H, Solak O, Sahin DA, Sezer M. Blunt and penetrating traumatic ruptures of the diaphragm. *Thorac Cardiovasc Surg*. 2006;54:324–327.
26. Williams M, Carlin AM, Tyburski JG, et al. Predictors of mortality in patients with traumatic diaphragmatic rupture and associated thoracic and/or abdominal injuries. *Am Surg*. 2004;70:157–162.
27. Rosati C. Acute traumatic injury of the diaphragm. *Chest Surg Clin North Am*. 1998;8:371–379.
28. Boulanger BR, Milzman DP, Rosati C, et al. A comparison of right and left blunt traumatic diaphragmatic rupture. *J Trauma*. 1993;35:255–260.
29. Khan MA, Verma GR. Traumatic diaphragmatic hernia presenting as a tension fecopneumothorax. *Hernia*. 2011;15:97–99.
30. Shanmuganathan K, Killeen K, Mirvis SE. CT diagnosis of diaphragmatic injuries. *Emerg Radiol*. 2001;8:6–14.
31. Eren S, Kantarci M, Okur A. Imaging of diaphragmatic rupture after trauma. *Clin Radiol*. 2006;61:467–477.
32. Thillois JM, Tremblay B, Cerceau E, et al. Traumatic rupture of the right diaphragm. *Hernia*. 1998;2:119–121.
33. Nursal TZ, Ugurlu M, Kologlu M, Hamaloglu E. Traumatic diaphragmatic hernias: a report of 26 cases. *Hernia*. 2001;5:25–29.
34. Killeen KL, Mirvis SE, Shanmuganathan K. Helical CT of diaphragmatic rupture caused by blunt trauma. *AJR Am J Roentgenol*. 1999;173: 1611–1616.
35. Iochum S, Ludig T, Walter F, et al. Imaging of diaphragmatic injury: a diagnostic challenge? *Radiographics*. 2002;22:103–118.
36. Morgan BS, Watcyn-Jones T, Garner JP. Traumatic diaphragmatic injury. *J R Army Med Corps*. 2010;156:139–144.
37. Mihos P, Potaris K, Gakidis J, et al. Traumatic rupture of the diaphragm: experience with 65 patients. *Injury.* 2003;34:169–172.
38. Scharff JR, Naunheim KS. Traumatic diaphragmatic injuries. *Thorac Surg Clin*. 2007;17:81–85.

Featured Articles for CME Credit June 2013

Emergency surgery for acute diverticulitis: Which operation? A National Surgical Quality Improvement Program study

Mathew Tadlock, Efstathios Karamanos, Dimitra Skiada, Kenji Inaba, Peep Talving, Anthony Senagore, and Demetrios Demetriades
(*J Trauma Acute Care Surg.* 2013;74(6):1385–1391)

Presentations and outcomes in patients with traumatic diaphragmatic injury: A 15-year experience

Ahmad M. Zarour, Ayman El-Menyar, Hassan Al-Thani, Thomas M. Scalea, and William C. Chiu
(*J Trauma Acute Care Surg.* 2013;74(6):1392–1398)

CME ARTICLE 1

Emergency surgery for acute diverticulitis: Which operation? A National Surgical Quality Improvement Program study
Mathew Tadlock, Efstathios Karamanos, Dimitra Skiada, Kenji Inaba, Peep Talving, Anthony Senagore, and Demetrios Demetriades. (*J Trauma Acute Care Surg.* 2013;74(6):1385–1391)

Impact Statement: Our findings suggest that resection and primary anastomosis is a safe alternative to the Hartmann's procedure in the emergent operative management of acute diverticulitis.

Learning Objectives: To compare the post-operative outcomes of three common techniques utilized in the emergency management of acute diverticulitis utilizing the NSQIP database.

Please consider how the content of this article may be applied to your practice.

QUESTION 1:

Based on this study, what is the most common operative strategy utilized in the United States for the emergent surgical management of acute diverticulitis?

A. Three-stage operative approach (initial diversion, resection, and subsequent anastomosis).
B. Resection, primary anastomosis with proximal diversion.
C. Resection of diseased segment, closure of rectal stump, and end colostomy.
D. Resection and primary anastomosis only.

QUESTION 2:

In this article, which of the following complications or outcomes were more likely to occur in patients undergoing resection and primary anastomosis compared to the Hartmann's procedure?

A. Deep incisional surgical site infection
B. Acute kidney injury
C. 30-day mortality
D. There were no significant differences in adjusted outcomes.

QUESTION 3:

A 55-year-old male presents to the emergency room with CT-verified acute diverticulitis requiring emergent surgery. What is the expected incidence of a post-operative surgical site infection for this patient undergoing emergency surgery for acute diverticulitis?

A. 30%
B. 16%
C. 5%
D. 7%

QUESTION 4:

Association between body mass index (BMI) and surgical site infection after emergency surgery for diverticulitis

A. There was no association between BMI and surgical site infection.
B. Overweight (BMI 25–29.9) but not obesity (BMI >30) had a protective effect.
C. Underweight (BMI < 18.5) had a protective effect.
D. Overweight and obesity were associated with an increased risk of surgical site infection.

CME ARTICLE 2

Presentations and outcomes in patients with traumatic diaphragmatic injury: A 15-year experience
Ahmad M. Zarour, Ayman El-Menyar, Hassan Al-Thani, Thomas M. Scalea, and William C. Chiu. (*J Trauma Acute Care Surg.* 2013; 74(6):1392–1398)

Impact Statement: Diaphragmatic injuries are infrequent and difficult to report owing to a significant number of missed or delayed diagnoses and prehospital deaths.

Learning Objective: This study gives us a chance for contemporary analysis of the etiology, MOI, treatment, and outcome in patients with TDI from a primary adult resource center for trauma.

Please consider how the content of this article may be applied to your practice.

QUESTION 1:
In a patient with traumatic diaphragmatic injury, an independent predictor for mortality is:

A. Young age
B. Penetrating mechanism of injury
C. Associated cardiac injury
D. Operative management

QUESTION 2:
The most common location for blunt diaphragmatic injury is:

A. Left side
B. Right side
C. Hiatus
D. Equal on both sides

QUESTION 3:
The primary attention in the management of the acute phase of Traumatic Diaphragmatic Injury (TDI) should be directed toward which of the following?

A. Immediate repair of the diaphragm.
B. CT scan for confirmation of diagnosis.
C. Management of life-threatening injuries.
D. Laparoscopic exploration.

QUESTION 4:
A 45-year-old man involved in a motor vehicle crash presented with abdominal pain and difficulty breathing. His vital signs were: pulse rate, 92 beats/min; respiratory rate, 25 breaths/min; blood pressure, 128/64 mmHg; and body temperature, 36.8°C. Physical examination revealed decreased breath sounds on the left side. Chest x-ray demonstrated findings suggestive of an elevated left hemi-diaphragm and CT scan revealed that the stomach had herniated into the left chest with associated ruptured spleen. The most appropriate management of this patient is:

A. Observation
B. Thoracoscopy
C. Laparoscopy
D. Laparotomy