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ORIGINAL ARTICLE

Rectal trauma injuries: outcomes from the U.S. National Trauma Data Bank

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Abstract

Background There is a lack of general consensus and a little published data regarding the management of trauma-related rectal injuries and outcomes. The aim of the present study was to evaluate the surgical management and corresponding outcomes for this patient cohort, using a nationwide trauma database.

Methods Rectal injuries and procedures performed over a 2-year period (2013 and 2014) were identified through ICD-9 clinical modification codes, from the United States National Trauma Data Bank. Patient factors, management variables, and outcomes were evaluated.

Results Of 1.7 million patients, 1472 (0.1%) sustained a rectal injury; 81% male, median age 30 years (range 16–89 years) and 60% due to penetrating trauma. Seven hundred and seventy-eight (52.8%) had an isolated extraperitoneal injury and 694 (47.2%) had isolated Intraperitoneal or combined intra- and extraperitoneal injuries. Overall, 726 patients (49.3%) underwent fecal diversion. Injuries following blunt trauma were associated with higher injury severity scores (ISS), lower stoma rates, longer hospital and intensive-care unit (ICU) stay, and higher mortality rates than penetrating trauma (all $p \leq 0.001$). Patients with stoma formation had lower mortality than undiverted patients (8.6 vs. 4.0%, $p < 0.001$) despite a higher ISS and more intraperitoneal injuries, but longer hospital and ICU stay (all $p \leq 0.001$). On multivariate regression analysis, older age, higher ISS, intraperitoneal injury, and return to the ICU were independently associated with higher rates of mortality, while stoma formation was associated with a lower mortality rate. For isolated extraperitoneal rectal injuries, 494 patients (63.5%) were managed by resection/repair without stoma and had significantly lower overall postoperative morbidity rates (12.7 vs. 30.2%, $p = 0.009$) and shorter hospital stay (14 vs. 23 days, $p < 0.001$), than those who underwent resection/repair + stoma ($n = 284$; 36.5%), despite no significant difference in ISS (29 vs. 27, $p = 0.780$). There was no significant difference in mortality.

Conclusions Our results showed that trauma-related rectal injuries are rare and there is wide variation in their management. These data support a low threshold for stoma formation in patients with intraperitoneal or combined injuries, while suggesting that isolated extraperitoneal defects may be safely managed without fecal diversion.

Keywords Rectal · Colorectal · Trauma · Injury · Surgery · Outcomes

Introduction

Rectal injuries due to blunt or penetrating trauma are associated with significant morbidity and mortality, yet there is a lack of consensus regarding their optimal management. Although intra- and extraperitoneal rectal injuries are both relatively uncommon, largely due to the protected position of the rectum within the bony pelvis, they can be difficult to diagnose and are often missed at patients' initial presentation [1].

There are numerous studies in the literature examining the management options and outcomes following colonic trauma, with considerable evidence that most colonic

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injuries can be safely managed by primary repair or resection and anastomosis [2, 3]. Diverting stomas are only indicated in the sickest of patients following colonic trauma, i.e., those with high Injury Severity Scores (ISS) or significant comorbidities, and in the elderly population [4, 5]. However, the management of rectal trauma entails complex decision-making regarding the need for fecal diversion (end or loop colostomy), distal rectal irrigation, and presacral drainage, as well as the need for suture repair or resection and anastomosis [6]. There is currently insufficient information from robust rectal trauma data to accurately inform this process.

The aim of this study was to evaluate the incidence of rectal trauma, identify the common mechanisms of injury, assess treatment strategies adopted, and analyze patient outcomes.

Materials and methods

Data were obtained from the United States (U.S.) National Trauma Data Bank (NTDB) for a 2013 and 2014. The NTDB is the largest U.S. trauma database and is coordinated by the American College of Surgeons [7]. It consists of de-identified Health Insurance Portability and Accountability Act (HIPAA)-compliant data from over 400 level I–IV trauma centers across the U.S. Institutional Review Board (IRB) approval was obtained from Columbia University Medical Center. All patients over the age of 16 years with a rectal injury were included in the study. Injuries to the colon or anal canal were excluded from analysis. This distinction was made based on the surgeon identification of site of injury. ICD-9 codes were used to classify procedures (Table 1) [8].

Rectal injuries were identified from NTDB using International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) codes: 863.45 for extraperitoneal injury *(* "Injury to rectum without open wound into cavity"*)* and 863.55 for intraperitoneal injury ("Injury to rectum with open wound into cavity"*)* (Table 2) [8]. Using a combination of clinical, radiological, and operative factors, rectal injuries had been entered in the NTDB as 863.45 or 863.55. NTDB uses the ISS, which enables the interpretation of complex and variable patient data into a number (range 0–75) representing the patient's degree of critical injury (0 = lowest degree of injury) [9–11].

Table 2 Rectal injury classified as per ICD-9 clinical modification codes

ICD-9 code	Injury
863.45	Isolated extraperitoneal
863.55	Isolated intraperitoneal or combined intra- and extra-peritoneal

Data points examined included patient factors [age, comorbidities, mechanism of injury, ISS, type of injury (intra/extraperitoneal), concomitant urological injuries, and vital signs*];* management variables (procedure performed, fecal diversion); outcomes return to operating room (OR), length of intensive-care unit (ICU) stay, overall length of stay (LoS), number of ventilator days, mortality, and specific complications [acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), cardiac arrest, myocardial infarction, deep/superficial/organ-space surgical site infection (SSI), deep vein thrombosis (DVT), pneumonia, pulmonary embolism (PE), cerebrovascular accident (CVA)]. Overall in-hospital mortality was analyzed, with deaths in the emergency department excluded from sub-analysis to remove mortality on day 1 from causes other than rectal injury.

Outcomes were stratified by:

(a) Type of rectal injury:

Isolated extraperitoneal (863.45) vs.
Isolated intraperitoneal or combined Intra- and extra-peritoneal (863.55).

(b) Mechanism of injury: blunt vs. penetrating trauma.
(c) Fecal diversion vs. no stoma.

Statistical analysis

Statistical analysis was performed with SPSS for Windows. Multivariate regression analysis was used to evaluate the influence of ostomy creation on mortality. ANOVA or Student's t test was used to determine the significance of means between the groups. Categorical variables were compared with Chi-squared test; $p \leq 0.05$ was used to determine significance.

Table 1 International Classification for Diseases (ICD-9) procedure codes used to identify the surgical management of rectal injuries

Procedure	ICD-9 procedure code
Resection of rectum: including anterior resection of rectum and abdominoperineal excision of rectum	48.61–48.65, 48.69, 48.50–48.52, 48.59
Repair: suture repair of laceration of rectum	48.71, 48.79
Stoma: including colostomy and ileostomy	46.10–46.13, 46.20–46.23, 48.62

Results

Between 2013 and 2014, 1.7 million patients were entered into the NTDB, of whom 1700 (0.1%) sustained a rectal injury. Of these, 1472 were aged 16 years or over and were included in the study. Isolated extraperitoneal injuries occurred in 52.8% (778 patients) and isolated intraperitoneal and combined intra-/extraperitoneal in 47.2% (694 patients). Overall, 81% were male, the median age was 30 years (range 16–89 years), 60% of injuries ($n = 879$) were secondary to penetrating trauma, and, of all patients, 49.3% ($n = 726$) underwent fecal diversion. Surgical management included: defunctioning stoma alone in 33.2% of patients ($n = 488$); resection + stoma in 4.1% ($n = 61$); resection without stoma in 1.3% ($n = 19$); primary suture repair + stoma in 12% ($n = 177$); primary suture repair alone in 8.0% ($n = 118$). The remaining 41.4% did not undergo surgical intervention. Overall, mean LoS was 14.4 days (SD = 19.7) and mean ICU stay was 9.0 days (SD = 12.0). Overall morbidity was 17.1% ($n = 251$) and overall mortality 7.8% ($n = 115$).

Extraperitoneal vs. intraperitoneal rectal injury

Data for isolated extraperitoneal rectal injuries (extraperitoneal) ($n = 778$) and isolated intraperitoneal or combined intra- and extraperitoneal (intraperitoneal) rectal injuries ($n = 694$) are outlined in Table 3. For patients with extraperitoneal injuries, surgical management included: defunctioning stoma alone in 25.5% ($n = 198$); resection/repair + stoma in 11.0% ($n = 86$); resection without stoma in 9.1% ($n = 71$); primary repair alone in 8.2% ($n = 64$). The remaining 46.2% ($n = 359$) did not undergo surgical intervention. Intraperitoneal injuries were more common in younger patients, followed penetrating trauma,

Table 3 Characteristics and outcomes for patients with (a) isolated extraperitoneal vs. (b) isolated intraperitoneal or combined intra and extraperitoneal rectal injuries

	Isolated extraperitoneal ($n = 778$, 52.8%)	Isolated intraperitoneal and combined intra- and extraperitoneal ($n = 694$, 47.2%)	p value
Mean age (years)	38.5 (17.3)	31.4 (12.7)	< 0.001
Male gender	604 (77.6%)	585 (84.3%)	
Systolic blood pressure (mmHg)	121.4 (27.3)	122.7 (33.3)	0.130
Respiratory rate (bpm)	18.7 (6.0)	19.7 (6.4)	0.018
Heart rate (bpm)	97.1 (26.8)	96.6 (23.8)	0.117
Injury severity score	17.9 (14.0)	16.6 (10.1)	< 0.001
Stoma (Y)	284 (36.5%)	442 (63.7%)	< 0.001
Penetrating trauma	285 (36.6%)	594 (85.6%)	< 0.001
Postoperative morbidity			
Acute kidney injury	32 (4.1%)	15 (2.2%)	0.03
Adult respiratory distress syndrome	23 (3.0%)	17 (2.4%)	0.732
Cardiac arrest with cardiopulmonary resuscitation	22 (2.8%)	21 (3.0%)	0.822
Myocardial infarction	1 (0.1%)	1 (0.1%)	0.936
Decubitus ulcer	9 (1.2%)	10 (1.4%)	0.63
Deep SSI	17 (2.2%)	28 (4.0%)	0.04
Superficial SSI	12 (1.5%)	16 (2.3%)	0.285
Organ-space SSI	20 (2.6%)	28 (4.0%)	0.114
Deep vein thrombosis	21 (2.7%)	20 (2.9%)	0.832
Pneumonia	59 (7.6%)	31 (4.5%)	0.013
Pulmonary embolism	5 (0.6%)	12 (1.7%)	0.05
Cerebrovascular accident	1 (0.1%)	4 (0.6%)	0.14
Return to the operating room	24 (3.1%)	22 (3.2%)	0.925
Length of stay (days)	28.4 (27.0)	23.7 (26.9)	0.001
ICU length of stay (days)	13.8 (14.9)	10.2 (12.6)	< 0.001
Ventilator (days)	9.1 (11.1)	6.2 (8.1)	0.056
Overall in-hospital mortality, excluding deaths in ED	64 (8.2%)	51 (7.4%)	0.531

Refer to Table 2 for definitions. For mean values, standard deviation is given in brackets

SSI surgical site infection, *ICU* intensive-care unit, *ED* emergency department presented with a significantly higher respiratory rate and associated with significantly higher rates of deep SSI and PE. They were more likely than extraperitoneal injuries to be managed by fecal diversion (63.7 vs. 36.5%, $p<0.001$), including stoma alone 41.8% ($n=290$), or resection/repair + stoma 21.9% ($n=152$). A further 66 patients (9.5%) were managed with surgical resection or primary repair but without fecal diversion, while 186 (26.8%) did not undergo surgery. For extraperitoneal injuries, primary suture repair alone (without stoma) was associated with a 12.5% overall morbidity rate and mortality rate of 4.7% [excluding deaths in the emergency department (ED) on day 1], which was comparable to the suture repair of intraperitoneal injuries (overall morbidity 13% and mortality 5.6%). Analysis of management outcomes according to type of injury is outlined in the "Surgical management" section.

Mechanism of injury

Table 4 gives the details for patients who had penetrating (60%, $n=879$) versus blunt (40%, $n=587$) rectal injuries. Six patients were excluded as they did not have a mechanism of injury recorded. Compared to penetrating trauma, patients with blunt trauma were younger, male, had significantly higher heart rate at presentation and injuries that were usually extraperitoneal, while penetrating trauma was more likely to produce intraperitoneal injuries. Penetrating rectal injuries were managed with defunctioning stoma alone 40.0% ($n=352$), resection/repair + stoma 19.4% ($n=171$), resection without stoma 1.7% ($n=15$), or suture repair alone 7.6% ($n=67$). The remaining 31.3% ($n=274$) did not undergo surgery. Blunt injuries ($n=587$) were mostly managed conservatively (56.6%, $n=332$); however, operative treatment included defunctioning stoma in 23.0% of patients with blunt trauma ($n=135$), resection/repair + stoma in 11.2% ($n=66$), resection without stoma in 0.7% ($n=4$), or

Table 4 Characteristics of patients and outcomes who sustained rectal injury after blunt vs. penetrating trauma

	Blunt ($n=587$, 40%)	Penetrating ($n=879$, 60%)	*p* value
Mean age (years)	41.3 (17.8)	31.8 (12.5)	< 0.001
Male gender	438 (74.6%)	746 (84.9%)	< 0.001
Systolic blood pressure (mmHg)	111 (29.6)	118 (35.0)	0.889
Respiratory rate (beats per minute)	18.9 (7.7)	20.8 (7.5)	0.846
Heart rate (beats per minute)	109 (25.1)	101 (26.7)	0.002
Injury severity score	30.4 (14.9)	19.3 (10.2)	< 0.001
Isolated intraperitoneal or combined intra and extraperitoneal injuries	100 (17.0%)	594 (67.6%)	< 0.001
Stoma creation	201 (34.2%)	523 (59.5%)	< 0.001
Postoperative morbidity			
Acute kidney injury	32 (5.5%)	15 (1.7%)	< 0.001
Adult respiratory distress syndrome	23 (3.9%)	17 (1.9%)	0.067
Cardiac arrest with cardiopulmonary resuscitation	23 (3.9%)	20 (2.3%)	0.171
Myocardial infarction	2 (0.3%)	0 (0.0%)	0.221
Decubitus ulcer	14 (2.4%)	5 (0.6%)	0.01
Deep SSI	26 (4.4%)	19 (2.2%)	0.04
Superficial SSI	12 (2.0%)	16 (1.8%)	0.9
Organ-space SSI	19 (3.2%)	29 (3.3%)	0.901
Deep vein thrombosis	24 (4.1%)	17 (1.9%)	0.045
Pneumonia	57 (9.7%)	33 (3.8%)	< 0.001
Pulmonary embolism	7 (1.2%)	10 (1.1%)	0.961
Cerebrovascular accident	4 (0.7%)	1 (0.1%)	0.185
Return to the operating room	19 (3.2%)	27 (3.1%)	0.893
Length of stay (days)	31.8 (31.6)	21.4 (22.2)	< 0.001
ICU length of stay (days)	15.8 (16.8)	8.9 (10.4)	< 0.001
Ventilator (days)	9.9 (11.7)	5.7 (7.6)	0.005
Overall in-hospital mortality, excluding deaths in ED	62 (10.6%)	53 (6.0%)	< 0.001

For mean values, standard deviation is given in brackets

SSI surgical site infection, *ICU* intensive-care unit, *ED* emergency department suture repair alone in 8.5% ($n = 50$). Patients with penetrating trauma were more likely to undergo fecal diversion than blunt trauma patients. Blunt trauma was associated with a higher mean ISS, (30.4 (SD = 14.9) vs. 19.3 (SD = 10.2), $p < 0.001$), longer mean length of stay (31.8 days (SD = 31.6) vs. 21.4 days (SD = 22.2), $p < 0.001$), longer ICU stay (15.8 days (SD = 16.8) vs. 8.9 days (SD = 10.4), $p < 0.001$), and significantly more morbidity (including AKI, deep SSI, pneumonia, deep vein thrombosis—Table 4) and mortality [10.6% ($n = 62$) vs. 6% ($n = 53$), $p < 0.001$] (excluding deaths in ED on day 1), than penetrating trauma.

Fecal diversion and outcomes

Fecal diversion (including resection or suture repair with a diverting stoma, or stoma alone) was more commonly performed in patients with a higher ISS and elevated heart rate on admission to the ED; however, other baseline observations (systolic blood pressure, respiratory rate) were similar (Table 5). Patients who had stoma formation ($n = 726$) were younger [mean age 32.9 (SD = 13.7) vs. 37.3 years (SD = 17.2), $p < 0.001$], and were more likely to have penetrating trauma [72.0% ($n = 522$) vs. 47.7% ($n = 356$)] than those who did not receive a stoma, ($p < 0.001$). Patients with intraperitoneal injuries were more likely to be managed with a stoma (60.9% vs. no stoma 33.8%, $p < 0.001$) than those with extraperitoneal injuries (39.1% vs. 66.2%, $p < 0.001$). Patients with a stoma had longer hospital and ICU stay and were more likely to develop deep SSI (5.2 vs. 0.9%, $p < 0.001$), organ-space SSI (5.2 vs. 1.3%, $p < 0001$), PE (2.1 vs. 0.3%, $p = 0.001$), and pneumonia (7.4 vs. 4.8%, $p = 0.036$), but had a lower mortality rate than patients without a stoma (4.0% vs. 8.6%, $p < 0.001$). When stratifying by the mechanism of injury, 59.5% ($n = 523$) of patients with penetrating trauma

Table 5 Rectal injuries managed by stoma vs. no stoma formation

	Stoma* 726 (49.3%)	No stoma 746 (50.7%)	*p* value
Mean age (years)	32.9 (13.7)	37.3 (17.2)	< 0.001
Male gender	616 (84.8%)	573 (76.8%)	< 0.001
Systolic blood pressure (mmHg)	123.1 (29.1)	121.0 (28.0)	0.084
Respiratory rate (bpm)	19.8 (6.0)	18.6 (6.5)	0.357
Heart rate (bpm)	98.5 (22.6)	94.5 (28.1)	0.016
Injury severity score	17.9 (11.6)	16.2 (13.3)	< 0.001
Penetrating	522 (72.0%)	356 (47.7%)	< 0.001
Isolated extraperitoneal	284 (39.1%)	494 (66.2%)	< 0.001
Isolated intraperitoneal or combined intra- and extraperitoneal	442 (60.9%)	252 (33.8%)	< 0.001
Postoperative morbidity			
Acute kidney injury	28 (3.9%)	19 (2.5%)	0.153
Adult respiratory distress syndrome	19 (2.6%)	21 (2.8%)	0.815
Cardiac arrest with cardiopulmonary resuscitation	22 (3.0%)	21 (2.8%)	0.806
Myocardial infarction	1 (0.1%)	1 (0.1%)	0.985
Decubitus ulcer	13 (1.8%)	6 (0.8%)	0.094
Deep SSI	38 (5.2%)	7 (0.9%)	< 0.001
Superficial SSI	15 (2.1%)	13 (1.7%)	0.650
Organ-space SSI	38 (5.2%)	10 (1.3%)	< 0.001
Deep vein thrombosis	26 (3.6%)	15 (2.0%)	0.067
Pneumonia	54 (7.4%)	36 (4.8%)	0.036
Pulmonary embolism	15 (2.1%)	2 (0.3%)	0.001
Cerebrovascular accident	4 (0.6%)	1 (0.1%)	0.169
Return to the operating room	29 (4.0%)	17 (2.3%)	0.059
Length of stay (days)	28.6 (27.5)	22.6 (28.5)	< 0.001
ICU length of stay (days)	13.6 (15.6)	10.1 (11.0)	0.004
Ventilator (days)	8.4 (10.6)	6.7 (8.8)	0.540
Overall in-hospital mortality, excluding deaths in ED	29 (4.0%)	64 (8.6%)	< 0.001

For mean values, standard deviation is given in brackets.

SSI surgical site infection, *ICU* intensive-care unit, *ED* emergency department

*Stoma group includes resection or repair with stoma formation, and defunctioning stoma alone underwent fecal diversion, compared with only 34.2% of blunt trauma patients ($p < 0.001$), (Table 4).

Concomitant urological injuries, including bladder, ureteric, or urethral injuries, occurred in 25% of patients ($n = 375$). Of these, 60% ($n = 225$) had an intraperitoneal vs. 40% extraperitoneal rectal injury ($p < 0.001$). Patients with concomitant urological injuries were more likely to have stoma formation than those without urological injuries (64.3 vs. 44.2%, $p < 0.001$). Apart from AKI, (5.3 vs. 2.5%, $p = 0.006$), complications and mortality were similar regardless of the occurrence of urological injuries.

Surgical management

A subgroup analysis was performed for patients who had rectal resection or primary suture repair with stoma formation (RR + Stoma) ($n = 238$) vs. rectal resection or suture repair without a stoma (RR–Stoma) ($n = 137$). The RR + Stoma group had significantly more male patients (87 vs. 76.6%, $p = 0.03$) and patients with intraperitoneal rectal injuries (63.9 vs. 48.2%, $p = 0.003$). There were no significant differences in admission observations, ISS, complications, LoS, or mortality between the two groups.

For extraperitoneal rectal injuries, patients managed with resection/repair + stoma had a significantly longer hospital stay (23 vs. 14 days, $p < 0.001$) and higher overall postoperative morbidity rates (30.2 vs. 12.7%, $p = 0.009$) compared to resection/repair without stoma, despite no significant difference in ISS (27 vs. 29, $p = 0.780$). There was no significant difference in mortality. Patients with intraperitoneal injuries who had a stoma created (with or without resection / repair) had similar postoperative outcomes including overall complications (19.0 vs. 21.2%, $p = 0.672$) compared to those who underwent repair or resection without stoma creation, but a lower mortality rate, although this did not reach significance (3.4 vs. 9.1%, $p = 0.078$).

Multivariate regression analysis (Table 6)

On multivariate regression analysis, greater age, ISS, and admission to ICU were significant independent predictors of increased mortality (deaths on day 1 in ED were again excluded). Stoma formation reduced mortality. Resection/repair without stoma was associated with significantly higher mortality than ostomy alone (HR 3.32, 95% CI 1.39–7.94, $p < 0.007$).

Discussion

Although rectal injuries are relatively rare (1700/24 months in the U.S.), they are associated with a significant mortality rate and most commonly occur in young, male patients following penetrating trauma. We identified the substantial morbidity associated with such injuries, including high rates of SSI, pneumonia, and AKI, in addition to a prolonged length of ICU and overall hospital stay. Over the last century, mortality rates following rectal injuries have fallen,

Table 6 Multivariate regression analysis of factors independently predictive of mortality following rectal injury

Mortality	*p* value	Hazards ratio (HR)	95% confidence interval for HR	
			Lower bound	Upper bound
Injury severity score	< 0.0001	1.073	1.046	1.101
Age	< 0.0001	1.044	1.019	1.069
Colostomy only	Reference			
Resection/suture + ostomy	0.542	1.304	0.555	3.065
Resection/suture without ostomy	0.007	3.322	1.389	7.941
No return to the operating room	Reference			
Return to the operating room	0.054	3.063	0.983	9.542
Isolated intraperitoneal or combined intra- and extraperitoneal	Reference			
Isolated extraperitoneal	0.348	0.659	0.275	1.575
Males	Reference			
Females	0.778	0.863	0.309	2.407
Admission to the ICU	Reference			
No admission to the ICU	0.034	3.511	1.099	11.214
No urological trauma	Reference			
Urological trauma	0.734	0.875	0.406	1.887
Penetrating	Reference			
Blunt	0.635	0.791	0.301	2.077

ICU intensive-care unit

but much controversy still remains regarding the optimal management of such injuries. The introduction of primary suture repair with occasional use of diverting colostomy during World War I reduced mortality from 90 to 67% [12]. Subsequently, during World War II with standard fecal diversion and presacral drainage, mortality was reduced to 30%. With improved resuscitation techniques and antibiotic prophylaxis, primary repair and distal rectal washout further reduced mortality during the Vietnam War to 15% [12–14].

The majority of published data relating to the management of such injuries is available from only single institution, retrospective case series. Although there is some evidence from national registries regrading colonic trauma, there is a lack of such published data on rectal injuries. To get an accurate evaluation of the scope of the problem, we chose to include data from the NTDB, which collects information from over 400 level I–IV trauma centers across the U.S. We found that the majority of rectal injuries sustained by the 1472 patients were secondary to penetrating trauma (60%) and overall most injuries were isolated extraperitoneal (52.8%). Higher grades of injury (i.e., isolated intraperitoneal or combined intra- and extraperitoneal) were more likely to occur following penetrating trauma (85.6%) and were more frequently managed with a stoma (63.7%). As one might expect, our study demonstrated that blunt trauma was associated with a significantly higher ISS and greater mortality rate than penetrating wounds, due to the risk of death resulting from other injuries.

For extraperitoneal low rectal injuries, the current guidance advocates proximal diversion, with the avoidance of routine presacral drains or distal rectal washout [15, 16]. We found that, for isolated extraperitoneal injuries, primary suture repair alone (without stoma) was associated with a comparable overall complication rate and mortality, to the suture repair of intraperitoneal injuries. For extraperitoneal rectal injuries, patients managed with resection/repair + stoma had a significantly longer hospital stay and higher postoperative morbidity compared to resection/repair without stoma despite no significant difference in ISS. Thus, suture repair or resection without ostomy may offer sufficient surgical management for isolated extraperitoneal injuries. This is supported by other, smaller studies in the literature. Gonzalez et al. prospectively analyzed outcomes for 14 patients with penetrating, non-destructive extraperitoneal rectal injuries, managed without stoma formation, demonstrating good results and advocating avoidance of fecal diversion [17]. Similarly, Levine et al. investigated whether primary repair without diversion was adequate management for extraperitoneal rectal injuries [18]. Of the 30 patients included, six were managed with primary suture repair and no stoma [repair + stoma ($n=11$) and defunctioning stoma alone ($n=13$)]. There was no significant difference in morbidity or mortality for the no stoma group. They concluded that it was feasible to avoid a stoma, in stable patients with minimal contamination, without major associated injuries, but advise fecal diversion where the laceration cannot be safely visualized and repaired without extensive rectal mobilization. A further study outlined the implementation of a clinical pathway to standardize care of patients with rectal trauma, according to the characterization of the injury relative to retroperitoneal involvement [19]. Stomas were avoided in selected patients with extraperitoneal injury—where the defect could be safely repaired, although inaccessible injuries were diverted. Infective complications were significantly lower (13 vs. 31%, $p<0.05$) when compared with a prepathway matched cohort.

For intraperitoneal injuries, or for extensive low rectal injuries that cannot be satisfactorily sutured transanally, laparotomy and primary repair are currently advocated, with or without distal rectal washout, presacral drainage, and/or stoma formation. While the posterior rectal wall should ideally be examined in anterior wall injuries, whether the extraperitoneal rectum should be mobilised remains a matter of debate [20]. Patients in our study with intraperitoneal injuries who had a stoma created (with or without resection/repair) had similar postoperative outcomes including complications and mortality compared to those who underwent repair or resection without stoma creation, suggesting that an ostomy can selectively be avoided. However, multivariate analysis showed that stoma formation (either alone or in conjunction with resection/repair) was associated with significantly lower mortality, and that resection/repair without stoma was associated with higher mortality when controlling for other factors, thus supporting a low threshold for the consideration of an ostomy for significant/intraperitoneal rectal injuries.

Diversion is usually advocated in patients in whom an anastomosis may not heal, i.e., those with delayed diagnosis or hemorrhagic/septic shock with potential compromise of gut perfusion. If primary repair is not feasible or the patient is compromised, forming a defunctioning loop colostomy, which diverts feces away from the defect and can be easily closed at a later date, has been advocated [20]. With extensive extraperitoneal injury, a Hartmann's procedure may be indicated, or if a rectal defect could be repaired transanally, but the patient also has significant pelvic or perineal injuries, it is considered appropriate to perform fecal diversion [21]. In such patients, stomas reduce the rates of necrotizing fasciitis in pararectal fat from contamination [22]. For all injuries, we found that the mortality rate was lower when a stoma was created regardless of whether the patient underwent resection/repair despite the stoma group having a significantly higher ISS.

Concomitant urological injuries are common with rectal injuries (25% in this study), and although more frequent following penetrating wounds, 40% occurred after blunt trauma. Therefore, urinary symptoms, significant intra-abdominal fluid, or poor urine output despite adequate resuscitation and catheterization should create a high index of suspicion and be further investigated with a cysto-urethrogram or contrast-computed tomography (CT) scan. In this data series, patients with combined urological and rectal injuries were more likely to undergo the stoma formation than those without urological injury and had equivalent outcomes.

On multivariate regression analysis, greater age, ISS, and admission to ICU were independently associated with higher rates of mortality, with ostomy creation being associated with a lower risk. These findings need to be considered in the context of some potential limitations of the study. Some inherent limitations of the NTDB include lack of information relating to whether returns to the operating room were planned or unplanned, and relating to time from diagnosis to surgery. We were also unable to ascertain the value of presacral drainage, as this was not recorded, although it previously been advocated in some studies [23, 24], while others have questioned its use [6, 20, 25]. Given the number of trauma centers and the vast variations in the presentation of rectal injuries, their site, and severity, we were unable to assess the influence of level of trauma center or experience of surgeon as factors in this study. However, as the incidence of rectal trauma is relatively low, the use of large population data such as this provides a unique opportunity to study the outcomes of different treatment modalities and the effects of various injury mechanisms and grades. The use of ISS and baseline observations facilitates comparisons between groups and the NTDB has been shown to be a robust, reliable data source [26]. The findings of the study are hence expected to guide management of rectal injuries.

Conclusions

Trauma, or unintentional injury, is the leading cause of death in USA for those aged 1–44 years and a major cause of economic burden [27]. While prompt trauma assessment and immediate attention to life-threatening injuries as per advanced trauma life support (ATLS) protocol is crucial, thereafter, the management of rectal injuries is multifactorial and requires considerable judgment to tailor treatment to specific patients to optimise outcomes. Rectal injuries should be considered in all pelvic trauma patients and managed appropriately. It may be feasible and safe to manage isolated extraperitoneal injuries without stoma formation; however, fecal diversion should be considered in patients with intraperitoneal rectal injuries, as this may reduce mortality.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Institutional Review Board (IRB) approval was obtained from Columbia University Medical Center (IRB-AAAQ7032). The database consists of de-identified, HIPPA-compliant data.

Informed consent For this type of study, formal consent is not required.

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