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Occult bowel injury after blunt abdominal trauma

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Abstract

Background: Following blunt abdominal trauma, bowel injuries are often missed on admission computed tomography (CT) scan.

Methods: Multicenter retrospective analysis of 176 adults with moderate-critical blunt abdominal trauma and admission CT scan who underwent operative exploration. Patients with a bowel injury missed on CT (n =36, 20%) were compared to all other patients (n=140, 80%).

Results: The missed injury group had greater incidence free fluid without solid organ injury on CT scan (44% vs. 25%, p=0.038) and visceral adhesions (28% vs. 6%, p=0.001). Independent predictors of missed bowel injury included prior abdominal inflammation (OR 3.74, 95% CI 1.37–10.18), CT evidence of free fluid in the absence of solid organ injury (OR 2.31, 95% CI 1.03–5.19) and intraoperative identification of visceral adhesions (OR 4.46, 95% CI 1.52–13.13).

Conclusions: Patients with visceral adhesive disease and indirect evidence of bowel injury on CT scan were more likely to have occult bowel injury.

Summary:

Following blunt abdominal trauma, bowel injuries are often missed on admission computed tomography (CT) scan. In this multicenter retrospective analysis of 176 adults with moderate-critical blunt abdominal trauma and admission CT scan who underwent operative exploration, patients with visceral adhesive disease and indirect evidence of bowel injury on CT scan were more likely to have occult bowel injury.

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Keywords

Surgery; adhesions; computed tomography; trauma; bowel injury

Introduction

The prevalence of intra-abdominal injury among adult patients with blunt abdominal trauma is approximately 13%.[1] Selecting patients who will benefit from operative exploration remains difficult, with serious consequences associated with non-therapeutic laparotomy as well delayed recognition of conditions requiring operative intervention. At level I trauma centers, the rate of non-therapeutic laparotomy has ranged from to 27.1%, reported in 1995 by Renz and Feliciano,[2] down to 3.9%, reported in 2012 by Schnuriger, Demetirades, et al.[3] In the more recent study, 14.5% of all non-therapeutic laparotomies had associated complications, underscoring the importance of patient selection. A missed injury may be an even greater detriment, particularly when a bowel injury is missed on initial workup, resulting in delayed operative exploration after the patient develops peritonitis.[4–7] Although multidetector computed tomography (CT) has improved the diagnosis of bowel injury,[8, 9] its sensitivity and specificity have been reported as 55–64% and 80–92%, respectively.[10, 11] Therefore, better methods are needed to accurately identify patients with bowel injury following blunt abdominal trauma.

The purposes of this study were to assess the incidence of bowel injury missed on CT scan and to identify predictors of missed bowel injury among adult blunt trauma patients who undergo CT scan with subsequent operative exploration to confirm the presence or absence of bowel injury. Based on previous work,[4, 11] we hypothesized that patients who are likely to have adhesive disease secondary to prior abdominal inflammation or surgery and patients with indirect evidence of bowel injury on CT scan (e.g. free fluid in the absence of solid organ injury) would be at increased risk for missed bowel injury.

Methods

We performed a retrospective cohort analysis of 176 consecutive adult (age≥18 years) patients admitted to St. Mary's Medical Center in West Palm Beach, Florida or University of Florida Health in Gainesville, Florida following blunt trauma with abdominal injury severity score ranging from 2 (moderate) to 5 (critical) and had preoperative CT scan of the abdomen and pelvis with subsequent operative exploration by laparoscopy or laparotomy. Patients were identified by searching institutional data registries at both participating institutions. Patients with abdominal injury severity score 1 (mild) or 6 (non-survivable) were not included because prediction of missed bowel injury would not be clinically useful for these patients. Patients were excluded if they had penetrating or burn injuries. Derivation of the study population is illustrated in Figure 1. Patients with a bowel injury that was missed on preoperative CT scan and identified during operative exploration (n =36) were compared to patients who did not have a bowel injury that was missed on preoperative CT scan (n=140).

Data were collected from institutional databases and by retrospective review of electronic medical records. Factors associated with intra-abdominal injury described by previous

studies were assessed, including prior abdominal inflammation (documentation of an infectious or non- infectious inflammatory intra-abdominal process, e.g. diverticulitis, Crohn's disease, spontaneous bacterial peritonitis), prior abdominal surgery, low GCS, endotracheal intubation, hypotension, acidosis, anemia, focused assessment with sonography for trauma (FAST) exam findings, diagnostic peritoneal aspirate/lavage (DPA/DPL), and pelvic facture.[12–19] Abdominal pain and tenderness were not considered in this analysis because the accuracy of this data on retrospective review cannot be assured. They are often confounded by medications administered prior to arrival in the trauma bay, and the absence of abdominal pain and tenderness has limited utility in ruling out abdominal injury.[18] CT scan findings were obtained from radiology reports signed by board-certified radiologists. Management parameters included laparoscopic versus open operative approach, the interval from admission to surgery, performance of a bowel resection or repair, and the performance of a non-therapeutic laparotomy. The decision to perform operative exploration was at the discretion of the attending surgeon, informed by the presence or development of peritonitis as well as concern for hemorrhage from an intra- abdominal source or hollow visceral injury per clinical presentation or radiographic findings. Operative findings were obtained from operative reports signed by board-certified surgeons. Operative findings included the identification of adhesive disease, solid organ injury, mesenteric injury, and bowel injury.

Statistical analysis was performed in SPSS (version 24; Armonk, NY). Continuous variables were compared by the Kruskal-Wallis test and reported as median [interquartile range]. Discrete variables were compared by Fisher's Exact test and reported as n (%). Correlations were assessed by Pearson's r. Univariate logistic regression was performed to identify risk factors for bowel injury missed on CT scan. Factors that were significant on univariate analysis were entered into a multivariate regression model to identify independent predictors of missed bowel injury. A multivariable regression model should contain approximately ten outcome events for each variable in the model.[20] In this study, there were 36 cases of bowel injury missed on CT scan. Therefore, this study was adequately powered to include up to three covariates in multivariable modeling. Two models were created: one based on findings available only in the preoperative setting, and one based on preoperative and intraoperative findings, including the presence of visceral adhesive disease on initial exploration. Model strength was assessed by calculating area under the receiver operating characteristic curve (AUROC).

Results

Patient characteristics are listed in Table 1. Median age was 40 years. Thirty-two percent of all patients were female. Twenty-three percent of all patients had a history of an abdominal inflammatory process, 17% had previous abdominal surgery, and 12% had previous open abdominal surgery. The prevalence of prior abdominal inflammation was significantly higher in the missed injury group (42% vs. 19%, p=0.007). The prevalence of prior laparotomy was similar between groups (19% vs. 10%, p=0.148). Twenty-one percent of all patients were intubated in the field, 13% were intubated in the trauma bay, and only two patients (1%) had a cardiac arrest in the field or trauma bay. A seatbelt sign was noted in 13% of all patients, with similar incidence between groups (17% vs. 12%, p=0.579). A FAST exam was performed in 63% of all patients, with equivocal or positive findings in 24% of all patients.

CT scan findings are listed in Table 2. Four patients (2%) had a normal CT scan. Solid organ injuries were identified in 60% of all patients, with a lower proportion of solid organ injuries occurring in patients with a missed bowel injury (44% vs. 64%, p=0.036). Free fluid was identified in 74% of all patients, with no significant differences between groups. Free fluid occurred in the absence of solid organ injury in 44% of all patients with a missed bowel injury, compared with 25% of all other patients (p=0.038). Rates of pelvic fracture, bladder injury, and mesenteric injury were similar between groups.

Operative findings and outcomes are listed in Table 3. The median number of days between admission and operative exploration was zero days in both groups. Intraoperative identification of visceral adhesions was significantly more common in the missed injury group (28% vs. 6%, p=0.001). The presence of adhesive disease correlated with history of an abdominal inflammatory process (r=0.269, p<0.001) and history of laparotomy (r=0.396, p < 0.001) but not history of laparoscopy (r=0.145, p=0.054). Similar to CT findings, there was a lower proportion of patients with solid organ injury in the missed bowel injury group (39% vs. 64%, p=0.008). There were 14 patients (10% of the cohort) in the no missed injury group with a bowel injury that was identified on preoperative CT scan by free air, bowel wall thickening, or bowel wall stranding and inflammation. Hospital length of stay was longer in the missed injury group (13 vs. 9 days, p=0.029), though this observation does not establish or imply causality. Overall inpatient mortality was 13%, with no significant differences between groups.

Predictors of missed bowel injury are listed in Table 4. On univariate analysis, prior abdominal inflammation (OR 5.16, 95% CI 2.02–13.20) and CT evidence of free fluid in the absence of solid organ injury (OR 2.40, 95% CI 1.12–5.14) were associated with increased odds of missed bowel injury. Together, these factors each contributed significantly to a preoperative multivariable model with AUROC 0.70, 95% CI 0.60–0.80, p<0.001. The intraoperative identification of visceral adhesions was also associated with increased odds of missed bowel injury (OR 6.35, 95% CI 2.29–17.61, p<0.001). In a combined preoperative/intraoperative model, all three factors contributed significantly as independent predictors of missed bowel injury (AUROC 0.74, 95% CI 0.64–0.84, p<0.001).

Discussion

These findings suggest that blunt traumatic bowel injuries are commonly missed on preoperative CT scan, and that patients with a predilection for visceral adhesive disease and indirect evidence of bowel injury on CT scan are at increased risk for occult bowel injury. These findings, along with the low sensitivity of CT scan in identifying bowel injuries, suggest that assessing likelihood of intra-abdominal adhesions may be a valuable adjunct in weighing the risks and benefits of operative exploration for patients with blunt abdominal trauma.[10, 11] As expected, intraoperative identification of adhesive disease correlated with prior abdominal inflammation and prior laparotomy, but not prior laparoscopy. Although this study was not designed to assess pathophysiologic mechanisms, it seems plausible that visceral adhesions tether the bowel and create shearing forces during blunt abdominal trauma, similar to the mechanism by which traumatic aortic injury occurs near the ligamentum arteriosum in deceleration injuries. The same adhesions may then obscure CT

scan evidence of bowel wall injury, apart from the finding of free fluid in the absence of solid organ injury. Although missed injury was not associated with a significant delay in operative exploration or increased mortality, it was associated with longer hospital length of stay, which may have been attributable to the increased incidence of bowel resection or repair in this group.

A recent study reported similar rates of missed injury. In a retrospective review of patients who underwent CT scan following motor vehicle crashes at a single center in Virginia, 24% of all patients had a delay of at least 24 hours before the diagnosis of bowel or mesenteric injury was established.[21] Based on previous work,[4–7] such delays are associated with increased morbidity and mortality. Until imaging technology improves, the ability to accurately identify patients who will benefit from operative exploration remains highly dependent on clinical suspicion. Unfortunately, the absence of abdominal pain and tenderness has limited utility in ruling out abdominal injury.[18] However, clinical assessment may be improved by incorporating other elements of the history and physical exam. Based on our findings, we propose that eliciting a history of an abdominal inflammatory process or prior laparotomy may be a useful adjunct in the decision for or against operative exploration.

This study was limited by selection bias inherent to retrospective review. Selection bias was limited as much as possible by including all consecutive cases meeting study criteria at two institutions. In addition, although including only patients with abdominal injury severity score ranging from 2 (moderate) to 5 (critical) was advantageous for the purposes of this study by focusing the analysis on patients for whom the decision for or against operative exploration is relevant, this design also limits the generalizability of these findings. For example, the observation that solid organ injuries were identified on CT and by intraoperative assessment in a lower proportion of patients with a missed bowel injury is likely attributable to study design, i.e. all patients had a moderate-critical abdominal injury, the incidence of bowel injury must be higher (100%) in the cohort of patients with a missed bowel injury, and so the control group must have other injuries to obtain similar abdominal injury severity scores. Future investigations should seek to validate these findings in a prospective fashion including a broad cohort of patients with blunt abdominal trauma, and to ascertain whether acceleration and deceleration visceral shearing forces cause bowel injuries among patients with abdominal adhesions.

Conclusions

Bowel injuries were missed on preoperative CT scan in one out of five patients with moderate-critical blunt abdominal trauma. Patients with a predilection for visceral adhesive disease and indirect evidence of bowel injury on CT scan were at increased risk for occult bowel injury. Future research should validate these findings in a prospective fashion and ascertain whether visceral shearing forces due to adhesive disease predispose to bowel injury.

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Highlights

- Occult bowel injury after blunt trauma is common and delayed diagnosis is morbid
- At two centers, the incidence of bowel injury missed on admission CT scan was 20%
- Free fluid without solid organ injury was associated with occult bowel injury
- Visceral adhesions were associated with occult bowel injury

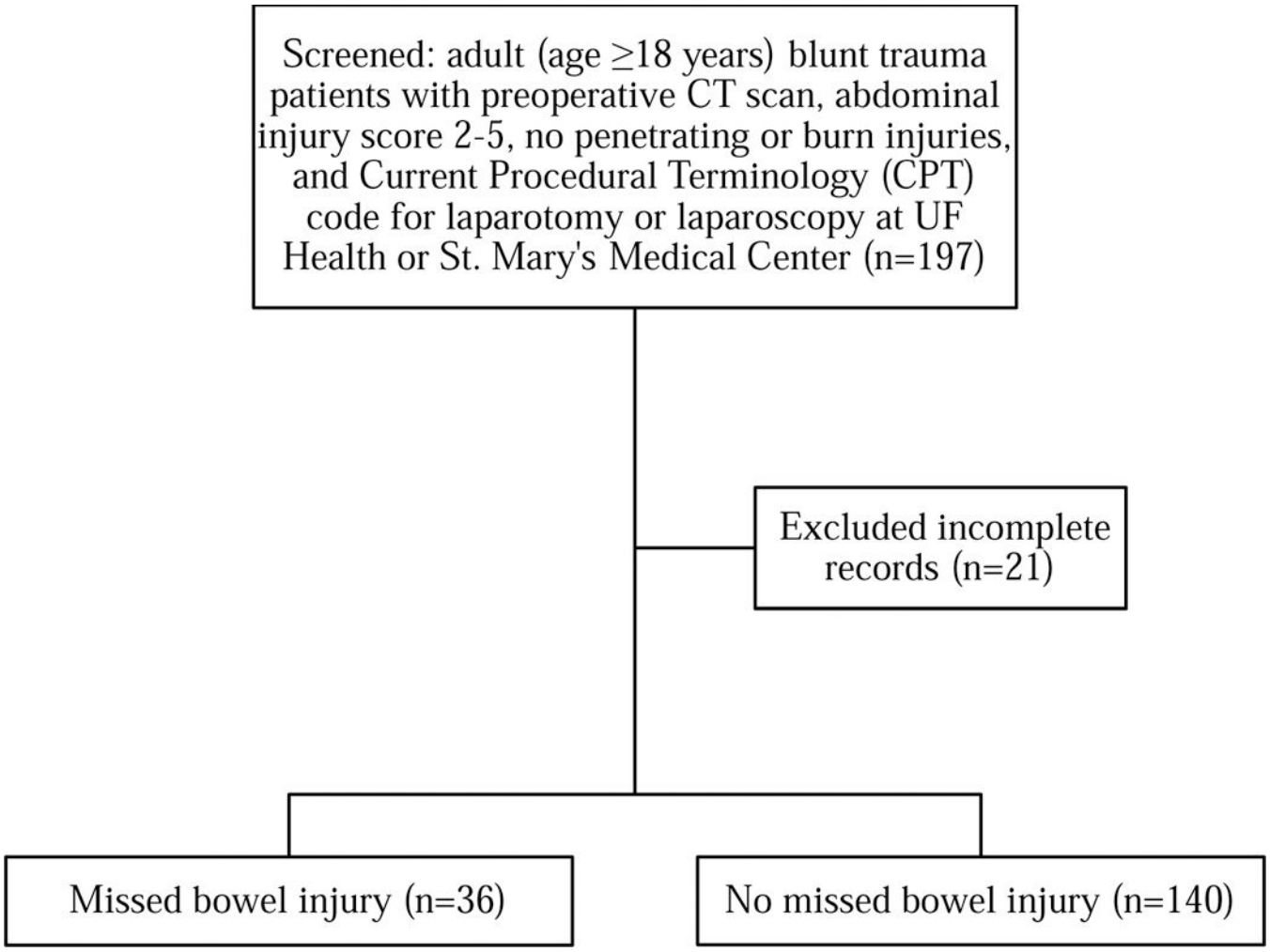

Figure 1:
Derivation of the study population (CT: computed tomography).

Table 1:

Summary of baseline characteristics for the study population.

Patient characteristics	All patients (n=176)	CT missed Bowel injury (n=36)	No missed Bowel injury (n=140)	*p*
Age (years)	40 [27–58]	36 [26–51]	41 [27–58]	0.356
Female	56 (32%)	14 (39%)	42 (30%)	0.321
Prior abdominal inflammation	41 (23%)	15 (42%)	26 (19%)	0.007
Prior abdominal surgery	29 (16%)	8 (22%)	21 (15%)	0.317
Open abdominal surgery	21 (12%)	7 (19%)	14 (10%)	0.148
Injury severity score	26 [16–35]	21 [13–34]	27 [17–36]	0.112
Abdominal injury score	3 [2–4]	3 [2–3]	3 [2–4]	0.073
Glasgow coma scale score	15 [13–15]	15 [13–15]	15 [11–15]	0.164
Intubated in field	36 (20%)	5 (14%)	31 (22%)	0.357
Intubated in trauma bay	23 (13%)	4 (11%)	19 (14%)	>0.999
Cardiac arrest in field	1 (1%)	0 (0%)	1 (1%)	>0.999
Cardiac arrest in trauma bay	1 (1%)	0 (0%)	1 (1%)	>0.999
Admission heart rate	98 [80–115]	97 [84–116]	98 [80–115]	0.915
Admission SBP (mmHg)	121 [103–140]	132 [112–142]	120 [102–139]	0.071
Admission lactate (mmol/L)	2.5 [1.9–3.8]	2.2 [1.8–4.0]	2.8 [2.0–3.7]	0.292
Admission Hb (g/dL)	12.3 [10.6–13.8]	12.5 [11.2–13.7]	12.3 [10.5–13.8]	0.338
Seatbelt sign	23 (13%)	6 (17%)	17 (12%)	0.579
FAST performed	111 (63%)	20 (56%)	91 (65%)	0.335
Negative	69 (39%)	15 (42%)	54 (39%)	0.850
Equivocal	6 (3%)	0 (0%)	6 (4%)	0.346
Positive	36 (20%)	5 (14%)	31 (22%)	0.356
DPA/DPL performed	8 (5%)	2 (6%)	6 (4%)	0.667
Negative	2 (1%)	1 (3%)	1 (1%)	0.368
Positive	6 (3%)	1 (3%)	5 (4%)	>0.999
FAST or DPA/DPL positive	38 (22%)	6 (17%)	32 (23%)	0.502
Abdominal X-ray performed	142 (81%)	29 (81%)	113 (81%)	>0.999
Normal	104 (59%)	24 (67%)	80 (57%)	0.345
Pelvic fracture	33 (19%)	5 (14%)	28 (20%)	0.480
Open book deformity	10 (6%)	2 (6%)	8 (6%)	>0.999

SBP: systolic blood pressure, Hb: hemoglobin, FAST: focused assessment with sonography for trauma, DPA: diagnostic peritoneal aspirate, DPL: diagnostic peritoneal lavage. Data are presented as median [interquartile range] or n (%).

Table 2:

Summary of abdominal and pelvic computed tomography (CT) scan findings.

CT findings	All patients (n=176)	CT missed bowel injury (n=36)	No missed bowel injury (n=140)	*p*
Normal CT scan	4 (2%)	2 (6%)	2 (1%)	0.186
Solid organ injury	106 (60%)	16 (44%)	90 (64%)	0.036
Bleeding pseudoaneurysm	29 (16%)	2 (6%)	27 (19%)	0.074
Free fluid	131 (74%)	24 (67%)	107 (76%)	0.284
Without solid organ injury	51 (29%)	16 (44%)	35 (25%)	0.038
Bowel injury	26 (15%)	0 (0%)	26 (19%)	0.003
Pelvic fracture	47 (27%)	8 (22%)	39 (28%)	0.673
Bladder injury	9 (5%)	1 (3%)	8 (6%)	0.684
Intraperitoneal	6 (3%)	1 (3%)	5 (4%)	>0.999
Extraperitoneal	3 (2%)	0 (0%)	3 (2%)	>0.999
Mesenteric stranding	29 (16%)	9 (25%)	20 (14%)	0.135
Mesenteric hematoma	28 (16%)	7 (19%)	21 (15%)	0.609

Data are presented as n (%).

Table 3:

Summary of operative findings and outcomes.

Operative findings and outcomes	All patients (n=176)	CT missed bowel injury (n=36)	No missed bowel injury (n=140)	*p*
Operative approach				
Laparotomy	163 (93%)	29 (81%)	134 (96%)	0.006
Laparoscopy	3 (2%)	0 (0%)	3 (2%)	>0.999
Laparoscopy converted to laparotomy	10 (6%)	7 (19%)	3 (2%)	0.001
Days from admission to surgery	0 [0–1]	0 [0–1]	0 [0–1]	0.339
Identified adhesive disease	18 (10%)	10 (28%)	8 (6%)	0.001
Identified solid organ injury	104 (59%)	14 (39%)	90 (64%)	0.008
Missed on CT scan	6 (3%)	2 (6%)	4 (3%)	0.604
Identified mesenteric injury	60 (34%)	22 (61%)	38 (27%)	<0.001
Missed on CT scan	24 (14%)	12 (33%)	12 (9%)	<0.001
Identified bowel injury	50 (28%)	36 (100%)	14 (10%)	<0.001
Partial thickness	23 (13%)	18 (50%)	5 (4%)	<0.001
Full thickness	27 (15%)	18 (50%)	9 (6%)	<0.001
Bowel resection or repair	53 (30%)	35 (97%)	18 (13%)	<0.001
Non-therapeutic laparotomy	12 (7%)	0 (0%)	12 (9%)	0.130
Hospital length of stay (days)	10 [5–22]	13 [8–27]	9 [5–20]	0.029
Inpatient mortality	23 (13%)	3 (8%)	20 (14%)	0.419

Data are presented as n (%) or median [interquartile range].

Table 4:

Predictors of missed bowel injury. Factors that were statistically significant on univariable analysis were entered into the multivariable regression model.

Model	Univariable regression			Multivariable regression		
Factors	**OR**	**95% CI**	***p***	**OR**	**95% CI**	***p***
Preoperative model						
Prior abdominal inflammation	5.16	2.02–13.20	0.001	5.07	1.95–13.21	0.001
CT free fluid, no solid organ injury	2.40	1.12–5.14	0.024	2.35	1.06–5.19	0.035
Preoperative/intraoperative model						
Prior abdominal inflammation	5.16	2.02–13.20	0.001	3.74	1.37–10.18	0.010
CT free fluid, no solid organ injury	2.40	1.12–5.14	0.024	2.31	1.03–5.19	0.043
Presence of adhesive disease	6.35	2.29–17.61	<0.001	4.46	1.52–13.13	0.007

OR: odds ratio, CI: confidence interval, SBP: systolic blood pressure. Area under the receiver operating characteristic curve for the preoperative multivariate model was 0.70 (95% CI 0.60– 0.80), p <0.001. Area under the receiver operating characteristic curve for the preoperative/ intraoperative multivariate model was 0.74 (95% CI 0.64–0.84), p <0.001.