Blunt small bowel perforation (SBP): An Eastern Association for the Surgery of Trauma multicenter update 15 years later

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BACKGROUND: Previous work demonstrated diagnostic delays in blunt small bowel perforation (SBP) with increased mortality and inability of scans to reliably exclude the diagnosis. We conducted a follow-up multicenter study to determine if these challenges persist 15 years later.

METHODS: We selected adult cases with blunt injury, *International Classification of Diseases, Ninth Revision* or current procedural terminology (CPT) indicating small bowel surgery, no other major injury and at least one abdominal computed tomography (CT) within initial 6 hours. Controls had blunt trauma with abdominal CT but not SBP. After institutional review board approval, data from each center were collected and analyzed.

RESULTS: Data from 39 centers (from October 2013 to September 2015) showed 127,919 trauma admissions and 94,743 activations. Twenty-five centers were Level 1. Centers submitted 77 patients (mean age, 39; male, 68%; mean length of stay, 11.3 days) and 131 controls (mean age, 44; male, 64.9%; length of stay, 3.6 days). Small bowel perforation cases were 0.06% of admissions and 0.08% of activations. Mean time to surgery was 8.7 hours (median, 3.7 hours). Initial CT showed free air in 31 cases (43%) and none in controls. Initial CT was within normal in three cases (4.2%) and 84 controls (64%). Five cases had a second scan; two showed free air (one had an initial normal scan). One death occurred among the patients (mortality, 1.4%; and time to surgery, 16.9 hours). Regression analysis showed sex, abdominal tenderness, distention, peritonitis, bowel wall thickening, free fluid, and contrast extravasation were significantly associated with SBP.

CONCLUSIONS: Blunt SBP remains relatively uncommon and continues to present a diagnostic challenge. Trauma centers have shortened time to surgery with decreased case mortality. Initial CT scans continue to miss a small number of cases with potentially serious consequences. We recommend (1) intraperitoneal abnormalities on CT scan should always evoke high suspicion and (2) strong consideration of additional diagnostic/therapeutic intervention by 8 hours after arrival in patients who continue to pose a clinical challenge. (*J Trauma Acute Care Surg.* 2019;86: 642–650. Copyright © 2019 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Observational study, level III.

KEY WORDS: Blunt small bowel perforation; diagnosis.

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Small bowel perforation (SBP) is a rare complication of blunt abdominal trauma. Estimates of the frequency of small bowel injury in blunt abdominal trauma range from 5% to 15%,[1] with perforation occurring in 1% or less of blunt abdominal traumas.[2,3] Reliable diagnosis of SBP remains problematic.[4] The difficulty of consistently diagnosing or excluding SBP based on CT scan has been demonstrated. Computed tomography (CT) sensitivity estimates range from 50% to 94%, but CT specificity decreased markedly as sensitivity increased, suggesting different standards in reading the CT scans.[1,5–7] Additionally, the highest sensitivity value was calculated based on suggestive injuries; only 50% of the patients met diagnostic criteria for SBP on CT scan.[8]

Since the advent of CT scan as the primary diagnostic tool for blunt abdominal trauma, delays in the diagnosis of blunt SBP with associated mortality have been documented.[2,3,6] Because of the pervasive role of CT scan in the diagnostic evaluation of the modern blunt trauma patient, approximately 15 years ago, we conducted an Eastern Association for the Surgery of Trauma (EAST) multicenter study of blunt hollow viscous injury in the age of CT scan. The study showed that blunt SBP was uncommon, initial CT scan failed to detect as many as 13% of cases subsequently proven at surgery to have SBP, and that delays in diagnosis of more than 24 hours resulted in increased mortality.[3,6] Other work suggests mortality increases with delays of more than 8 hours.[2]

The present study aimed to examine whether increased awareness of diagnostic challenges and/or improved technology since the publication of our 2003 multicenter study has improved diagnostic efficiency and time to surgery, thereby decreasing case mortality. Specifically, we aimed to describe, for patients with blunt abdominal trauma, (1) current diagnostic methods of blunt near-isolated nonduodenal SBP; (2) current mortality and morbidity due to blunt near-isolated nonduodenal SBP; (3) the current average time to surgery for these patients; (4) the frequency and use of a second abdominal CT scan, and its association with time to surgery; and (5) incidence of postoperative complications in these patients. Finally, we aimed to determine the sensitivity and specificity of diagnostic findings for blunt near-isolated nonduodenal SBP.

METHODS

Design

This was an international multicenter retrospective data collection study conducted as an approved EAST multi-institutional study in follow-up to our similarly constructed 2003 multicenter study. Hospital-level data were collected on trauma level, continent, presence of a protocol for a second CT in blunt abdominal trauma, number of yearly adult trauma admissions, number of yearly adult trauma activations, number of yearly adult blunt trauma admissions, and approximate number of yearly adult blunt trauma admissions with suspected abdominal injury (i.e., those having CT scan of the abdomen). Patients were identified via medical records for inclusion in the study, and records were screened for the inclusion and

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exclusion criteria (discussed in the next subsection). Data collection from a review of the patients' charts included patients' demographics, medical history, injury-related details, physiologic details, diagnostic tests and findings, CT capability (i.e., 32, 64, 128 slice), surgical timing and results, complications, length of stay (LOS), intensive care unit (ICU) LOS, and disposition.

Candidate centers completed an electronic survey to determine eligibility. The coordinating center developed and disseminated to the participating centers a data dictionary and detailed data collection protocols. Before beginning data collection, a series of e-mail exchanges and conference calls were conducted to support the participating centers, answer queries, and distribute standardized responses so that all centers were well prepared. De-identified data were submitted from the participating centers to the coordinating center via a secure REDCap database and stored on a password-protected institutional server. Two of the primary investigators (S.M.F. and P.L.F.) reviewed the submitted data files and contacted centers for missing or inconsistent data and related questions. In particular, each submitted case was individually reviewed to ensure adherence to the study protocol and data integrity.

We performed this study after obtaining the approval of and in accordance with our institutional review board guidelines and in compliance with the Health Insurance Portability and Accountability Act. Primary institutional review board approval was obtained at the coordinating center and also from each participating hospital before their data submission.

Subjects

We included adult patients (18 years or older) admitted to participating hospitals between October 1, 2013 and September 30, 2015 with blunt trauma, no duodenal injury (i.e., no *International Classification of Diseases, Ninth Revision, Clinical Modification* code of 863.21 or 863.31), and all nonabdominal Abbreviated Injury Scores (AISs) < 3. The coordinating center obtained three groups of patients from each participating trauma center:

1) *Potential cases of isolated SBP*: patients with an *International Classification of Diseases, Ninth Revision* procedure or CPT code indicating small-bowel surgery with at least one abdominal CT performed within the initial 6 hours from admission;
2) *Potential controls*: patients with no procedure code indicating small bowel surgery, no AIS greater than 2 including the abdominal region, a trauma activation, and an abdominal CT performed within the initial 6 hours of admission; and
3) *Potential SBP diagnosed without CT scan*: patients with a procedure code for small-bowel surgery but no abdominal CT done before surgery (the rare case in which a diagnostic technique other than CT was used).

Once these groups were identified, sites performed further medical record abstraction to confirm that patients in the first and third groups had a surgical report stating the presence of nonduodenal SBP and no other major operative findings requiring repair or resection, and confirm patients in the second group did not have abdominal surgery. Each center also selected potential controls from their Trauma Registry by selecting patients from the same time interval as the cases who had no AIS greater than 2 for any injury (abdominal and nonabdominal) and an abdominal CT performed within the initial 6 hours from admission. From this list, each study team attempted to match

TABLE 1. Patient Findings

Variables	Levels	Control (N = 131)	Case (N = 72)	*p*	Unadjusted OR	95% CI	*p*
Age		41 [26–61.25]	38.5 [24–50]	0.240	0.99	0.97-1.00	0.130
Sex	Male	85 (64.89%)	49 (68.06%)	-	-	-	-
	Female	46 (35.11%)	23 (31.94%)	0.760	0.87	0.47-1.60	0.650
Abdominal	No	105 (80.15%)	7 (9.72%)	-	-	-	-
tenderness	Yes	26 (19.85%)	65 (90.28%)	<0.001	37.50	15.40-91.32	<0.001
Abdominal	No	130 (99.24%)	57 (79.17%)	-	-	-	-
distension	Yes	1 (0.76%)	15 (20.83%)	<0.001	34.21	4.41-265.22	0.001
Peritoneal signs	No	130 (99.24%)	50 (69.44%)	-	-	-	-
	Yes	1 (0.76%)	22 (30.56%)	<0.001	57.2	7.51-435.56	<0.001
Seat belt sign	No	124 (94.66%)	51 (70.83%)	-	-	-	-
	Yes	7 (5.34%)	21 (29.17%)	<0.001	7.29	2.92-18.22	<0.001
Initial PH	Normal	11 (57.89%)	3 (25%)	-	-	-	-
	Abnormal	8 (42.11%)	9 (75%)	0.140	4.12	0.84-20.28	0.080
Initial base deficit	Normal	2 (10.53%)	7 (46.67%)	-	-	-	-
	Abnormal	17 (89.47%)	8 (53.33%)	0.020	0.13	0.02-0.80	0.030
Initial lactate	Normal	21 (48.84%)	9 (31.03%)	-	-	-	-
	Abnormal	22 (51.16%)	20 (68.97%)	0.150	2.12	0.79-5.70	0.140
Initial WBC	Normal	62 (53.45%)	18 (28.57%)	-	-	-	-
	Abnormal	54 (46.55%)	45 (71.43%)	0.002	2.87	1.49-5.54	0.002

The numbers of missing data records for age, initial PH, base deficit, lactate, and WBC were 1, 172, 169, 131, and 24.
CI, Confidence interval; OR, odds ratio; WBC, white blood cell count.

TABLE 2. Frequencies of Diagnostic Testing Used

Test	All (N = 203)	Control (n = 131)	Case (n = 72)
CT scan	203 (100%)	131 (100%)	72 (100%)
Chest x-ray	159 (78.33%)	105 (80.15%)	54 (75%)
FAST	81 (39.9%)	52 (39.69%)	29 (40.28%)
Abdominal x-ray	14 (6.9%)	6 (4.58%)	8 (11.11%)
DPL	0 (0%)	0 (0%)	0 (0%)

DPL, Diagnostic peritoneal lavage; FAST, focused assessment with sonography for trauma.

two controls to each case, with age within 5 years and date of admission within 30 days, although not all sites were able to provide that number of controls.

Data Analysis

We calculated descriptive statistics on hospital level data. Descriptive statistics were used to describe current methods trauma centers are using to diagnose near-isolated nonduodenal SBP in patients with blunt abdominal trauma in conjunction with abdominal CT, focused assessment with sonography in trauma, abdominal ultrasound, x-ray, and/or diagnostic peritoneal lavage. Percentages of positive findings for each diagnostic modality, as well as physical examination, laboratory values, and vital signs, were calculated for patients with SBP and those without SBP.

To describe current mortality and morbidity due to blunt near-isolated nonduodenal SBP, we calculated overall mortality rate of patients with SBP, mortality rates by time to surgery, and morbidity rate of types of complications. To describe the current average time to surgery for patients with blunt near-isolated nonduodenal SBP, we calculated overall time to surgery, as well as percentages of patients with SBP going to surgery in less than 8 hours, less than 16 hours, less than 24 hours, and 24 hours or more. To describe the frequency and use of a second abdominal CT scan, and its association with time to surgery and incidence of postoperative complications in patients with blunt near-isolated nonduodenal SBP who did not go to surgery emergently (within 4 hours) after an initial CT, we calculated the percentage of patients with SBP who had a second

TABLE 4. Sensitivities and Specificities of the Diagnostic Findings

	Sensitivity	Specificity	PPV	NPV	Accuracy
Physical examination at admission					
Abdominal tenderness	90.28%	80.15%	71.43%	93.75%	83.74%
Abdominal distention	20.83%	99.24%	93.75%	69.52%	71.43%
Peritoneal signs	30.56%	99.24%	95.65%	72.22%	74.88%
Seat belt sign/bruising	29.17%	94.66%	75.00%	70.86%	71.43%
Other	18.06%	71.76%	26.00%	61.44%	52.71%
Initial laboratory results (abnormal)					
Arterial pH	75.00%	57.89%	52.94%	78.57%	64.52%
Base deficit	53.33%	10.53%	32.00%	22.22%	29.41%
Lactate, mmol/L	68.97%	48.84%	47.62%	70.00%	56.94%
WBC count	71.43%	53.45%	45.45%	77.50%	59.78%
CT findings (initial)					
Free fluid	83.33%	91.6%	84.51%	90.91%	88.67%
Free air	43.06%	100%	100%	76.16%	79.80%
Bowel wall thickening	37.50%	99.24%	96.43%	74.29%	77.34%
Mesenteric stranding	23.61%	99.24%	94.44%	70.27%	72.41%
Contrast extravasation	11.11%	99.24%	88.89%	67.01%	67.98%
Solid organ injury	6.94%	90.84%	29.41%	63.98%	61.08%
Retroperitoneal blood	8.33%	96.18%	54.55%	65.62%	65.02%
Chance fracture	2.78%	98.47%	50.00%	64.82%	64.53%

TABLE 3. Initial CT Scan Findings

Findings	Levels	Control	Case	*p*	Unadjusted OR	95% CI	*p*
Free air*	No	131(0%)	41 (56.94%)	-	-	-	-
	Yes	0 (0%)	31(43.06%)	<0.001	-	-	-
Free fluid	No	120 (91.6%)	12 (16.67%)	-	-	-	-
	Yes	11 (8.4%)	60 (83.33%)	<0.001	54.55	22.74-130.83	<0.001
Bowel wall thickening	No	130 (99.24%)	45 (62.5%)	-	-	-	-
	Yes	1 (0.76%)	27 (37.5%)	<0.001	78	10.31-590.03	<0.001
Mesenteric stranding	No	130 (99.24%)	55 (76.39%)	-	-	-	-
	Yes	1 (0.76%)	17 (23.61%)	<0.001	40.18	5.22-309.41	<0.001
Contrast extravasation	No	130 (99.24%)	64 (88.89%)	-	-	-	-
	Yes	1 (0.76%)	8 (11.11%)	0.001	16.25	1.99-132.73	0.009
Solid organ injury	No	119 (90.84%)	67 (93.06%)	-	-	-	-
	Yes	12 (9.16%)	5 (6.94%)	0.79	0.74	0.25-2.19	0.590
Retroperitoneal blood	No	126 (96.18%)	66 (91.67%)	-	-	-	-
	Yes	5 (3.82%)	6 (8.33%)	0.2	2.29	0.67-7.79	0.180
Chance fracture	No	129 (98.47%)	70 (97.22%)	-	-	-	-
	Yes	2 (1.53%)	2 (2.78%)	0.62	1.84	0.25-13.37	0.550

* Due to complete separation, unadjusted OR and 95% CI were not calculated for free air.

TABLE 5. Regression Analysis

	OR	95% CI	*p*
Multivariate Logistic Regression Model			
Age	0.98	0.93-1.03	0.427
Sex (female vs. male)	0.1	0.01-0.85	0.035
Abdominal tenderness	46.1	5.33-398.88	0.001
Abdominal distention	443.92	1.73-114068.66	0.031
Peritoneal signs	268.81	6.47-11159.85	0.003
Seatbelt signs	2.76	0.37-20.59	0.323
Free fluid	93.39	11.8-738.93	<0.001
Bowel wall thickening	583.36	10.85-31372.37	0.002
Mesenteric stranding	24.49	0.02-33496.01	0.385
Contrast extravasation	87.12	1.06-7172.57	0.047
Stepwise Regression Model			
Sex (female vs. male)	0.14	0.02-0.89	0.037
Abdominal tenderness	45.59	5.99-347.08	<0.001
Abdominal distention	434.2	3.91-48219.57	0.011
Peritoneal signs	174.91	5.91-5176.21	0.003
Free fluid	93.3	13.31-654.2	<0.001
Bowel wall thickening	751.46	13.53-41737.43	0.001
Contrast extravasation	29.64	0.82-1070.24	0.064

abdominal CT scan before surgery. We calculated the sensitivity, specificity, positive predicative value (PPV), negative predicative value (NPV), and accuracy for each individual finding from physical examination, initial CT scan, and laboratory test results. Unadjusted odds ratios (ORs) were calculated from univariate logistic regression models along with 95% confidence intervals for demographic factors and diagnostic findings. After stepwise regression (forward and backward) including covariates that had $p < 0.1$ from univariate analysis, a multivariate logistic regression model was used to obtain adjusted ORs. We calculated descriptive statistics on hospital level data and rate of false-negative CT scans.

RESULTS

Centers and Cases

Data were available from 39 centers** with 127,919 trauma admissions and 94,743 trauma activations from October 2013 to September 2015. Twenty-nine centers were Level 1 trauma centers, 7 were Level 2, 1 was Level 3, and 2 were international. Thirty-three centers (85%) were able to identify and submit 77 SBP potential cases (Groups 1 and 3). The SBP patients were 0.06% of admissions and 0.08% of activations. There were 77 patients enrolled (mean age, 39 years; male, 68%; mean hospital LOS, 11.3 days) and 131 non-SBP controls (mean age, 44 years; male, 64.9%; LOS, 3.6 days). Of the 77 patients with near-isolated nonduodenal SBP, 5 underwent surgery without a CT scan and were not included in subsequent analyses (did not meet inclusion criteria). The subsequent analysis considered the 72 enrolled patients with proven SBP at surgery and a qualifying CT scan as cases. The median number of cases each center contributed was 2 (interquartile range [IQR], 1–3). Fifteen centers had only one case, five centers had two cases, eight centers had three cases, two centers had four cases, and three centers had five cases. Overall, the median injury severity score (ISS) was 8, IQR [5–10]; median ISS for cases was 10, IQR [9–14] and median ISS for controls was 5, IQR [4–9]. The most common mechanism of injury by far was motor vehicle crash (65% of cases and 50% of controls) followed by falls (9.7% of cases and 15% of controls) and motorcycle crashes (5.6% for cases and 10.7% for controls).

Diagnostic Testing

Patient findings are shown in Table 1. On univariate analysis, cases (patients with proven SBP and qualifying preoperative CT scan) were significantly more likely than controls (patients without SBP) to have abdominal tenderness, abdominal distention, a seat belt sign, peritoneal signs, abnormal base deficit, and elevated white blood cell count. Initial pH and lactate levels were not significantly associated with the finding of SBP. Very limited conclusions should be drawn involving the laboratory results because of significant missing data.

The frequency of diagnostic testing used among those patients with an initial CT scan is shown in Table 2. All controls and 72 of the 77 cases had an initial CT scan. Initial CT scan showed free air in 31 cases (43%) and none of the controls (Table 3). Free fluid (in most cases without solid organ injury) was present in 60 cases (83.3%) but only 11 controls (8.4%). Bowel wall thickening, mesenteric stranding, and contrast extravasation were almost never seen in controls and occurred at varying and statistically significant rates (37.5%, 23.61%, and 11.11%, respectively) in cases. The unadjusted ORs for free fluid, bowel wall thickening, and mesenteric stranding were 54, 78, and 40, respectively.

Initial CT scan was reported as within normal limits in three case patients (4.2%) and 84 controls (64%). The three normal CT scans in case patients were performed in machines with 64 or more detectors. Two of the three patients whose initial CT scan was normal went on to surgery without further imaging, while the third had a second CT scan that showed free air prompting exploratory laparotomy. An additional four case patients had a second CT scan (for a total of five case patients having a second CT scan). One of the four follow-up CT scans showed free air; thus, two of the five second CT scans showed free air.

The sensitivity and specificity of diagnostic findings in initial CT scans are shown in Table 4. Free air on CT scan was highly specific (100% PPV) but only somewhat sensitive (43% NPV) for SBP. The sensitivity and specificity values for

TABLE 6. Complications

Complication	All Patients	Controls	Cases	*p*
Wound infection	3 (1.44%)	0 (0%)	3 (3.9%)	0.049
Abscess	4 (1.92%)	0 (0%)	4 (5.19%)	0.018
Sepsis	4 (1.92%)	0 (0%)	4 (5.19%)	0.018
Pneumonia	6 (2.88%)	2 (1.53%)	4 (5.19%)	0.197
ARDS	4 (1.92%)	1 (0.76%)	3 (3.9%)	0.144
AKI	4 (1.92%)	0 (0%)	4 (5.19%)	0.018
VTE	2 (0.96%)	0 (0%)	2 (2.6%)	0.136
Unplanned return to surgery	4 (1.92%)	0 (0%)	4 (5.19%)	0.018
Other	18 (8.65%)	3 (2.29%)	15 (19.48%)	<0.001

AKI, acute kidney injury; ARDS, acute respiratory distress syndrome; VTE, venous thromboembolism.

free fluid on CT scan were both relatively high, resulting in the highest overall accuracy (88.67%) for the diagnosis of SBP. Other CT abnormalities such as bowel wall thickening, mesenteric stranding, and contrast extravasation had high specificity but low sensitivity rates with resultant lower accuracy rates.

Multivariate logistic regression analysis and stepwise regression (for variable selection) was performed incorporating demographic factors, physical examination results, and CT scan findings (Table 5). Stepwise regression model dropped both seatbelt sign and mesenteric stranding from the model. Both models showed that female sex, abdominal tenderness, abdominal distention, peritoneal signs, free fluid, and bowel wall thickening were significantly associated with SBP. Contrast extravasation reached significance in the first model but was no longer significant in the second, more parsimonious model.

Time to Surgery

Mean time to surgery was 8.43 hours (median, 3.74 hours; IQR, 2.00–10.53). Most cases (52 patients, 78%) went to surgery within 8 hours. Nine patients (12.5%) went to surgery between 8 and 16 hours, four patients (5.6%) went between 16 and 24 hours, and seven patients (9.7%) went after the first 24 hours.

The five patients who had a second CT scan went to surgery 22, 13.9, 9.7, 25.5, and 4.5 hours after admission. All five survived and were discharged home. Of the three patients whose initial CT scan was negative, two went to surgery 50.3 and 10.3 hours after admission, while the third had a second CT scan then went to surgery 22 hours after admission (shown as one of the five cases previously mentioned). All three of these patients survived and went home.

Complications and Mortality

Complications were uncommon in the control patients. A number of complications occurred significantly more often in case patients including wound infection, abscess, sepsis, acute kidney injury, unplanned return to surgery, and others (Table 6). Pneumonia, acute respiratory distress syndrome, and venous thromboembolism occurred more frequently in cases than in controls, but the rates did not attain statistical significance likely owing to the relatively small numbers encountered.

One death occurred among the case patients for an overall mortality rate of 1.4%. The patient who died was a 71-year-old male with an admission Glasgow Coma Scale score of 15 and an ISS of 8. His initial temperature was normal, his heart rate was 66 beats per minute, and his white blood cell count was 4,000. This patient's initial CT scan was performed 93 minutes after admission and showed free fluid. He went to surgery 16.9 hours after admission.

DISCUSSION

Conducted 15 years after our initial EAST multicenter study of hollow viscous injury,[3,6] the present study confirmed our previous findings that SBP is rare (0.06% of admissions and 0.08% of activations in this study), CT scans fail to detect any abnormality in a small but significant number of patients with proven SBP (4.2%), and delays to surgery are associated with mortality in some patients. There seems to have been progress, however, in several areas: a decrease in the rate of false-negative CT scans from 13% to 4.2%; a decrease in case mortality from 6% to 1.3%, and shortened time to surgery. Despite these improvements, a patient who went to surgery 16.9 hours after admission died of complications after what is essentially a simple injury to repair.[9]

The ability of physical examination to reliably diagnose SBP continues to be limited. In this study, the absence of peritoneal signs did not exclude SBP, as 69.4% of patients with proven SBP were reported as not having peritonitis on presentation. The limitations of physical examination findings were highlighted in our 2003 study,[6] and the recent literature supports this inability to rely solely or primarily on physical examination.[10–12] Caution should be exercised in interpreting these data, however, as physical findings alone may be unreliable for the accurate diagnosis of SBP, but abdominal examination remains a key element in decision making for operative intervention in nearly all studies. This is supported by the appearance of abdominal examination elements in most recommendations and regression-based models for prediction of this injury, including the one developed in the present study.[6,11,12]

The use of CT scan in hemodynamically stable blunt trauma patients at risk of intra-abdominal injury remains ubiquitous, and as such, CT scan findings receive special consideration in determining whether patients have important intra-abdominal injuries. The presence of free air on CT scan is perhaps the most widely accepted indication for exploratory laparotomy in a hemodynamically stable patient. It should be noted, however, that although it was present in none of the patients without SBP, it was present in only 43% of patients with proven SBP. Thus, free air on CT scan is highly specific (100% PPV) but only somewhat sensitive (76% NPV) for SBP; stated differently, it is a sufficient but not necessary condition for the presence of SBP, and its absence does not exclude the diagnosis. Free fluid (especially without solid organ injury) was significantly more likely to be present in patients with SBP than in those without. The sensitivity and specificity values for free fluid on CT scan were both relatively high, resulting in the highest overall accuracy (88.67%) for the diagnosis of SBP. Other CT abnormalities such as bowel wall thickening, mesenteric stranding, and contrast extravasation occurred at varying rates in cases but were almost never seen in controls. As such, the presence of these findings on CT scan should raise suspicion of the presence of SBP. Several recent studies also advocate increased scrutiny of patients with CT scan abnormalities such as bowel wall thickening and mesenteric stranding because of their frequent association with bowel injury.[12–14]

Based on the results of this study and several recent publications, the limitations of CT scan in the diagnosis of patients with SBP should be re-emphasized. Despite improvements in technical quality of CT scanners and better identification of CT findings that raise the suspicion of SBP,[10,14] reports of false-negative CT scan results continue to appear. In a single-center study, Becker et al. reported a 28% rate of negative CT scans in patients ultimately proven to have SBP.[11] In another single-center study, McNutt et al. reported that as many as 25% of the patients they selected for nonoperative management failed that regimen and required surgery, suggesting that their initial CT scans were insufficiently precise for the diagnosis.[12]

As a result, reliance on CT scan to exclude this uncommon diagnosis must be tempered with the knowledge drawn from numerous studies that false-negative rates of CT scan for SBP continue to be significant even with advanced scanner technology and expert interpretation with rates from 4.2% to 28%. Assuming a 5% miss rate on initial CT scan (a low estimate) and a prevalence of SBP of 0.5% of activations (a high estimate), a trauma center that has 1,500 activations a year will see 22.5 patients with SBP every 3 years and can expect to miss the diagnosis on initial CT scan in approximately one patient. It is worth noting that in the present study, there were five centers (15%) with no cases over the 2-year period of the study, confirming the low rates at which this injury is encountered.

Modalities other than CT scan have less established roles for the diagnosis of blunt SBP. Ultrasonography is useful when patients have intraperitoneal free air or fluid, but is not sensitive in the absence of those markers.[15] Laparoscopy and peritoneal lavage are the most sensitive methods, with most sensitivity measured at 100%, but laparoscopy especially may not be feasible in all patients and under all circumstances.[1,5,16,17] Although SBP is clearly a time-sensitive injury, these data suggest that short delays (likely <8 hours) to use the more sensitive diagnostic method of laparoscopy could be beneficial, rather than relying solely on CT scan.

Since increased delay in surgical repair is associated with increased morbidity and mortality, improving sensitivity of existing examination methods is critical. Mortality from hollow viscous injury has been shown to increase from 13.0% with surgery within 8 hours to 30.8% when surgery is delayed for more than 24 hours.[6] In addition, delay in surgery results in increased likelihood of wound infection, wound dehiscence, intra-abdominal abscess, acute respiratory distress syndrome, and sepsis.[6] Delay in surgery past 24 hours has also been associated with increased hospital stay.[5] The mortality in the present study occurred despite surgery occurring at 16.9 hours from admission. This is consistent with data that suggest that surgery in less than 24 hours is necessary in these patients, with surgery in less than 8 hours preferred.[2,5] The rarity of this type of injury, combined with the low sensitivity of many diagnostic tests and findings, makes this a difficult diagnosis and, as a result, surgery may be significantly delayed for as long as 50 or more hours from admission as noted in the present study and others as well. Faria et al. noted that all patients with SBP in their study who ultimately died (n = 5) had surgery performed after the first 24 hours (median, 48 hours) compared to 4 hours for the patients who survived ($p < 0.001$).[10] It is clear that delays in the diagnosis of SBP can result in serious complications and death, making timely diagnosis critical in the treatment of these patients. It remains to be determined why some patients suffer serious complications and even death with surgical intervention occurring within the 24-hour window, while others survive despite prolonged delays. Additional research into individual variables such as phenotypic expression of genomic characteristics in response to peritoneal contamination and sepsis is needed to explain the observed variations in pathophysiology and outcomes.

This work strongly suggests that progress has been made in the 15 years since our 2003 study. It is not clear if this is because of better CT scan technology and/or interpretation or heightened clinical acumen with a shortened time to surgery or a combination of all of these. Other less obvious factors may also have contributed to this apparent improvement in outcomes. It is also unclear whether we will be able to completely eliminate mortality from this relatively simple injury that can be readily repaired surgically. Individual patient factors may render a small number of patients exquisitely sensitive to the inflammatory response triggered by peritoneal contamination.

Our research has a number of limitations. This was an unfunded study that relied on the resources available at each of the participating centers. Despite our extensive efforts to standardize data retrieval and collection, there may have been deviations from the protocol that we could not identify and remedy. The controls in this study were not tightly matched to the cases because of limitations of numbers and resources, and this could bias the results of the study. Due to the retrospective nature of the research, differing approaches and interpretations of findings (e.g., reading of CT scans) likely contribute to significant variation in results. Because SBP is an uncommon condition, extremely large numbers of cases would be needed to ensure that our conclusions are sound. This is difficult to accomplish without funding, and it is unlikely that significant funding could be secured for this purpose. This nonrandom sample of trauma centers is not entirely representative of the universe of facilities where injured patients are treated, and this may introduce occult biases. Subtle differences in methodology prevent exact comparison to the earlier study. Finally, the ultimate decision to operate upon an injured patient remains a subjective one, and the impact of differing surgical decision making and the subsequent effects on diagnostic choices and patient outcomes cannot be accounted for by this research.

CONCLUSION

Blunt small bowel perforation continues to present a clinically challenging triad: a relatively rare injury with an often insidious presentation (and therefore little accumulated clinical experience); a small but significant incidence of missed diagnosis by CT scan, the most relied on diagnostic modality; and serious consequences including morbidity and increased mortality when the diagnosis is delayed. This study demonstrates that blunt SBP remains relatively uncommon and continues to present a diagnostic challenge 15 years after our initial multicenter study. Trauma centers seem to have shortened time to surgical intervention with a gratifying associated decrease in case mortality. Initial CT scans continue to miss a small but significant number of cases with potentially serious consequences making heightened awareness of this injury and continued clinical vigilance paramount. Until more definitive solutions are available, we recommend that (1) intraperitoneal abnormalities on CT scan should always evoke high suspicion and (2) strong consideration of additional diagnostic or therapeutic intervention by 8 hours after arrival in patients who continue to pose a clinical challenge.

AUTHORSHIP

SMF developed the study concept. SMF, PLF, and AA participated in the study design; all authors performed data collection. SMF, AA, PLF, ABN, and CL collated and analyzed the data. All authors participated in data interpretation. SMF and PLF wrote the manuscript; SMF, AA, PLF, CPM, ABN, and MRB performed critical review and revisions.

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DISCLOSURE

The authors declare no conflicts of interest.
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APPENDIX

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