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Performance of three predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury: A 12-year retrospective cohort study

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Fabio Agri, Basile Pache, Mylène Bourgeat, Vincent Darioli, Nicolas Demartines, Sabine Schmidt, and Tobias Zingg have nothing to disclose.

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BACKGROUND:	Avoiding missed diagnosis and therapeutic delay for significant blunt bowel and mesenteric injuries (sBBMIs) after trauma is still challenging despite the widespread use of computed tomography (CT). Several scoring tools aiming at reducing this risk have been published. The purpose of the present work was to assess the incidence of delayed (>24 hours) diagnosis for sBBMI patients and to compare the predictive performance of three previously published scores using clinical, radiological, and laboratory findings: the Bowel Injury Prediction Score (BIPS) and the scores developed by Raharimanantsoa Score (RS) and by Faget Score (FS).
METHODS:	A population-based retrospective observational cohort study was conducted; it included adult trauma patients after road traffic crashes admitted to Lausanne University Hospital, Switzerland, between 2008 and 2019 (n = 1,258) with reliable information about sBBMI status (n = 1,164) and for whom all items for score calculation were available (n = 917). The three scores were retrospectively applied on all patients to assess their predictive performance.
RESULTS:	The incidence of sBBMI after road traffic crash was 3.3% (38 of 1,164), and in 18% (7 of 38), there was a diagnostic and treatment delay of more than 24 hours. The diagnostic performances of the FS, the RS, and the BIPS to predict sBBMI, expressed as the area under the receiver operating characteristic curve, were 95.3% (95% confidence interval [CI], 92.7–97.9%), 89.2% (95% CI, 83.2–95.3%), and 87.6% (95% CI, 81.8–93.3%) respectively.
CONCLUSION:	The present study confirms that diagnostic delays for sBBMI still occur despite the widespread use of abdominal CT. When CT findings during the initial assessment are negative or equivocal for sBBMI, using a score may be helpful to select patients for early diagnostic laparoscopy. The FS had the best individual diagnostic performance. However, the BIPS or the RS, relying on clinical and laboratory variables, may be helpful to select patients for early diagnostic laparoscopy when there are unspecific CT signs of bowel or mesenteric injury. (<i>J Trauma Acute Care Surg</i> . 2024;96: 820–830. Copyright © 2023 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)
LEVEL OF EVIDENCE:	Prognostic and Epidemiological; Level III.
KEY WORDS:	Predictive scores; blunt bowel and mesenteric injuries; delayed diagnosis; diagnostic performance; diagnostic laparoscopy.

Significant blunt bowel and mesenteric injuries (sBBMIs) include full-thickness perforations, seromuscular tears, and mesenteric lacerations and require emergent treatment. Relatively rare, this type of injury has a reported incidence of 1% of all trauma admissions and 3% for patients admitted for abdominal trauma.^{1–3} This low incidence may result in a challenging decision-making process and any delay in establishing a diagnosis has a negative impact on survival. Nonrecognized sBBMI is the most frequent cause for delayed laparotomies (LTs) after blunt abdominal trauma.^{4,5} Even a relatively short deferral of 5 to 8 hours of an intervention may lead to an increased morbidity and mortality.^{6,7}

Clinical findings such as abdominal tenderness or the “seat-belt sign,” white blood cell (WBC) count, or the presence of vertebral or pelvic fractures have been reported to be associated with small bowel injury, but in isolation, they lack sensitivity and specificity.^{8–15} Plain X-rays and abdominal ultrasound are of limited value in the assessment for mesenteric and bowel injury and are no longer recommended.⁸ Intravenously contrast-enhanced computed tomography (CT) is considered standard of care for investigation of hemodynamically stable patients suffering from

blunt abdominal trauma,¹⁶ with excellent overall sensitivity and specificity for intra-abdominal injuries.^{17,18} However, false-negative CT rates of up to 13% have been reported for sBBMI,^{19,20} especially in the setting of multiple-injury patients with concurrent solid organ or bladder injuries.^{21,22} Hence, missing a diagnosis of sBBMI is still an issue, leading to delayed surgical treatment and to its negative impact on survival.^{4,23} This is particularly true when managing blunt abdominal trauma patients with a CT showing unspecific or no signs of blunt bowel and mesenteric injury (BBMI), especially in the presence of clinical findings or in obtunded patients with an unreliable physical examination.²² For these situations and given the potential consequences of delayed diagnosis, surgical exploration is recommended. Because of its morbidity rates of 8% to 41%, nontherapeutic exploratory LT should be avoided.^{24–27} Diagnostic laparoscopy (LS) is a less invasive alternative with fewer associated complications.²⁸

To optimize decision making and select patients for early surgical exploration, several tools predictive for sBBMI have been developed and published.^{14,29–31} These scores are based on either clinical, laboratory, or radiological variables, or a combination thereof, to predict the presence or absence of sBBMI. Because of its complex grading system for abdominal tenderness, the performance of the Z score by Zarour et al.³⁰ could not be reliably evaluated using a retrospective study design. Moreover, it is not applicable on patients with a solid organ injury (SOI). The three scores retained for performance comparison are the Bowel Injury Prediction Score (BIPS),¹⁴ the score developed by Raharimanantsoa et al.,³¹ and the score by Faget et al.²⁹ The latter two scores not having a proper term such as the BIPS, the authors of the present study have named them according to the first authors of the publication describing them: the Raharimanantsoa Score (RS) and the Faget Score (FS). The FS is built exclusively on a combination of CT findings and is easy to assess with a retrospective study design. Depending on the cutoff used, its originally reported sensitivity and specificity are, respectively, 91.1% to 100% and 85.7% to 97.6%, with a positive predictive value (PPV) of 41.4% to 82% and an negative predictive value (NPV) of 98.9%

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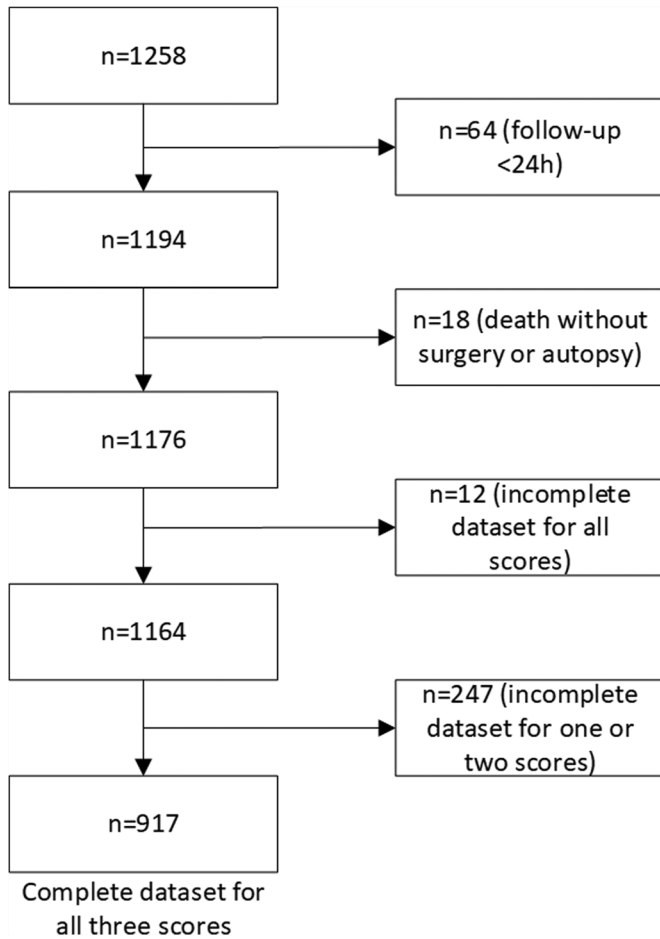


Figure 1. Flowchart of RTC victims from January 2008 to December 2019.

to 100%.²⁹ Depending on the cutoff used, the reported sensitivities and specificities of the BIPS and RS are 85.7% and 76.2%, and 96% and 86.4% respectively, with respective PPVs of 70.6% and 48%, and NPVs of 88.9% and 99.4%.^{14,29,31} Like the FS, the BIPS and the RS are suitable for a retrospective analysis and applicable on patients with SOI.^{14,17,29,31} When applied to a series of patients with surgically proven sBBMI, only 56.3% had a “positive” BIPS (≥ 2 points—BBMI requiring surgery as defined by McNutt et al.¹⁴).³² A recent prospective multicenter study validated the BIPS as a predictor of sBBMI.³³

The aim of the present study was to determine the incidence of delayed diagnosis and treatment of sBBMI in patients undergoing CT after a road traffic crash (RTC) and to evaluate the predictive performance of the FS, the BIPS, and the RS.^{14,29,31}

PATIENTS AND METHODS

Study Design

A single-center, registry-based retrospective cohort study, prepared to conform to the STrengthening the Reporting of OBservational studies in Epidemiology guidelines, was conducted.³⁴ The study protocol was approved by the local institutional review board (2016-00928).

Study Setting and Participants

This study was based on the prospective trauma registry of Lausanne University Hospital, a level I trauma center, including all consecutive patients older than 16 years admitted to the trauma resuscitation area of the emergency department (ED) following an RTC from January 2008 to December 2019. Patients with an initial observation period of less than 24 hours or without consecutive follow-up and patients with unavailable information about the presence or absence of sBBMI were excluded. For comparison of the scores, patients lacking items for score calculation were also excluded (Fig. 1).

TABLE 1. Score Points per Item for the Three Scores

BIPS (Range, 0–3; Cutoff, ≥ 2 Pts)	Pts	RS (Range, 0–14; Cutoff ≥ 8 Pts)	Pts	FS (Range, –1 to 24; Cutoff ≥ 5 Pts)	Pts
WBC count ≥ 17 G/L	1	Free abdominal fluid	3	Hemoperitoneum ≤ 200 mL	1
Abdominal tenderness	1	Admission lactate level ≥ 1.82 mmol/L	2	Hemoperitoneum >200 mL	3
Mesenteric injury grade ≥ 4	1	Long bone fracture	1	Mesenteric pneumoperitoneum	5
Mesenteric Injury Grade		Abdominal tenderness	2	Bowel wall thickening	2
1. Isolated mesenteric contusion* without associated bowel wall thickening or adjacent interloop fluid collection		Impact against a vehicle in motion	2	Active mesenteric extravasation	3
2. Mesenteric hematoma** < 5 cm without associated bowel wall thickening or adjacent interloop fluid collection		Patient was on a motorbike	1	Mesenteric stranding	3
3. Mesenteric hematoma** >5 cm without associated bowel wall thickening or adjacent interloop fluid collection		Patient was in a car	3	Reduced bowel wall enhancement compared with nearby bowel segments	1
4. Mesenteric contusion or hematoma (any size) with associated bowel wall thickening† or adjacent interloop fluid collection‡				Bowel wall discontinuity	5
5. Active vascular or oral contrast extravasation bowel transection or pneumoperitoneum				Anterior abdominal wall injury	2
				Concurrent splenic injury	–1

*Ill-defined ground glass haziness or wispy or streaky opacities within the mesenteric fat.
 **Discrete, measurable, soft tissue density within the mesentery.
 †Small bowel wall thickening >3 mm.
 ‡Small triangular collection of free fluid within the mesentery and/or between the bowel loops.
 Pts, points.

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Variables

Data included all items necessary to obtain each of the three tested scores (Table 1). Of note, the CT grading scale for mesenteric injury was purposefully created by McNutt et al.¹⁴ for its proposed BIPS. For the calculation of the FS (range, -1 to 24), 1 point was deducted in case of a concurrent splenic injury.

Demographic data, mortality, Injury Severity Score (ISS), abdominal and extremity Abbreviated Injury Scale, diagnosis of sBBMI, and types of therapeutic intervention were obtained. The delayed treatment definition used in the present study is based on the consensus that operations performed >24 hours after admission for trauma constitute a serious delay.⁴ Blunt bowel and mesenteric injuries requiring either surgical or radiological treatment or obvious BBMI documented at autopsy were considered as significant. Patients who had none of the aforementioned injuries but who were alive at discharge after an observation period of more than 24 hours were considered not to have sBBMI.

Data Source

Data were extracted from our prospective trauma registry and, when unavailable (abdominal pain, CT-based variables, impact against a vehicle in motion), were collected from the electronic patient records. The results of forensic autopsies were obtained with the permission of the Attorney General. All available clinical data, laboratory, and imaging results were obtained and recorded during the initial phase of care in the ED. When abdominal tenderness was not evaluable (intubated patients), 0 points were scored for this item. These patients were included in our analysis because the nonavailability of this information reflects reality and is not a limitation of the retrospective nature of the study.

The institutional multiple-injury CT protocol was performed with a 64-detector row multidetector CT system from January 2008 to August 2015 (Light Speed VCT 64 Pro; GE Healthcare, Milwaukee, WI) and a 256-row MDCT system (Revolution CT; GE Healthcare) from September 2015 to December 2019. With both machines, 1.25-mm reconstructed axial slices were acquired with increments of 1 mm during the arterial phase (25 seconds) centered on the thorax, and 2.5-mm reconstructed axial slices, with increments of 2 mm during the venous phase (80 seconds) centered on the abdomen and pelvis, after intravenous injection of iodinated contrast medium Accupaque (GE Healthcare, Milwaukee, WI) at a flow rate of 4 mL/s (120 kV; 300 mA; table speed, 55 mm per rotation [0.8 seconds]; pitch, 1.375). Automatic tube current modulation in all three axes (SmartmA) was used as well as adaptive statistical iterative reconstruction algorithm. All CT images were reviewed by one of the authors with >20 years of expertise in abdominal imaging for the presence or absence of free abdominal fluid, grade of bowel and mesenteric injury, and CT findings according to McNutt et al.¹⁴ and Faget et al.²⁹

Statistical Methods

Statistical and graphic analyses were performed using R software version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria).³⁵ For qualitative variables, results are expressed in frequencies and percentages. For continuous variables, a measure of dispersion was given using median, with interquartile ranges (IQRs) or with IQR (IQR = $Q_3 - Q_1$). Qualitative variables

were compared using Fisher's exact or χ^2 test. Continuous variables were compared using Student's *t* test when distribution was bell shaped, and they were compared using a Kruskal-Wallis test if distribution was skewed. A significance threshold with a *p* value of 0.05 was adopted for all statistical analyses. Variables included in the multivariate analysis were selected based on their *p* value (<0.001) after univariate analysis. The variable "CT mesenteric injury grade ≥ 4 " (BIPS) was included as a surrogate for all significant individual radiological variables to avoid overfitting. The predictive accuracy of the risk scores was compared with receiver operating characteristic (ROC) curve analysis.^{36,37} The areas under the ROC curve was calculated with 95% confidence interval (CI) and statistical comparisons used the DeLong method.³⁸

RESULTS

Participants

From January 2008 to December 2019, 1,258 patients were admitted to the trauma resuscitation area of our institution ED following an RTC. Patients who underwent abdominal CT without radiological evidence of injury and were discharged home or transferred to another care facility after an observation period available of less than 24 hours (*n* = 64) were excluded from analysis. Among all patients with a follow-up period of ≥ 24 hours, 18 were excluded since they died without any abdominal intervention or autopsy and therefore having an unknown sBBMI status. Finally, 12 patients were excluded because of their incomplete data sets for the calculation of any of the scores (Fig. 1). The performance comparison of the FS, the BIPS, and the RS was carried out using a common dataset where all items were available for the calculation of the three scores. In total, 247 patients were excluded because of one or more missing items for the calculation of one or more scores, resulting in a population of 917 patients on whom all 3 scores could be tested.

Descriptive Data and Outcome

The prevalence of sBBMI in the group of patients with known sBBMI status was 3.3% (38 of 1,164). Overall (*n* = 1,164), 48 patients (4%) died before any intervention, and their sBBMI status was revealed by forensic autopsy findings. Significant blunt bowel and mesenteric injury was found in one of these patients. Table 2 shows the characteristics of the study population with and without sBBMI. Table 3 summarizes the characteristics of the three subtypes of sBBMI (isolated bowel/combined bowel and mesenteric/isolated mesenteric).

Median length of stay (18 days vs. 9 days, *p* < 0.001), Injury Severity Score (25 vs. 14, *p* < 0.001), abdominal tenderness (68.5% vs. 17.2%, *p* < 0.001), and free abdominal fluid on CT scan (73.7% vs. 15.8%, *p* < 0.001) were significantly higher in patients with sBBMI. Thirty-day mortality (13.2% vs. 6.3%, *p* = 0.10) was not significantly higher in patients with sBBMI. Among the variables used for score calculation, presence of free abdominal fluid (*p* < 0.001), BIPS CT grade ≥ 4 (*p* < 0.001), traveling in a car (*p* = 0.001), and abdominal tenderness (*p* < 0.001) were all significantly associated with sBBMI in univariate analysis, whereas WBC counts ≥ 17 (*p* = 0.47), lactate levels ≥ 1.82 mmol/L (*p* = 0.30), collision with a moving vehicle (*p* = 0.14), presence of a long bone fracture (*p* = 0.79), and

TABLE 2. Characteristics of the Study Population With (+) and Without (–) sBBMI (n = 1,164)

Patient Characteristics and Score Items	sBBMI + n = 38 (3.3%)	sBBMI – n = 1,126 (96.7%)	p
Age			
Median (IQR), y	37 (24–56)	38 (24–54)	0.97
Sex, n (%)			0.25
Male	25 (65.8)	834 (74.1)	
Female	13 (34.2)	292 (25.9)	
ISS			
Median (IQR), score	25 (17–34)	14 (9–24)	<0.001
LOS			
Median (IQR), d	18 (9–39)	9 (3–19)	<0.001
Mortality			
30 d, n (%)	5 (13.2)	71 (6.3)	0.10
Admission to death, median (IQR), d	1.5 (0.7–8.2)	0.4 (0.1–3.4)	0.42
WBC count			
≥17 G/L, n (%)	14 (36.8)	340 (30.2)	0.47
NA, n (%)	0	38 (3.4)	
Lactate			
≥1.8 mmol/L, n (%)	26 (68.4)	612 (54.4)	0.30
NA, n (%)	0	107 (9.5)	
Type of collision, n (%)			
Collision with a moving object	22 (57.9)	521 (46.3)	0.14
NA	2 (5.3)	51 (4.5)	
Abdominal tenderness, n (%)			
Abdominal tenderness	26 (68.4)	194 (17.2)	<0.001
NA (intubated)	8 (21.1)	209 (18.6)	
NA	0	12 (1.1)	
Free abdominal fluid on CT, n (%)			
Free abdominal fluid	28 (73.7)	178 (15.8)	<0.001
NA	3 (7.9)	60 (5.3)	
Long bone fracture, n (%)			
Long bone fracture	13 (34.2)	409 (36.3)	0.79
NA	0	1 (0.1)	
Patient's vehicle type, n (%)			
Car	26 (68.4)	462 (41.0)	<0.001
Motorbike	8 (21.1)	356 (31.6)	0.17
NA	0	0	
CT findings, n (%)			
Hemoperitoneum ≤200 mL	15 (39.5)	84 (7.5)	<0.001
Hemoperitoneum >200 mL	10 (26.3)	67 (6.0)	<0.001
Mesenteric pneumoperitoneum	7 (18.4)	1 (0.1)	<0.001
Bowel wall thickening	22 (57.9)	163 (14.5)	<0.001
Arterial mesenteric vessel extravasation	11 (28.9)	3 (0.3)	<0.001
Mesenteric stranding	29 (76.3)	151 (13.4)	<0.001
Reduced bowel wall enhancement	4 (10.5)	3 (0.3)	<0.001
Bowel wall discontinuity	2 (5.3)	0	<0.001
Splenic injury	7 (18.4)	50 (4.4)	<0.001
Anterior abdominal wall injury	6 (15.8)	79 (7.0)	0.03
CT mesenteric injury grade ≥4 (BIPS)	25 (65.8)	56 (5.0)	<0.001
NA	7 (18.4)	74 (6.6)	

ISS, Injury Severity Score; LOS, length of stay; NA, not available because of incomplete medical chart; NA (intubated), not available because of sedation-intubation of the patient.

traveling on a motorcycle ($p = 0.17$) were not significantly associated with sBBMI. Results of the multivariate analysis using the statistically significant variables after univariate analysis used for the three score calculations are presented in Figure 2. Mesenteric

injury grade ≥4 of the BIPS was used as a surrogate for all significant items of the FS after univariate analysis. The score item “Patient was in a car” of the RS was no longer significant after multivariate analysis.

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TABLE 3. Characteristics of the Three Subtypes of sBBMI

Patient Characteristics and Score Items	Bowel Perforation Only n = 10 (0.9%)	Mesenteric Injury With Bowel Perforation n = 17 (1.5%)	Mesenteric Injury Only n = 11 (0.9%)
Age			
Median (IQR), y	24 (22–32)	38 (29–54)	48 (34–58)
Sex, n (%)			
Male	7 (70)	11 (64.7)	7 (63.6)
Female	3 (30)	6 (35.3)	4 (36.4)
ISS			
Score, median (IQR)	18 (17–23)	34 (21–36)	18 (13–28)
LOS			
Median (IQR), d	15 (10–31)	16 (5–26)	36 (24–46)
Mortality			
30 d, n (%)	0	5 (29.4)	0
Admission to death, median (IQR), d	—	1.5 (0.7–8.2)	—
WBC count			
≥17 G/L, n (%)	2 (20)	8 (47.1)	4 (36.4)
NA, n (%)	0	0	0
Lactate			
≥1.8 mmol/L, n (%)	6 (60)	12 (70.6)	8 (72.7)
NA, n (%)	0	0	0
Type of collision, n (%)			
Collision with a moving object	4 (40)	11 (64.7)	7 (63.6)
NA	0	0	0
Abdominal tenderness, n (%)			
Abdominal tenderness	8 (80)	11 (64.7)	7 (63.6)
NA (intubated)	1 (10)	5 (29.4)	2 (18.2)
NA	0	0	0
Free abdominal fluid on CT, n (%)			
Free abdominal fluid	9 (90)	11 (64.7)	8 (72.7)
NA	1 (10)	1 (5.9)	1 (9.1)
Long bone fracture, n (%)			
Long bone fracture	2 (20)	6 (35.3)	5 (45.5)
NA	0	0	0
Patient's vehicle type, n (%)			
Car	8 (80)	12 (70.6)	6 (54.5)
Motorbike	2 (20)	2 (11.8)	4 (36.4)
NA	0	0	0
CT findings, n (%)			
Hemoperitoneum ≤200 mL	6 (60)	4 (23.5)	5 (45.5)
Hemoperitoneum >200 mL	1 (10)	7 (41.2)	2 (18.2)
Mesenteric pneumoperitoneum	4 (40)	3 (17.6)	0
Bowel wall thickening	7 (70)	11 (64.7)	4 (36.4)
Arterial mesenteric vessel extravasation	0	5 (29.4)	6 (54.5)
Mesenteric stranding	8 (10)	13 (76.5)	8 (72.7)
Reduced bowel wall enhancement	1 (10)	2 (11.8)	1 (9.1)
Bowel wall discontinuity	0	2 (11.8)	0
Splenic injury	3 (30)	2 (11.8)	2 (18.2)
Anterior abdominal wall injury	1 (10)	3 (17.6)	2 (18.2)
CT mesenteric injury grade ≥4 (BIPS)	7 (70)	11 (64.7)	7 (63.6)
NA	1 (10)	3 (17.6)	3 (27.3)

ISS, Injury Severity Score; LOS, length of stay; NA, not available because of incomplete medical chart; NA (intubated), not available because of sedation-intubation of the patient.

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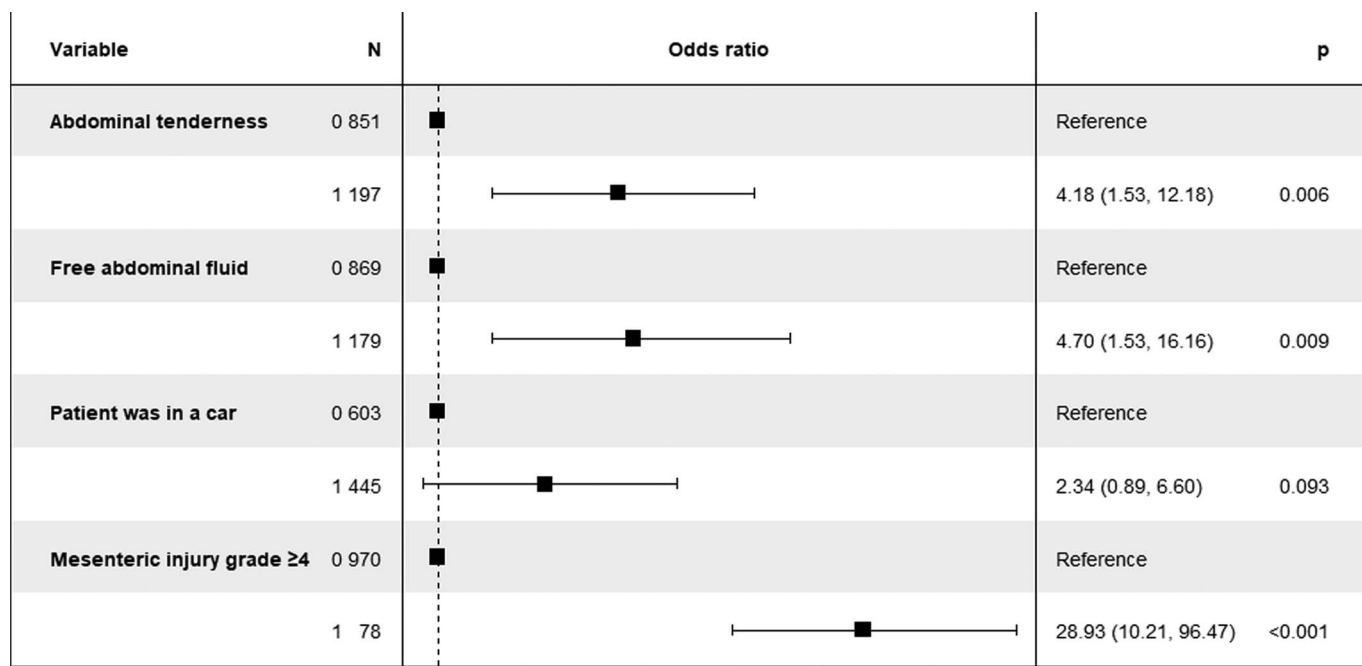


Figure 2. Multivariate analysis of the score items significantly associated with sBBMI in univariate analysis. Variables included in the multivariate analysis were selected based on their p value ($p < 0.001$) from the univariate analysis. The item of CT mesenteric injury grade ≥ 4 (BIPS) was used to represent all individual significant CT variables.

Patient Management

Of the 38 patients with sBBMI, 33 (86.8%) required surgical treatment and 4 (10.5%) underwent angioembolization (AE). One patient died before any treatment, and sBBMI was found at autopsy.

The most frequent sBBMIs found at exploration were active bleeding from a mesenteric vessel ($n = 24$) and bowel perforation ($n = 26$), either isolated or in association. Laparotomy was performed in 28 patients with sBBMI, of which 8 were conversions from LS. Five patients were successfully managed with LS alone. For the 33 patients with sBBMI undergoing surgical exploration of the abdomen, the median interval from ED arrival to operation was 143 minutes (IQR, 90–880 minutes). Seven patients (18%) with sBBMI underwent surgical exploration more than 24 hours after ED arrival, with a median time interval to operation of 56 hours (IQR, 33.4–100.8). Two directly underwent an LT, and five a diagnostic LS, of which four were converted to LT.

For the four patients undergoing successful AE for active mesenteric bleeding on CT, the median interval from ED arrival to embolization was 122 minutes (IQR, 105–138 minutes). One patient underwent a left colectomy for bowel necrosis 4 days after AE of the inferior mesenteric artery. Mortality was similar for patients with sBBMI who underwent early treatment (13.3%) compared with patients with delayed intervention (14.3%).

Performance of CT

For evaluation of CT performance, 81 patients were excluded from the initial population of 1,164 patients. These underwent no abdominal CT for either hemodynamic instability or absence of a clinical indication. Blunt bowel and mesenteric injury was found in 7 unstable patients without prior CT, leaving 31 patients with sBBMI in the subpopulation who underwent CT ($n = 1,083$).

Overall, 176 patients (16.3%) had free abdominal fluid. Among patients with sBBMI, 28 of 31 (90.3%) had free abdominal fluid on CT, in 19 cases as an isolated finding and in 9 cases with concomitant SOI (7 splenic and 2 liver injuries).

Specific CT Signs for sBBMI

Of the 31 patients with sBBMI undergoing CT, 16 (51.6%) presented CT signs specific for sBBMIs, either active mesenteric bleeding ($n = 9$), pneumoperitoneum ($n = 5$), or both ($n = 2$). Of these 16 patients with specific sBBMI signs on CT, 15 underwent immediate treatment (surgery in 12, AE in 3). One patient had a delayed surgical treatment (27.6 hours) because of missed free air in the CT and finally required a segmental resection of perforated small bowel. None of the patients with specific signs for sBBMI died.

Unspecific CT Signs for sBBMI

Of all 31 patients with sBBMI undergoing CT, 15 (48.4%) had no specific signs of significant bowel or mesenteric injury. Of these 15 patients (1 without any sign, 8 with a mesenteric contusion, 1 with free fluid without SOI, and 5 with both mesenteric contusion and free fluid), 1 died before any abdominal intervention 35 hours after his arrival because of severe traumatic brain injury, and 6 (40%) had a delay in diagnosis and treatment of more than 24 hours (Table 4). In five of six cases, LS or LT was motivated by developing peritoneal signs. Among these five patients, three underwent a second CT before surgery, which confirmed an sBBMI in two cases. In one case, specific signs of sBBMI were discovered during a CT of the pelvis obtained to assess a previous internal pelvic fixation. Diagnostic and surgical treatment delays of more than 24 hours were significantly more frequent in patients without specific sBBMI signs on CT (6 of 15) compared with patients with specific signs (1 of 16) ($p = 0.04$).

TABLE 4. Patients Without Specific CT Signs and Delayed sBBMI Diagnosis and Treatment (n = 6)

Patients (n = 6)	Delay (h)	2nd CT	Abdominal Intervention		sBBMI	Detailed Intervention
			Initial	Delayed		
1	56.2	Yes	—	LS → LT	Mesenteric laceration and SB ischemia	SB SR
2	74	Yes	—	LS → LT	Rectosigmoid SMT and ischemia	Rectosigmoid SR + colostomy
3	166.8	Yes*	—	LS → LT	SB necrotic segment	SB SR
4	38.2	No	—	LT	SB perforation	SB SR
5	25.4	Yes	—	LS → LT	SB ischemia and SMT	SB SR
6	139.4	No	AE**	LT	Cecal perforation and SMT of the right colon	Right colectomy

*Second CT of the pelvis obtained to assess a previous internal pelvic fixation.

**AE for SOI.

LS → LT, laparoscopy converted to laparotomy; SB, small bowel; SR, segmental resection; SMT, seromuscular tear.

Performance of Risk Scores

Overall (n = 917), there were 29 patients with sBBMI and 888 without. The BIPS, with a cutoff at 2, had a sensitivity of 69% and specificity of 90.3%, a PPV of 18.9% and an NPV of 98.9%. The RS with a cutoff at 8 had a sensitivity of 75.9% and a specificity of 84.6%, a PPV of 13.8%, and an NPV of 99.1%. The FS with a cutoff at 5, had a sensitivity of 75.6%, a specificity of 92.6%, a PPV of 25%, and an NPV of 99.2%. The best thresholds were 2 for the BIPS, 8 for the RS, and 5 for the FS (Fig. 3). The area under ROC curve was 87.6% (95% CI, 81.8–93.3%) for the BIPS, 89.2% (95% CI, 83.2–95.3%) for the RS, and 95.3% (95% CI, 92.7–97.9%) for the FS.

The comparison of the three curves showed a trend toward better performance for the FS compared with the BIPS ($p = 0.08$) and the RS ($p = 0.31$), while the RS had a better performance

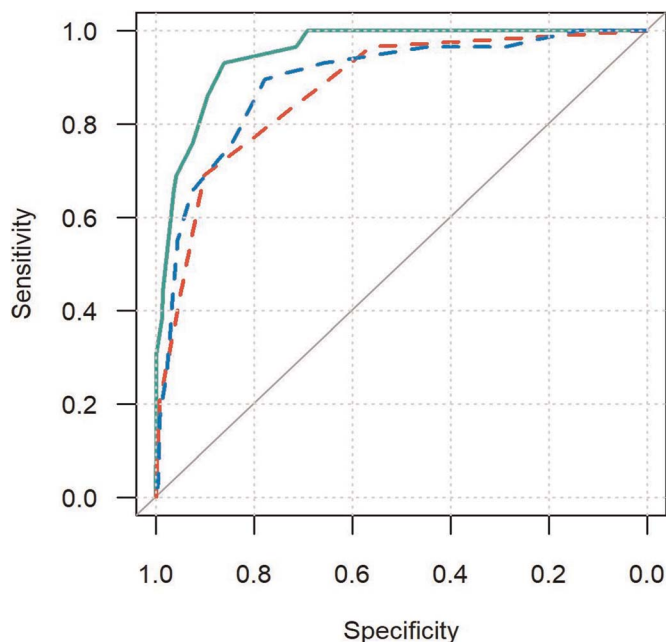


Figure 3. Receiver operating characteristic curves of the three scores. — Faget et al. score (FS), AUC of 95.3% (95% CI, 91.7–97.9%); - - - Raharimanantsoa et al. score (RS), AUC of 89.2% (95% CI, 83.2–95.3%); - - - McNutt et al. score (BIPS), AUC of 87.6% (95% CI, 81.8–93.3%). AUC, area under the curve.

compared with the BIPS ($p = 0.27$). The performances of the scores for each subtype of sBBMI (isolated bowel, combined bowel and mesenteric, isolated mesenteric) are summarized in Supplemental Digital Content (Supplementary Fig. 1A, <http://links.lww.com/TA/D461>). The FS still had the best performance, except for isolated bowel injuries, where the RS performed better than the two other scores.

Among the seven patients with delayed diagnosis and treatment (>24 hours), the BIPS and the RS would have indicated an sBBMI in four of seven cases, and the FS in three of seven cases. All scores identified the same patients, with the FS missing one. Only the RS would have identified the patient who died from severe head injury more than 24 hours after admission with a seromuscular colon injury found later at autopsy.

A total of 30 patients underwent a surgical intervention (29 LTs and 1 LS) in which no sBBMI was identified. In 24 cases, the indication for surgery was an intraoperatively confirmed high-grade SOI. In the remaining six cases, the indication was based on clinical suspicion. Five LTs and one LS were nontherapeutic surgical procedures. Among these, all three scores would have been truly negative in the same five and falsely positive in one of these cases.

DISCUSSION

The results of the present study show that delays in diagnosis and treatment of sBBMI are not uncommon. Despite the widespread use of abdominal CT, which is considered as the standard of care for the evaluation of hemodynamically stable trauma patients, 18% (7 of 38) of patients with sBBMI had a diagnostic and treatment delay of more than 24 hours after arrival in the ED. If the BIPS and the RS has been applied, more than half of the cases with a diagnostic and therapeutic delay would have been identified as having an sBBMI, which could have allowed for a more timely intervention. Hence, when CT findings during the initial assessment are negative or equivocal for sBBMI, using a score combining clinical, laboratory, and radiological findings may be helpful to select patients for early diagnostic LS.

When pathognomonic signs for sBBMI (pneumoperitoneum, active mesenteric bleeding, bowel wall discontinuity) are found on CT, a therapeutic delay is highly unlikely, since the presence of these signs usually mandates either surgery or interventional radiology. However, as demonstrated by one case, even when “hard” signs of sBBMI are present, they may be missed without

careful examination of the CT images and thus lead to a delay in diagnosis. Patients undergoing CT showing no or only unspecific signs of sBBMI suffered from diagnostic delays significantly more frequently (6 of 15) than patients with “hard” signs (1 of 16) ($p = 0.04$). Since 1 of the 15 patients with equivocal sBBMI findings underwent LT anyway because of diaphragmatic injury seen on CT and thus had no delay in sBBMI diagnosis, the absence of specific CT signs of sBBMI in patients without another indication for abdominal intervention on CT likely caused a diagnostic and treatment delay in 42.8% (6 of 14) of patients. Interestingly, CT in two patients with sBBMI undergoing intervention for another CT diagnosis (diaphragmatic rupture) or with sBBMI found at autopsy (3 of 31 [9.7%]) had a CT without any signs of BBMI. In line with our results, a recently published study by LeBedis et al.³² found a rate of false-negative CT of 9.1% in a series of patients with surgically proven BBMI.

Theoretically, systematic surgical exploration of symptomatic or obtunded patients with equivocal CT findings for sBBMI could allow for early treatment of all sBBMI. However, nontherapeutic LTs have complication rates of 8% to 41%.²² To avoid nontherapeutic interventions without delaying treatment in patients with unclear CT findings, several risk scores have been developed. Faget et al.²⁹ have proposed a scoring system exclusively based on nine CT criteria, with a sensitivity of 96.4%, a specificity of 91.5%, a PPV of 56.2%, and an NPV of 99.6%. The strength of this score is that all items are objective and easily obtainable if a CT is available. However, the authors of that study acknowledge the limited value of mesenteric stranding and hematoma. Of the 13 patients of our series with sBBMI who had only mesenteric stranding on CT, either isolated or with a small amount of free fluid, 7 patients would not have been identified as being at risk. Zarour et al.³⁰ developed the Z score for patients without SOI. It is based on CT signs (free fluid and signs of bowel injury) and clinical findings (abdominal tenderness and abdominal wall bruising). A Z score >9 was found to be an independent predictor for the need of exploratory LT. Other than the fact that it cannot be applied to patients with SOI (4 of the 31 patients with sBBMI in our series), it was judged impractical to assess this score's performance on a retrospective cohort since information bias would have made scoring impossible (i.e., grading of abdominal pain: absent, mild, moderate, and severe). Like in the present series, Schnuriger et al.⁹ have found a rather limited value of serial WBC counts to predict hollow viscus injury. The “BIPS” published by McNutt et al.¹⁴ also uses the WBC count (≥ 17 G/L) as one of the score variables. The two other items of the BIPS are abdominal tenderness and degree of mesenteric injury, based on a CT grading scale created by the same authors. The most recent score proposed by Raharimanantsoa et al.³¹ includes six clinical, CT- and injury mechanism–based variables and applies to patients injured in RTC. Had either of the last two scores^{14,31} been applied to the 16 patients with sBBMI in our cohort without specific signs on CT, 9 (56.3%) with the BIPS and 11 (68.8%) with the RS would have been correctly identified as at risk. Interestingly, only seven of them (43.8%) would have been identified with the FS. An unnecessary and potentially harmful delay in diagnosis could have been avoided in three of seven patients (42.9%) with the FS, four (57.1%) with the BIPS score, and five (71.4%) with the RS. However, all scores would have failed to recognize the likelihood of injury for two patients with delayed

diagnosis who had a nonbleeding mesenteric vascular injury with consecutive small bowel ischemia. The BIPS and the FS, but not the RS, would have failed to identify one patient who died from severe head injury more than 24 hours after admission with a seromuscular colon injury found later at autopsy.

Of the 38 patients with sBBMI in our series, 5 patients could be treated with LS without the need for conversion. Diagnostic LS in the context of abdominal trauma has been shown to be safe with very little associated morbidity and mortality.^{26,39–42} Two patients underwent early LS with intention to treat (sBBMI identified by CT), and no case was converted to LT. In the other three patients, LS was a diagnostic measure in the context of an unfavorable clinical course and allowed for correct identification and treatment of sBBMI. Moreover, all patients who underwent LS survived and no procedure-related complications occurred.

In analogy to the nonoperative management of SOI, AE is being increasingly used to treat active bleeding from other sources, including mesenteric vessels. Recently, Shin et al.⁴³ published 10 cases of traumatic mesenteric bleeding undergoing AE, with a success rate of 90% and no ischemic complications. This is not in line with the present findings, since one in four patients who underwent successful AE developed bowel ischemia and required segmental colon resection followed by a complicated postoperative course.

Limitations

Given the retrospective nature of the study, information bias is inherent. Also, data accuracy is subject to documentation errors in the trauma registry and patient record. Moreover, the study population is a selection of patients after RTC, but since this is by far the main accidental mechanism for blunt abdominal injuries worldwide, the scores should be applicable in most situations. Some, especially radiological, items and their correlation with others were studied based on a small number of cases, which affects the interpretability of certain results. These scores need to be studied prospectively. Moreover, scores that include imaging based or other noncategorical variables, such as the quantity of hemoperitoneum of the FS, are subject to interobserver reliability.⁴⁴ Because of the low incidence of sBBMI in general and in the present cohort, the results should be interpreted with caution. The low incidence may be responsible for the absence of a significant difference in mortality (twice as high in those with sBBMI) between patients with and without sBBMI. Also, because of the association between deceleration against a seatbelt and development of sBBMI, as well as the higher incidence of sBBMI among patients in cars in our study, including only patients who were in cars might have resulted in a more appropriate study population. However, such a restriction would have diminished the total number of observations, and it would not have been possible to assess the RS. Whatever the clinical or laboratory findings of a score, “hard” (pneumoperitoneum, active mesenteric bleeding, and bowel wall discontinuity) CT signs of mesenteric or bowel injury usually mandate a therapeutic intervention. However, limiting the study population to only patients with no or unclear radiological findings would have significantly diminished the event rate and would have rendered the assessment of the score performances impossible.

CONCLUSION

The present findings confirm that diagnostic and therapeutic delays for sBBMI are not uncommon despite the use of abdominal CT. Although none of the studied scores is 100% reliable, the FS had the best individual diagnostic performance among the three scores. However, the BIPS or the RS, which, in addition, relies on clinical and laboratory variables, may be helpful to select patients for early diagnostic LS when there are unspecific CT signs of bowel or mesenteric injury.

AUTHORSHIP

T.Z., F.A., B.P., and S.S. contributed in the literature review and study design. S.S. reviewed all CT images. F.A., M.B., and B.P. collected the data. T.Z., F.A., B.P., and M.B. analyzed and interpreted the data. F.A. and M.B. created the figures and the tables, and F.A., T.Z., S.S., B.P., M.B., V.D., and N.D. wrote the manuscript. All authors performed critical revision and editing, and read and approved the final manuscript.

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DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (<http://links.lww.com/TA/D462>). Ethics approval and consent to participate: The study protocol was approved by the local institutional review board (2016-00928), and all methods were carried out in accordance with relevant guidelines and regulations. Availability of data and materials: The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request. Funding: I, Fabio Agri, MD, attest on behalf of all authors that we had full access to the data of the study, conducted all data analyses independently from the funding entity, and take complete responsibility for the integrity and accuracy of the data reported in the manuscript. Trial registration: The study protocol was approved by the local institutional review board (CER-VD 2016-00928).

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