Journal of Trauma and Acute Care Surgery, Publish Ahead of Print
DOI: 10.1097/TA.0000000000004231

OPEN

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

Fabio Agri[1,2], Basile Pache[3], Mylène Bourgeat[1], Vincent Darioli[4], Nicolas Demartines[1,5], Sabine Schmidt[6**], Tobias Zingg[1**]

[1]Department of Visceral Surgery, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland

[2]Department of Administration and Finance, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland

[3]Department of Women-Mother-Child, Gynecology and Obstetrics Unit, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland.

[4]Department of Emergency Medicine, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland

[5]General Direction, General Director, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland

[6]Department of Diagnostic and Interventional Radiology, Lausanne University Hospital and University of Lausanne, 1011 Lausanne, Switzerland

[**]shared last authorship

Authors:

Fabio Agri, MD, fabio.agri@chuv.ch

Basile Pache, MD, basile.pache@chuv.ch

Mylène Bourgeat, mylene.bourgeat@chuv.ch

Vincent Darioli, MD, vincent.darioli@chuv.ch

Nicolas Demartines, Professor, demartines@chuv.ch

Sabine Schmidt, Professor, sabine.schmidt@chuv.ch

Tobias Zingg, PD MER, tobias.zingg@chuv.ch

Corresponding author:

Dr Tobias Zingg

Rue du Bugnon 46

1011 Lausanne

Switzerland

orcid.org/0000-0003-0905-2299

International member of EAST (ID 2880)

tobias.zingg@chuv.ch

Conflict of interest disclosure: No conflict of interest to disclose. All JTACS Disclosure forms have been supplied and are provided as supplemental digital content (http://links.lww.com/TA/D462).

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.

Author's contributions

TZ, FA, BP ans SS contributed to the literature review and study design. S.S. reviewed all CT images. FA, MB and BP collected the data. TZ, FA, BP and MB analysed and interpreted the data. FA and MB created the figures and the tables, and FA, TZ, SS, BP, MB, VD and ND wrote the manuscript. All authors performed critical revision and editing, and read and approved the final manuscript.

Acknowledgements

The authors thank the team of datamanagers of the trauma registry of Lausanne University Hospital (Centre Hospitalier Universitaire Vaudois – CHUV), Mrs Fabienne Ruefli and Mrs Aleksandra Chervet, for their availability and expertise concerning the registry data.

Trial registration: The study protocol was approved by the local institutional review board (CER-VD 2016-00928).

ABSTRACT

Background: Avoiding missed diagnosis and therapeutic delay for significant blunt bowel and mesenteric injuries (sBBMI) after trauma is still challenging despite the widespread use of computed tomography. Several scoring tools aiming at reducing this risk have been published. The purpose of the present work was to assess the incidence of delayed (>24h) 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 (RS) and by Faget (FS).

Methods: Population-based retrospective observational cohort study of adult trauma patients after road traffic crashes (RTC) admitted to Lausanne University Hospital, Switzerland, between 2008 and 2019 (n=1258) with reliable information about sBBMI status (n=1164) 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 RTC was 3.3% (38/1164) and in 18% (7/38) there was a diagnostic and treatment delay of more than 24 hours. The diagnostic performance of the FS, the RS and the BIPS to predict sBBMI, expressed as the area under the receiver operating characteristic (ROC) curve, were 95.3% (95% 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.

Level of evidence and study type: Level III, Prognostic/Epidemiological

Key words: Predictive scores, blunt bowel and mesenteric injuries, delayed diagnosis, diagnostic performance, diagnostic laparoscopy.

List of a abbreviations

AE: Angio-Embolization; AIS: Abbreviated Injury Scale; BBMI: Blunt Bowel and Mesenteric Injury; BIPS: Bowel Injury Prediction Score; CT: Computed Tomography; ED: Emergency Department; FA: Forensic Autopsy; FS: Faget Score; ISS: Injury Severity Score; LOS: Length Of Stay; LS: Laparoscopy; LT: Laparotomy; NPV: Negative Predictive Value; PPV: Positive Predictive Value; ROC: Receiver Operating Characteristc; RS: Raharimanantsoa Score; RTC: Road Traffic Crashes; SOI: Solid Organ Injury; sBBMI: Significant Blunt Bowel and Mesenteric Injury; WBC: White Blood Cell

BACKGROUND

Significant blunt bowel and mesenteric injuries (sBBMI) include full-thickness perforations, sero-muscular 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. Non-recognized sBBMI is the most frequent cause for delayed laparotomies (LT) after blunt abdominal trauma [4,5]. Even a relatively short deferral of 5-8 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 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 polytrauma 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 BBMI, especially in the presence of clinical findings or in obtunded patients with an unreliable physical exam [22]. For these situations and given the potential consequences of delayed diagnosis, surgical exploration is recommended. Due to its morbidity rates of 8-41%, non-therapeutic exploratory laparotomy should be avoided [24-27]. Diagnostic laparoscopy 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. Due to 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 developped 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 cut-off used, its originally reported sensitivity and specificity is respectively 91.1-100% and 85.7-97.6%, with a PPV of 41.4-82% and a NPV of 98.9-100% [29]. Depending on the cut-off 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.) [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].

METHODS

Study design

Single-center, registry-based retrospective cohort study, prepared to conform to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [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 *our institution*, a level I Trauma Center, including all consecutive patients over sixteen years old admitted to the trauma resuscitation area of the emergency department (ED) following a 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 (**Figure 1**).

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

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 for its proposed BIPS [14]. For the calculation of the FS (range -1-24), 1 point was deducted in case of a concurrent splenic injury.

Table 1. Score points per item for the three scores.

Demographic data, mortality, Injury Severity Score (ISS), abdominal and extremity Abbreviated Injury Scale (AIS), 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 constitutes a serious delay [4]. BBMI requiring either surgical or radiological treatment or obvious BBMI documented at autopsy were considered as significant. Patients who had none of the above, 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 non-availability of this information reflects reality and is not a limitation of the retrospective nature of the study.

The institutional polytrauma CT protocol was performed with a 64-detector row MD(multi-detector)CT system from January 2008 to August 2015 (Light Speed VCT 64 Pro; GE Healthcare, Milwaukee, WI, USA), and a 256-row MDCT system (Revolution CT; GE Healthcare, Milwaukee, WI, US) 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 (25s) centered on the thorax, and 2.5 mm reconstructed axial slices with increments of 2 mm during the venous phase (80s) centered on the abdomen and pelvis, after intravenous injection of iodinated contrast medium Accupaque® at a flow rate of 4 ml/s (120 kV, 300 mA, table speed 55mm per rotation (0.8s), pitch 1.375). Automatic tube current modulation in all three axes (SmartmA) was used as well as iterative reconstruction algorithm ASIR. 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 [14] and Faget [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 lower and upper interquartile ranges or with interquartile range ($IQR=Q_3-Q_1$). Qualitative variables were compared using Fisher 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 (AUC) was calculated with 95% CI and statistical comparisons used the DeLong method [38].

RESULTS

Participants

From January 2008 to December 2019, 1258 patients were admitted to the trauma resuscitation area of *our institution* ED following a 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 due to their incomplete datasets for the calculation of any of the scores (**Figure 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 due to one or more missing items for the calculation of one or more scores, resulting in a population of 917 patients on whom all three scores could be tested.

Descriptive data and outcome

The prevalence of sBBMI in the group of patients with known sBBMI status was 3.3% (38/1164). Overall (n=1164), 48 patients (4%) died before any intervention and their sBBMI status was revealed by forensic autopsy (FA) findings. sBBMI was found in one of these patients. **Table 2a** shows the characteristics of the study population with and without sBBMI.

Table 2b summarizes the characteristics of the 3 subtypes of sBBMI (isolated bowel/combined bowel and mesenteric/isolated mesenteric).

Table 2a. Characteristics of the study population with (+) and without (-) sBBMI (n=1164).

Table 2b. Characteristics of the 3 sub-types of sBBMI.

Median LOS (18 days vs 9 days, $p<0.001$), ISS (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. 30-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 ($p<0.001$), travelling 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 travelling 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 employed 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.

Figure 2. Multivariate analysis of the score items significantly associated with sBBMI in univariate analysis.

Patient management

Of the 38 patients with sBBMI, 33 (86.8%) required surgical treatment and four (10.5%) underwent 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. LT was performed in 28 patients with sBBMI, of which eight 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). 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 a LT, five a diagnostic LS, of which four were converted to LT.

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

Performance of CT

For evaluation of CT performance, 81 patients were excluded from the initial population of 1164 patients. These underwent no abdominal CT for either hemodynamic instability or absence of a clinical indication. sBBMI was found in seven unstable patients without prior CT, leaving 31 patients with sBBMI in the sub-population who underwent CT (n=1083).

Overall, 176 (16.3%) patients had free abdominal fluid. Among patients with sBBMI, 28/31 (90.3%) had free abdominal fluid on CT, in 19 cases as an isolated finding and in nine cases with concomitant SOI (seven splenic and two 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 three). One patient had a delayed surgical treatment (27.6 hours) due to missed free air in the CT, and finally required a segmental resection of perforated small bowell. 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 (one without any sign, eight with a mesenteric contusion, one with free fluid without SOI and five with both mesenteric contusion and free fluid), one died before any abdominal intervention 35 hours after his arrival due to severe traumatic brain injury, and six (40%) had a delay in diagnosis and treatment of more than 24 hours (**Table 3**). In 5/6 cases, LS or LT was motivated by developing peritoneal signs. Among these five patients, three underwent a second CT before surgery which confirmed a sBBMI in 2 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 (6/15) compared to patients with specific signs (1/16) (p=0.04).

Table 3. Patients without specific CT signs and delayed sBBMI diagnosis and treatment (n=6).

Performance of risk scores

Overall (n=917), there were 29 patients with sBBMI and 888 without. The BIPS, with a cut-off at 2, had a sensitivity of 69% and specificity of 90.3%, a PPV of 18.9% and a NPV of 98.9%. The RS with a cut-off at 8, had a sensitivity of 75.9% and a specificity of 84.6%, a PPV of 13.8% and a NPV of 99.1%. The FS with a cut-off at 5, had a sensitivity of 75.6%, a specificity of 92.6%, a PPV of 25% and a NPV of 99.2%. The best thresholds were 2 for the BIPS, 8 for the RS and 5 for the FS (**Figure 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.

Figure 3. ROC curves of the three scores.

The comparison of the three curves showed a trend towards better performance for the FS compared to the BIPS (p=0.08) and the RS (p=0.31), while the RS had a better performance compared to the BIPS (p=0.27). The performances of the scores for each sub-type of sBBMI (isolated bowel, combined bowel and mesenteric, isolated mesenteric) are summarized in **Supplementary Figure A, 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 7 patients with delayed diagnosis and treatment (>24 hours), the BIPS and the RS would have indicated a sBBMI in 4/7 cases, and the FS in 3/7 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 sero-muscular colon injury found later at autopsy.

A total of 30 patients underwent a surgical intervention (29 laparotomies and 1 laparoscopy) in which no sBBMI was identified. In 24 cases, the indication for surgery was an intraoperatively confirmed high-grade solid organ injury. In the remaining six cases, the indication was based on clinical suspicion. Five laparotomies and one laparoscopy were non-therapeutic 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% (7/38) 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 a 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 laparoscopy.

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. But 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 (6/15) than patients with “hard” signs (1/16) (*p*=0.04). Since one 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% (6/14) of patients. Interestingly, CT in two patients with sBBMI undergoing intervention for another CT diagnosis (diaphragmatic rupture) or with sBBMI found at autopsy (3/31 = 9.7%) had a CT without *any* signs of BBMI. In line with our results, a recently published study by LeBedis et al. found a rate of false negative CT of 9.1% in a series of patients with surgically proven BBMI [32].

Theoretically, systematic surgical exploration of symptomatic or obtunded patients with equivocal CT findings for sBBMI could allow for early treatment of all sBBMI. But non-therapeutic laparotomies have complication rates of 8-41% [22]. To avoid non-therapeutic interventions without delaying treatment in patients with unclear CT findings, several risk scores have been developed. Faget et al. 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 a NPV of 99.6% [29]. 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, seven patients would not have been identified as being at risk. Zarour et al. 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 laparotomy [30]. 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 – severe). Like in the present series, Schnüriger et al. have found a rather limited value of serial WBC counts to predict hollow viscus injury (HVI) [9]. The “BIPS” published by McNutt et al. also uses the WBC count (≥17 G/l) as one of the score variables [14]. 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 recently score proposed by Raharimanantsoa et al. includes six clinical, CT- and injury mechanism-based variables and applies to patients injured in RTC [31]. 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, nine (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 out 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 non-bleeding 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 sero-muscular colon injury found later at autopsy.

Of the 38 patients with sBBMI in our series, five patients could be treated with LS without the need for conversion. Diagnostic laparoscopy 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 laparoscopy survived and no procedure-related complications occurred.

In analogy to the non-operative management of SOI, AE is being increasingly used to treat active bleeding from other sources, including mesenteric vessels. Recently, Shin et al. published 10 cases of traumatic mesenteric bleeding undergoing AE, with a success rate of 90% and no ischemic complications [43]. This is not in line with the present findings, since 1 in 4 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 non-categorical variables, such as the quantity of hemoperitoneum of the FS, are subject to inter-observer reliability [44]. Due to 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, due to the association between deceleration against a seatbelt and development of sBBMI, and 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 rely 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.

DECLARATIONS

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.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding source to declare

REFERENCES

1. Dauterive AH, Flancbaum L, Cox EF. **Blunt intestinal trauma. A modern-day review**. *Ann surg.* 1985;**201**(2):198-203.
2. Watts DD, Fakhry SM, Group EM-IHVIR. **Incidence of hollow viscus injury in blunt trauma: an analysis from 275,557 trauma admissions from the East multi-institutional trial**. *J Trauma.* 2003;**54**(2):289-294.
3. Guarino J, Hassett JM, Jr., Luchette FA. **Small bowel injuries: mechanisms, patterns, and outcome**. *J Trauma.* 1995;**39**:1076-1080.4.
4. Sorensen VJ, Mikhail JN, Karmy-Jones RC. **Is delayed laparotomy for blunt abdominal trauma a valid quality improvement measure in the era of nonoperative management of abdominal injuries?** *J Trauma.* 2002;**52**:426-433.
5. Smyth L, Bendinelli C, Lee N, Reeds MG, Loh EJ, Amico F et al. **WSES guidelines on blunt and penetrating bowel injury: diagnosis, investigations, and treatment.** World J Emerg Surg. 2022;17:13.
6. Fakhry SM, Brownstein M, Watts DD, Baker CC, Oller D. **Relatively short diagnostic delays (<8 hours) produce morbidity and mortality in blunt small bowel injury: an analysis of time to operative intervention in 198 patients from a multicenter experience**. *J Trauma.* 2000;**48**:408-414; discussion 414-405.
7. Malinoski DJ, Patel MS, Yakar DO, Green D, Qureshi F, Inaba K et al. **A diagnostic delay of 5 hours increases the risk of death after blunt hollow viscus injury**. *J Trauma.* 2010;**69**:84-87.
8. Fakhry SM, Watts DD, Luchette FA, Group EM-IHVIR. **Current diagnostic approaches lack sensitivity in the diagnosis of perforated blunt small bowel injury: analysis from 275,557 trauma admissions from the EAST multi-institutional HVI trial**. *J Trauma.* 2003;**54**:295-306.

9. Schnuriger B, Inaba K, Barmparas G, Eberle BM, Lustenberger T, Lam L et al. **Serial white blood cell counts in trauma: do they predict a hollow viscus injury?** *J Trauma.* 2010;**69**:302-307.

10. Wotherspoon S, Chu K, Brown AF. **Abdominal injury and the seat-belt sign**. *Emerg Med (Fremantle).* 2001;**13**:61-65.

11. Chandler CF, Lane JS, Waxman KS. **Seatbelt sign following blunt trauma is associated with increased incidence of abdominal injury**. *Am Surg.* 1997;**63**:885-888.

12. Chidester S, Rana A, Lowell W, Hayes J, Groner J. **Is the "seat belt sign" associated with serious abdominal injuries in pediatric trauma?** *J Trauma.* 2009;**67**:S34-36.

13. Porter RS, Zhao N. **Patterns of injury in belted and unbelted individuals presenting to a trauma center after motor vehicle crash: seat belt syndrome revisited**. *Ann Emerg Med.* 1998;**32**:418-424.

14. McNutt MK, Chinapuvvula NR, Beckmann NM, Camp EA, Pommerening MJ, Laney RW et al. **Early surgical intervention for blunt bowel injury: the Bowel Injury Prediction Score (BIPS)**. *J Trauma Acute Care Surg.* 2015;**78**:105-111.

15. Livingston DH, Lavery RF, Passannante MR, Skurnick JH, Fabian TC, Fry DE et al. **Admission or observation is not necessary after a negative abdominal computed tomographic scan in patients with suspected blunt abdominal trauma: results of a prospective, multi-institutional trial**. *J Trauma.* 1998;44:273-280; discussion 280-272.

16. Rutledge R, Hunt JP, Lentz CW, Fakhry SM, Meyer AA, Baker CC et al. **A statewide, population-based time-series analysis of the increasing frequency of nonoperative management of abdominal solid organ injury**. *Ann Surg.* 1995;**222**:311-322; discussion 322-316.

17. Butela ST, Federle MP, Chang PJ, Thaete FL, Peterson MS, Dorvault CJ et al. **Performance of CT in detection of bowel injury**. *AJR Am J Roentgenol.* 2001;**176**:129-135.

18. Peitzman AB, Makaroun MS, Slasky BS, Ritter P. **Prospective study of computed tomography in initial management of blunt abdominal trauma**. *J Trauma.* 1986;**26**:585-592.

19. Malhotra AK, Fabian TC, Katsis SB, Gavant ML, Croce MA. **Blunt bowel and mesenteric injuries: the role of screening computed tomography**. *J Trauma.* 2000;**48**:991-1000.

20. Matsushima K, Mangel PS, Schaefer EW, Frankel HL. **Blunt hollow viscus and mesenteric injury: still underrecognized**. *World J Surg.* 2013;**37**:759-765.

21. Joseph DK, Kunac A, Kinler RL, Staff I, Butler KL. **Diagnosing blunt hollow viscus injuries: Is computed tomography the answer?** Am J Surg. 2013;205:414-418.

22. Blackley SK, Smith WC, Lee YL, Kinnard C, Williams AY, Butts CC *et al.* **Identifying radiographic and clinical indicators to reduce the occurrence of nontherapeutic laparotomy for blunt bowel mesenteric injury.** Am Surg. 2023;**28**:31348231174009. doi: 10.1177/00031348231174009.

23. Zingg T, Agri F, Bourgeat M, Yersin B, Romain B, Schmidt S *et al*. **Avoiding delayed diagnosis of significant blunt bowel and mesenteric injuries: Can a scoring tool make the difference? A 7-year retrospective cohort study.** *Injury.* 2018;**49**:33-41

24. Renz BM, Feliciano DV. **Unnecessary laparotomies for trauma: a prospective study of morbidity**. *J Trauma.* 1995;**38**:350-356.

25. Demetriades D, Vandenbossche P, Ritz M, Goodmann D, Kowalszik J. **Non-therapeutic operations for penetrating trauma: early morbidity and mortality**. *Br J surg.* 1993;**80**:860-861.

26. Hasaniya N, Demetriades D, Stephens A, Dubrowskiz R, Berne T. **Early morbidity and mortality of non-therapeutic operations for penetrating trauma**. *Am Surg.* 1994;**60**:744-747.

27. Li T, Robertson-More C, Maclean AR, Dixon E, Navsaria P, Nicol AJ et al. **Bowel obstructions and incisional hernias following trauma laparotomy and the nonoperative therapy of solid organ injuries: A retrospective population-based analysis**. *J Trauma Acute Care Surg.* 2015;**79**:386-392.

28. Li Y, Xiang Y, Wu N, Wu L, Yu Z, Zhang M et al. **A Comparison of Laparoscopy and Laparotomy for the Management of Abdominal Trauma: A Systematic Review and Meta-analysis**. *World J Surg.* 2015;**39**:2862-2871.

29. Faget C, Taourel P, Charbit J, Ruyer A, Alili C, Molinari N et al. **Value of CT to predict surgically important bowel and/or mesenteric injury in blunt trauma: performance of a preliminary scoring system**. *Eur Radiol.* 2015;**25**:3620-3628.

30. Zarour A, El-Menyar A, Khattabi M, Tayyem R, Hamed O, Mahmood I et al. **A novel practical scoring for early diagnosis of traumatic bowel injury without obvious solid organ injury in hemodynamically stable patients**. *Int J Surg.* 2014;**12**:340-345.

31. Raharimanantsoa M, Zingg T, Thiery A, Brigand C, Delhorme JB, Romain B. **Proposal of a new preliminary scoring tool for early identification of significant blunt bowel and mesenteric injuries in patients at risk after road traffic crashes**. *Eur J Trauma Emerg Surg.* 2018;**44**:779-785.

32. LeBedis CA, Anderson SW, Bates DD, Khalil R, Matherly D, Wing H, Burke PA et al. **CT imaging signs of surgically proven bowel trauma**. *Emer Radiol.* 2016;**23**:213-219.

33. Wandling M, Cuschieri J, Kozar R, O'Meara L, Celii A, Starr W et al. **Multi-center validation of the Bowel Injury Predictive Score (BIPS) for the early identification of need to operate in blunt bowel and mesenteric injuries.** Injury. 2022;**53**:122-128. doi: 10.1016/j.injury.2021.07.026. Epub 2021 Jul 21. PMID: 34380598.

34. Vandenbroucke JP, von Elm E, Altman DG, Gotzsche PC, Mulrow CD, Pocock SJ, et al. STROBE Initiative. **Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration**. *Int J Surg.* 2014;**12**:1500-1524.

35. R Core Team (2023): **R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2023. https://www.R-project.org/. Accessed 12 July 2023.**

36. Hanley JA, McNeil BJ. **The meaning and use of the area under a receiver operating characteristic (ROC) curve**. *Radiology.* 1982;**143**:29-36.

37. Robin X, Turck N, Hainard A, Tiberti N, Lisacek F, Sanchez JC, Muller M. **pROC: an open-source package for R and S+ to analyze and compare ROC curves**. *BMC Bioinformatics.* 2011;**12**:77.

38. DeLong ER, DeLong DM, Clarke-Pearson DL. **Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach**. *Biometrics.* 1988;**44**:837-845.

39. Mathonnet M, Peyrou P, Gainant A, Bouvier S, Cubertafond P. **Role of laparoscopy in blunt perforations of the small bowel**. *Surg Endosc.* 2003;**17**:641-645.

40. Mitsuhide K, Junichi S, Atsushi N, Masakazu D, Shinobu H, Tomohisa E et al. **Computed tomographic scanning and selective laparoscopy in the diagnosis of blunt bowel injury: a prospective study**. *J Trauma.* 2005;**58**:696-701; discussion 701-693.

41. Rossi P, Mullins D, Thal E. **Role of laparoscopy in the evaluation of abdominal trauma**. *American journal of surgery* 1993, **166**:707-710; Discussion 710-701.

42. Villavicencio RT, Aucar JA. **Analysis of laparoscopy in trauma**. *J Am Coll Surg.* 1999;**189**:11-20.

43. Shin JS, Shin JH, Ko HK, Kim JW, Yoon HK. **Transcatheter arterial embolization for traumatic mesenteric bleeding: a 15-year, single-center experience**. *Diagn Interv Radiol.* 2016;**22**:385-389.

44. Zingg T, Uldry E, Omoumi P, Clerc D, Monier A, Pache B et al. Interobserver reliability of the Tile classification system for pelvic fractures among radiologists and surgeons. Eur Radiol. 2021;31:1517-1525.

List of figure titles/legends

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

RS : Raharimanantsoa Score ; FS : Faget Score ; BIPS : Bowel Injury Prediction Score

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 included but not all individual items.

Figure 3. ROC curves of the three scores.

— Faget et al. score (FS), area under the curve (AUC) 95.3% (95% CI: 91.7%-97.9)

– – Raharimanantsoa et al. score (RS), AUC 89.2% (95% CI:83.2%-95.3%)

– – McNutt et al score (BIPS), AUC 87.6% (95% CI: 81.8%-93.3%)

Supplementary Figure A. Performances of the scores for different sub-type of sBBMI.

a) Bowel perforation only (n=9)

— Faget et al. score (FS): AUC 91.5% (95% CI: 84.9%-98.1%)

– –Raharimanantsoa et al. score (RS): AUC 93.1% (95% CI: 87.1%-99.2%)

– –McNutt et al score (BIPS): AUC 87.8% (95% CI:79.8%-95.8%)

b) Mesenteric injury with bowel perforation (n=13)

— Faget et al. score (FS): AUC 95.7% (95% CI: 92%-99.4%)

– –Raharimanantsoa et al. score (RS): AUC 83.8% (95% CI: 71.3%-96.2%)

– –McNutt et al score (BIPS): AUC 87.4% (95% CI: 80.4%-94.4%)

c) Mesenteric injury only (n=7)

— Faget et al. score (FS): AUC 95.7% (95% CI: 93.3%-98.1%)

– –Raharimanantsoa et al. score (RS): AUC 91.1% (95% CI: 85.9%-96.2%)

– –McNutt et al score (BIPS): AUC 84.3% (95% CI: 85.9%-96.2%)

d) Bowel perforation with and without mesenteric injury (n=22)

— Faget et al. score (FS): AUC 95.7% (95% CI: 93.3%-98.1%)

– –Raharimanantsoa et al. score (RS): AUC 91.1% (95% CI: 85.9%-96.2%)

– –McNutt et al score (BIPS): AUC 84.3% (95% CI: 85.9%-96.2%)

AUC: Area under the curve

Figure 1

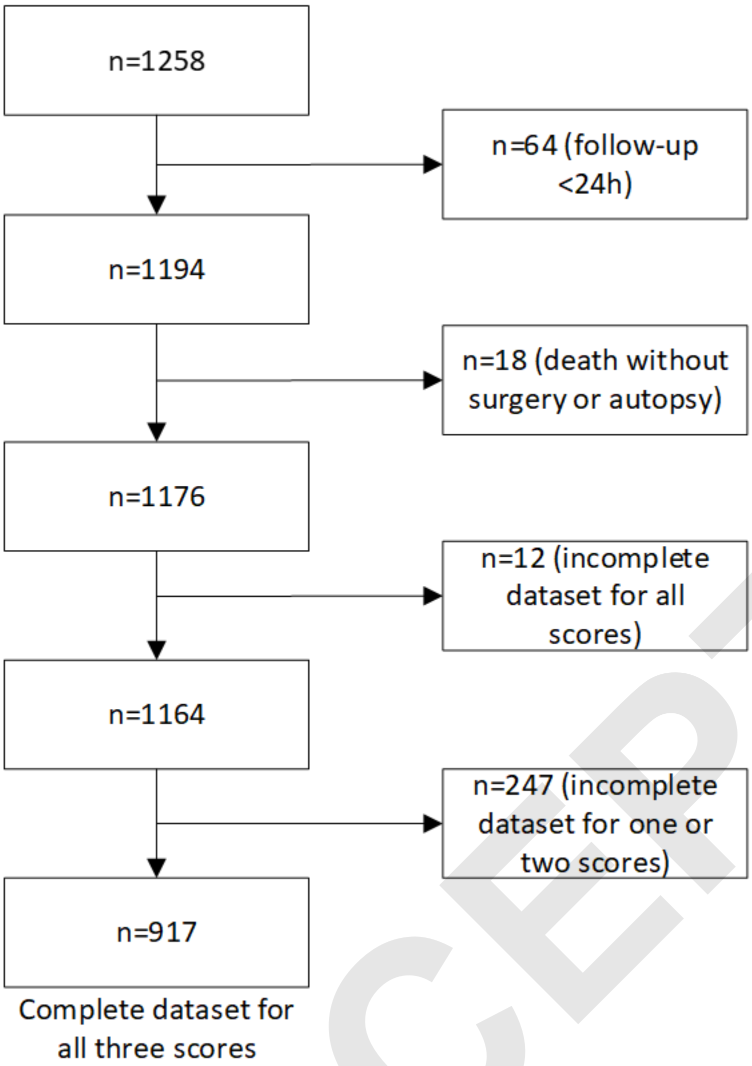

n=1258
n=64 (follow-up <24h)
n=1194
n=18 (death without surgery or autopsy)
n=1176
n=12 (incomplete dataset for all scores)
n=1164
n=247 (incomplete dataset for one or two scores)
n=917
Complete dataset for all three scores

Figure 2

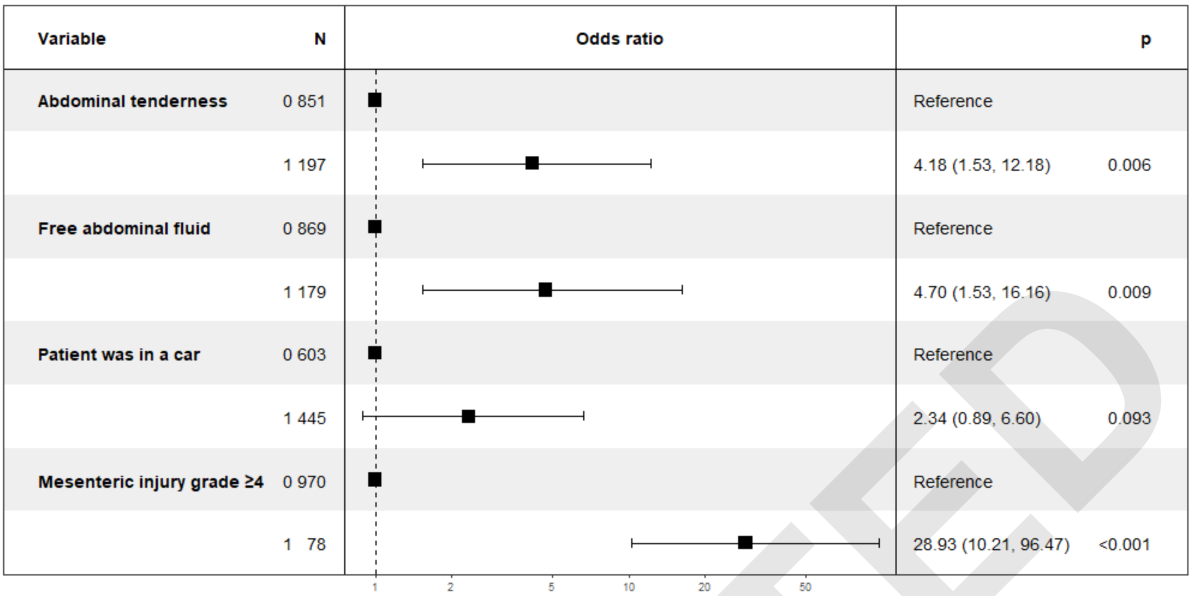

Variable
N
Odds ratio
p
Abdominal tenderness
0 851
Reference
1 197
4.18 (1.53, 12.18)
0.006
Free abdominal fluid
0 869
Reference
1 179
4.70 (1.53, 16.16)
0.009
Patient was in a car
0 603
Reference
1 445
2.34 (0.89, 6.60)
0.093
Mesenteric injury grade ≥4
0 970
Reference
1 78
28.93 (10.21, 96.47)
<0.001
1
2
5
10
20
50

Figure 3

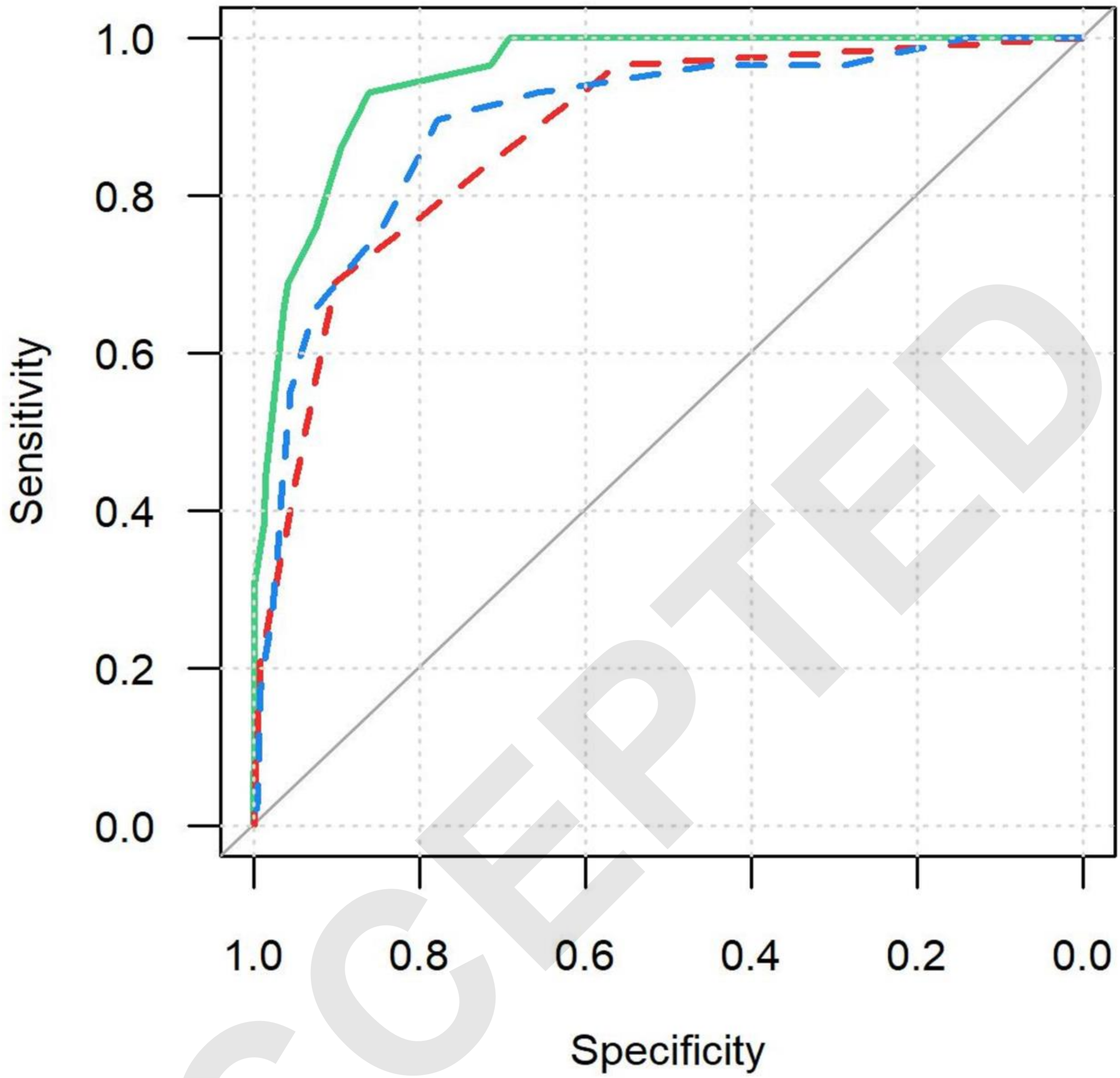


Table 1. Score points per item for the three scores.

BIPS (range 0-3, cut-off ≥2 pts)	Pts	RS (range 0-14, cut-off ≥8 pts)	Pts	FS (range -1-24, cut-off ≥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 >200ml	3
Mesenteric injury grade ≥4	1			Mesenteric pneumoperitoneum	5
Mesenteric injury grade		Long bone fracture	1	Bowell wall thickening	2
1. Isolated mesenteric contusion* without associated bowel wall thickening or adjacent interloop fluid collection		Abdominal tenderness	2	Active mesenteric extravasation	3
		Impact against a vehicle in motion	2	Mesenteric stranding	3
				Reduced bowel wall enhancement compared to nearby bowel segments	1
2. Mesenteric hematoma** <5cm without associated bowel wall thickening or adjacent interloop fluid collection		Patient was on a motorbike	1		
		Patient was in a car	3	Bowel wall discontinuity	5
				Anterior abdominal wall injury	2
3. Mesenteric hematoma > 5cm without associated bowel wall thickening or adjacent interloop fluid collection				Concurrent splenic injury	-1
4. Mesenteric contusion or hematoma (any size) with associated bowel wall thickening† or adjacent interloop fluid collection‡					
5. Active vascular or oral contrast extravasation bowel transection or pneumoperitoneum					

*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; BIPS: Bowel Injury Prediction Score; RS: Raharimanantsoa Score; FS: Faget Score.

Table 2a. Characteristics of the study population with (+) and without (-) sBBMI (n=1164).

Patient characteristics and score items	**sBBMI + n=38 (3.3 %)**	**sBBMI n=1126 (96.7 %)**	***p-value***
Age			
Years, median (IQR)	37 (24-56)	38 (24-54)	0.97
Sex, n (%)			
Male	25 (65.8)	834 (74.1)	0.25
Female	13 (34.2)	292 (25.9)	
ISS			
Score, median (IQR)	25 (17-34)	14 (9-24)	< **0.001**
LOS			
Days, median (IQR)	18 (9-39)	9 (3-19)	< **0.001**
Mortality			
30-days, n (%)	5 (13.2)	71 (6.3)	0.10
Admission to death (days), median (IQR)	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 ≤200ml	15 (39.5)	84 (7.5)	< **0.001**
Hemoperitoneum >200ml	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)	

Table 2b. Characteristics of the 3 sub-types 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			
Years, median (IQR)	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			
Days, median (IQR)	15 (10-31)	16 (5-26)	36 (24-46)
Mortality			
30-days, n (%)	0	5 (29.4)	0
Admission to death (days), median (IQR)	-	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 ≤200ml	6 (60)	4 (23.5)	5 (45.5)
Hemoperitoneum >200ml	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)

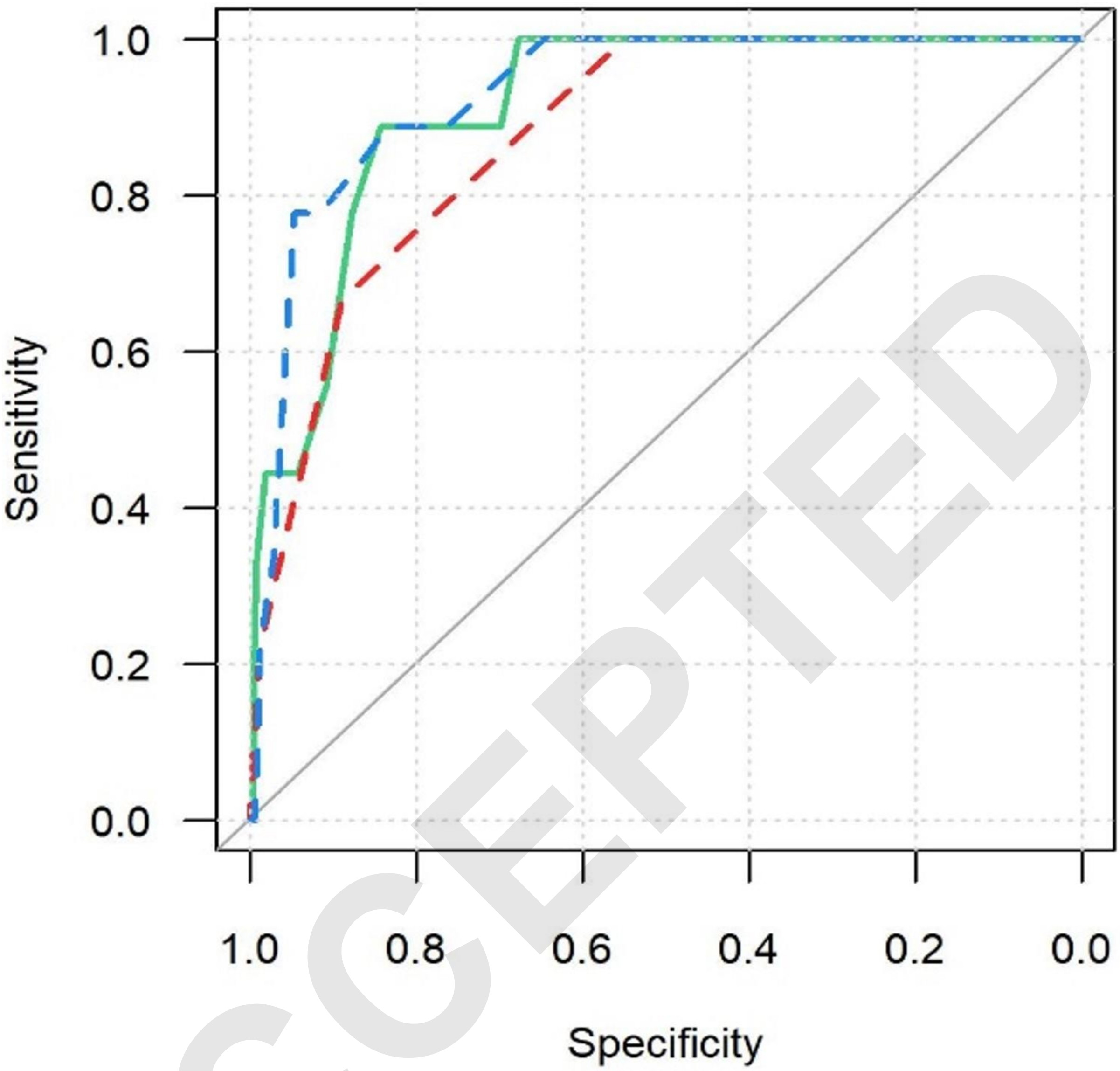
ISS: Injury Severity Score; LOS: Length of stay; NA: not available due to incomplete medical chart; NA (intubated): not available due to sedation-intubation of the patient.

Table 3. Patients without specific CT signs and delayed sBBMI diagnosis and treatment (n=6).

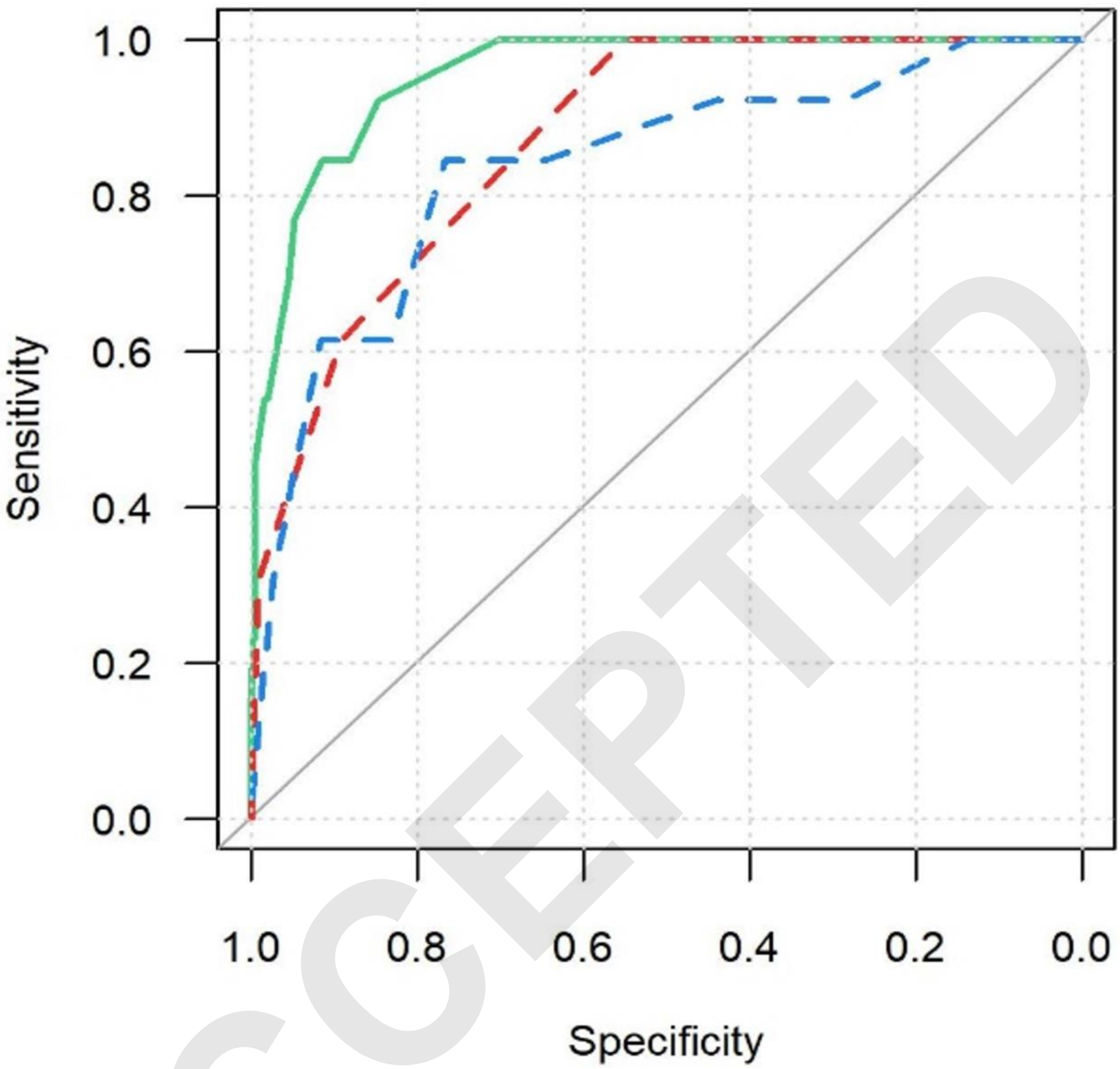
Patients (n=6)	Delay (h)	2nd CT	Abdominal intervention		sBBMI	Detailed intervention
			Initial	Delayed		
1	56.2	Yes	-	LS → LT	Mesenteric laceration & SB ischemia	SB SR
2	74	Yes	-	LS → LT	Recto-sigmoid SMT & ischemia	Recto-sigmoid SR + colostomy
3	166.8	Yes†	-	LS → LT	SB Necrotic segment	SB SR
4	38.2	No	-	LT	SB perforation	SB SR
5	25.4	Yes	-	LS → LT	SB ischemia & SMT	SB SR
6	139.4	No	AE‡	LT	Caecal perforation & SMT of the right colon	Right colectomy

†2nd CT of the pelvis obtained to assess a previous internal pelvic fixation; ‡AE for SOI; LS → LT: laparoscopy (LS) converted to laparotomy (LT); SB: Small Bowel; SR: Segmental Resection; SMT: Sero-Muscular Tear.

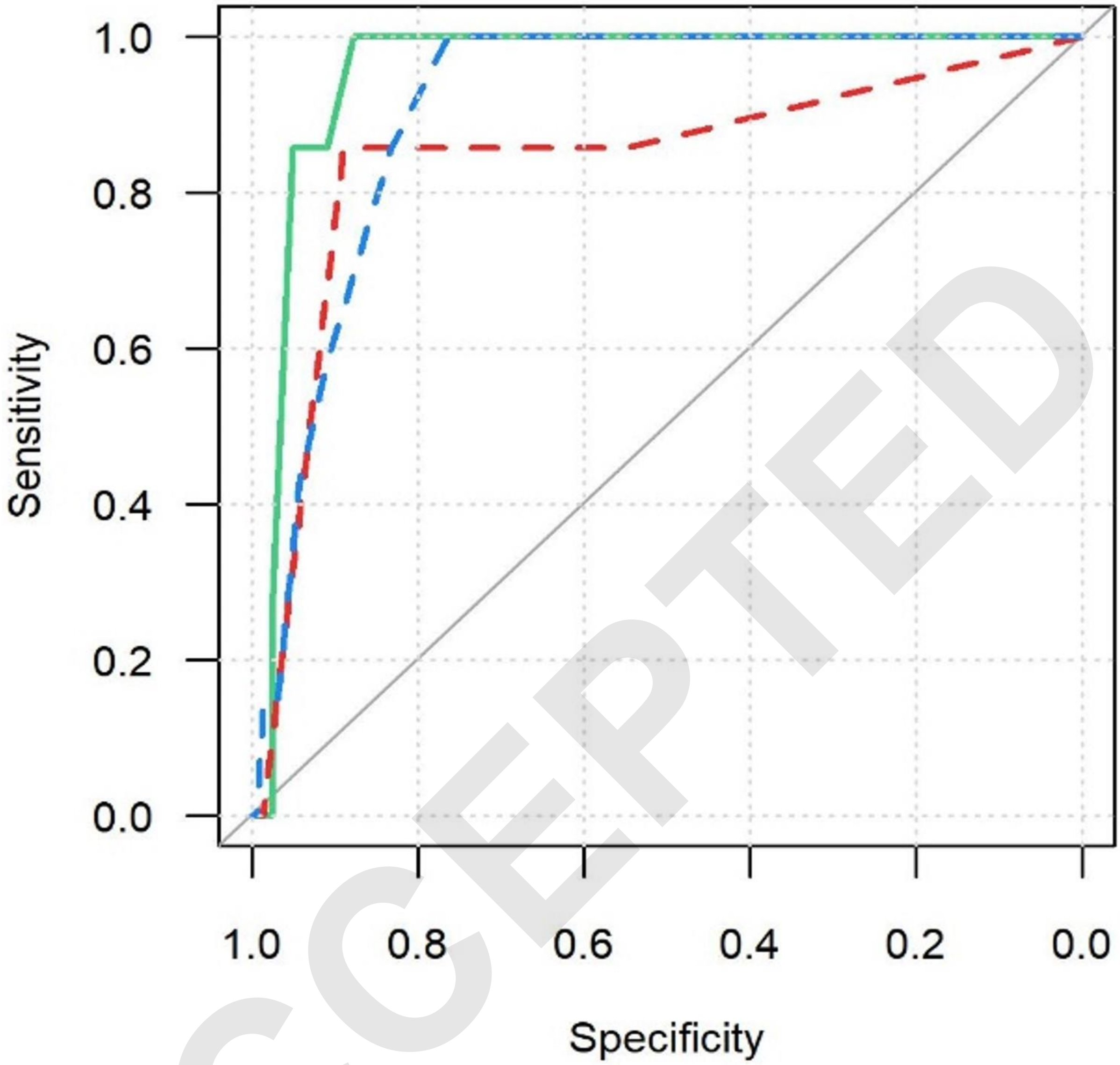
Supplementary Figure A



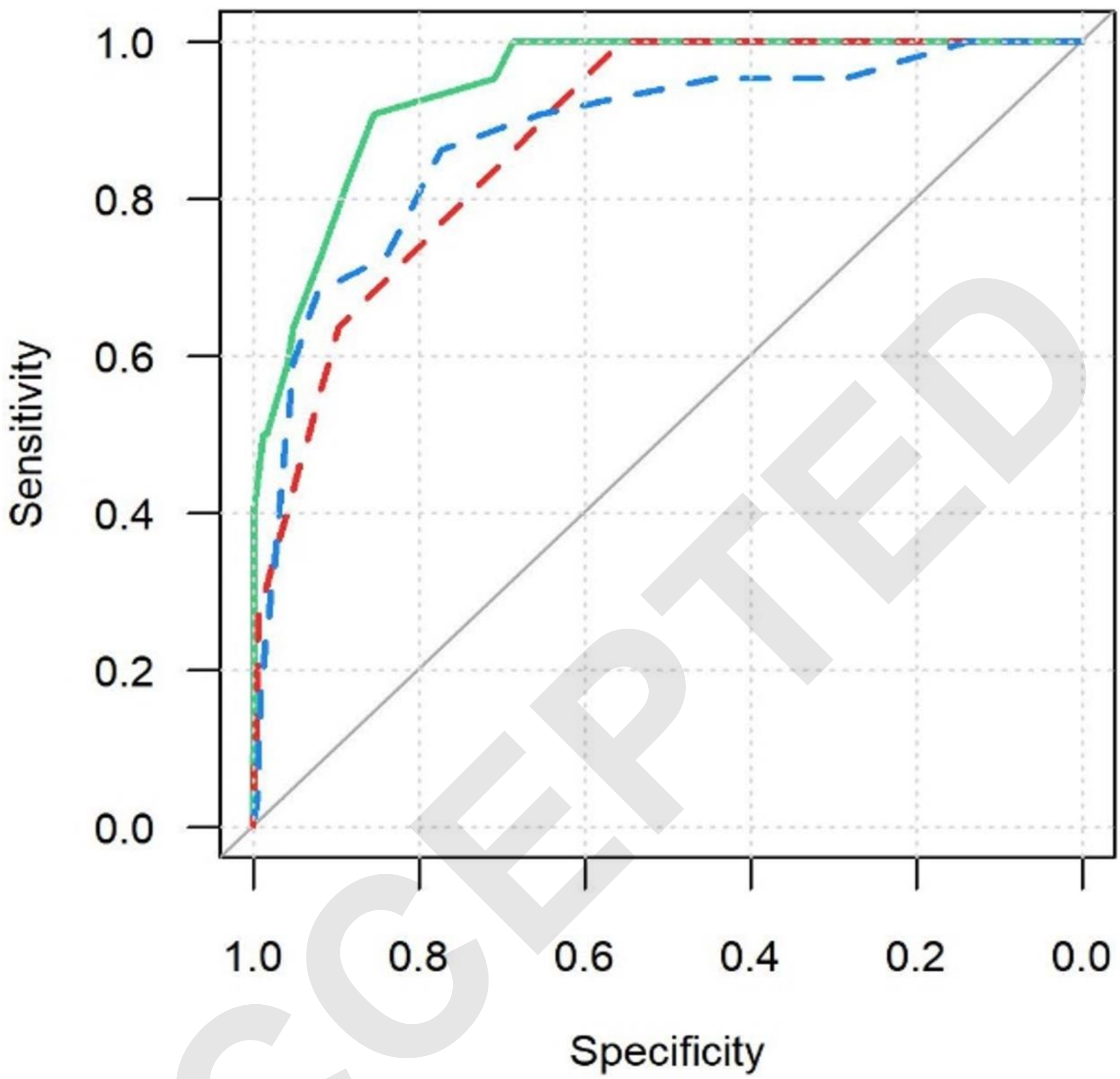
Supplementary Figure B



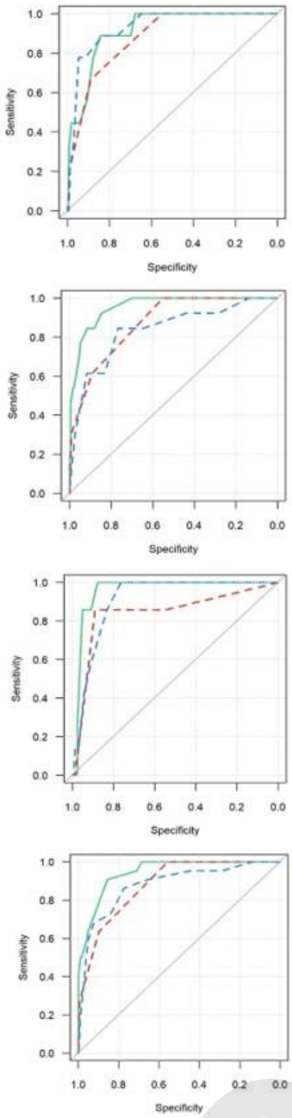
Supplementary Figure C



Supplementary Figure D



Supplementary Figure abcd



a) Bowel perforation only (n=9)
— Faget et al. score (FS): AUC 91.5%
(95% CI: 84.9%-98.1%)
– –Raharimanantsoa et al. score (RS): AUC 93.1%
(95% CI: 87.1%-99.2%)
– –McNutt et al score (BIPS): AUC 87.8%
(95% CI:79.8%-95.8%)

b) Mesenteric injury with bowel perforation (n=13)
— Faget et al. score (FS): AUC 95.7%
(95% CI: 92%-99.4%)
– –Raharimanantsoa et al. score (RS): AUC 83.8%
(95% CI: 71.3%-96.2%)
– –McNutt et al score (BIPS): AUC 87.4%
(95% CI: 80.4%-94.4%)

c) Mesenteric injury only (n=7)
— Faget et al. score (FS): AUC 95.7%
(95% CI: 93.3%-98.1%)
– –Raharimanantsoa et al. score (RS): AUC 91.1%
(95% CI: 85.9%-96.2%)
– –McNutt et al score (BIPS): AUC 84.3%
(95% CI: 85.9%-96.2%)

d) Bowel perforation with and without mesenteric injury (n=22)
— Faget et al. score (FS): AUC 95.7%
(95% CI: 93.3%-98.1%)
– –Raharimanantsoa et al. score (RS): AUC 91.1%
(95% CI: 85.9%-96.2%)
– –McNutt et al score (BIPS): AUC 84.3%
(95% CI: 85.9%-96.2%)

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date: 9/8/2023

Your Name: Basile Pache

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

Manuscript Number (if known): Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
		Time frame: Since the initial planning of the work	
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) **No time limit for this item.**		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date:	9/8/2023
Your Name:	Mylène Bourgeat
Manuscript Title:	Performance of three predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury. A 12-year retrospective cohort study.
Manuscript Number (if known):	Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial** and **non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
Time frame: Since the initial planning of the work			
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) **No time limit for this item.**		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

The Journal of
Trauma and
Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date:	9/8/2023
Your Name:	Nicolas Demartines
Manuscript Title:	Performance of three predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury. A 12-year retrospective cohort study.
Manuscript Number (if known):	Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
Time frame: Since the initial planning of the work			
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) No time limit for this item.		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date: 9/8/2023

Your Name: Sabine Schmidt

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

Manuscript Number (if known): Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
		Time frame: Since the initial planning of the work	
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) No time limit for this item.		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date:	9/8/2023
Your Name:	Tobias Zingg
Manuscript Title:	Performance of three predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury. A 12-year retrospective cohort study.
Manuscript Number (if known):	Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal financial and non-financial relationships, over the previous 36 months with an ineligible company (formerly defined as a commercial interest). Financial relationships are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an ineligible company, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from ineligible companies are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
		Time frame: Since the initial planning of the work	
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) **No time limit for this item.**		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date:	9/8/2023
Your Name:	Fabio AGRI
Manuscript Title:	Performance of three predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury. A 12-year retrospective cohort study.
Manuscript Number (if known):	Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
		Time frame: Since the initial planning of the work	
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) No time limit for this item.		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None Swiss National Association for Promotion of Quality in Hospitals and Clinics	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

	Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.		

The Journal of Trauma and Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date: 9/8/2023

Your Name: Vincent Darioli

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

Manuscript Number (if known): Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

Research grants from **ineligible companies** are financial relationships that should be disclosed, even if the funds go to the researcher's institution and not to the individual researcher.

The author's relationships/activities/interests should be defined broadly and not only related to the manuscript in question. For example, if your manuscript pertains to the epidemiology of shock, you should declare all relationships with manufacturers of treatments used in shock, even if that form of treatment is not mentioned in the manuscript.

According to federal regulations approved by the US Senate, any amount equal to above $10 USD must be disclosed. Although disclosure of the total amount is not required on this form. Authors are encouraged to search the CMS Open Payments Database found at https://openpaymentsdata.cms.gov and report on the JTACS Conflict of Interest Disclosure form ALL COI, and any other conflicts related or unrelated to the manuscript being submitted to the Journal for the last 36 months/3 years.

In item #1 below, report all support for the work reported in this manuscript without time limit. For all other items, the time frame for disclosure is the past 36 months.

If the article is accepted, all author JTACS COI forms will be published as supplemental material with the article.

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
		Time frame: Since the initial planning of the work	
1	All support for the present manuscript (e.g., funding, provision	☒ None	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
	of study materials, medical writing, article processing charges, etc.) **No time limit for this item.**		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

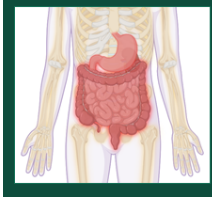
Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

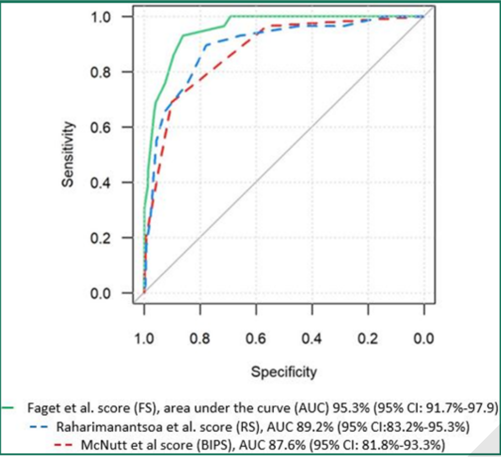
Performance of 3 predictive scores to avoid delayed diagnosis of significant blunt bowel and mesenteric injury: A 12-year retrospective cohort study

Population-based retrospective observational cohort study of adult trauma patients after road traffic crashes (n=917)

➢ 3 scores were retrospectively applied to assess their predictive performance for:



- Full-thickness perforations
- Sero-muscular tears
- Mesenteric lacerations



1. Diagnostic & therapeutic delays are not uncommon despite the use of abdominal CT
2. The FS, purely radiological, had the best individual diagnostic performance
3. The BIPS or the RS may be helpful to select patients for early diagnostic laparoscopy when there are unspecific CT signs of bowel or mesenteric injuries

Zingg T et al. *Journal of Trauma and Acute Care Surgery*. DOI: 10.1097/TA.0000000000004231

@JTraumAcuteSurg

The Journal of Trauma and Acute Care Surgery®