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COMPUTED TOMOGRAPHY

Value of early repeated abdominal CT in selective non-operative management for blunt bowel and mesenteric injury

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Abstract

Objectives To evaluate the performance of an early repeated computed tomography (rCT) in initially non-operated patients with blunt bowel and mesenteric injuries (BBMI).

Methods This was a monocentric retrospective observational study from 2009 to 2017 of patients with a BBMI on initial CT (iCT). Patients initially non-operated on were scheduled for a rCT within 48 h. Initial CT and rCT diagnostic performance were compared based on a surgical injury prediction score previously described. For statistical analysis, we used the chi-square analyses for paired data (McNemar test).

Results Eighty-four patients (1.9% of trauma) had suspected BBMI on iCT. Among these patients, 22 (26.2%) were initially operated on, 18 (21.4%) were later operated on, and 44 (52.4%) were not operated on. The therapeutic laparotomy rate was 85%. Thirty-four patients initially non-operated on had a rCT. The absolute value of the CT scan score increased for 15 patients (44.1%). The early rCT diagnostic performance, compared with iCT, showed an increase in sensitivity (from 63.6 to 91.7%), in negative predictive value (from 77.4 to 94.7%), and in AUC (from 0.77 to 0.94).

Conclusion In initially non-operated patients with BBMI lesions, the performance of an early rCT improved the sensitivity of lesion detection requiring surgical repair and the security of patient selection for non-operative treatment.

Key Points

- *Selective non-operative treatment for hemodynamically stable patients with blunt bowel and/or mesenteric injuries on CT is developing but remains controversial.*
- *An early repeated CT improved the sensitivity of lesion detection requiring surgical repair and the security of patient selection for conservative treatment.*

Keywords Wounds and injuries · Intestines · Tomography, X-ray computed · Conservative treatment

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Abbreviations

−LR	Negative likelihood ratio
+LH	Positive likelihood ratio
AIS	Abbreviated injury scale
AUC	Area under the curve
BBMI	Blunt bowel and/or mesenteric injury
BIPS	Bowel injury prediction score
FOV	Field of view
iCT	Initial computed tomography
IQR	Interquartile range
ISS	Injury severity score
NPV	Negative predictive value
PPV	Positive predictive value
rCT	Early repeated computed tomography
ROC	Receiver operating characteristic

Se Sensibility
Sp Specificity

Introduction

Blunt bowel and/or mesenteric injuries (BBMI) are present in 3 to 5% of patients with blunt abdominal trauma, accounting for 16% of all lesions found in these traumas and ranking third in order of frequency of abdominal lesions after liver and spleen [1]. Since the codification and validation of non-operative treatment of solid abdominal organ trauma (liver, spleen, kidney), intestinal and mesenteric injuries now represent the leading cause of surgery for non-penetrating abdominal trauma [2].

The management of BBMI is not yet codified; however, the typical management corresponds to operate on any patient with a suspicion of bowel and/or mesenteric injury to avoid the risk of delaying surgery for a perforating lesion, a condition recognized to be associated with increased morbidity and mortality. Nevertheless, 45% [3] to 70% [4] of patients with BBMI on initial computed tomography (iCT) do not require surgical repair. Surgery in these cases leads to a non-therapeutic laparotomy, which is associated with short-term (pulmonary and parietal complications) and long-term (adhesions and eventrations) morbidity. Non-operative treatment for selected, hemodynamically stable patients, without clinical signs of peritoneal irritation or perforating lesions on CT, has been proposed by some authors [5]. Scores using clinical, biological, or radiological signs have been developed to help the selection of patients who may be eligible for non-operative treatment [3, 6, 7]. This approach remains controversial, and the appropriate way to select patients remains debatable. Moreover, there is no consensus on how to monitor patients for initial non-operative treatment. Close clinical monitoring during the first hours is surely a key element, similar to abdominal penetrating trauma treated non-operatively [8]. Some teams proposed early repeated abdominal CT, since the delay between trauma and CT affects the detection rate of lesions [9]; however, no studies have assessed this approach specifically for BBMI.

The current study evaluated the benefit, in patients with BBMI on iCT who were not initially operated on, of performing an early repeated CT (rCT) within 48 h, using one of the published risk scores [7].

Methods

Study population

The data collection was carried out following an agreement by the "Commission Nationale de l'Informatique et des Libertés" according to French law.

All CT scan reports made for suspected abdominal trauma in our Level 1 Regional Trauma Center between March 2009 and March 2017 were retrospectively reviewed to select patients with a BBMI. Among the 4374 patients who fulfilled this criterion, 4290 were excluded for reasons detailed in Fig. 1. Finally, 84 patients had a BBMI on the iCT and 34 had a rCT.

Patient outcome

Patient management was standardized. For each patient with BBMI, surgical indication was collegially determined based on clinical, laboratory, and CT scan findings. Surveillance of non-operated patients included clinical and biological examinations. The medical team decided, from 2009, to set up a reinforced monitoring for non-operated BBMIs, including the realization of a rCT, performed within 48 h of the iCT. This rCT was scheduled even in patients with a reassuring clinical examination, looking for early subclinical modification. A delayed laparotomy decision was made based on the clinical course or the findings of the early rCT scan. Initial surgery corresponded to a surgery performed on the day of admission. Laparotomies were classified as therapeutic (suture of intestinal perforation, intestinal resection, hemostasis of active mesenteric bleeding) or non-therapeutic (intestinal serosal tear, intestinal or mesenteric hematomas without active bleeding). Non-intestinal and intestinal mesenteric therapeutic procedures were not considered in the present study. The existence of postoperative complications (using Clavien–Dindo's classification), the intra-hospital mortality, and the length of stay were noted.

CT technique and analysis

A whole-body CT scan (OPTIMA CT660, GE Healthcare) was performed in our institution within 1 h of admission to the trauma center. The CT images were reconstructed at 3-mm section thickness in the axial, coronal, and sagittal plane with native images available for interpretation. Intravenous contrast material (iohexol [Omnipaque 300], GE Healthcare) was administrated at a rate of 3–4 mL/s via a power injector. The CT protocol (FOV 50 cm, 512 × 512 matrix, kV; variable, mAs; variable, pitch 1.5, collimation 0.625 mm) at our institution included multi-phase acquisition with an arterial phase initiated using an automatic bolus-tracking program and a venous phase at a 70–80-s delay. A delayed sequence (3–5 min) was performed at the emergency radiologist's discretion. CT was performed without oral contrast in all cases.

Given the retrospective nature of the present study and a large amount of missing data concerning clinical parameters, the clinical data could not be included in the analysis. A retrospective analysis of the iCT and the rCT was

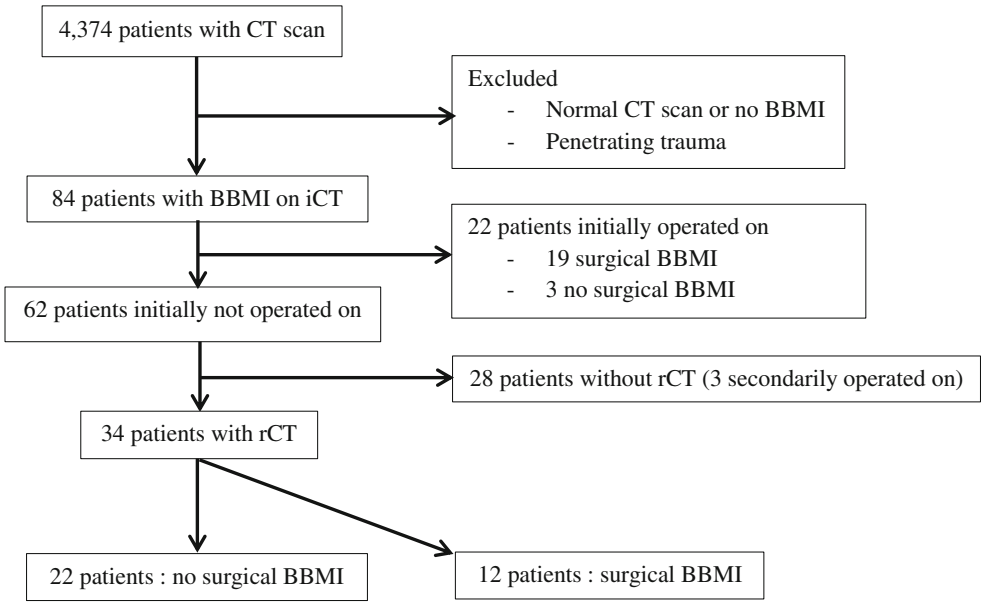

Fig. 1 Flow chart. BBMI, blunt bowel and/or mesenteric injury; iCT, initial CT scan; rCT, early repeated CT scan (between D0 and D2). No surgical BBMI = not operated on + non-therapeutic laparotomy. Surgical BBMI = operated on with therapeutic laparotomy

performed using the nine items described by Faget et al [7]: hemoperitoneum (small, abundant), mesenteric pneumoperitoneum, bowel wall thickening, arterial mesenteric vessel extravasation, mesenteric stranding, bowel wall discontinuity, reduced bowel wall enhancement, splenic injury, and anterior abdominal wall injury. The evolution of these items between the iCT and the rCT was analyzed. For each patient, the Faget et al surgical injury prediction score was calculated from the weighting of these nine CT signs (Table 1). In this score, the weighting of each item corresponds to the probability of requiring surgical repair; a score ≥ 5 indicates a laparotomy. In this series, the Faget et al score was only used retrospectively and not for treatment decisions.

Table 1 List of the CT signs independently associated with surgical BBMI and their assigned numerical CT score in the Faget et al study [7]. In this study, a score ≥ 5 indicates a laparotomy

CT findings	Score
Hemoperitoneum	
- Small	1
- Abundant	3
Mesenteric pneumoperitoneum	5
Bowel wall thickness	2
Arterial mesenteric vessel extravasation	3
Mesenteric stranding	2
Reduced bowel wall enhancement	1
Bowel wall discontinuity	5
Splenic injury	− 1
Anterior abdominal wall injury	2

BBMI, blunt bowel and/or mesenteric injury

Statistical analysis

Computer software (IBM SPSS Statistics, Version 20.0) was used to perform the statistical analyses.

Firstly, we performed a descriptive analysis of patients who had a CT at the initial phase (iCT, $n = 84$) and those who had an early repeated CT scan (rCT, $n = 34$) with an estimation of intra-hospital mortality, intra-hospital morbidity, and length of stay (Table 2) and used a Student's t test to compare these data between groups. Then, we compared the CT findings according to Faget et al criteria between iCT ($n = 34$) and rCT ($n = 34$) patients using the chi-square analyses for paired data (McNemar test) (Table 3). Lastly, the Faget et al score was calculated for all iCT patients ($n = 84$) and rCT ($n = 34$) patients. The area under the receiver operation characteristics curve (AUC under ROC) was derived to evaluate the discriminative ability of this risk score between iCT and rCT patients. Using the threshold of 5, sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (+LR), negative likelihood ratio (−LR), the Youden index, and the chi-square were calculated.

Results

1. Study population and outcome

During the study period, 84 patients (1.9% of all patients with CT scan) had suspected BBMI on the iCT (Table 2). Twenty-two patients were initially operated on (26.2%). Initial surveillance was performed for 62 patients (73.8%). Eighteen patients were later operated on (21.4%), and 44 were

Table 2 Characteristics of patients who had a CT at the initial phase (iCT) and those who had an early repeated CT (rCT)

Characteristics	Patients with iCT $n = 84$	Patients with rCT $n = 34$
Mean age in years (range)	43 (8–84)	44 (8–78)
Gender, *n* (%)		
Male	68 (81%)	30 (88%)
Female	16 (19%)	4 (12%)
Transferred from another facility, *n* (%)	12 (14%)	6 (17.6%)
Public road accident, *n* (%)	65 (77%)	26 (76.4%)
- Bicycle	22 (34%)	10 (38%)
- Light vehicle	40 (61%)	14 (54%)
- Pedestrian	3 (5%)	2 (8%)
Mean Hb in g/dL (range)	11.7 (5.2–18.3)	12 (6.5–18.3)
Median Injury Severity Score (IQR)	16.5 (10.5)	13 (9.5)
Isolated abdominal trauma, *n* (%)	5 (6%)	1 (3%)
Isolated BBMI, *n* (%)	4 (5%)	1 (3%)
Associated injury, *n* (%)	80 (95%)	33 (97%)
- Neurological	20 (25%)	6 (18%)
- Thoracic	47 (59%)	18 (54%)
- Orthopedic	30 (37,5%)	13 (39%)

Data are absolute values

Hb, hemoglobin; *IQR*, interquartile range; *BBMI*, blunt bowel and/or mesenteric injury

not operated on (52.4%). The therapeutic laparotomy rate was 86% (19/22) for initial surgery and 83% (15/18) for delayed surgery. The average time between admission and intervention was 2.5 days ± 2 (range 0–7). A total of 40 patients were operated on (47.6% of all patients), of which 34 (85%) had therapeutic laparotomies.

Eight (9.5%) patients died. The causes of death were neurological injury ($n = 6$), heart failure ($n = 1$), and multiorgan failure ($n = 1$). The mortality rates of the patients who were initially operated on, later operated on, and not operated on were 4.5%, 5.5%, and 13.6%, respectively. There was no significant difference ($p = 0.4$) between groups regarding mortality. The Clavien–Dindo 3 and 4 morbidity rates of patients who were initially operated on, later operated on, and not operated on were 13.6%, 33.3%, and 4.5%, respectively. There was a significant difference ($p = 0.01$) between groups regarding morbidity. The median length of stay for all patients was 15 days (range 12–308). The median length of stay for patients who were initially operated on, later operated on, and not operated on were 22, 53, and 13 days, respectively. There was a significant difference ($p < 0.01$) between groups regarding the length of stay.

2. Comparison of CT findings between iCT and rCT

The CT findings of the 34 patients who had both iCT and rCT are presented in Table 3. The rCT was performed on day 0 for 2 (5.9%) patients, on day 1 for 21 (61.8%) patients, and on day 2 for 11 (32.3%) patients. The three most common CT signs on both iCT and rCT were hemoperitoneum, mesenteric stranding, and bowel wall thickening. An abundant hemoperitoneum and a pneumoperitoneum were significantly more frequent on the rCT than on the iCT. A mesenteric stranding was significantly less frequent on the rCT than on the iCT. A bowel wall thickening and a bowel wall discontinuity were more frequent on the rCT than on the iCT but not statistically significant.

3. Evaluation of the iCT using Faget et al score

Thirty-one (36.9%) patients had a Faget et al score on the iCT ≥ 5, and 53 (63.1%) had a score < 5. The median score on the iCT was 3.5 (IQR = 2). Among the 31 patients with an initial score ≥ 5, 17 (55%) were initially operated on (100% therapeutic laparotomy ($n = 17$)), 4 (13%) were later operated on (100% therapeutic laparotomy ($n = 4$)), and 9 (29%) were not operated on (note that among these 9 patients, 4 died early without any direct link to abdominal lesions). Among the 53 patients with an initial score < 5, 5 (9.5%) were initially operated on (40% of therapeutic laparotomies ($n = 2$)), 13 (24.5%) were later operated on (77% of therapeutic laparotomies ($n = 10$)), and 35 (66%) were not operated on. The two patients who had an initial therapeutic laparotomy with a score < 5 had a mesenteric stranding, a small hemoperitoneum, and an abdominal wall injury on iCT: one was treated by suture of a sigmoid perforation and the other one by hemostasis of active mesenteric bleeding.

Using the threshold of 5, the Faget et al score calculated on the iCT had a Se of 63.6%, a Sp of 80.4%, a PPV of 67.7%, a

Table 3 Comparison between CT scan findings on iCT and rCT according to Faget et al criteria for the 34 patients who had both iCT and rCT

CT finding according to Faget et al criteria	iCT, $n = 34$ (%)	rCT, $n = 34$ (%)	p value[a]
Hemoperitoneum			
- Small	20 (59%)	13 (38%)	$p = 0.09$
- Abundant	6 (18%)	15 (44%)	$p = 0.02$
Mesenteric pneumoperitoneum	0 (0%)	5 (15%)	$p = 0.02$
Bowel wall thickening	8 (23%)	11 (32%)	$p = 0.4$
Arterial mesenteric vessel extravasation	0 (0%)	0 (0%)	$p = 1$
Mesenteric stranding	21 (62%)	14 (41%)	$p = 0.03$
Reduced bowel wall enhancement	7 (21%)	4 (12%)	$p = 0.3$
Bowel wall discontinuity	0 (0%)	2 (6%)	$p = 0.15$
Splenic injury	6 (18%)	6 (18%)	$p = 1$
Anterior abdominal wall injury	3 (9%)	3 (9%)	$p = 1$

[a] Student's t test

iCT, initial CT scan; *rCT*, early repeated CT scan

NPV of 77.4%, a +LR of 3.2, a −LR of 0.45, a Youden index of 0.47, and a chi-square of 19 for the prediction of therapeutic laparotomy. The ROC curve for the iCT with the scoring system (Fig. 2) showed an AUC of 0.77 (95% CI 0.65–0.89).

4. Evaluation of early rCT using Faget et al score

The median Faget et al score on the rCT was 4 (IQR = 3). Comparison of the scores between the iCT and the rCT revealed a decrease in the score absolute value in 9 cases (26.5%), a stagnation in 10 cases (29.4%), and an increase in 15 cases (44.1%).

Fifteen patients (44.1%) had a Faget et al score on the rCT ≥ 5 and 19 patients (55.9%) had a score < 5. Among the 15 patients who had a score on the rCT ≥ 5, 12 (80%) were operated on (including 10 (83.3%) therapeutic laparotomies) and 3 (20%) were not operated on. Among the 19 patients who scored < 5, 3 (16%) were operated on (including 1 (33%) therapeutic laparotomy), and 16 (84%) were not operated on.

Using the threshold of 5, the Faget et al score calculated on the rCT had a Se of 91.7%, a Sp of 81.8%, a PPV of 73.3%, a NPV of 94.7%, a +LR of 5, a −LR of 0.1, a Youden index of 0.7, and a chi-square of 14.4 for the prediction of therapeutic laparotomy. The only patient who had a therapeutic laparotomy with a rCT score < 5 had an increase in score between the two CTs (from 3 to 4). During laparotomy performed on day 2, this patient had a localized mesenteric ischemia secondary to mesenteric avulsion. The ROC curve for the rCT with the scoring system (Fig. 3) showed an AUC of 0.94 (95% IC 0.87–1).

Discussion

In initially non-operated patients with BBMI lesions, an early rCT improved sensitivity (from 63.6 to 91.7%) and negative predictive value (from 77.4 to 94.7%) for the detection of injuries requiring surgical repair, increasing the safety of selective non-operative management. In this monocentric, retrospective observational study of a series of patients with BBMI found on a CT scan, a therapeutic surgical procedure on the bowel and/or the mesentery was necessary in 41.7% of patients. The addition of early repeated CT (rCT) in the surveillance of initially non-operated patients revealed changes from the initial imaging in 71% of cases (Fig. 4).

The diagnosis of BBMI requiring therapeutic action remains a delicate issue. With the first generation of CT scans, the false-negative rate for the detection of BBMI was high, at 13%, in a multicentric study by Fakhri et al 2003 [10]. With the improved performance of the second generation of CT scans, the sensitivity of CT for the diagnosis of BBMI requiring repair is approaching 100% [11, 12].

Nevertheless, it remains difficult to correctly evaluate whether BBMI found on the initial CT (iCT) requires surgical repair. A significant number of BBMI are visualized on the iCT, while the patients have a reassuring clinical evaluation. Operation on all patients, as generally recommended, leads to a significant number of non-therapeutic laparotomies, and it is for this reason that non-operative management has gradually developed. However, while non-operative management is codified for solid abdominal organs (liver, spleen, kidney [13]) in blunt traumas and has existed for penetrating abdominal trauma since the 1960s [14], non-operative management for BBMI remains to be codified. Some authors have proposed that the surgical decision can be assisted by the existence of risk factors for injuries requiring therapeutic repair. In a prior study in 2014 [5], we showed that any BBMI sign on a CT scan associated with peritoneal effusion needed surgical repair. Since then, at least three therapeutic laparotomy prediction scores, using a combination of clinical, biological, and CT scan data, have been published: the z-score [6], the BIPS [3], and the Faget et al score [7]. None of these scores have yet

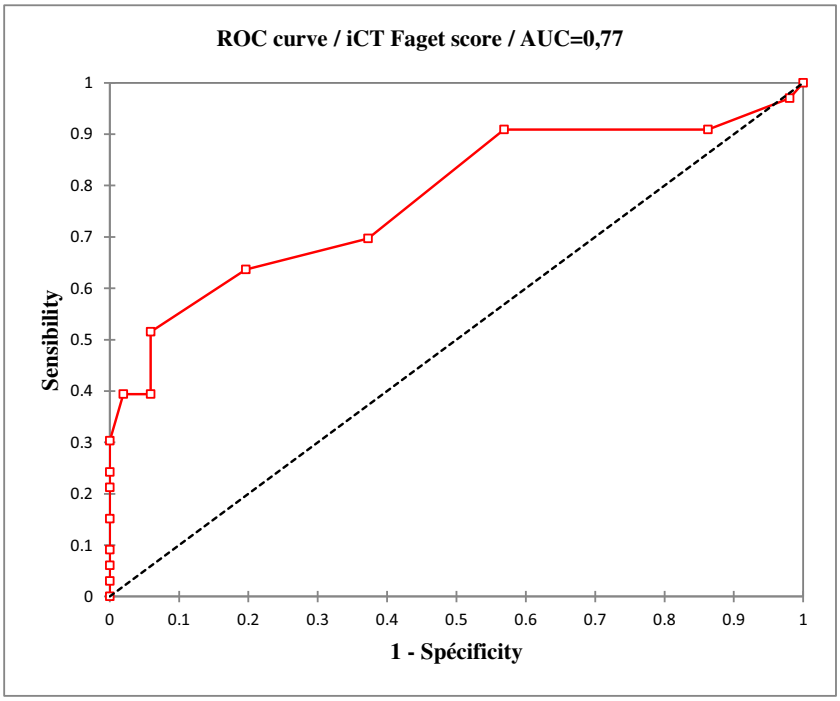

Fig. 2 ROC curve built from the Faget et al score for the iCT. ROC, receiver operating characteristic; iCT, initial CT scan

been widely adopted. The *z*-score combines clinical elements (pain, skin marks) and CT scan findings (peritoneal effusion, bowel/mesenteric lesions) but is complicated to calculate because it has 18 different items and is subjective because it requires the quotation of pain. The BIPS score combines clinical signs (abdominal defense), biological signs (hyperleukocytosis), and CT scan findings, using a specific classification with five stages. A recent external evaluation of BIPS [4] showed that the leukocyte count was unreliable and did not represent an independent risk factor for surgical injury ($p = 0.30$). The BIPS score also had a low positive predictive value (19%). Conversely, the Faget et al score attracted our attention since it is relatively simple to use, but being based solely on CT findings, it makes it possible to overcome the potential subjectivity of the clinical examination or situations where the clinical examination can be unreliable

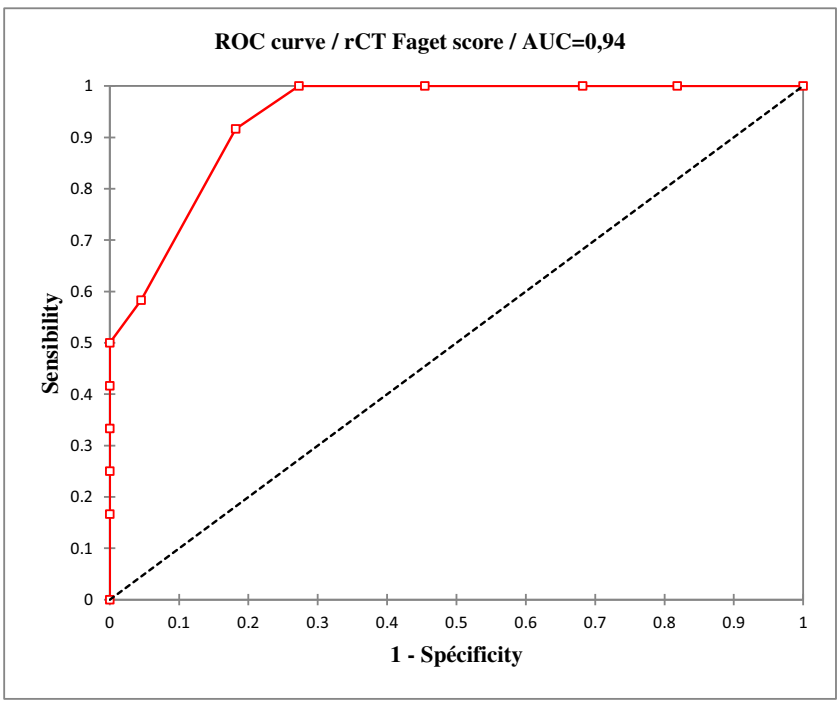

Fig. 3 ROC curve built from the Faget et al score for the rCT. ROC, receiver operating characteristic; rCT, early repeated CT scan

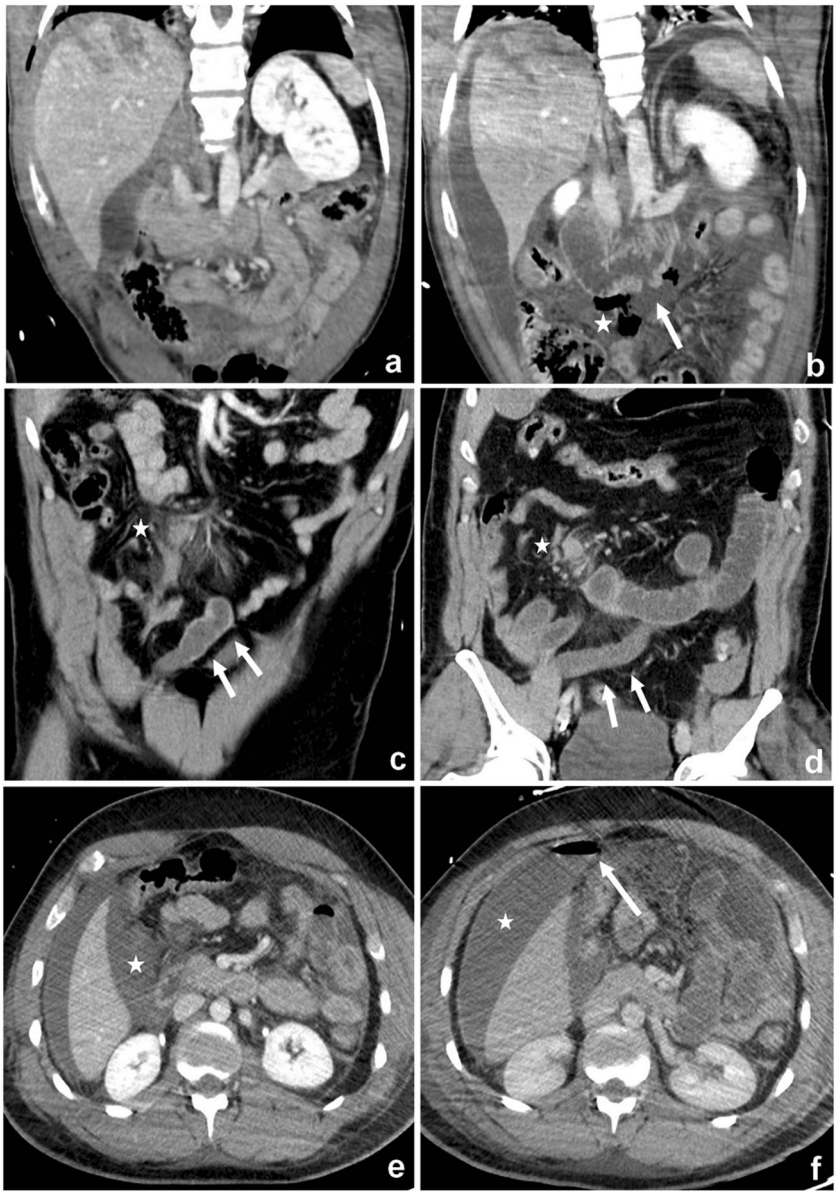

Fig. 4 Abdominal contrast material-enhanced CT image. a and b: Blunt abdominal trauma with AAST 4 liver trauma. Initial CT (**a**) showed a massive hemoperitoneum related to the liver trauma which was treated conservatively. Early repeated CT (**b**) for persistent hemodynamic shock showed a thickening and a discontinuity (*arrow*) of the third duodenum wall, with a retro-pneumoperitoneum (*star*). The Faget et al score was modified (− 12) and surgery confirmed the duodenum perforation. c and d: Blunt abdominal trauma with mesenteric injury. Initial CT (**c**) showed a mesenteric hematoma (*star*) and an abdominal wall injury. Early repeated CT (**d**) for persistent abdominal pain showed a reduced ileum wall enhancement (*arrows*). The Faget et al score was modified (− 1) and surgery confirmed an ileum necrosis without perforation. e and f: Blunt abdominal trauma with hemorrhagic shock due to pelvic fracture and extra-peritoneal bladder rupture. Initial CT (**e**) showed a massive free peritoneum fluid (*star*) without liver, spleen or bowel abnormality. Early repeated CT (**f**) showed a free pneumoperitoneum (*arrow*) with a diffuse bowel wall thickening. The Faget et al score was modified (− 8) and surgery confirmed an ileum perforation

(coma, agitation), as in retrospective studies such as this study where clinical examination data are not sufficiently accurate. In addition, it has exceptional sensitivity (96.4%) and an excellent negative predictive value (99.6%) according to its creators [7]. Nevertheless, in the present study, which constitutes the first external evaluation of the Faget et al score, we found a lower sensitivity (63.6%) and NPV (77.4%) for this score at initial evaluation. This difference in score performance for the iCT may be explained by a difference in selection criteria between the two studies. In our study, we included only patients with signs of BBMI, while Faget et al included all patients with an abbreviated injury scale (AIS) for the abdomen-pelvis area of ≥ 1 (e.g., liver injury without any BBMI). Although we are able to better select patients for non-operative treatment, the modalities of their surveillance and the means of early detection of patients failing non-operative treatment are unknown. It is important to remember that surgical delay is associated with increased morbidity [10]. The surveillance must be primarily clinical and very close. In penetrating trauma, clinical examination proved to be the most cost-effective [8]. It is therefore important to consider, even in the context of blunt trauma, any change in abdominal symptomatology that should lead to a surgical decision (preceded by a CT scan). Nevertheless, these clinical signs are not always easy to evaluate or follow (restless, inebriated, or intubated patient). A CT scan is a major element of the therapeutic decision. Lawson et al [15] showed that, with the exception of peripheral musculoskeletal lesions, BBMI are the most frequently missed lesions on iCT, especially in patients over 50 years old with ISS > 14 [15]. This statement reinforces the usefulness of an iCT rereading by an experienced radiologist, as suggested by Eurin et al [16]. Saku et al noted the

effectiveness of a CT scan at least 8 h after trauma in the detection of BBMI, particularly in free pneumoperitoneum and densification of mesenteric fat detection [17]. These data were confirmed by Brooke et al who reported a significant improvement in Se, Sp, PPV, and NPV on the rCT as compared with the iCT in the diagnosis of traumatic abdominopelvic injuries [18]. Using the Faget et al score when reading rCT seems to be a reliable practice for BBMI surgical screening (Se, NPV, and AUC were respectively 91.7%, 94.7%, and 0.94 for the rCT vs 63.9%, 77.4%, and 0.77 for the iCT). The increase of the score between the iCT and the rCT, while remaining less than or equal to 5, could also be considered as an additional tool in the therapeutic decision, since it allowed us, in our sample, to obtain a maximum NPV (100%).

The present study does have some limitations. Only 55% of initially monitored patients had a rCT. This could have been the consequence of logistical difficulties (difficulties in mobilizing seriously injured patients, CT availability, rCT organization during weekends). Furthermore, considering the retrospective nature of this study and the lack of information on clinical data, it was not possible to determine the specific contribution of the CT scan in relation to the possible clinical signs of the patient. As pointed out by other authors [7], the retrospective calculation of an intestinal injury score is by nature of limited value. There are also specific risks associated with X-ray (additional irradiation) and with the repeated use of iodinated contrast media (renal risk of two CTs close together in precarious patients) which should be specifically studied. The delay in which the rCT must be done has not been evaluated. The determination of an optimal delay, allowing to optimize the diagnostic performance of CT without causing an increase in morbidity and mortality due to late treatment, could be the subject of further studies.

Thus, it becomes important to set up new registry or multicentric studies, with more patients (all published series include fewer than 100 patients), using the selective non-operative approach in hemodynamically stable and clinically reassuring patients that have BBMI on an iCT. This would make possible to compare the different scores and to confirm the interest of early rCT, as well as selective exploratory laparoscopy [19, 20] or promising biological markers such as lactates [18] and alpha binding protein [21].

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Compliance with ethical standards

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Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors (Laurent Boyer; Aix-Marseille University, Marseille, France; Public Health and Chronic Disease Research Unit, APHM, CHU Timone, Marseille, France) carried out the statistics of this study.

We used computer software (IBM SPSS Statistics, Version 20, USA and XLStat-Premium v.2018.3) to do the statistics.

Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- retrospective
- observational
- performed at one institution

References

1. Watts DD, Fakhry SM (2003) Incidence of hollow viscus injury in blunt trauma: an analysis from 275,557 Trauma Admissions from the EAST Multi-Institutional Trial. J Trauma 54:289–294. https://doi.org/10.1097/01.TA.0000046261.06976.6A
2. Pande R, Saratzis A, Winter Beatty J et al (2017) Contemporary characteristics of blunt abdominal trauma in a regional series from the UK. Ann R Coll Surg Engl 99:82–87. https://doi.org/10.1308/rcsann.2016.0223
3. McNutt MK, Chinapuvvula NR, Beckmann NM et al (2015) Early surgical intervention for blunt bowel injury: the Bowel Injury Prediction Score (BIPS). J Trauma Acute Care Surg 78:105–111. https://doi.org/10.1097/TA.0000000000000471
4. Zingg T, Agri F, Bourgeat M et al (2017) Avoiding delayed diagnosis of significant blunt bowel and mesenteric injuries: can a scoring tool make the difference? A 7-year retrospective cohort study. Injury. https://doi.org/10.1016/j.injury.2017.09.004
5. Bège T, Chaumoître K, Léone M et al (2014) Blunt bowel and mesenteric injuries detected on CT scan: who is really eligible for surgery? Eur J Trauma Emerg Surg 40:75–81. https://doi.org/10.1007/s00068-013-0318-y
6. Zarour A, El-Menyar A, Khattabi M et al (2014) A novel practical scoring for early diagnosis of traumatic bowel injury without obvious solid organ injury in hemodynamically stable patients. Int J Surg 12:340–345. https://doi.org/10.1016/j.ijsu.2014.01.011
7. Faget C, Taourel P, Charbit J et al (2015) Value of CT to predict surgically important bowel and/or mesenteric injury in blunt trauma: performance of a preliminary scoring system. Eur Radiol 25:3620–3628. https://doi.org/10.1007/s00330-015-3771-7
8. Inaba K, Okoye OT, Rosenheck R et al (2013) Prospective evaluation of the role of computed tomography in the assessment of abdominal stab wounds. JAMA Surg 148:810–816. https://doi.org/10.1001/jamasurg.2013.2521
9. Malinoski DJ, Patel MS, Yakar DO et al (2010) A diagnostic delay of 5 hours increases the risk of death after blunt hollow viscus injury. J Trauma 69:84–87. https://doi.org/10.1097/TA.0b013e3181db37f5
10. Fakhry SM, Watts DD, Luchette FA, EAST Multi-Institutional Hollow Viscus Injury Research Group (2003) 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 54:295–306. https://doi.org/10.1097/01.TA.0000046256.80836.AA
11. Tan K-K, Liu JZ, Go T-S et al (2010) Computed tomography has an important role in hollow viscus and mesenteric injuries after blunt abdominal trauma. Injury 41:475–478. https://doi.org/10.1016/j.injury.2009.09.028
12. Petrosoniak A, Engels PT, Hamilton P, Tien HC (2013) Detection of significant bowel and mesenteric injuries in blunt abdominal trauma with 64-slice computed tomography. J Trauma Acute Care Surg 74:1081–1086. https://doi.org/10.1097/TA.0b013e3182827178
13. McCombie SP, Thyer I, Corcoran NM et al (2014) The conservative management of renal trauma: a literature review and practical clinical guideline from Australia and New Zealand: Conservative management of renal trauma. BJU Int 114:13–21. https://doi.org/10.1111/bju.12902
14. Goin G, Massalou D, Bege T et al (2017) Feasibility of selective non-operative management for penetrating abdominal trauma in France. J Visc Surg 154:167–174. https://doi.org/10.1016/j.jviscsurg.2016.08.006
15. Lawson CM, Daley BJ, Ormsby CB, Enderson B (2011) Missed injuries in the era of the trauma scan. J Trauma 70:452–458. https://doi.org/10.1097/TA.0b013e3182028d71
16. Eurin M, Haddad N, Zappa M et al (2012) Incidence and predictors of missed injuries in trauma patients in the initial hot report of whole-body CT scan. Injury 43:73–77. https://doi.org/10.1016/j.injury.2011.05.019
17. Saku M, Yoshimitsu K, Murakami J et al (2006) Small bowel perforation resulting from blunt abdominal trauma: interval change of radiological characteristics. Radiat Med 24:358–364. https://doi.org/10.1007/s11604-006-0042-1
18. Raharimanantsoa M, Zingg T, Thiery A et al (2017) 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. https://doi.org/10.1007/s00068-017-0893-4
19. Mitsuhide K, Junichi S, Atsushi N et al (2005) Computed tomographic scanning and selective laparoscopy in the diagnosis of blunt bowel injury: a prospective study. J Trauma 58:696–701 discussion 701–703
20. Sitnikov V, Yakubu A, Sarkisyan V, Turbin M (2009) The role of video-assisted laparoscopy in management of patients with small bowel injuries in abdominal trauma. Surg Endosc 23:125–129. https://doi.org/10.1007/s00464-008-9910-3
21. Matsumoto S, Sekine K, Funaoka H et al (2017) Early diagnosis of hollow viscus injury using intestinal fatty acid–binding protein in blunt trauma patients. Medicine (Baltimore) 96:e6187. https://doi.org/10.1097/MD.0000000000006187