

Guidelines

Early management of severe abdominal trauma^{☆,☆☆}

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ABSTRACT

Objective: To develop French guidelines on the management of patients with severe abdominal trauma. **Design:** A consensus committee of 20 experts from the French Society of Anaesthesiology and Critical Care Medicine (*Société française d'anesthésie et de réanimation*, SFAR), the French Society of Emergency Medicine (*Société française de médecine d'urgence*, SFMU), the French Society of Urology (*Société française d'urologie*, SFU) and from the French Association of Surgery (*Association française de chirurgie*, AFC), the Val-de-Grâce School (*École du Val-De-Grâce*, EVG) and the Federation for Interventional Radiology (*Fédération de radiologie interventionnelle*, FRI-SFR) was convened. Declaration of all conflicts of interest (COI) policy by all participants was mandatory throughout the development of the guidelines. The entire guideline process was conducted independently of any industry funding. The authors were advised to follow the principles of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system for assessment of the available level of evidence with particular emphasis to avoid

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formulating strong recommendations in the absence of high level. Some recommendations were left ungraded.

Methods: The guidelines are divided in diagnostic and, therapeutic strategy and early surveillance. All questions were formulated according to Population, Intervention, Comparison, and Outcomes (PICO) format. The panel focused on three questions for diagnostic strategy: (1) What is the diagnostic performance of clinical signs to suggest abdominal injury in trauma patients? (2) Suspecting abdominal trauma, what is the diagnostic performance of prehospital FAST (Focused Abdominal Sonography for Trauma) to rule in abdominal injury and guide the prehospital triage of the patient? and (3) When suspecting abdominal trauma, does carrying out a contrast enhanced thoraco-abdominal CT scan allow identification of abdominal injuries and reduction of mortality? Four questions dealt with therapeutic strategy: (1) After severe abdominal trauma, does immediate laparotomy reduce morbidity and mortality? (2) Does a “damage control surgery” strategy decrease morbidity and mortality in patients with a severe abdominal trauma? (3) Does a laparoscopic approach in patients with abdominal trauma decrease mortality or morbidity? and (4) Does non-operative management of patients with abdominal trauma without bleeding reduce mortality and morbidity? Finally, one question was formulated regarding the early monitoring of these patients: In case of severe abdominal trauma, which kind of initial monitoring does allow to reduce the morbi-mortality? The analysis of the literature and the recommendations were conducted following the GRADE[®] methodology.

Results: The SFAR/SFMU Guideline panel provided 15 statements on early management of severe abdominal trauma. After three rounds of discussion and various amendments, a strong agreement was reached for 100% of recommendations. Of these recommendations, five have a high level of evidence (Grade 1±), six have a low level of evidence (Grade 2±) and four are expert judgments. Finally, no recommendation was provided for one question.

Conclusions: Substantial agreement exists among experts regarding many strong recommendations for the best early management of severe abdominal trauma.

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1. Introduction

Severe abdominal trauma is diagnosed in up to 20% of severe trauma patients and is associated with a high mortality rate of around 20% [1]. In Europe, the majority of abdominal traumas results from a blunt mechanism, whereas penetrating lesions are less frequent. Severe haemorrhage is the leading cause of death and may be preventable, particularly when an abdominal injury is involved [2]. Despite numerous guidelines on severe trauma management, no specific guideline on abdominal trauma is

available for the French context. Management of abdominal trauma requires, in particular, a trans-professional and multidisciplinary approach, ranging from the prehospital and intensive care unit (ICU). Over the last ten years, the non-operative management including angio-embolisation has greatly changed the management and outcome of these patients. This circumstance required specific attention in the present guideline.

The French Society of Anaesthesia and Critical Care (*Société française d'anesthésie et de réanimation*, SFAR), the French Society of Emergency Medicine (*Société française de médecine d'urgence*, SFMU), the French Society of Urology (*Société française d'urologie*, SFU), the French Association of Surgery (*Association française de chirurgie*, AFC), the Val-de-Grâce School (*École du Val-De-Grâce*, EVG) and the Federation for Interventional Radiology (*Fédération de radiologie interventionnelle*, FRI-SFR) have joined forces to generate original guidelines dedicated to the management of patients with, or with a suspicion, of severe abdominal trauma within the first 48 hours. Severe abdominal trauma was defined by:

- a suspicion of an abdominal injury in a patient with at least one Vittel criteria in the prehospital setting [3];
- an abdominal injury of a score ≥ 3 on the abbreviated injury scale (AIS) [4].

The aim of these guidelines is to provide a decision-making framework for physicians practicing in a non-specialised setting, managing patients with suspected abdominal trauma. In consequence, the target audience is large, defined by all health care professionals involved in trauma care. The group agreed to generate a limited amount of recommendations to focus on the most important messages. In the absence of high-level evidence, the available body of evidence was still considered superior to the expert opinion in the formulation of a recommendation. The basic rules of universal good medical practice in intensive care, emergency medicine and emergency surgery were assumed to be known and thus were not included in the guidelines.

2. Methods

A group of experts developed these guidelines on behalf of the Société française d'anesthésie et de réanimation, the Société française de médecine d'urgence, the Société française d'urologie, the Association française de chirurgie, the École du Val-De-Grâce and the Fédération de radiologie interventionnelle. The organising committee defined a list of questions to be addressed and assigned experts to each question. The questions were formulated using the PICO (Patient Intervention Comparison Outcome) format. Three sections were defined: the diagnostic strategy, the therapeutic strategy and the early surveillance.

The GRADE method (Grade of Recommendation Assessment, Development and Evaluation) was used to assess the level of available evidence. Following a quantitative analysis of the literature, the method can be used to separately determine the quality of the evidence available, i.e. to estimate the level of confidence required to analyse the effects of the quantitative intervention, and the level of recommendation. The quality of evidence is rated as follows:

- high quality of evidence: further research is very unlikely to affect confidence in the estimate of the effect;
- moderate quality of evidence: further research is likely to have an impact on confidence in the estimate of the effect and could change this estimate of the effect;
- low quality of evidence: further research is very likely to have an impact on confidence in the estimate of the effect and is likely to change this estimate of the effect;
- very low quality of evidence: any estimate of the effect is very unlikely.

The level of recommendation is binary (either positive or negative) and strong or weak:

- strong recommendation: we recommend (GRADE 1+) or do not recommend (GRADE 1–) this action;
- weak recommendation: we suggest (GRADE 2+) or do not suggest (GRADE 2–) this action.

The strength of the recommendations was determined according to key factors and validated by the experts after a vote using the GRADE Grid method.

The compilation of a guideline required that at least 50% of voting participants had an opinion and that fewer than 20% of participants voted for the opposite proposal. The compilation of a strong agreement required the approval of at least 70% of the voting participants.

3. Results

Section 1: Diagnostic strategy

Question 1: What is the diagnostic performance of clinical signs to suggest abdominal injury in trauma patients?

R1 – In patients after severe trauma, clinical signs are insufficient to rule in or rule out abdominal injury.
(GRADE 1), STRONG AGREEMENT

Rationale

A systematic review of existing literature, including 12 articles published between 1950 and 2012, has evaluated the predictive value of several clinical signs to assess abdominal injury [5] and has demonstrated an overall weak discriminative power.

As a reminder, a positive likelihood ratio (LHR+) > 10 is considered as an acceptable threshold to use a test to rule in a condition, and a negative likelihood ratio (LHR–) > 0.1 is considered as an acceptable threshold to rule out a condition. LHR+ for clinical signs of abdominal injuries were: pain on compression 6,5 [95% CI: 1.8–24]; haematuria 4.1 [95% CI: 3–4,9]; abdominal distension 3,8 [CI 95%: 1.9–7.6]; guarding 3,7 [95% CI: 2–5.9]; spontaneous pain 1,6 [95% CI: 1.3–2]; pain on palpation 1.4 [95% CI: 1.3–1.5]. For the seatbelt sign, the LHR+ was between 5,6 and 9,9.

All LHR– were > 0.1. The absence of abdominal pain on palpation does not allow ruling out an intra-abdominal injury, pain being absent in 10–14% of severe trauma patients [6,7].

Question 2: Suspecting abdominal trauma, what is the diagnostic performance of prehospital FAST (Focused Abdominal Sonography for Trauma) to rule in abdominal injury and guide the prehospital triage of the patient?

R2.1 – When suspecting abdominal trauma, it is probably recommended to perform a prehospital FAST to rule in intra-abdominal free fluid.
(GRADE 2+), STRONG AGREEMENT

No recommendation: After studying the available literature, the experts are not in the position to provide a recommendation in favour or against the use of prehospital FAST to guide the prehospital triage of patients with suspected severe abdominal trauma.

Rationale

FAST aims to detect free intra-abdominal fluid after trauma. This exam requires integration into a so-called E-FAST (Extended Focused Assessment with Sonography for Trauma) attempting to detect pleural fluid or pneumothorax. Overall, the level of evidence remains low and further comparative studies are required on the diagnostic, prognostic and decision-making impact in the prehospital field. In a recent meta-analysis evaluating the usefulness of prehospital ultrasound use, only 3 from 27 were investigating severe trauma [8]. Positive and negative predictive values to predict the need for laparotomy varied from 50 to 96%. One prospective, single-centre study demonstrated a weak sensitivity (64 and 46% respectively) but an acceptable specificity of 94%. Using prehospital FAST for detecting intra-abdominal free fluid, positive and negative likelihood ratios were 12.8 and 0.38, respectively [9,10]. However, the FAST being absolutely feasible in the prehospital arena [10], its diagnostic performance remains inferior to the intrahospital FAST [11]. Moreover, the feasibility may be impeded by poor conditions, obesity and low operator experience. Finally, two major limitations characterise this test:

- the negative result of a the very early performance may not rule out slowly accumulating intra-abdominal free fluid;
- a retroperitoneal haematoma can generate intra-abdominal effusion, in particular in the case of patients with complex pelvic injury.

Although suggested by some authors [12], the current level of evidence does not allow to recommend the use of prehospital FAST to guide triage. The exam can be repeated during transport but should in no case delay rapid transfer to an appropriate centre.

R2.2 – When suspecting abdominal trauma, we recommend to perform a FAST on admission to the hospital to: (i) rule in or out free intra-abdominal fluid; (ii) rule out more than 500 ml of free fluid if the exam is negative.

(GRADE 1+), STRONG AGREEMENT

R2.3 – When suspecting abdominal trauma, we do not recommend to perform a FAST on admission to the hospital to: (i) rule out a specific intra-abdominal injury; (ii) rule out the presence of a retroperitoneal haematoma.

(GRADE 1–), STRONG AGREEMENT

Rationale

A recent meta-analysis demonstrated a satisfying performance of intra-hospital extended FAST to identify a thoraco-abdominal injury with a sensitivity (Se) of 74% [95% CI: 65%–81%] and specificity (Sp) of 96% [95% CI: 94%–98%], which corresponds to a LHR + of 18, and a LHR– of 0,27 [11]. This performance allows ruling in the presence of intra-abdominal free fluid with FAST without clinical or radiological signs of pelvic injury, in particular in unstable patients [13]. A negative FAST does not rule out an amount of < 500 ml of free fluid [14–16] or the presence or nature of specific organ injury [17], despite some requiring surgical repair [18]. In analogy, a positive FAST does not characterise the nature of the free fluid (blood, ascites, urine). Although FAST facilitates appropriate decisions in the resuscitation area in 99% of cases [18], no study could yet demonstrate a mortality reduction associated with its use.

Question 3: When suspecting abdominal trauma, does carrying out a contrast-enhanced thoraco-abdominal CT scan allow identification of abdominal injuries and reduction of mortality?

R3.1 – When suspecting abdominal trauma, we recommend carrying out a contrast-enhanced thoraco-abdominal CT scan to identify abdominal injuries.

(GRADE 1+), STRONG AGREEMENT

R3.2 – When suspecting abdominal trauma, we recommend carrying a contrast-enhanced thoraco-abdominal CT scan to reduce mortality.

(GRADE 2+), STRONG AGREEMENT

Rationale

The diagnostic performance of contrast-enhanced CT scan for the diagnosis of abdominal injuries varies according to the type of trauma (penetrating or non-penetrating) and the type of organ injured (solid or hollow) [19–21].

A systematic review of the usefulness of CT for the diagnosis of solid organ lesions shows a likelihood ratio + (LHR +) of at least 45 and a negative likelihood ratio (LHR–) of 0.09 (sensitivity 98% and specificity 98%) [4]. Performance is lower for hollow organ lesions with an LHR + of 21 and a LHR– of 0.16 (sensitivity 85% and specificity 96%). Certain CT signs such as pneumoperitoneum or mesenteric infiltration used to diagnose lesions of hollow organs show very poor diagnostic performance with sensitivity at 9% and specificity at 49% [22]. For penetrating injuries of the abdomen, a systematic review published in 2018 reports a CT performance with a LHR + 5.4 and LHR– of 0.22 (sensitivity 81% and specificity of 85%) [23]. These overall performances justify the systematic

diagnosis of a CT scan with systematic contrast enhancement when suspecting severe abdominal trauma. However, the performance of the CT for the diagnosis of hollow organ lesions and penetrating lesions indicates not to rely exclusively on the CT scan for clinical reasoning.

In the context of severe abdominal trauma, carrying out an injected CT scan can help quickly identify bleeding lesions and obtain a complete picture of all haemorrhagic sources and injuries, expediting the appropriate therapeutic strategy [24]. Evidence in favour of this recommendation stems from one randomised controlled trial (REACT-2) [24] and five observational studies with a level of acceptable methodological rigor [25–28]. The randomised REACT-2 study [24] was unable to demonstrate a reduction in mortality comparing a systematic whole-body contrast CT scan in 541 patients with a control group of 542 patients with conventional imaging assessment and selective CT scanning. Although this study was conducted with great rigor, some elements may explain the failure to demonstrate a benefit. REACT-2 was intended to achieve a 5% reduction in mortality, whereas observational studies suggest a reduction in mortality around 3%. Under this assumption, the REACT-2 study did not have the power to detect a difference between the two groups. In addition, 46% of patients in the control group received a full-body scan, but those results were obtained with an intention-to-treat analysis. For these two reasons, the results of REACT-2 invite to remain cautious before concluding on the absence of a benefit of the whole-body scanner on mortality. Five observational studies compare observed mortality with a predicted mortality rate using either the TRISS or RISC method [25–28]. With a total of 31,514 patients included, these studies suggest a benefit in terms of reducing mortality with an Odds Ratio of 0.75 [95% CI: 0.7–0.79]. This finding appears applicable to cases with active haemorrhage and haemodynamic instability [25,29]. Several systematic reviews [30–32] confirm these results, but also indicate considerable heterogeneity and a non-negligible risk of bias. A CT scan could therefore increase the ISS score and lead to bias in favour of the CT group, as the CT scan can detect and describe more lesions. A possible benefit is to be weighed against a real risk of irradiation. It is estimated that between 322 and 1250 full-body scanners are required to cause lethal cancer [30,33]. In comparison, with a mortality rate of 17% [24] and an Odds Ratio of 0.7, it takes between 20 and 40 patients scanned to save a patient; the potential benefit therefore seems to outweigh the risk. The risk of irradiation is even lower as current irradiation levels decrease gradually to reach between 10–15 mSv per examination [25].

Section 2: Therapeutic strategy

Question 4: After severe abdominal trauma, does immediate laparotomy reduce morbidity and mortality?

R4 – In patients with severe abdominal trauma and large peritoneal effusion, the experts suggest to carry out an immediate laparotomy in patients that remain haemodynamically unstable after initial resuscitation to undergo a CT scan.

EXPERT OPINION, STRONG AGREEMENT

Rationale

The review of the literature shows no high-level evidence to provide a high GRADE recommendation. Findings from retrospective studies and US recommendations allow us to present an expert opinion.

The usual indication for immediate laparotomy after penetrating trauma is shock (SAP < 90–100 mmHg and/or no response to a fluid challenge). In these patients, whole body CT scanning delays laparotomy (up to 90 min) and may increase mortality up to 70%,

as shown by a retrospective study of the national trauma data bank [34].

In case of haemodynamic instability after blunt abdominal trauma with large peritoneal effusion, a delayed laparotomy increases the odds of death by 1% every 3 min [35] (Fig. 1). An ancillary study of the PROMMT trial investigated patients with at least one packed red blood cell transfusion and a laparotomy performed 90 min after the diagnostic of a positive FAST [36]. In these patients, time from admission to FAST was 8 ± 10 min and all patients were not hypotensive. In a multivariate analysis, every 10-minute delay from admission to laparotomy and from FAST to laparotomy increased 24h-mortality by a factor of 1.5 and 1.3, respectively, and in-hospital mortality by a factor of 1.4. Based on the same data set, Barbosa et al. documented a low incidence of non-therapeutic laparotomies (2.6%) and no patient endured a pointless laparotomy when SAP was lower than 90 mmHg [37]. In another study, patients with a delayed laparotomy (> 24 h) had a higher rate of complication than patients with immediate laparotomy [37].

In case of blunt renal trauma, indications for immediate surgical exploration are: associated intraperitoneal lesions, expansive, pulsatile haematoma with Grade V lesion of the kidney [38].

Finally, the need for immediate laparotomy in case of circulatory insufficiency and large intraperitoneal effusion is recommended by the German [39], European [40] and American [41] guidelines. The recent analysis of the literature cannot provide enough evidence to specify the place of REBOA in these patients [42].

Question 5: Does a “damage control surgery” strategy decrease morbidity and mortality in patients with a severe abdominal trauma?

R5 – When a laparotomy is performed in patients with haemodynamic instability after blunt or penetrating abdominal trauma, a damage control surgery strategy is probably recommended to decrease mortality.
(GRADE 2+), STRONG AGREEMENT

Rationale

Stone et al. provided the first description of the damage control technique in 1983 [43]. In this retrospective study, the authors found 14 survivors out of 17 patients in the damage control group vs one patient out of 14 patients in the classic surgery group. The concept of damage control surgery is based on limited surgical intervention in order to control both haemorrhage and contamination and limit physiological decompensation. Definitive repair is carried out after acceptable correction of physiological derangement. In 1993, Rotondo et al. called this technique “damage control laparotomy” in a limited retrospective study [44]. In this study, the sub-group of patients with complex lesions had a survival rate of 70%. Based on these two low-level evidence studies, the doctrine was promoted in the USA. Asensio et al. compared retrospectively two groups of patients before and after the implementation of a damage control protocol. They found a reduced stay in ICU without any effect on mortality [45]. Regarding postoperative complications, a prospective cohort study in 2018 found more complications in the group of patients treated with a damage control strategy, but none of them was clinically significant [46]. Criteria to perform a damage control laparotomy are based on: pH, temperature, shock, packed RBC transfusion, blood loss, lactate

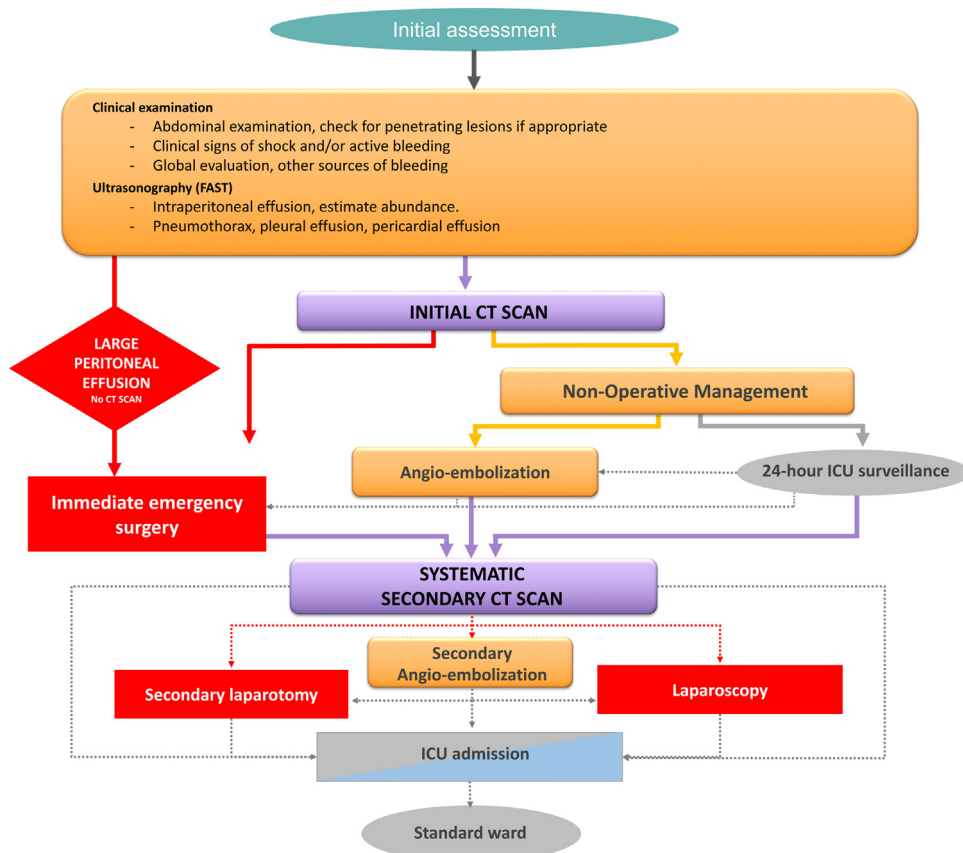


Fig. 1. Algorithm for the management of severe blunt abdominal trauma in adults.

concentration and/or coagulopathy [47–51]. Diverse thresholds have been described, but none proven to be superior. Currently proposed criteria are: haemorrhagic shock with metabolic acidosis (pH < 7.2), hypothermia (temperature < 34 °C) and/or coagulopathy [52].

Question 6: Does a laparoscopic approach in patients with abdominal trauma decrease mortality or morbidity?

R 6.1– In haemodynamically stable patients with blunt abdominal trauma, the experts suggest that a laparoscopic approach may be considered for diagnostic and/or therapeutic purposes to reduce morbidity in the following situations: (i) in the acute phase when the radiologic survey suspects a diaphragmatic or hollow viscus injury and (ii) later on, to complete a non-operative management.

EXPERT OPINION, STRONG AGREEMENT

Rationale

Contrary to penetrating trauma, reports on laparoscopic treatment of blunt abdominal trauma are rare, and no randomised controlled trial compares laparoscopy to laparotomy in blunt abdominal trauma. In the three monocentric cohorts published so far [53–55], the conversion rate to laparotomy varied from 8.5 to 40% and conversion was mainly driven by technical constraints, to allow the definitive repair of intestinal injuries with satisfactory surgical exposure. Laparoscopy was reported to reduce the rate of laparotomies (including non-therapeutic laparotomies) and to provide definitive diagnosis when clinical examination and imaging survey were inconclusive. In the acute phase, exploratory laparoscopy is indicated whenever the initial CT scan cannot rule out hollow viscus injury, since operative delay significantly increases morbidity and mortality (fourfold increase in mortality when surgical delay exceeds 24 h after bowel perforation [56]). Moreover, laparoscopy conveys the benefit of minimally invasive surgery, including cosmetic perquisites and enhanced recovery after surgery. In the future, delayed laparoscopy may also be indicated in patients with persistent, poorly tolerated biloma or hemoperitoneum, occurrence of abdominal compartment syndrome, persistent occult bleeding or suspicion of hollow viscus perforation [57].

R 6.2– Whenever peritoneal violation is deemed likely after penetrating abdominal trauma, exploratory laparoscopy is probably recommended to rule out peritoneal perforation after initial radiologic survey in patients without clinical signs of peritonitis or evisceration

(GRADE 2+), STRONG AGREEMENT

Rationale

In haemodynamically stable patients with penetrating abdominal trauma after stab wound, a peritoneal violation is found in less than 50% of cases [58]. In such patients, with no clinical sign of peritonitis (without diffuse abdominal tenderness) or evisceration, the main concerns are undiagnosed diaphragmatic lacerations (found in 10–15% of cases [59]) and perforation of hollow viscus (5–10%). The question as to whether systematic laparotomy should be undergone in such situations is not straightforward. Indeed, non-therapeutic laparotomy increases hospital length of stay and carries a significant risk of both immediate (surgical wound infection) and long-term complications (eventration and occlusion in 10 to 40% of cases) in otherwise young and healthy patients [60]. O'Malley et al. performed a meta-analysis of 51 cohort studies (including 13 prospective) dealing with exploratory laparoscopy

(n = 2563) after penetrating abdominal trauma [61]. Peritoneal perforation was found in 46.1%, which indicated conversion to laparotomy in 34% of cases; 16% of which were non-therapeutic and 11.5% of which were negative. In summary, laparotomy (when performed) was therapeutic in 73% of cases and 1497 patients were spared a non-therapeutic laparotomy. Sensitivity ranged from 66.7 to 100%, specificity from 33.3 to 100% and accuracy from 50 to 100%. Twenty-three of the 51 studies reported sensitivity, specificity and accuracy of 100%, including the four most recent studies. Laparoscopy and laparotomy following abdominal stab wound were also compared in another systematic review and meta-analysis including eight observational studies and one randomised controlled trial [62]. Compared to laparotomy, laparoscopy was associated with a reduced incidence of surgical wound infection (Odd ratio (OR): 0.55; 95% confidence interval (95% CI): 0.37–0.81) and pneumonia (OR: 0.22; 95% CI: 0.13–0.37), a reduction of both procedure time (mean difference [MD]: –27.99 min; 95% CI: –43.17 to –12.80 min) and length of hospital stay (MD: –3.05 days; 95% CI: –4.68 to –1.42 days). Laparoscopy was 100% sensitive in most of the included studies and avoided non-therapeutic laparotomies in 46% of patients. The authors of the meta-analysis concluded that, compared to laparotomy, laparoscopy reduced complication rate and length of hospital stay, while promoting enhanced recovery after surgery.

Question 7: Does non-operative management of patients with abdominal trauma without bleeding reduce mortality and morbidity?

R 7.1– In patients with abdominal trauma without active peritoneal bleeding or bowel perforation, non-operative management should probably be recommended to reduce morbidity and mortality.

(GRADE 2+), STRONG AGREEMENT

R 7.2– In patients suffering abdominal trauma with established ongoing intraperitoneal bleeding, emergent haemostatic angio-embolisation should probably be considered, among other possible therapeutic options, to reduce morbidity and mortality.

(GRADE 2+), STRONG AGREEMENT

Rationale

Since 1970, non-operative management (NOM) of abdominal trauma patients has evolved to become a standard of care. This was facilitated by:

- a better understanding of the mechanisms leading to death after injury;
- the technical improvements in CT scan imaging;
- the recent breakthroughs in interventional radiology [63].

The expertise gained in both diagnostic and interventional radiology nowadays allows a NOM in more than 80% of abdominal trauma, especially when haemorrhagic shock and bowel perforation are ruled out [64]. In haemodynamically stable patients after blunt abdominal trauma, NOM can be the first option in most cases. Accordingly, 90% of traumatic renal injuries and 70–80% of traumatic splenic and hepatic injuries are treated non-operatively. Even the most severe traumatic abdominal injuries (Organ Injury Scale [OIS] 4 and 5) can benefit from a NOM, given that close and repeated clinical and radiological assessment are provided whatever the involved organ [38,65]. In some of these patients, close monitoring may subsequently mandate an intervention

(laparotomy, laparoscopy, interventional radiology, gastro-intestinal endoscopy), without meaning a failure of the non-operative management strategy [66]. Moreover, in the case of splenic [67,68], hepatic [69], kidney [70] or adrenal [71] traumatic injuries with documented active bleeding, therapeutic haemostatic angio-embolisation can significantly reduce the failure rate of NOM. However, preventive haemostatic angio-embolisation should be applied cautiously: it was demonstrated to be very efficient in traumatic liver injuries with moderate (blush) contrast extravasation [72], it remains controversial in blunt splenic trauma [73] and did not provide any benefit in high-grade traumatic kidney injuries [70]. The awaited results of the “SPLASH” trial (NCT02021396) will provide additional insight as to whether splenic embolisation improves salvage rate at one month in a population of haemodynamically stable (systolic BP \geq 90 mmHg and no haemorrhagic shock) closed splenic trauma patients with a high risk of splenectomy. In patients with haemorrhagic shock or ongoing bleeding after splenic, kidney or adrenal injury, therapeutic haemostatic angio-embolisation, if immediately available, may replace haemostatic laparotomy [74–76]. In 269 trauma patients with high-grade abdominal injuries (OIS grade 3–5, many of them with multiple haemorrhagic foci), Hagiwara et al. demonstrated that transcatheter arterial embolisation was safe and effective (100% success rate), even in hypotensive patients, provided the latter showed transient response to fluid resuscitation [74]. Concerning traumatic hepatic injuries, haemostatic angio-embolisation can represent the first-line haemostatic option in some cases, but it is regularly followed by complementary haemostatic laparotomy [77]. In haemodynamically stable, penetrating abdominal trauma patients, NOM can also be performed, provided the following injuries were ruled out: active bleeding, bowel perforation, biliary, vesical or pyelocaliceal injuries [78,79]. In such cases, the secondary manifestation of a pneumoperitoneum is highly suggestive of bowel perforation and mandates exploratory laparotomy. First line haemostatic angio-embolisation may also be considered in some penetrating solid organ injuries treated under the NOM paradigm [79].

Section 3: Early monitoring in the intensive care unit

Question 8: In case of severe abdominal trauma, which kind of initial monitoring does allow to reduce the morbidity and mortality?

R 8.1– In patients at risk of intra-abdominal pressure elevation, it is probably recommended to monitor the intra-abdominal pressure in an intensive care unit in order to early detect abdominal compartment syndrome.

(GRADE 2+), STRONG AGREEMENT

Rationale

An intra-abdominal pressure higher than 25 mmHg in association with any organ dysfunction defines the abdominal compartment syndrome (ACS) and requires an emergent treatment [80]. A recent review has confirmed that the early detection of ACS is decisive to provide a favourable outcome in such patients [81]. Incidence of ACS was described in the literature between 0.2 and 20% following abdominal trauma [82]. This incidence was slightly higher following laparotomy. Risk factors of ACS are BMI \geq 27 kg.m⁻², APACHE score II \geq 18, abdominal distension, PEEP \geq 7 cm H₂O under mechanical ventilation, haemodynamic shock, massive transfusion and/or massive fluid expansion [81,82]. Two prospective observational studies on trauma patients highlighted that the abdominal hypertension was significant on the first day. One-third of these cases developed ACS during the ICU stay [82,83]. In the most recent series, incidence of ACS was lower

between 3 and 6%, but ACS remained an independent risk factor of mortality (OR 3.3, 95% CI 1.5–7.6), with a fatality rate of 90% if left untreated. Early laparotomy significantly reduces the complications rate associated with ACS [84].

R 8.2– In the case of severe abdominal injury (AIS \geq 3) treated by non-operative management, the experts suggest the following modalities of monitoring and follow up:

- Admission to an institution with the 24/7 capacity to perform an emergency haemostatic laparotomy, for at least the first 24 hours in a unit with continuous monitoring, followed by clinical and biological observation for a minimum of 3 to 5 days.
- Execution of an abdominopelvic CT scan with intravascular contrast media for all abdominal injuries at-risk before hospital discharge and/or when a complication is suspected.

EXPERT OPINION, (STRONG AGREEMENT)

Rationale

The main objective of monitoring is to detect early and delayed complications of haemorrhagic or infectious type. Most of these complications occur within the 5 first days following trauma [85,86]. Haemorrhagic risk (persistence of bleeding, delayed organ rupture) is maximal within the 24 first hours, which justifies an hospitalisation in an intensive care unit when the risk is significant [69]. The duration of observation is variable and depends particularly of the organ, OIS grade, associated injuries and age of patients. This concern was largely studied in splenic trauma. Smith et al., for example, published in 2008 the experience from more than 21,000 blunt splenic trauma initially treated by observation. From this cohort, 95% of delayed splenic bleeding were observed in the 72 first hours [87]. During this period, a strict bed rest is largely recommended. However, it has not been proven that early ambulation increases the risk of delayed bleeding or NOM failure [88,89].

The performance of a second CT scan in the early phase of management, 48–72 hours after admission, has demonstrated its potential for increasing the success chances of NOM [88]. The objective of this second imaging is to detect the occurrence or the increasing of a contrast media extravasation, strongly predictive of an intervention or a pseudo-aneurysm. Velmahos et al. thus showed in high-grade splenic trauma (OIS \geq 3) that a contrast media extravasation $>$ 15 mm in association with a hypotension had a positive predictive value of 100% for delayed splenic rupture [89].

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Disclosure of interest

The authors declare that they have no competing interest.

References

- [1] MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med* 2006;354(4):366–78.
- [2] Kreis Jr DJ, Plasencia G, Augenstein D, Davis JH, Echenique M, Vopal J, et al. Preventable trauma deaths: Dade County, Florida. *J Trauma* 1986;26(7):649–54.
- [3] Babaud J, Ridereau-Zins C, Bouhours G, Lebogot J, Le Gall R, Bertrains S, et al. Benefit of the Vittel criteria to determine the need for whole body scanning in a severe trauma patient. *Diagn Interv Imaging* 2012;93(5):371–9.

- [4] Palmer CS, Gabbe BJ, Cameron PA. Defining major trauma using the 2008 Abbreviated Injury Scale. *Injury* 2016;47(1):109–15.
- [5] Nishijima DK, Simel DL, Wisner DH, Holmes JF. Does this adult patient have a blunt intra-abdominal injury? *JAMA* 2012;307(14):1517–27.
- [6] Michetti CP, Sakran JV, Grabowski JG, Thompson EV, Bennett K, Fakhry SM. Physical examination is a door screening test for abdominal-pelvic injury in adult blunt trauma patients. *J Surg Res* 2010;159(1):456–61.
- [7] Neeki MM, Hendy D, Dong F, Toy J, Jones K, Kuhnen K, et al. Correlating abdominal pain and intra-abdominal injury in patients with blunt abdominal trauma. *Trauma Surg Acute Care Open* 2017;2(1):e000109.
- [8] Bötter MT, Jacobsen L, Rudolph SS, Knudsen L. The role of point of care ultrasound in prehospital critical care: a systematic review. *Scand J Trauma Resuscit Emerg Med* 2018;26(1).
- [9] Press GM, Miller SK, Hassan IA, Alade KH, Camp E, Junco DD, et al. Prospective evaluation of prehospital trauma ultrasound during aeromedical transport. *J Emerg Med* 2014;47(6):638–45.
- [10] O'Dochartaigh D, Douma M. Prehospital ultrasound of the abdomen and thorax changes trauma patient management: A systematic review. *Injury* 2015;46(11):2093–102.
- [11] Stengel D, Leisterer J, Ferrada P, Ekkernkamp A, Mutze S, Hoening A. Point-of-care ultrasonography for diagnosing thoracoabdominal injuries in patients with blunt trauma. *Coch Database of Syst Rev* 2018;12:CD012669.
- [12] Walcher F, Weinlich M, Conrad G, Schweigkofler U, Breitkreutz R, Kirschning T, et al. Prehospital ultrasound imaging improves management of abdominal trauma. *Brit J Surg* 2006;93(2):238–42.
- [13] Rozycki GS, Ballard RB, Feliciano DV, Schmidt JA, Pennington SD. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg* 1998;228(4):557–67.
- [14] Branney SW, Wolfe RE, Moore EE, Albert NP, Heinig M, Mestek M, et al. Quantitative sensitivity of ultrasound in detecting free intraperitoneal fluid. *J Trauma* 1995;39(2):375–80.
- [15] Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so FAST. *J Trauma* 2003;54(1):52–9 [discussion 9–60].
- [16] Poletti PA, Kinkel G, Vermeulen B, Irmay F, Unger P-F, Terrier F. Blunt abdominal trauma: should US be used to detect both free fluid and organ injuries? *Radiology* 2003;227(1):95–103.
- [17] Brown MA, Casola G, Sirlin CB, Patel NY, Hoyt DB. Blunt abdominal trauma: screening us in 2,693 patients. *Radiology* 2001;218(2):352–8.
- [18] Zieleskiewicz L, Fresco R, Duclos G, Antonini F, Mathieu C, Medam S, et al. Integrating extended focused assessment with sonography for trauma (eFAST) in the initial assessment of severe trauma: Impact on the management of 756 patients. *Injury* 2018;49(10):1774–80.
- [19] Hare NP, Macdonald AW, Mellor JP, Younus M, Chatha H, Sammy I. Do clinical guidelines for whole body computerised tomography in trauma improve diagnostic accuracy and reduce unnecessary investigations?. A systematic review and narrative synthesis. *Trauma* 2017;19(3):163–74.
- [20] Holmes JF, McGahan JP, Wisner DH. Rate of intra-abdominal injury after a normal abdominal computed tomographic scan in adults with blunt trauma. *Am J Emerg Med* 2012;30(4):574–9.
- [21] Stengel D, Ottersbach C, Matthes G, Weigeldt M, Grundei S, Rademacher G, et al. Accuracy of single-pass whole-body computed tomography for detection of injuries in patients with major blunt trauma. *Can Med Assoc J* 2012;184(8):869–76.
- [22] Abdel-Aziz H, Dunham CM. Effectiveness of computed tomography scanning to detect blunt bowel and mesenteric injuries requiring surgical intervention: a systematic literature review. *Am J Surg* 2018.
- [23] Baron BJ, Benabbas R, Kohler C, Biggs C, Roudnitsky V, Paladino L, et al. Accuracy of computed tomography in diagnosis of intra-abdominal injuries in stable patients with anterior abdominal stab wounds: a systematic review and meta-analysis. *Acad Emerg Med* 2018;25(7):744–57.
- [24] Sierink JC, Treskes K, Edwards MJR, Beuker BJA, den Hartog D, Hohmann J, et al. Immediate total-body CT scanning versus conventional imaging and selective CT scanning in patients with severe trauma (REACT-2): a randomised controlled trial. *Lancet* 2016;388(10045):673–83.
- [25] Huber-Wagner S, Biberthaler P, Häberle S, Wierer M, Dobritz M, Rummeny E, et al. Whole-body F.C.T. in haemodynamically unstable severely injured patients – A retrospective multicentre study. *PLoS ONE* 2013;8(7):e68880.
- [26] Hutter M, Woltschmann A, Hierholzer C, Gärtner C, Bühren V, Stengel D. Association between a single-pass whole-body computed tomography policy and survival after blunt major trauma: a retrospective cohort study. *Scand J Trauma Resuscit Emerg Med* 2011;19(1):73.
- [27] Kanz K-G, Paul AO, Lefering R, Kay MV, Kreimeier U, Linsenmaier U, et al. Trauma management incorporating focused assessment with computed tomography in trauma (FACTT) – potential effect on survival; 2010;10.
- [28] Wada D, Nakamori Y, Yamakawa K, Yoshikawa Y, Kiguchi T, Tasaki O, et al. Impact on survival of whole-body computed tomography before emergency bleeding control in patients with severe blunt trauma. *Crit Care* 2013;17(4):R178.
- [29] Treskes K, Saltzherr TP, Edwards MJR, Beuker BJA, den Hartog D, Hohmann J, et al. Emergency bleeding control interventions after immediate total-body CT scans in trauma patients. *World J Surg* 2019;43(2):490–6.
- [30] Jiang L, Ma Y, Jiang S, Ye L, Zheng Z, Xu Y, et al. Comparison of whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis; 2014;11.
- [31] Hajibandeh S, Hajibandeh S. Systematic review: effect of whole-body computed tomography on mortality in trauma patients. *J Inj Violence Res* 2015;7(2):64–74.
- [32] Chidambaram S, Goh EL, Khan MA. A meta-analysis of the efficacy of whole-body computed tomography imaging in the management of trauma and injury. *Injury* 2017;48(8):1784–93.
- [33] Long B, April MD, Summers S, Koyfman A. Whole body CT versus selective radiological imaging strategy in trauma: an evidence-based clinical review. *Am J Emerg Med* 2017;35(9):1356–62.
- [34] Neal MD, Peitzman AB, Forsythe RM, Marshall GT, Rosengart MR, Alarcon LH, et al. Over reliance on computed tomography imaging in patients with severe abdominal injury: is the delay worth the risk? *J Trauma* 2011;70(2):278–84.
- [35] Clarke JR, Trooskin SZ, Doshi PJ, Greenwald L, Mode CJ. Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes. *J Trauma* 2002;52(3):420–5.
- [36] Barbosa RR, Rowell SE, Fox EE, Holcomb JB, Bulger EM, Phelan HA, et al. Increasing time to operation is associated with decreased survival in patients with a positive FAST examination requiring emergent laparotomy. *J Trauma Acute Care Surg* 2013;75:S48–52.
- [37] Crookes BA, Shackford SR, Gratton J, Khaleel M, Ratliff J, Osler T. Never be wrong: the morbidity of negative and delayed laparotomies after blunt trauma. *J Trauma* 2010;69(6):1386–91 [discussion 91–92].
- [38] Keihani S, Xu Y, Presson AP, Hotaling JM, Nirula R, Piotrowski J, et al. Contemporary management of high-grade renal trauma: results from the American Association for the surgery of trauma genitourinary trauma study. *J Trauma Acute Care Surg* 2018;84(3):418–25.
- [39] Bouillon B, Marzi I. The updated German “Polytrauma – Guideline”: an extensive literature evaluation and treatment recommendation for the care of the critically injured patient. *Eur J Trauma Emerg Surg* 2018;44(Suppl 1):1.
- [40] Rossaint R, Bouillon B, Cerny V, Coats TJ, Duranteau J, Fernández-Mondéjar E, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. *Crit Care* 2016;20(1).
- [41] Martin MJ, Brown CVR, Shatz DV, Alam HB, Brasel KJ, Hauser CJ, et al. Evaluation and management of abdominal stab wounds: a Western Trauma Association critical decisions algorithm. *J Trauma Acute Care Surg* 2018;85(5):1007–15.
- [42] Aggarwal G, Peden CJ, Mohammed MA, Pullyblank A, Williams B, Stephens T, et al. Evaluation of the collaborative use of an evidence-based care bundle in emergency laparotomy. *JAMA* 2019:e190145.
- [43] Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. *Ann Surg* 1983;197(5):532–5.
- [44] Rotondo MF, Schwab CW, McGonigal MD, Phillips GR, Fruchterman TM, Kauder DR, et al. ‘Damage control’: an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma* 1993;35(3):375–82. discussion 82–83.
- [45] Asensio JA, Petrone P, Roldán G, Kuncir E, Ramicone E, Chan L. Has evolution in awareness of guidelines for institution of damage control improved outcome in the management of the posttraumatic open abdomen? *Arc Surg* 2004;139(2):209–14 [discussion 15].
- [46] George MJ, Adams SD, McNutt MK, Love JD, Albarado R, Moore LJ, et al. The effect of damage control laparotomy on major abdominal complications: a matched analysis. *Am J Surg* 2018;216(1):56–9.
- [47] Asensio JA, McDuffie L, Petrone P, Roldán G, Forno W, Gambaro E, et al. Reliable variables in the exsanguinated patient which indicate damage control and predict outcome. *Am J Surg* 2001;182(6):743–51.
- [48] Burch JM, Ortiz VB, Richardson RJ, Martin RR, Mattox KL, Jordan GL. Abbreviated laparotomy and planned reoperation for critically injured patients. *Ann Surg* 1992;215(5):476–83. discussion 83–84.
- [49] Cosgriff N, Moore EE, Sauaia A, Kenny-Moynihan M, Burch JM, Galloway B. Predicting life-threatening coagulopathy in the massively transfused trauma patient: hypothermia and acidosis revisited. *J Trauma* 1997;42(5):857–61. discussion 61–62.
- [50] Moore EE, Thomas G. Orr memorial lecture staged laparotomy for the hypothermia, acidosis, and coagulopathy syndrome. *Am J Surg* 1996;172(5):405–10.
- [51] Morris JA, Eddy VA, Blinman TA, Rutherford EJ, Sharp KW. The staged celiotomy for trauma: Issues in unpacking and reconstruction. *Ann Surg* 1993;217(5):576–84 [discussion 84–86].
- [52] Roberts DJ, Bobrovitz N, Zygun DA, Ball CG, Kirkpatrick AW, Faris PD, et al. Indications for use of damage control surgery in civilian trauma patients: a content analysis and expert appropriateness rating study. *Ann Surg* 2016;263(5):1018–27.
- [53] Lin H-F, Chen Y-D, Chen S-C. Value of diagnostic therapeutic laparoscopy for patients with blunt abdominal trauma: a 10-year medical center experience. *PLoS ONE* 2018;13(2):e0193379.
- [54] Lin H-F, Chen Y-D, Lin K-L, Wu MC, Wu CY, Chen S-C. Laparoscopy decreases the laparotomy rate for hemodynamically stable patients with blunt hollow viscus and mesenteric injuries. *Am J Surg* 2015;210(2):326–33.
- [55] Koto MZ, Matsevych OY, Mosai F, Patel S, Aldous C, Balabyeki M. Laparoscopy for blunt abdominal trauma: a challenging endeavor. *Scand J Surg* 2018. 145749691881692.
- [56] 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):289–94.
- [57] Letoublon C, Chen Y, Arvieux C, Voinin D, Morra I, Broux C, et al. Delayed celiotomy or laparoscopy as part of the nonoperative management of blunt hepatic trauma. *World J Surg* 2008;32(6):1189–93.
- [58] Barbois S, Abba J, Guigard S, Quesada JL, Pirvu A, Waroquet PA, et al. Management of penetrating abdominal and thoraco-abdominal wounds: a retrospective study of 186 patients. *J Visceral Surg* 2016;153(4 Suppl):69–78.

- [59] Testini M, Girardi A, Isernia RM, De Palma A, Catalano G, Pezzolla A, et al. Emergency surgery due to diaphragmatic hernia: case series review. *World J Emerg Surg* 2017;12:23.
- [60] Di Saverio S, Birindelli A, Podda M, Segalini E, Piccinini A, Coniglio C, et al. Trauma laparoscopy and the six w's: why, where, who, when, what, and how? *J Trauma Acute Care Surg* 2019;86(2):344–67.
- [61] O'Malley E, Boyle E, O'Callaghan A, Coffey JC, Walsh SR. Role of laparoscopy in penetrating abdominal trauma: a systematic review. *World J Surg* 2013;37(1):113–22.
- [62] Hajibandeh S, Hajibandeh S, Gumber AO, Wong CS. Laparoscopy versus laparotomy for the management of penetrating abdominal trauma: a systematic review and meta-analysis. *Int J Surg* 2016;34:127–36.
- [63] Richardson JD. Changes in the management of injuries to the liver and spleen. *J Am College of Surg* 2005;200(5):648–69.
- [64] Tinkoff G, Esposito TJ, Reed J, Kilgo P, Fildes J, Pasquale M, et al. American association for the surgery of trauma organ injury scale i: spleen, liver, and kidney, validation based on the national trauma data bank. *J Am College of Surg* 2008;207(5):646–55.
- [65] Kozar RA, Moore FA, Cothren CC, Moore EE, Sena M, Bulger EM, et al. Risk factors for hepatic morbidity following nonoperative management: multicenter study. *Arch Surg* 2006;141(5):451–8 [discussion 8–9].
- [66] Marzano E, Rosso E, Oussoultzoglou E, Collange O, Bachelier P, Pessaux P. Laparoscopic treatment of biliary peritonitis following nonoperative management of blunt liver trauma. *World J Emerg Surg* 2010;5:26.
- [67] Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. *J Trauma* 2005;58(3):492–8.
- [68] Sabe AA, Claridge JA, Rosenblum DI, Lie K, Malangoni MA. The effects of splenic artery embolization on nonoperative management of blunt splenic injury: A 16-Year Experience. *J Trauma* 2009;67(3):565–72.
- [69] Hagiwara A, Murata A, Matsuda T, Matsuda H, Shimazaki S. The efficacy and limitations of transarterial embolization for severe hepatic injury. *J Trauma* 2002;52(6):1091–6.
- [70] Charbit J, Manzanera J, Millet I, Roustan J-P, Chardon P, Taourel P, et al. What are the specific computed tomography scan criteria that can predict or exclude the need for renal angioembolization after high-grade renal trauma in a conservative management strategy? *J Trauma* 2011;70(5):1219–27 [discussion 27–28].
- [71] Liao C-H, Ouyang C-H, Fu C-Y, Wang S-Y, Lin K-J, Kuo I-M, et al. The current status and management of blunt adrenal gland trauma. *Surgery* 2015;157(2):338–43.
- [72] Wang Y-C, Fu C-Y, Chen Y-F, Hsieh C-H, Wu S-C, Yeh C-C. Role of arterial embolization on blunt hepatic trauma patients with type I contrast extravasation. *Am J Emerg Med* 2011;29(9):1147–51.
- [73] Brault-Noble G, Charbit J, Chardon P, Barral L, Guillon F, Taourel P, et al. Age should be considered in the decision making of prophylactic splenic angioembolization in nonoperative management of blunt splenic trauma: a study of 208 consecutive civilian trauma patients. *J Trauma Acute Care Surg* 2012;73(5):1213–20.
- [74] Hagiwara A, Murata A, Matsuda T, Matsuda H, Shimazaki S. The usefulness of transcatheter arterial embolization for patients with blunt polytrauma showing transient response to fluid resuscitation. *J Trauma* 2004;57(2):271–6. discussion 6–7.
- [75] Hagiwara A, Fukushima H, Murata A, Matsuda H, Shimazaki S. Blunt splenic injury: usefulness of transcatheter arterial embolization in patients with a transient response to fluid resuscitation. *Radiology* 2005;235(1):57–64.
- [76] Brewer ME, Strnad BT, Daley BJ, Currier RP, Klein FA, Mobley JD, et al. Percutaneous embolization for the management of grade 5 renal trauma in hemodynamically unstable patients: initial experience. *J Urology* 2009;181(4):1737–41.
- [77] MacKenzie S, Kortbeek JB, Mulloy R, Hameed SM. Recent experiences with a multidisciplinary approach to complex hepatic trauma. *Injury* 2004;35(9):869–77.
- [78] Plackett TP, Fleurat J, Putty B, Demetriades D, Plurad D. Selective nonoperative management of anterior abdominal stab wounds: 1992–2008. *J Trauma* 2011;70(2):408–13. discussion 13–14.
- [79] Inaba K, Branco BC, Moe D, Barmparas G, Okoye O, Lam L, et al. Prospective evaluation of selective nonoperative management of torso gunshot wounds: when is it safe to discharge? *J Trauma Acute Care Surg* 2012;72(4):884–91.
- [80] Kirkpatrick AW, Roberts DJ, De Waele J, Jaeschke R, Malbrain MLNG, De Keulenaer B, et al. Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome. *Intens Care Med* 2013;39(7):1190–206.
- [81] Holodinsky JK, Roberts DJ, Ball CG, Blaser A, Starkopf J, Zygun DA, et al. Risk factors for intra-abdominal hypertension and abdominal compartment syndrome among adult intensive care unit patients: a systematic review and meta-analysis. *Crit Care* 2013;17(5):R249.
- [82] Reintam Blaser A, Regli A, De Keulenaer B, Kimball EJ, Starkopf L, Davis WA, et al. Incidence, risk factors, and outcomes of intra-abdominal hypertension in critically ill patients – a prospective multicenter study (IROI Study). *Crit Care Med* 2019;47(4):535–42.
- [83] Murphy PB, Parry NG, Sela N, Leslie K, Vogt K, Ball I. Intra-abdominal hypertension is more common than previously thought: a prospective study in a mixed medical-surgical ICU. *Crit Care Med* 2018;46(6):958–64.
- [84] Balogh Z, McKinley BA, Holcomb JB, Miller CC, Cocanour CS, Kozar RA, et al. Both primary and secondary abdominal compartment syndrome can be predicted early and are harbingers of multiple organ failure. *J Trauma* 2003;54(5):848–59 [discussion 59–61].
- [85] 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(3):408–14 [discussion 14–15].
- [86] Peitzman AB, Heil B, Rivera L, Federle MB, Harbrecht BG, Clancy KD, et al. Blunt splenic injury in adults: multi-institutional study of the Eastern Association for the Surgery of Trauma. *J Trauma* 2000;49(2):13.
- [87] Smith J, Armen S, Cook CH, Martin LC. Blunt splenic injuries: have we watched long enough? *J Trauma* 2008;64(3):656–65.
- [88] London JA, Parry L, Galante J, Battistella F. Safety of early mobilization of patients with blunt solid organ injuries. *Arch Surg* 2008;143(10):972–6 [discussion 7].
- [89] Velmahos GC, Zacharias N, Emhoff TA, Feeney JM, Hurst JM, Crookes BA. Management of the most severely injured spleen: a multicenter study of the Research Consortium of New England Centers for Trauma (ReCONNECT). *Arch Surg* 2010;145(5):456–60.