World J Surg (2011) 35:27–33
DOI 10.1007/s00268-010-0782-z

Management of Penetrating Abdominal Trauma in the Conflict Environment: The Role of Computed Tomography Scanning

Jonathan J. Morrison · Jon C. Clasper · Iain Gibb · Mark Midwinter

Published online: 16 September 2010

Abstract
Background Computed tomography (CT) scanning is a vital imaging technique in selecting patients for nonoperative management of civilian penetrating abdominal trauma. This has reduced the rate of nontherapeutic laparotomies and associated complications. Battlefield abdominal injuries conventionally mandate laparotomy, and with the advent of field deployable CT scanners it is unclear whether some ballistic injuries can be managed conservatively.
Methods A retrospective 12 month cohort of patients admitted to a forward surgical facility in Afghanistan who sustained penetrating abdominal injury severe enough to warrant laparotomy or CT scan were studied. Patient details were retrieved from a prospectively maintained operative log and CT logs. Case notes were then reviewed and data pertaining to injury pattern, operative intervention, and survival were collected.
Results A total of 133 patients were studied: 73 underwent immediate laparotomy (Lap group) and 60 underwent CT scanning (CT group). Of those undergoing CT scanning 17 underwent laparotomy and 43 were selected for nonoperative management. There were 15 deaths in the Lap group and none in the CT group. The median New Injury Severity and Revised Trauma Score was 29 and 7.55 in the Lap group and 9 and 7.8408 in the CT group, which is statistically significantly different ($p < 0.001$). Five patients in the CT-Lap group had nontherapeutic laparotomies and 1 patient failed nonoperative management.
Conclusions Computed tomography scanning can be used in stable patients who have sustained penetrating battlefield abdominal injury to exclude peritoneal breach and identify solid abdominal organ injury that can be safely managed nonoperatively.

J. J. Morrison (✉) · J. C. Clasper · M. Midwinter
Academic Department of Military Surgery and Trauma, Royal Centre for Defence Medicine, Birmingham Research Park, Vincent Drive, Edgbaston, Birmingham B15 2SQ, UK
e-mail: jonny_morrison@doctors.org.uk

J. C. Clasper
e-mail: jonclasper@aol.com

M. Midwinter
e-mail: m_midwinter@hotmail.com

I. Gibb
Centre for Defence Imaging, Horton Block, Fort Blockhouse, Gosport PO12 2AB, UK
e-mail: IainGibb@dsca.mod.uk

Introduction

The conventional surgical doctrine for the management of civilian penetrating abdominal trauma prior to the 1980s was one of mandatory laparotomy [1]. This led to a significant nontherapeutic laparotomy rate (37–40% [2, 3]) with a complication rate quoted as high as 41% in some studies [4]. To reduce this rate, the concept of selective nonoperative management (SNOM) has emerged, initially with stab wounds [5], but more recently with ballistic injury [6, 7]. The SNOM approach has largely been possible because of the use of computed tomography (CT) scanning to characterize and grade injury pattern [8].

Mandatory laparotomy for penetrating injuries sustained in conflict is currently considered standard management [9]. However, as CT scanners have now become reliably available in more forward, austere locations [10], surgeons have an additional tool with which to evaluate stable patients with such injuries.

Computed tomography scanning has become a feature of deployed medical services in recent years [10], but only in recent engagements have there been sufficient patients leading to useful clinical publications [11–13]. The bulk of published experience pertains mainly to imaging of neurological and neck trauma [11, 12]. There has been little published material on the role of CT scanning in evaluating stable patients with penetrating abdominal trauma in conflict. Crucially, prior to applying civilian lessons, it is important to understand how conflict injuries differ from low-velocity civilian trauma.

Injuries sustained in conflict are generally caused by a spectrum of mechanisms ranging from low-energy projectiles such as secondary fragments to high-energy projectiles from assault weapons [9, 14]. Wounds vary from minor fragmentation injuries with no or minor body cavity breach to those high-energy transfer wounds destroying and heavily contaminating tissues. Figure 1 illustrates a fragmentation injury to the liver, and Fig. 2 shows no peritoneal breach, whereas Fig. 3 illustrates a gunshot wound to the liver. While a wound sustained in conflict always requires debridement, careful selection of stable patients whose abdominal cavity has not been violated or have sustained a solid organ injury, will prevent nontherapeutic laparotomy.

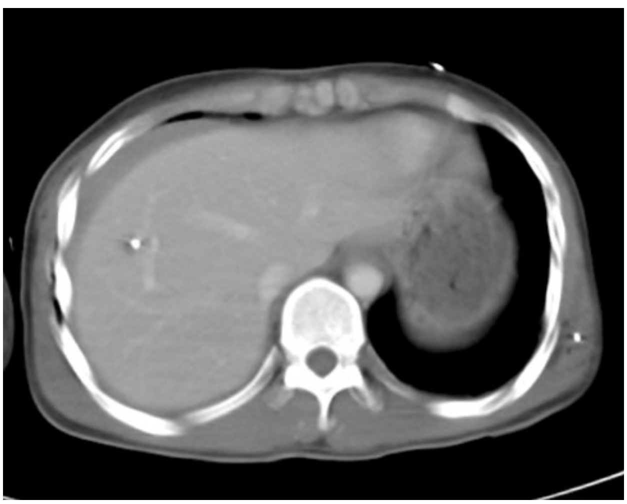

Fig. 1 Axial image of a fragmentation injury with a metallic fragment lying in the liver associated with a hemoperitoneum

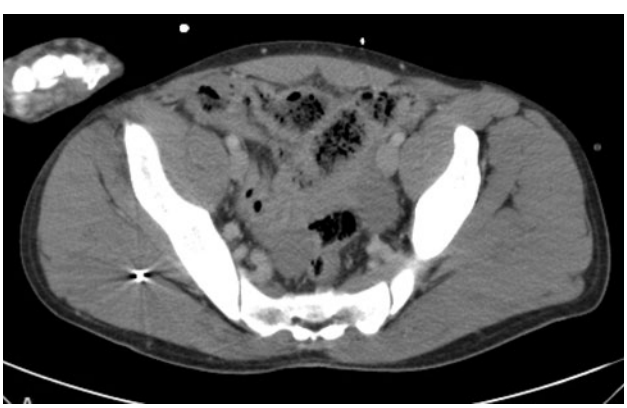

Fig. 2 Axial image identified a metallic fragment in the right flank with no peritoneal breach

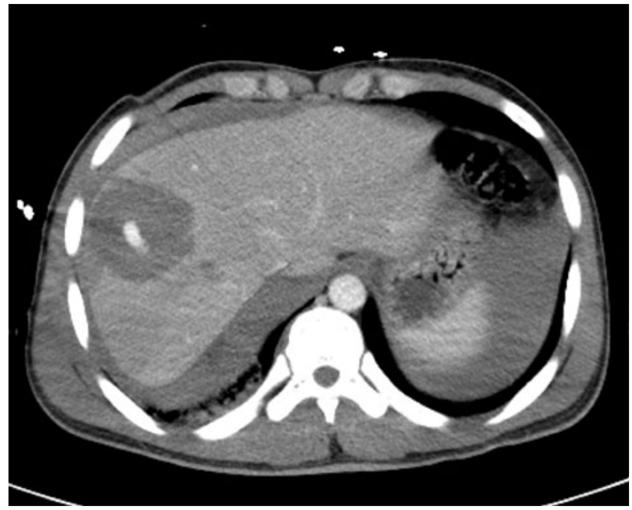

Fig. 3 Gunshot wound to the right upper quadrant successfully managed nonoperatively. Image shows large hemoperitoneum with liver laceration and active extravasation. Round not demonstrated

The aim of the present study was to assess the role of CT in the management of all types of penetrating abdominal trauma in the conflict environment, and to determine if it could help select patients for nonoperative management, thereby avoiding nontherapeutic laparotomy.

Methods and patients

During the 12-month period October 2007 to September 2008, all data from patients who had sustained a penetrating wound to the abdomen (defined as a penetrating injury between the xiphisternum and the pubic symphysis) severe enough to warrant laparotomy or computed tomography (CT) scanning of the chest, abdomen and pelvis were retrieved from a prospectively maintained operative and CT log. Patients displaying any hemodynamic instability, evisceration, or peritonism underwent urgent laparotomy (i.e., following resuscitation and plain radiography). Any stable patient without peritonism underwent a CT scan with intravenous contrast, during the portal-venous phase. With approval of the local Calldicott Guardian (senior clinician in charge of ensuring responsible use of confidential patient data) we retrospectively reviewed the in-patient records of these patients.

All notes were studied and 60 data points pertaining to the emergency department (ED), operating room, and in-patient management were recorded and analyzed. We were specifically interested in the anatomical site of injuries, type and timing of operative intervention, physiological parameters, and survival following surgery. These data allowed us to calculate the Revised Trauma Score (RTS), New Injury Severity Score (NISS), and the predicted percentage survival using Trauma Injury Severity Scoring (TRISS) methodology. The NISS was specifically used because it has been demonstrated to be more accurate in military casualties [15]. It was calculated using Abbreviated Injury Score-90 criteria [16]. We statistically compared the RTS, NISS, and TRISS of patients undergoing immediate laparotomy to those undergoing CT scanning using a two-sample *t*-test. A further comparison, using the same methodology, was made between patients who underwent laparotomy versus those managed conservatively following CT scanning.

Results

During the study period, 1,631 patients were admitted to the British Military Hospital in Helmand Province, Afghanistan. Of the 615 patients admitted for treatment of combat-related injuries, 133 had sustained penetrating injury in the abdominal region.

Seventy-three patients underwent urgent laparotomy following assessment by a consultant (attending) surgeon. Sixty patients whose mean arterial pressure was greater than 60 mmHg following resuscitation had unclear operative indications, and underwent CT scanning with intravenous contrast (Philips Brilliance, 6-slice CT scanner, Koninklijke Philips Electronics NV, Netherlands) to clarify their injury pattern. All scans were reported by a consultant (attending) radiologist. These 133 patients represent our study group and their demographic and admission physiological data are shown in Table 1.

Table 1 Demographic and admission physiological data

	Laparotomy group	Computed tomography (CT) group
Number	73	60
Median age (years)	24 (1–70)	22 (0.5–51)
Gender		
Male	66 (89%)	54 (90%)
Female	9 (11%)	6 (10%)
Mechanism of injury		
Gunshot	42 (58%)	16 (27%)
Fragmentation	23 (31%)	44 (73%)
Unknown	8 (11%)	0
Mean arterial pressure (mmHg)	81 (38–133)	93 (48–127)
pH	7.26 (6.58–7.38)	7.33 (6.84–7.62)
Base excess	−7 (−30 to 1)	−3.5 (−17 to 0)
Haemoglobin (g/dl)	11.4 (4.8–17)	12.9 (8.8–17.1)
Temperature (°C)	36.0 (28.6–39.1)	37.0 (35.2–38.2)

All figures are the median, with the percentage or range shown in parentheses

Trauma scores and injury pattern

The trauma scores and survival data are shown in Table 2—precise injury pattern data were missing in 8 patients undergoing immediate laparotomy, reducing this cohort to 65 patients. The RTS, NISS, and percentage predicted survival (TRISS) illustrate that those patients with immediate indications for operation had poorer physiologyand had sustained greater injury. Thus they had lower predicted survival than those going for CT scanning. The RTS, NISS, and TRISS predicted survival is statistically significantly different ($p < 0.001$). In total, 12% (15/125) patients died, all of whom had undergone immediate laparotomy—7 intraoperatively and 8 in intensive care. Of those who died intraoperatively, 5 underwent resuscitative thoracotomy followed by laparotomy and 2 underwent resuscitative laparotomy. Of the eight patients who died in the ICU, 7 died from multi-organ failure and 1 from a penetrating head injury.

Of the 60 patients who underwent CT scanning, 20 had a scan suggestive of a hollow organ injury and 17 subsequently underwent laparotomy. The remaining 43 patients underwent conservative management. In a comparison of the physiology-based RTS, the two groups are statistically indistinct ($p = 0.795$). In contrast, those undergoing laparotomy have a statistically significantly higher NISS, which is anatomically based ($p < 0.001$). Table 3 details these scores and statistics and Table 4 details the injury pattern and operative interventions undergone by all groups.

Indication for laparotomy without CT scanning

Seventy-three patients underwent laparotomy following initial assessment in the emergency department. Upon review of the operation notes to identify indications, 41 relate to mechanism of injury (8 fragmentation, 33 gunshot wounds), 13 eviscerations, 2 foreign bodies on plain film, and 2 cases of frank hematuria.

Indications for laparotomy after CT scanning

Of the 17 patients who underwent laparotomy, 15 (88%) were injured by fragmentation. There were five (29%) nontherapeutic laparotomies, all for suspected hollow organ injury. The CT scan identified intraperitoneal foreign bodies plus free fluid. The managing surgeon elected to

Table 2 Trauma scores and survival data of patients undergoing immediate operation and those undergoing CT scanning

	Laparotomy	CT—all	Two-sample *t*-test
Number	65[a]	60	
Revised Trauma Score (RTS)	7.55 (0–7.8408)	7.8408 (6.3756–7.8408)	$p < 0.001$
New Injury Severity Score (NISS)	29 (1–67)	9 (1–35)	$p < 0.001$
Predicted survival (TRISS)	92.85% (0.3–99.5)	99 (82–99.5)	$p < 0.001$
Deaths	15 (23%)	0	

[a] Data on injury pattern in 8 patients was unknown, therefore analysis was undertaken on 65 patients. Values are medians plus range in parenthesis

Table 3 RTS, NISS, and TRISS of patients undergoing laparotomy or conservative management post-CT

	CT—laparaotomy	CT—conservative	Two-sample *t*-test
Number	17	43	
RTS	7.8408 (6.3756–7.8408)	7.8408 (6.904–7.8408)	$p = 0.795$
NISS	17 (1–35)	9 (1–25)	$p < 0.001$
TRISS	98.4 (82–99.5)	99 (97.3–99.5)	$p = 0.122$

Values are medians plus range in parenthesis

operate on the basis of those findings. The remaining 12 (71%) therapeutic laparotomies all involved repair of hollow organs. Ten were due to fragmentation injury.

Nontherapeutic laparotomy and failure of conservative management

There were 13 nontherapeutic laparotomies: 8 in the laparotomy group and 5 in the CT –laparotomy group. Table 5 provides a summary of the indications for laparotomy in patients who underwent a nontherapeutic operation. In our short follow-up period, there were no complications from nontherapeutic laparotomy in this study cohort.

In the group selected for conservative management, the majority had solid organ injury (liver, spleen, kidney). Three patients' scans identified intraperitoneal foreign bodies with free fluid suspicious of hollow organ injury, and the managing surgeon elected to watch these with serial examination. There were no laparotomies required in these patients, and only one patient failed conservative management. His injury was a gunshot wound to the right upper quadrant. The patient sustained a grade III lung and liver injury initially managed by intercostal chest drainage only, as he was hemodynamically stable on admission. The patients' transfusion requirement continued to rise, and by day 4 post-injury he was taken to the operating room for liver packing. The chest injury was complicated by an empyema requiring thoracotomy and decortication on day 14 of admission.

Overall, CT scanning in conjunction with the surgeon's opinion was 90% accurate in selecting patients for operative or nonoperative management. In the selection of patients for therapeutic operative management of battlefield penetrating trauma, it had a positive predictive value of 71%, negative predictive value of 98%, sensitivity of 92%, and specificity of 89%.

Discussion

A common weakness of studies from conflict zones, and one that is shared by the present study, is their retrospective nature and incomplete data. We report a series of 133 patients with penetrating abdominal trauma in a conflict zone who were initially managed either by urgent laparotomy or by assessment by CT scan. An important consideration to note is that, over the study period, eight different consultant surgeons contributed to the management of the cohort. Patients were managed in a non-protocol way and thus there are variations in clinical approach: some surgeons adopted a more aggressive approach than others. Data were incomplete in 8 patients (6%), all of whom underwent immediate laparotomy. Additionally, although we lack long-term follow-up, this does not affect our measured outcome—injury pattern, mortality, and initial operative interventions.

Patients undergoing CT scanning were most commonly injured by secondary fragmentation from a blast (73%). These injuries can appear clinically innocuous but may have damaged vital structures that only become clinically apparent hours to days post-injury [17]. In our group, CT successfully excluded peritoneal breach in 29 patients (no delayed laparotomy) and 14 patients were selected for nonoperative management of solid organ injuries. It is important to note that 3 of these patients had sustained gunshot wounds to the right upper quadrant. While SNOM of this type of injury is accepted in civilian practice, it has not been reported successfully from a conflict environment [18]. One of the patients in the present series failed conservative management related to a liver injury.

Table 4 Injury pattern data

	Laparotomy	CT—laparotomy	CT—conservative
Number	65[a]	17	43
Hemothorax	14	3	9
Diaphragm	11	1	0
Liver	24	1	7
Spleen	9	1	1
Kidney	13	0	2
Stomach	14	0	0
Duodenum	4	1	0
Pancreas	7	1	0
Small bowel	27	6	0
Colon	28	4	0
Rectum	4	1	0
Bladder	4	1	0
Pelvic fracture	3	1	0
Mesentery	5	1	1
Retroperitoneal hematoma	10	0	0
No peritoneal breach	7	5	29
Head injury	1	0	2
Spinal	1	0	1
Extra-abdominal vascular	1	1	1
Limb soft tissue	3	3	11
Amputations	4	1	0
Laparotomy			
Therapeutic	57	12	0
Nontherapeutic	8	5	0
Late	0	0	1
Re-look	19	2	1
Thoracotomy			
Resuscitative	5	0	0
Urgent	5	0	0
Late	2	0	2

[a] Incomplete data in 8 cases

If the alternative was that any penetrating abdominal injury mandated laparotomy, the use of CT scanning assessment would have avoided nontherapeutic laparotomy in 42 of 43 of our patients. However, we accept that if the clinical judgement was that the wounds were superficial and sustained in hemodynamically stable patients, this number is likely to be lower. It was not possible to exclude hollow-organ injury by CT in 17 patients, and subsequent laparotomy confirmed hollow organ injury in 12; the remaining 5 patients (29%) were treated with nontherapeutic laparotomies.

Civilian studies have clearly identified the safety and effectiveness of SNOM in civilian penetrating injury. A recent review of the evidence by the Eastern Association for the Surgery of Trauma has formulated "Practice Management Guidelines for Non-Operative Management of Penetrating Abdominal Trauma" [19]. There was sufficient grade II evidence (prospective or retrospective clinical studies based on reliable data) for patients with hemodynamic instability, peritonism, or those with an unreliable examination (i.e., head injury) to undergo emergent laparotomy. Patients outside this cohort should be considered for triple-contrast (oral, rectal, and intravenous) abdomino-pelvic CT scan or serial abdominal examination. In terms of purely ballistic civilian experience, Velmahos et al. have recently reported successful SNOM in 712 (38%) of 1,856 cases with a nontherapeutic laparotomy rate of 14% [7].

Our study is different from most reported in that our scanning protocol only used intravenous contrast, with scanning during the portal venous phase. The reasons for this are multifactorial: skill set, time, and clinical priorities. Radiography staff deployed to the hospital were responsible for all imaging modalities, and thus a protocol was devised that placed minimal demands on staff during busy periods. The single contrast protocol places emphasis on

Table 5 Indications for laparotomy in patients who underwent nontherapeutic procedures

Laparotomy	CT—laparotomy group
2 × blast, bilateral traumatic amputation (unstable)	4 × fragment suspected bowel injury (stable)
1 × junctional gunshot wound, required lobectomy (unstable)	1 × gunshot wound to the flank, suspected colonic injury (stable)
1 × flank gunshot wound, grade I splenic and renal injury (stable)	
1 × pelvic gunshot wound, track behind rectum (stable)	
2 × multiple fragmentation of torso (stable)	
1 × intraperitoneal fragment on plain radiography (stable)	

the identification of solid organ hemorrhage, the main early threat to life from cavitating injuries [9, 14]. The use of oral and rectal contrast adds a further time demand when assessing multiple casualties delaying critical decision making. Undoubtedly, this approach has reduced the specificity of CT hollow organ injury detection, as our 5 (29%) nontherapeutic laparotomies demonstrate.

The only military publication to date that studies abdominal injury and CT scanning exclusively examined fragmentation injury. Beekley et al. analyzed 145 patients injured by fragmentation injury over 6 months [13]. All patients were hemodynamically stable (mean systolic BP was 129 and pH was 7.33) and had undergone a CT scan. Sixty patients underwent laparotomy following CT, with a nontherapeutic rate of 25%. The study concluded that CT (compared to physical examination and USS) was effective and safe, with a sensitivity of 97.8%, specificity of 84.8%, positive predictive value of 75%, and negative predictive value of 98.8%. Our results compare favorably, although the two studies are not directly comparable as we included all types of penetrating battlefield trauma.

Computed tomography scanning is not the only modality with which to assess penetrating abdominal trauma. There have been several prospective trials on Focused Abdominal Sonography in Trauma (FAST) in penetrating abdominal trauma [20, 21]. The FAST system has a low sensitivity and rarely contributes to the management of patients with penetrating trauma. It may be useful in certain injury complexes such as thoracoabdominal injury where opening the correct body cavity is a vital step in decision making [22].

Within our cohort, we have identified 18 patients (2 that underwent urgent laparotomy and 16 that underwent CT scanning) that sustained gunshot wounds to the abdomen and were hemodynamically stable on admission. Of the 2 patients that underwent immediate laparotomy both had nontherapeutic procedures, which may have been avoided by CT scanning assessment. Within the CT group 12 were managed nonoperatively, with 2 therapeutic, 1 nontherapeutic, and 1 delayed laparotomy.

Gunshot wounds to the abdomen sustained in combat are different from civilian wounds: they involved higher energy transfer creating more extensive wounds with greater bacterial contamination, often in combination with extended pre-hospital timelines [14]. For gunshot wounds of the abdomen sustained in conflict, operative intervention will always be the mainstay of management, and we do not advocate against that. However, we believe our evidence supports the use of CT scanning to select those few stable patients suitable for nonoperative management if tactically appropriate.

Conclusions

We have demonstrated that CT scanning can be used in a forward environment to safely assess penetrating abdominal trauma and reduce nontherapeutic laparotomy rates. It can be used to select for conservative management stable patients with solid organ injury, injured by either gunshot wound or fragmentation. Patients selected for operative management by CT scanning mainly have hollow organ injuries, although this can be difficult to interpret, leading to some nontherapeutic procedures. Further work is needed to improve the ability of medical personnel to exclude hollow organ injury caused by battlefield penetrating trauma. There should be a shift from mandatory laparotomy in stable patients, and CT scanning should be performed in all such patients to select those suitable for nonoperative management, allowing for tactical constraints.

Acknowledgments The authors are grateful to the personnel of 204 Field Hospital who helped with the identification of patient case notes.

References

1. Moore EE, Moore JB, van Duzer-Moore S et al (1980) Mandatory laparotomy for gunshot wounds penetrating the abdomen. Am J Surg 140:847–851
2. Sirinek KR, Page CP, Root HD et al (1990) Is exploratory celiotomy necessary for all patients with truncal stab wounds? Arch Surg 125:844–848
3. Leppaniemi A, Salo J, Haapiainen R (1995) Complications of negative laparotomy for truncal stab wounds. J Trauma 38:54–58
4. Renz BM, Feliciano DV (1995) Unnecessary laparotomies for trauma: a prospective study of morbidity. J Trauma 38:350–356
5. Thanvendran A, Vijayaragavan A, Rasaratnam R (1975) Selective surgery for abdominal stab wounds. Br J Surg 62:750–752
6. Muckart DJ, Abdool-Carim AT, King B (1990) Selective conservative management of abdominal gunshot wounds: a prospective study. Br J Surg 77:652–655
7. Velmahos GC, Demetriades D, Toutouzas KG et al (2001) Selective nonoperative management of 1,856 patients with abdominal gunshot wounds: should routine laparotomy still be the standard of care? Ann Surg 234:395–403
8. Shanmuganathan K, Mirvis SE, Chiu W et al (2004) Penetrating torso trauma: triple-contrast helical CT in peritoneal violation and organ injury—a prospective study in 200 patients. Radiology 231:775–784
9. Mahoney PF, Ryan JM, Brooks AJ et al (2005) Ballistic trauma, 2nd edn. Springer, London
10. O'Reilly DJ, Kilbey J (2007) Analysis of the initial 100 scans from the first CT scanner deployed by the British Armed Forces in a land environment. J R Army Med Corp 153:165–167
11. Statler JD, Tempel CG, Harcke HT et al (2005) Computed tomography of craniofacial trauma at a combat support hospital in Afghanistan. Mil Med 170:206–210
12. Mabry RL, Holcomb JB, Baker AM et al (2000) United States Army Rangers in Somalia: an analysis of combat casualties on an urban battlefield. J Trauma 49:515–529

13. Beekley AC, Blackbourne LH, Sebesta JA et al (2008) Selective nonoperative management of penetrating torso injury from combat fragmentation wounds. J Trauma 64:s108–s117
14. Champion HR, Bellamy RF, Roberts P et al (2003) A profile of combat injury. J Trauma 54:s13–s19
15. Osler T, Baker SP, Long W (1997) A modification of the injury severity score that both improves accuracy and simplifies scoring. J Trauma 43:922–925 (discussion 925–926)
16. Association for the Advancement of Automotive Medicine, Committee on Injury Scaling (1990) The abbreviated injury scale—1990 revision (AIS-90). Association for the Advancement of Automotive Medicine, Des Plains
17. Cripps NP, Glover MA, Guy RJ (1999) The pathophysiology of primary blast injury and its implications for treatment. Part II: the auditory structures and abdomen. J R Nav Med Serv 85:13–24
18. Renz BM, Feliciano DV (1994) Gunshot wounds to the right thoracoabdomen: a prospective study of nonoperative management. J Trauma 37:737–744
19. Eastern Association for the Surgery of Trauma, Practice Management Guideline Committee (2010) Practice management guidelines for nonoperative management of penetrating abdominal trauma
20. Soffer D, McKenney MG, Cohn S et al (2004) A prospective evaluation of ultrasonography for the diagnosis of penetrating torso injury. J Trauma 56:953–957
21. Udobi KF, Rodriguez A, Chiu WC et al (2001) Role of ultrasonography in penetrating abdominal trauma: a prospective clinical study. J Trauma 50:475–479
22. Asensio JA, Arroyo H, Veloz W et al (2002) Penetrating thoracoabdominal injuries: ongoing dilemma—which cavity and when? World J Surg 26:539–543