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ORIGINAL ARTICLE

Characteristics and management of penetrating abdominal injuries in a German level I trauma center

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Abstract

Purpose Penetrating abdominal injuries caused by stabbing or firearms are rare in Germany, thus there is lack of descriptive studies. The management of hemodynamically stable patients is still under dispute. The aim of this study is to review and improve our management of penetrating abdominal injuries.

Methods We retrospectively reviewed a 10-year period from the Trauma Registry of our level I trauma center. The data of all patients regarding demographics, clinical and outcome parameters were examined. Further, charts were reviewed for FAST and CT results and correlated with intraoperative findings.

Results A total of 115 patients with penetrating abdominal trauma (87.8% men) were analyzed. In 69 patients, the injuries were caused by interpersonal violence and included 88 stab and 4 firearm wounds. 8 patients (6.9%) were in a state of shock at presentation. 52 patients (44.8%) suffered additional extraabdominal injuries. 38 patients were managed non-operatively, while almost two-thirds of all patients underwent surgical treatment. Hereof, 20 laparoscopies and 3 laparotomies were non-therapeutic. There were two missed injuries, but no patient experienced morbidity or mortality related to delay in treatment. 106 (92.2%) FAST and 91 (79.3%) CT scans were performed. Sensitivity and specificity of FAST were 59.4 and 94.2%, while those of CT were 93.2 and 85.1%, respectively.

Conclusion In hemodynamically stable patients presenting with penetrating abdominal trauma, CT is indicated and the majority of injuries can be managed conservatively. If surgical treatment is required, diagnostic laparoscopy for stable patients is feasible to avoid nontherapeutic laparotomy.

Keywords Penetrating abdominal trauma · Stab and gunshot wounds · Management algorithm · SNOM

Introduction

Abdominal-penetrating injuries caused by stabbing or firearms have a low incidence in Germany and Central Europe and, therefore, are rare challenges for trauma surgeons. Penetrating injuries show an incidence of 5% in Germany, 36% are caused by stabbing and 12% by firearms. The abdomen is affected in about 30% of these injuries [1].

Studies from other European countries confirmed the low incidence rate of stab wounds (SWs) and gunshot wounds (GSWs) [1–5]. In contrast, studies from the United States or South Africa report higher rates of penetrating trauma, e.g., 38% in the United States [6]. Even more impressive, in South African district hospitals up to 80% of all emergency visits due to trauma are caused by stabbing or gunshot injuries [7]. However, a rising trend of armed force can be observed in Europe. Firearm- and knife-associated crime was increasing up to 30% in the UK between the late 1990s and 2005 [8]. Similarly, in Germany, the incidence of firearm-associated crime strongly increased, e.g., the incidence of aggravated assault caused by firearms has increased about 24.5% since 2014 (Annual

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Report 2016, Polizeiliche Kriminalstatistik, http://www.bmi.bund.de). Despite the low incidence, medical management must be known also in European trauma departments, as abdominal-penetrating trauma is associated with significant morbidity and mortality [9].

The optimal management of patients with penetrating abdominal trauma is debated for decades. Traditionally, abdominal SWs required operative exploration. In 1960, selective non-operative management (SNOM) was described, suggesting that in certain patients laparotomy may not be mandatory and that a reduction of complications and nontherapeutic laparotomies may be achieved [10]. The observation, that only about 50% of all abdominal SWs do penetrate the peritoneum and of those only 20–40% cause a significant injury [11], subsequently resulted in the development of selective algorithms to efficiently manage patients with abdominal-penetrating trauma without signs for shock, peritonitis or evisceration [12, 13]. Different diagnostic procedures have been used in an attempt to identify significant injuries before operative exploration or clinical manifestation. Local wound exploration and diagnostic peritoneal lavage were used to determine whether the peritoneum had been violated or a significant intra-abdominal injury had been existent [14, 15]. Further, the introduction of imaging studies, such as ultrasound [16], computerized tomography (CT) [17, 18] and diagnostic laparoscopy [19–21], has contributed in the new trends of penetrating trauma management.

To establish a unifying algorithm which focuses on the balance between invasiveness, resource utilization, and safety, the Western Trauma Association Multicenter Trials Group developed management guidelines for patients with abdominal SWs. In this algorithm, patients who do not need immediate laparotomy undergo local wound exploration. In case of detection of a peritoneal violation and absence of clinical signs, the patient is admitted to serial clinical assessments [22]. A large number of the literature from the United States and South Africa validated this selective non-operative management to be safe and cost-effective [23–25].

Nevertheless, due to the low incidence of SWs and GSWs, there is a lack of routine in the management of these traumas in Germany. Compliance with the algorithm toward SNOM was shown to be poor in low-volume settings [26] and routine laparotomy and laparoscopy are still largely debated also for asymptomatic patients. In the backdrop of the low incidence of penetrating abdominal trauma in combination with significant differences in the health and emergency care systems, treatment algorithms have to be established also in European trauma departments to identify injuries requiring surgical repair, and avoid unnecessary laparotomy with its associated morbidity.

The objectives of our study were to describe the characteristics of patients with penetrating abdominal injuries to review our current management and compare it to international standards.

Patients and methods

We performed a retrospective analysis of all patients with any abdominal-penetrating trauma admitted to our urban level I trauma center between January 2006 and December 2015. Patients were identified from patient records using ICD-10 codes. The study was approved by the Ethics Committee of the University hospital Frankfurt. The data of all patients regarding patient demographics, injury details, clinical characteristics, diagnostic workup, surgical procedures, and patient outcome were examined. Outcome included morbidity, mortality and hospital length of stay. The standard diagnostic included clinical examination and Focused Abdominal Sonographic Examination (FAST). Additional technical examinations such as CT scanning were performed in selected cases.

A positive FAST was defined as any evidence of intraabdominal fluid accumulation or of solid organ injury. CT scans were classified as positive for any evidence of peritoneal violation including free intraperitoneal fluid or air, injury to a solid or hollow organ, suspected diaphragm injuries or wound trajectories clearly penetrating the peritoneal cavity.

Operative interventions were classified as positive or therapeutic for procedures resulting in surgical treatment, which includes hemostasis, evacuation of blood, and repair or resection of any injured structure including both, solid or hollow organ injury, diaphragm injury and abdominal wall repair. Negative or nontherapeutic operation was defined as any abdominal exploration without identification of intraabdominal organ injury requiring repair, ligation, or control of hemorrhage. Missed injuries were those that were not diagnosed at initial exploration but were detected by follow-up monitoring.

Further, records were reviewed for FAST and CT results and correlated with intraoperative or follow-up findings. FAST and CT findings were classified as follows: true positive (TP), in cases of positive FAST/CT findings and positive operation; true negative (TN), in cases of negative FAST/CT findings, and negative intraoperative or follow-up findings; false negative (FN), in cases of negative FAST/CT findings, and positive operative procedures; and false positive (FP), in cases of positive FAST/CT findings, and negative intraoperative or follow-up findings.

Statistical analyses were conducted using Microsoft Excel software. Data were expressed as means ± SD or as frequencies (%) when appropriate.

Results

Patient demographics

Over the 10-year study period, a total of 115 patients with penetrating abdominal injuries were admitted to our level I trauma center. As Fig. 1 shows, the incidence of penetrating abdominal trauma has increased since 2012 compared to the period from 2006 to 2011 (mean cases/year 8.0 vs. 16.75). 101 (87.8%) of the patients were male and mean age was 36.2 ± 14 years. This included 88 patients (76.5%) with SWs, 4 patients (3.5%) with GSWs and 23 patients (20%) with other penetrating traumas. The most common cause of all injuries was interpersonal violence (60%), whereas only 17.2% of injuries were self-inflicted. Almost half of our patients (44.8%) had associated extraabdominal injuries, hereof the most commonly injuries affected the chest or extremities (Fig. 2a). The vast majority of patients (76.5%) were admitted to hospital via trauma room and were hemodynamically stable (93.1%), with a mean initial Hb of 13.5 g/dl and mean Glasgow Coma Scale (GCS) of 13.5 on arrival. Mean Injury Severity Score was 8. Patient demographics, injury and clinical characteristics are shown in Table 1.

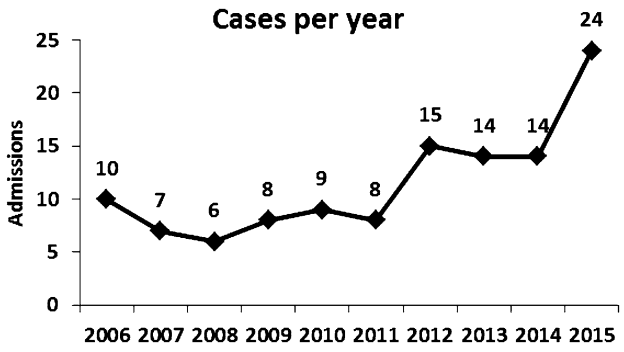

Fig. 1 Temporal trends in admission of penetrating abdominal traumas over a 10-year period

FAST and CT scanning

FAST was performed and recorded in 106 (92.2%) patients and was positive in 26 cases. Of this, 22 (84.6%) were TP according to intraoperative findings. 91 (79.1%) hemodynamically stable patients had FAST followed by emergency CT scanning. 43 patients had no evidence of intraperitoneal injury or fascial penetration on the CT scan. Conversely, CT scanning was positive in 48 cases, whereof 41 were TP. All patients with positive findings in FAST and/or CT scanning were taken to the operating room.

Table 1 Demographics, injury and clinical characteristics of patient cohort

N	115
Age (years mean ± SD)	36.2 ± 14
Male (%)	101 (87.8)
ISS (mean)	8
Type of injury (%)	
Stab wound	88 (76.5)
Gunshot wound	4 (3.5)
Other penetrating trauma	23 (20)
Self-inflicted (%)	20 (17.2)
Additional extraabdominal injuries (%)	52 (44.8)
Arrival via trauma room (%)	88 (76.5)
Haemodynamically unstable (%)	8 (6.9)
Hb (g/dl ± SD)	13.5 ± 2.9
GCS on arrival (mean)	13.5

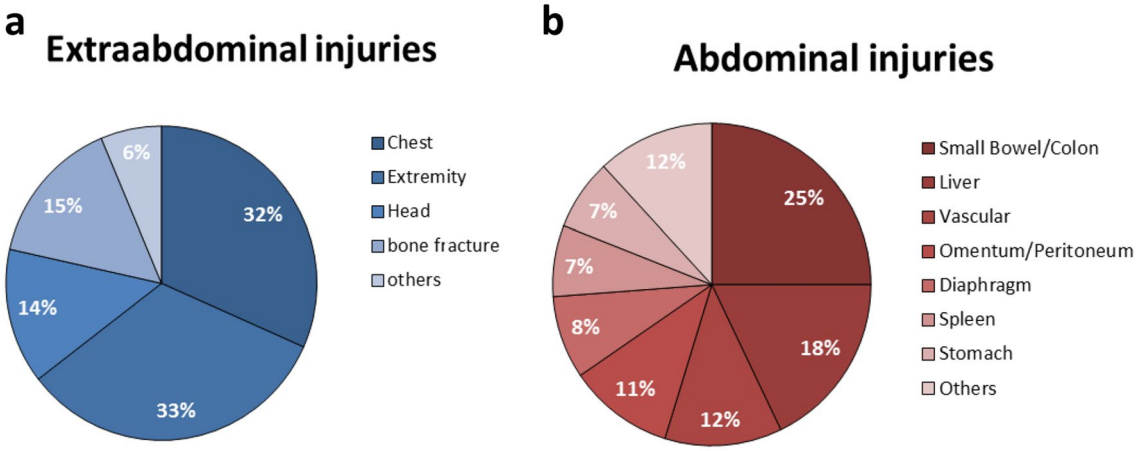

Fig. 2 **a** Distribution of additional extraabdominal injuries. **b** Distribution of intraabdominal organ injuries according to surgical findings

Table 2 Summary of sensitivity (Sens), specificity (Spec)and positive predictive value (PPV) of diagnostic procedures

Procedure	*N* (%)	TP	TN	FP	FN	Sens (%)	Spec (%)	PPV (%)
FAST	106 (92.2)	22 (20.7)	65 (61.3)	4 (3.8)	15 (14.1)	59.4	94.2	84.6
CT	91 (79.1)	41 (45.1)	40 (43.9)	7 (7.7)	3 (3.3)	93.2	85.1	85.4

TP true positive, *TN* true negative, *FP* false positive, *FN* false negative

Table 3 Therapeutic procedures

Procedure	*N*	%
Conservative/interventional	39/2	33.9/1.7
Exploratory laparotomy	26	22.6
Negative	3	11.5
Therapeutic	23	88.5
Diagnostic laparoscopy	45	39.1
Negative	20	44.4
Therapeutic	14	31.1
Conversion to laparotomy	11	24.5

Table 4 Identified abdominal injuries

Diaphragm	7
Omentum, peritoneum	9
Retroperitoneal haematoma	4
Vascular	10
Hollow organs	
Gallbladder	1
Stomach	6
Small bowel	13
Colon	8
Solid organs	
Liver	15
Spleen	6
Kidney	3

In this population of patients, sensitivity and specificity of FAST were 59.4 and 94.2%, respectively, while those of CT were 93.2 and 85.1%, respectively. The positive predictive value was 84.6% of FAST and 85.4% of CT imaging. Overall, 96 patients received both FAST and CT scan. If at least one or both of these diagnostic tools were positive, sensitivity achieved was 95.7%. Table 2 shows the summary of statistic values of each diagnostic procedure.

Therapeutic procedures

Table 3 summarizes the management strategies. Overall, 39 (33.9%) of all patients were successfully managed non-operatively with a 24-hour period of observation and no requirement for surgical intervention. Two patients with active bleeding had a successful endovascular intervention and did not need further therapeutic intervention. After initial diagnostic procedures and hemodynamic stabilization, one patient had to be transferred to another hospital. Almost two-third of all patients (61.7%) underwent surgical exploration and, if required, operative therapy. Indications of urgent laparotomy were visceral evisceration or hemodynamic instability. Further indications of surgical explorations were clinical signs for peritonitis or fascial defect, and positive FAST or CT findings.

Of the 71 patients, 45 (63.4%) underwent initial laparoscopy, while the remaining 26 (36.6%) underwent immediate laparotomy. After laparoscopy, 24.5% (11 of 45) patients were converted to laparotomy. The most common reason for conversion was discovery of injuries not amenable to laparoscopic repair (72.7%). Overall, nontherapeutic or negative operation was performed in 11.5% (3/26) of the patients undergoing laparotomy and 44.4% (20 of 45) of patients with initial laparoscopy. Of the 11 patients with conversion after initial laparoscopy, 2 were ultimately nontherapeutic and 9 therapeutic interventions.

Of those 23 patients, who underwent nontherapeutic operation, eleven (47.8%) had positive findings in the preoperative CT imaging. Hereof, seven findings were false positive and four did not require further surgical therapy. Conversely, eight patients (34.7%) who underwent nontherapeutic operation had a negative preoperative CT scanning, which was confirmed to be true negative according to intraoperative findings.

Intraabdominal injuries occurred in 42.6% (49 of 115) of the total patient cohort. The liver was the most frequently injured solid organ (18%), followed by the spleen (7%). Hollow viscus injury occurred in 33.2% of all injuries and affected most commonly the small bowel, followed by the large bowel and the stomach. The injured organs according to surgical findings are presented in Table 4 and Fig. 2b.

Outcome

Clinical outcomes for the entire patient cohort are summarized in Table 5. Over the 10-year period, there were two mortalities (1.7%) due to abdominal-penetrating trauma. Of those, one patient arrived in cardiac arrest to the emergency department after a gunshot trauma. The other one died because of multiorgan failure due to severe comorbidities. Overall, only ten patients (8.7%) suffered complications, of whom six needed unscheduled surgical reintervention. 15

Table 5 Outcome

Relaparotomy	11 (15.4%)
Second look	5
Missed injury	2 (1.7%)
Transfusion	15 (13%)
EK (mean ± SD)	9.3
Morbidity	10 (8.7%)
Pneumonia	2
Organ failure	3
Intraabdominal abscess	3
Wound infection	4
Mortality	2 (1.7%)
Hospital stay (Days)	7.9
Readmission	2 (1.7%)

patients (13%) needed blood transfusion. Complications included pneumonia, organ failure and infective complications (abdominal abscess, wound infection). There were 2 (1.7%) missed injuries in two patients who were initially managed non-operatively. In both patients, injury (comprising small bowel perforation) was detected within 12 h and delay before surgery, therefore, did not influence morbidity.

The mean length of hospital stay was found to be 7.4 days (range 0–152). 12.2% of patients were hospitalized for a single night, while 29.2% had a 3-day admission, and 9.4% of patients were discharged the same day. Two patients were readmitted to the hospital due to wound infection and impairment of general condition.

Discussion

The current study is the first analysis of German approach in the management of penetrating abdominal trauma over a 10-year period. Our trauma center is located in inner city area of Frankfurt close to the red light district and provides level I acute care to a population of approximately 690,000 inhabitants as well as the largest airport in Germany. As reported before, the incidence of penetrating trauma in an urbanized German region is almost twice as frequent when compared to data from the nationwide registry [27]. We could observe an increase of cases per year in our data since 2012, as described in other series of Europe [28, 29]. Similar, statistics of crime rate in Frankfurt showed an increase of 30% of sharp force violence since 2013 (153 vs 199 cases per year). This highlights the need for management guidelines also in low-volume regions to overcome the lack of institutional experience.

Patient demographics in our cohort is in line with previously published larger studies of the United States and South Africa, demonstrating that mainly middle-aged male patients are suffering from severe penetrating trauma [19, 30]. Similar to previous reports, multiple injuries involving the abdomen, chest and limbs were most common in our study. The mean ISS with eight was also consistent with the published literature, reflecting the comparability of our cohort with those of larger studies [19, 30]. For hemodynamically stable patients, numerous diagnostic tools may help to identify significant abdominal injuries. The reported specificity of FAST scanning in penetrating abdominal trauma is 94–98% with a sensitivity of only 21–46% [16, 31]. The sensitivity in the present study was slightly higher with 59.4% with a similar specificity of 94.2%. In fact, in our cohort 19% of patient with a negative FAST ultimately had a therapeutic laparotomy. In conclusion, the major value of FAST is probably in detecting hemoperitoneum, but a negative FAST in the presence of penetrating abdominal trauma requires additional imaging diagnostic studies to rule out significant injury.

In the setting of penetrating abdominal trauma, CT was found to have a high sensitivity and specificity in determining the need for laparotomy, while the positive predictive value was lower [12, 32, 33]. Based on other studies, the value of CT in the management of abdominal SWs is dubious due to high rates of false-positive findings leading to nontherapeutic laparoscopies or laparotomies [13, 18]. Results of the current study demonstrate that CT imaging is highly sensitive with 93.2% and mostly specific with 85.1% and a positive predictive value of over 80%. Nevertheless, similar to previous reports, seven asymptomatic patients (6.1%) were taken to the operating room based on false-positive CT findings and underwent nontherapeutic laparoscopy [23]. CT scan reveals evidence of injury that may be of questionable clinical significance. Consequently, in hemodynamically stable patients CT should be considered as a diagnostic tool to facilitate initial management decision, but positive CT findings should not be the sole determinant of the need for operative exploration.

One popular diagnostic procedure to determine the severity of intraabdominal injuries caused by SWs or GSWs is the performance of laparoscopy. Several groups currently recommend diagnostic laparoscopy based on peritoneal penetration as it has been shown to be safe and to significantly decrease the rate of nontherapeutic laparotomy from over 60% to 0–11% [19, 21, 34]. In contrast, others have criticized laparoscopy as being expensive and ineffective [23, 35] and so concluded that asymptomatic patients should simply be observed with serial clinical examinations. In the present study, with 61.7% we had a high rate of operative exploration for patients, likely due to a broad performance of laparoscopic evaluations in case of suspicious peritoneal violation. On the one hand, this led to a very low rate of nontherapeutic laparotomy of only 11.5%; on the other hand, almost 50% of performed laparoscopies were classified as negative or

nontherapeutic. Similar to previous reports, we found that a significant proportion (24.5%) of those patients were converted to open and the rate of therapeutic laparoscopies was quite low with only 30% [20, 36]. Nevertheless, we think, in low-volume areas, laparoscopy for hemodynamically stable patients with evidence for peritoneal penetration is feasible and efficient, avoiding morbidity associated with nontherapeutic laparotomy.

Regarding our data, admission of asymptomatic patients for a non-operative approach appears to be safe. We employed a conservative management not in response to a definite hospital policy, but as a result of the clinical viewpoints. Delayed laparotomy due to missed injury was conducted in only 1.7% of patients. Hereby, the delay to operative management was not associated with morbidity or mortality. This is in concordance with previous reports in which patients who failed SNOM and eventually required laparotomy did not suffer unnecessary morbidity [37, 38]. Further, it has been shown that the implementation of SNOM is able to reduce the rates of negative laparotomies [39].

These data support that in a level I trauma center the use of SNOM is safe and eases the unjustified fear of worse prognosis not only in centers handling a high trauma load, but also in low-volume settings. Thus, we propose the clinical algorithm outlined in Fig. 3.

This study has several limitations. As a retrospective design, we relied on the accurate documentation of patients' assessment. Due to the inconsistency of documented findings on wound exploration, we did not include it in our analysis. Patients were not followed up to assess for long-term complications. In addition, our data were collected over a 10-year period over which the management of abdominal-penetrating trauma has evolved. Finally, the number of patients is limited but typical and consistent with most trauma centers around Germany and Europe. In spite of these shortcomings, the results of this survey are representative of the management of penetrating trauma care in Germany and in some ways encouraging. Even though our trauma center cannot count on the daily experience of penetrating abdominal trauma care, we developed successful policies that allow the right patients to receive operation and those who do not require any intervention.

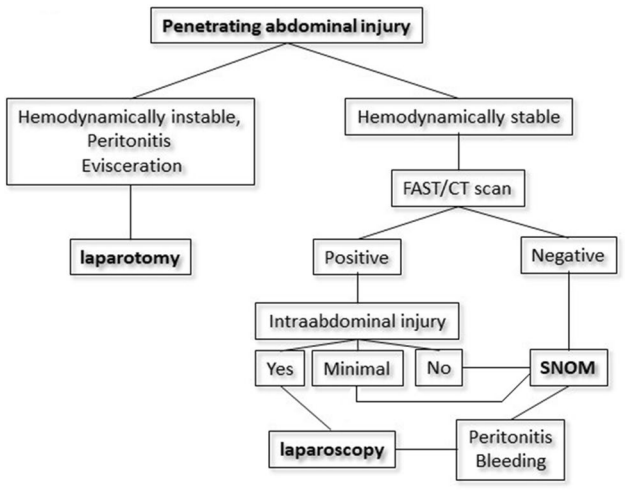

Fig. 3 Proposed clinical algorithm for the management of patients with penetrating abdominal injury

Conclusion

We conclude from this study that a routine laparotomy can be omitted in hemodynamically stable and asymptomatic patients with abdominal SWs or GSWs. Patients selected for SNOM should undergo CT scanning and serial clinical examination to detect intra-abdominal injuries and aid in decision-making. The increased use of SNOM and laparoscopy contributes in decreasing the incidence of unnecessary laparotomies.

Compliance with ethical standards

Conflict of interest Patrizia Malkomes, Philipp Störmann, Hanan El Youzouri, Sebastian Wutzler, Ingo Marzi, Thomas Vogl, Wolf Otto Bechstein and Nils Habbe declare that they have no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Human rights and animal participants This article does not contain any studies with animals performed by any of the authors.

References

1. Bieler D, Franke A. Gunshot and stab wounds: combination of clinical and forensic medical data. Unfallchirurg. 2015;118:726. https://doi.org/10.1007/s00113-015-0037-4.
2. Inkinen J, Kirjasuo K, Gunn J, Kuttila K. Penetrating trauma; experience from Southwest Finland between 1997 and 2011, a retrospective descriptive study. Eur J Trauma Emerg Surg. 2015;41:429–33. https://doi.org/10.1007/s00068-014-0445-0.
3. Hoffmann C, Goudard Y, Falzone E, Leclerc T, Planchet M, Cazes N, et al. Management of penetrating abdominal trauma: what we need to know? Ann Fr Anesth Reanim. 2013;32:104–11. https://doi.org/10.1016/j.annfar.2012.12.006.
4. Bege T, Berdah SV, Brunet C. Stab wounds in emergency department. Presse Med. 2013;42:1572–8. https://doi.org/10.1016/j.lpm.2013.09.003.
5. Kristoffersen S, Normann S-A, Morild I, Lilleng PK, Heltne J-K. The hazard of sharp force injuries: factors influencing outcome. J Forensic Leg Med. 2016;37:71–7. https://doi.org/10.1016/j.jflm.2015.10.005.

6. Kauvar DS, Lefering R, Wade CE. Impact of hemorrhage on trauma outcome: an overview of epidemiology, clinical presentations, and therapeutic considerations. J Trauma. 2006;60:S3–11. https://doi.org/10.1097/01.ta.0000199961.02677.19.
7. Lutge E, Moodley N, Tefera A, Sartorius B, Hardcastle T, Clarke D. A hospital based surveillance system to assess the burden of trauma in KwaZulu-Natal Province South Africa. Injury. 2016;47:135–40. https://doi.org/10.1016/j.injury.2015.08.020.
8. Maxwell R, Trotter C, Verne J, Brown P, Gunnell D. Trends in admissions to hospital involving an assault using a knife or other sharp instrument, England, 1997–2005. J Public Health (Oxf). 2007;29:186–90. https://doi.org/10.1093/pubmed/fdm018.
9. Allen SR, Scantling DR, Delgado MK, Mancini J, Holena DN, Kim P, et al. Penetrating torso injuries in older adults: increased mortality likely due to "failure to rescue". Eur J Trauma Emerg Surg. 2015;41:657–63. https://doi.org/10.1007/s00068-014-0491-7.
10. Shaftan GW. Indications for operation in abdominal trauma. Am J Surg. 1960;99:657–64.
11. Fabian TC, Croce MA, Stewart RM, Pritchard FE, Minard G, Kudsk KA. A prospective analysis of diagnostic laparoscopy in trauma. Ann Surg. 1993;217:557–64 (discussion 564–5).
12. Como JJ, Bokhari F, Chiu WC, Duane TM, Holevar MR, Tandoh MA, et al. Practice management guidelines for selective nonoperative management of penetrating abdominal trauma. J Trauma. 2010;68:721–33. https://doi.org/10.1097/TA.0b013e3181cf7d07.
13. Biffl WL, Moore EE. Management guidelines for penetrating abdominal trauma. Curr Opin Crit Care. 2010;16:609–17. https://doi.org/10.1097/MCC.0b013e32833f52d2.
14. Oreskovich MR, Carrico CJ. Stab wounds of the anterior abdomen. Analysis of a management plan using local wound exploration and quantitative peritoneal lavage. Ann Surg. 1983;198:411–9.
15. Cothren CC, Moore EE, Warren FA, Kashuk JL, Biffl WL, Johnson JL. Local wound exploration remains a valuable triage tool for the evaluation of anterior abdominal stab wounds. Am J Surg. 2009;198:223–6. https://doi.org/10.1016/j.amjsurg.2008.11.024.
16. Yildiz MK, Ozkan E, Odabasi HM, Eris C, Gunay E, Abuoglu HH, et al. Analysis of 120 patients with abdominal stab wound focusing on diagnostic role of fast. Int J Clin Exp Med. 2014;7:1386–90.
17. Rehm CG, Sherman R, Hinz TW. The role of CT scan in evaluation for laparotomy in patients with stab wounds of the abdomen. J Trauma. 1989;29:446–50.
18. Inaba K, Okoye OT, Rosenheck R, Melo N, Branco BC, Talving P, et al. Prospective evaluation of the role of computed tomography in the assessment of abdominal stab wounds. JAMA Surg. 2013;148:810–6. https://doi.org/10.1001/jamasurg.2013.2521.
19. Chestovich PJ, Browder TD, Morrissey SL, Fraser DR, Ingalls NK, Fildes JJ. Minimally invasive is maximally effective: Diagnostic and therapeutic laparoscopy for penetrating abdominal injuries. J Trauma Acute Care Surg. 2015;78:1076–83. https://doi.org/10.1097/TA.0000000000000655 (discussion 1083–5).
20. 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;37:113–22. https://doi.org/10.1007/s00268-012-1790-y.
21. Lin H-F, Wu J-M, Tu C-C, Chen H-A, Shih H-C. Value of diagnostic and therapeutic laparoscopy for abdominal stab wounds. World J Surg. 2010;34:1653–62. https://doi.org/10.1007/s00268-010-0485-5.
22. Biffl WL, Kaups KL, Cothren CC, Brasel KJ, Dicker RA, Bullard MK, et al. Management of patients with anterior abdominal stab wounds: a Western Trauma Association multicenter trial. J Trauma. 2009;66:1294–301. https://doi.org/10.1097/TA.0b013e31819dc688.
23. Biffl WL, Kaups KL, Pham TN, Rowell SE, Jurkovich GJ, Burlew CC, et al. Validating the Western Trauma Association algorithm for managing patients with anterior abdominal stab wounds: a Western Trauma Association multicenter trial. J Trauma. 2011;71:1494–502. https://doi.org/10.1097/TA.0b013e31823ba1de.
24. Murry JS, Hoang DM, Ashragian S, Liou DZ, Barmparas G, Chung R, et al. Selective Nonoperative Management of Abdominal Stab Wounds. Am Surg. 2015;81:1034–8.
25. Singh N, Hardcastle TC. Selective non operative management of gunshot wounds to the abdomen: a collective review. Int Emerg Nurs. 2015;23:22–31. https://doi.org/10.1016/j.ienj.2014.06.005.
26. Kevric J, O'Reilly GM, Gocentas RA, Hasip O, Pilgrim C, Mitra B. Management of haemodynamically stable patients with penetrating abdominal stab injuries: review of practice at an Australian major trauma centre. Eur J Trauma Emerg Surg. 2016;42:671–5. https://doi.org/10.1007/s00068-015-0605-x.
27. Stormann P, Gartner K, Wyen H, Lustenberger T, Marzi I, Wutzler S. Epidemiology and outcome of penetrating injuries in a Western European urban region. Eur J Trauma Emerg Surg. 2016;42:663–9. https://doi.org/10.1007/s00068-016-0630-4.
28. Pallett JR, Sutherland E, Glucksman E, Tunnicliff M, Keep JW. A cross-sectional study of knife injuries at a London major trauma centre. Ann R Coll Surg Engl. 2014;96:23–6. https://doi.org/10.1308/003588414X13824511649616.
29. Casali M, Di Saverio S, Tugnoli G, Biscardi A, Villani S, Cancellieri F, et al. Penetrating abdominal trauma: 20 years experience in a Western European Trauma Center. Ann Ital Chir. 2008;79:399–407.
30. Mnguni MN, Muckart DJJ, Madiba TE. Abdominal trauma in durban, South Africa: factors influencing outcome. Int Surg. 2012;97:161–8. https://doi.org/10.9738/CC84.1.
31. Udobi KF, Rodriguez A, Chiu WC, Scalea TM. Role of ultrasonography in penetrating abdominal trauma: a prospective clinical study. J Trauma. 2001;50:475–9.
32. Goodman CS, Hur JY, Adajar MA, Coulam CH. How well does CT predict the need for laparotomy in hemodynamically stable patients with penetrating abdominal injury? A review and meta-analysis. AJR Am J Roentgenol. 2009;193:432–7. https://doi.org/10.2214/AJR.08.1927.
33. Uzunosmanoglu H, Corbacioglu SK, Cevik Y, Akinci E, Hacifazlioglu C, Yavuz A, Yuzbasioglu Y. What is the diagnostic value of computed tomography tractography in patients with abdominal stab wounds? Eur J Trauma Emerg Surg. 2017;43:273–7. https://doi.org/10.1007/s00068-015-0625-6.
34. Karateke F, Ozdogan M, Ozyazici S, Das K, Menekse E, Gulnerman YC, et al. The management of penetrating abdominal trauma by diagnostic laparoscopy: a prospective non-randomized study. Ulus Travma Acil Cerrahi Derg. 2013;19:53–7. https://doi.org/10.5505/tjtes.2013.40799.
35. Villavicencio RT, Aucar JA. Analysis of laparoscopy in trauma. J Am Coll Surg. 1999;189:11–20.
36. Cherry RA, Eachempati SR, Hydo LJ, Barie PS. The role of laparoscopy in penetrating abdominal stab wounds. Surg Laparosc Endosc Percutan Tech. 2005;15:14–7.
37. Peev MP, Chang Y, King DR, Yeh DD, Kaafarani H, Fagenholz PJ, et al. Delayed laparotomy after selective non-operative management of penetrating abdominal injuries. World J Surg. 2015;39:380–6. https://doi.org/10.1007/s00268-014-2813-7.
38. Fikry K, Velmahos GC, Bramos A, Janjua S, Moya M de, King DR, Alam HB. Successful selective nonoperative management of abdominal gunshot wounds despite low penetrating trauma volumes. Arch Surg. 2011;146:528–32. https://doi.org/10.1001/archsurg.2011.94.
39. Lamb CM, Garner JP. Selective non-operative management of civilian gunshot wounds to the abdomen: a systematic review of the evidence. Injury. 2014;45:659–66. https://doi.org/10.1016/j.injury.2013.07.008.