CHAPTER 14

RADIOLOGICAL EVALUATION OF ABDOMINAL TRAUMA CASES

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INTRODUCTION

Abdominal trauma is among the important causes of death worldwide, especially in developed countries. These traumas are classified into two groups as blunt and penetrating traumas. The most common cause of blunt abdominal traumas is by far motor vehicle accidents followed by falls and assault, while penetrating abdominal traumas are mostly caused by stabbing and gunshot wounds. Emergency management of abdominal trauma consisted of several steps including resuscitation and stabilization of the patient, diagnosis with history/physical exam, laboratory tests and radiologic imaging and treatment either with surgery or non-operative options.

Radiological evaluation of abdominal trauma has evolved recently with the advent and developments in tomography and magnetic resonance imaging technologies, while the role of conventional radiography has been substantially decreased. The most commonly used imaging modalities as diagnostic tools are extended Focused Assessment with Sonography for Trauma (eFAST) and multislice computed tomography (MSCT). Enhancements in the resolution of images has further increased the effectiveness of these methods in help a rapid diagnosis and reduction of time between the injury and operation. This chapter begins with a brief definition, general evaluation and examination of abdominal trauma, and continues with emergency management of abdominal traumas. The most used radiological modalities are addressed in detail, and the chapter end with future projections and the use of artificial intelligence (AI) in the management of abdominal traumas.

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ABDOMINAL TRAUMAS

Trauma is the third most common cause of death in all ages worldwide (1). Abdominal traumas may be life threatening and should be approached carefully. Occult bleeding may present in the abdomen, and if not identified and corrected appropriately, may lead to harmful consequences. Because solid abdominal organs of the abdomen such as kidneys and liver may bleed profusely as a result of trauma. Although abdominal traumas mostly require conservative management, the overall mortality rate is reported between 10-36% (2). The lethal triad including acidosis, hypothermia and coagulopathy has been recognized as a significant cause of mortality in patients with traumatic injury (3). In order to prevent this triad clinicians have to control bleeding and prevent further heat loss.

Patients with abdominal trauma should be assessed and stabilized rapidly, and early surgical consultation should be made to maximize the likelihood of a successful outcome (4). Abdominal trauma is traditionally classified as blunt or penetrating (5). Blunt abdominal trauma is usually caused by motor vehicle accidents, falls and assaults, while penetrating abdominal trauma most commonly results from stabbing or gunshot wounds. The majority of abdominal traumas result from a blunt mechanism, whereas penetrating abdominal traumas are relatively infrequent (6).

General Evaluation of Abdominal Traumas

The initial assessment of patients with abdominal trauma is similar to that of patients with all other types of trauma and includes the evaluation of airway, breathing, circulation, disability, and exposure known as ABCDE assessment.

Airway: Recent studies have reported that when performed by experienced and skilled emergency medical services (EMS), management of airway can be performed in the prehospital setting professionals, preventing delay in arrival to hospital and significantly reducing the rate of mortality (7, 8).

Breathing: Breathing derangement causes death within minutes. In all trauma cases, it is possible to determine respiratory rate. If breathing is insufficient, assisted ventilation is performed by trained personnel using a bag mask if available. Breathing is assessed as airway patency breathing adequacy is checked.

Circulation: Circulation is assessed as oxygen supply, airway patency and adequacy are checked. In the case of insufficient circulation; external bleeding is stopped, large-bore IV lines are established and fluid administered is initiated, pulses, capillary refill and blood pressure are assessed (6).

Disability: Initial neurologic examination is performed to detect any disability

and to document the baseline status. This exam includes the evaluation of size and reactivity of pupils, determination of Glasgow Coma Scale (GCS) and any possible unilateral weakness (9).

Exposure: Trauma patient is completely undressed. Any mark of the trauma is sought, including seat belt to indicate a motor vehicle accident. Impaled foreigns bodies should not be removed as they may provide hemostasis in a source of bleeding. This can be done only under supervision of the surgeon (9).

General Examination

Steps of the general examination of abdominal trauma patients are shown in Figure 1. No further details are provided as this issue is not within the scope of this chapter. Radiological examinations are addressed below boardly.

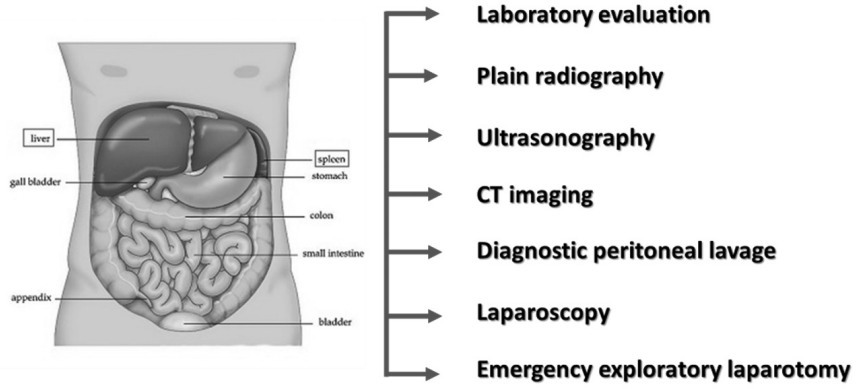

Figure 1. Steps of general examination in abdominal trauma

MANAGEMENT OF ABDOMİNAL TRAUMA IN EMERGENCY DEPARTMENT

At the Scene

The initial management of abdominal trauma is a critical emergency measure. An analgesic administered at the scene is followed by transfer of the patient to a place with sufficient facilities for definitive care (10). If the patient has already developed shock and time waste is anticipated for the transfer, the initial management is implemented by an infusion of blood plasma (11).

At the Hospital

Resuscitation of the trauma patient is started on arrival at the hospital. It is important to obtain a detailed history of injury and to perform a thorough physical

exam. Physical exam should not be prolonged and some other studies such as laboratory analysis may be done meanwhile, but nevertheless the examination usually will take a few hours (12).

The introduction of effective antibiotics and chemotherapeutics has significantly reduced the effect of time lag between the injury and the operation (13). The actual significant impact is the duration of shock. The urgently used effective measures to fight against shock has also reduced the effect of preoperative time lag on the mortality outcomes.

Resuscitation

During the resuscitation process, the trauma patient is placed in a warm room on a wheeled stretcher and made comfortable with reasonable use of analgesics as much as possible. Properly matched whole blood is then administered (12). The amount of blood transfusion is determined by the severity of trauma, degree of shock and response to treatment (14). Blood pressure measurement is a rough measure to monitor circulatory status, although it is useful for practical purposes . Systolic blood pressure may give an idea about the amount of blood to be transfused depending on the severity of shock (15).

The determination of intra-abdominal hemorrhage is of paramount importance as it may cause lethal consequences. In the presence of intra-abdominal bleeding, there is no response to the first few units of blood and resuscitation is almost impossible in these patients. Emergency operation in this setting becomes resuscitative in itself and helps further treatment. At the later stage of resuscitation, the stomach content is emptied through a gastric tube. Presence of blood in this content may indicate upper gastrointestinal bleeding (16).

Diagnosis

Blunt abdominal trauma: In blunt trauma, missed intra-abdominal injury and delays in surgery are associated with significant mortality and mortality (17). Therefore, efficient diagnostic modalities should be used to establish the definitive diagnosis as soon as possible. Physical exam, laboratory tests, conventional radiography, ultrasonography, computed tomography and diagnostic laparoscopy are the most commonly used tools for the diagnosis of abdominal trauma (18).

Penetrating abdominal trauma: Physical exam of an awake patient may show signs of peritonitis such as rebound. A detailed assessment should be attempted since the injury may often be intra-abdominal. Laboratory tests are routinely made, but they are not specific. Ultrasound, X-rays and Ct are the most commonly diagnostic tools (19).

Treatment

Blunt abdominal trauma: The treatment of blunt abdominal trauma has undergone significant changes over years. Today, the focus is on the damage control and underlying mechanism of the injury (20). In addition, advancements in interventional radiology have enabled control of inaccessible bleeding sites. Nonoperative management of blınt abdominal traumas can also be an option under certain conditions.

Penetrating abdominal trauma: Therapeutic approach to a patient with penetrating abdominal trauma depends on the type of instrument which has caused the injury and hemodynamic status. Patients with penetrating abdominal injury are generally treated with fluids and/or blood. Surgical approach is often needed in these patients (21). The impaled objects should be removed only in the operating room, because they may stop bleeding from an intraabdominal site.

RADIOLOGICAL EVALUATION OF ABDOMINAL TRAUMA CASES

Breakthrough innovations and developments in the field of radiology and technical advancements have made radiological assessment an inevitable diagnostic tool for the management of abdominal trauma. Especially increased resolution in imaging technologies enables to detect and assess even occult abnormalities within the abdominal region. Todays' most commonly used radiological modalities as diagnostic tools in the management of abdominal trauma are discussed below. Decision flow of a patient with abdominal trauma is shown in Figure 2.

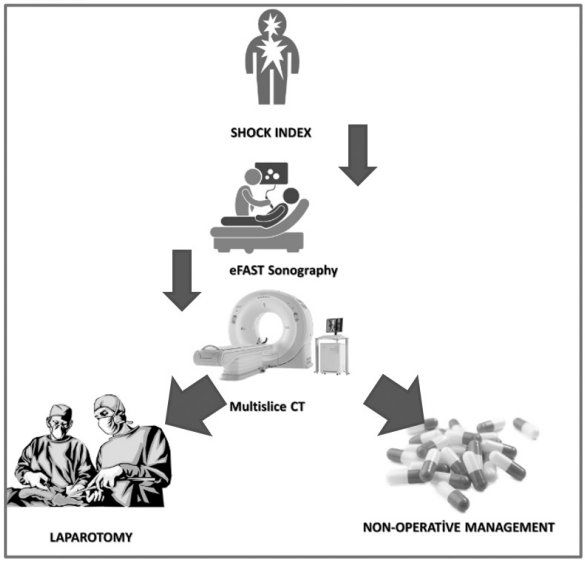

Figure 2. Decision flow chart in abdominal trauma

Conventional radiography

The diagnostic role of conventional radiography has considerably decreased with the advent of modern tomographic techniques. However, it remains one of the most commonly used diagnostic tools for abdominal trauma as it is widely available in almost each healthcare facility and can be performed rapidly. Its use is limited for the assessment of an isolated blunt trauma. In addition, it has a low sensitivity in detecting air (22). Conventional radiography can detect 60-90% of acute traumatic diaphragmatic ruptures, but most findings on radiographs can not be distinguished from hemothorax (23).

The most effective usage of radiography is the detection of indicator injuries that should be further assessed using the other imaging modalities (24). For instance, intra-abdominal injury is associated with pathological findings on chest radiography including spinal fractures and pelvic fractures. On the other hand, conventional radiography may be helpful in secondary follow-up of patients known to have duodenal and upper urinary tract injuries (25).

Focused Assessment with Sonography for Trauma (FAST)

FAST may not reveal every abnormality in the management of patients with abdominal trauma, although it maximizes the visualization of free fluid, hemorrhage and other abnormal fluids including bile and urine, suggesting source of the damage in these patients. The extended form of the FAST (eFAST) enables us to evaluate possible damage to hemothorax, pneumothorax, hemopericardium, solid organ and retroperitoneal injury (26).

According to the ACEP guidelines, indications for FAST include evaluation of the torso for evidence of abnormal fluids that may indicate injury in the pericardial, peritoneal and pleural cavities (27). With the development of eFAST, the indications for FAST have been expanded to include the lungs to investigate the possibility of pneumothorax (28, 29). Although sometimes FAST may be contraindicated in the case of patients scheduled for emergency operation, it may be necessary to perform FAST examination in order to rule out pneumothorax or pericardial tamponade before surgery.

In a meta-analysis including adult trauma patients, pooled sensitivity was found as 78.9% and specificity as 99.2% with FAST examination (23). In abdominal trauma patients, FAST has been shown to decrease the use of computed tomography, time between the injury and operation, and to shorten length of stay and thuse, lower health care costs (30).

Probe selection: In order to readily examine deeper structures, a US probe of lower frequency, either curvilinear (3-5 MHz) or phased array (3-4.5 MHz)

can be used (31). Curvilinear probe provides a better resolution in the abdomen compared to a phased array probe, but its use is not ideal for examining the heart. Whereas, a phased array probe is better for the evaluation of smaller areas such as scanning between the ribs (32).

RUQ view: this window is used to assess the perihepatic region and the potential space between the kidney and liver, also known as Morison's pouch, using the liver as the sonographic window. Because free intraperitoneal fluid tends to distribute here in a patient in the supine position, this view is more sensitive in this site. The detection of free fluid can be enhanced in the Trendelenburg position, if it is possible (31).

LUQ view: this window is used to evaluate the perisplenic region and the potential space between the spleen and kidney. Since phrenicocolic ligament limits the passage of fluids down, fluid flow is different in LUQ view compared to RUQ view (31).

Pelvic view: the bladder is used as the sonographic window to assess to make the assessment of free fluid. In the pelvic view, the reverse Trendelenburg position can be used to enhance the detection of free fluid. The detection is compromised in the bladder has been emptied to insert an urinary catheter (33).

Cardiac view: effusion and tamponade are assessed within the pericardium by observation of free fluid. The probe is placed between the 2nd and 4th intercostal spaces on the anterior chest wall. The entire heart should be assessed with FAST performed with cardiac view, because pericardial effusion can start from the posterior aspect of the pericardium. Cardiac tamponade is likely to occur in the case of collapse in any chamber during the cardiac cycle and a substantial amount of free fluid is found in the pericardial space (34).

Limitations of FAST

Solid organ injuries that do not cause significant hemoperitoneum can not be reliably graded using FAST. FAST is effectively used in the case of critical free fluid in the abdomen. The minimum volume of fluid needed to perform an efficient FAST has been reported as 668 mL in the supine and 444 mL in the Trendelenburg positions with RUQ view and 157 mL in the pelvic view (35). Therefore, FAST is not a suitable diagnostic tool for the detection of the small amount of intraperitoneal hemorrhage.

As another limitation, in case of delayed presentation following abdominal trauma FAST may give false-negative results since blood begins to clot, distinguishing it from the surrounding structures. A FAST examination, which is reported as negative, should not be considered as definitive and clinicians should progress the assessment with computed tomography.

Multislice Computed Tomography (MSCT)

Rapid and accurate diagnosis is essential for the management of abdominal traumas in the emergency department efficiently. Emergent abdominal surgeries account for nearly 53% of all trauma related surgical operations. Time lag between the injury and operation is critical and makes a rapid diagnosis paramount important. Radiological imaging modalities play an important role as diagnostic tools. One of the most commonly used imaging modality for this purpose is multislice computed tomography (MSCT). Injuries that can be detected with MSCT are shown in Figure 3.

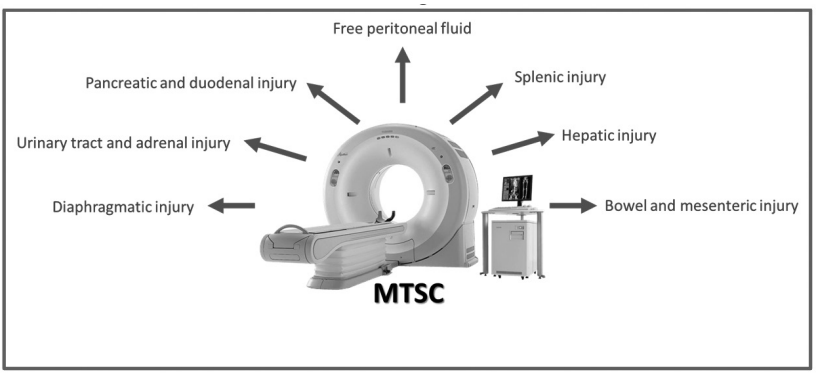

Figure 3. Abdominal injuries detected with MSCT scans

In abdominal trauma, treatment decisions are based on accurate imaging and depend on numerous factors such as clinical presentation. Therefore, MSCT has become the gold standard to evaluate abdominal traumas, and especially blunt traumas (36, 37). New generation CT scanners have high sensitivity and specificity in evaluation of the patient's entire body in a short time, and provides detailed information about the concomitant injuries. In order to increase the amount of data obtained from a CT scan, imaging should be performed using contrast-enhancement. Proper use of contrast material and acquisition of the appropriate number of contrast agent enhancement phases are important considerations to take into account when performing MSCT (38). Contrast agents should not be administered orally and should be given and instead, intravenous contrast enhancement should be preferred. Contrast agents allow clinicians to evaluate bowel perforation, but their use leads to delays in imaging and increases the risk of aspiration. In addition, radiation dose to be used should be minimized so as not to compromise quality of the scans.

High-resolution imaging scans permit evaluation of the gastrointestinal tract in emergency settings. Continuous technical advances improve a rapid scan. Detection of free air in the abdomen has long term been regarded as diagnostic for viscus injury and thus, as an indication for surgery. However, studies have shown that presence of free air may not be associated with viscus injury as suggested by imaging. Besides, free abdominal air can also occur in patients with pneımothorax, abdominal wall defects, barotrauma and tracheal injuries (39). Using CT and intravenous contrast agent is helpful in evaluation of parenchymal organs and vessels. Modern CT scanners can detect free air by 64 to 95% sensitivity and 94 to 100% specificity (40).

In a study on 5877 blunt abdominal trauma, free air was found in 74 patients and of these patients 61% had no significant intra-abdominal injury (39). In another study with 419 trauma patients, free air detected by CT predicted bowel injury with a 50% sensitivity and 94.5% specificity (41). Considering the results of these studies, free air alone is not useful. Therefore, some other parameters such as distribution and volume of free air should be evaluated together with patient history, and clinical signs and symptoms.

Multiphase Imaging

In order to perform an optimum CT scan, MSCT should be performed by maximum detection of critical abdominal injuries while minimizing patients' risks at the same time. Multidetector scanners allor acquisition of images at various phases of enhancement. Therefore, data continue to accumulate that support various approaches. A typical multitrauma MSCT involves portal venous phase images of the abdomen and pelvis that are acquired 65-80 seconds after the intravenous administration of contrast agent. Delayed phase (5-10 minutes after contrast administration images are also necessary in patients with suspected injuries.

Radiation dose

Considering that the majority of trauma victims are young people, risk of exposure to irradiation must be weighed against benefits that can be obtained with MSCT that help answer all clinically important answers. In addition, a need for additional tests causes adding to radiation doses. Therefore, the balance between diagnostic capability of CT scans and the risk of exposure to irradiation should be well assessed (42).

Several approaches can be used to optimize MSCT. The number of phases acquired should be selected carefully. By this way, a delated series is limited with

patients who have abnormalities detected on the portal venous phase images. In addition, automated dose modulation provides fluctuation during image acquisition on the basis of patients' size (43).

Future Projections

The role of eFAST screening will be increased in the future in acutely injured people with improving technology and imaging resolution. eFAST examination is already started to be incorporated into prehospital protocols, because it has serious potential to influence the management of abdominal trauma at the scene of injury. US images taken at the scan can be transferred by paramedics to expert reviewers in the emergency departments and trauma centers for evaluation and triage. Thus, resuscitation and operating rooms can be preferred early enough. The role of contrast-enhanced MSCT will be increased for the detection of solid organ injury.

CONCLUSION

Traumas are the third most common cause of death worldwide. Abdominal trauma is one of the most frequent visits to the emergency department and needs to be addressed as soon as possible to shorten time lag between the injury and surgery, if indicated. One of the critical steps in the management of blunt and penetrating abdominal traumas is radiological investigations that consists of conventional radiography, eFAST, MSCT and MRI. Using these techniques, as much as possible intra-abdominal injuries are discovered to help treatment. Radiological evaluatşon of traumas require a meticulous evaluation and close collaboration between the disciplines, especially between radiology and emergency medicine departments. On the other hand, resolution of the radiological scans is continuously increased and refinemed, increasing sensitivity and specificity of imaging modalities in detection of more obscure intra-abdominal injuries. With the incorporation of artificial intelligence and machine learning facilities, radiological assessment of abdominal trauma will be evolved to a much more efficient diagnostic study in near future.

REFERENCES

1. Kafadar H, Kafadar S, Tokdemir M. Comparison of internal organ injuries by blunt abdominal trauma in rats with empty or full stomach. Ulus Travma Acil Cerrahi Derg. 2014;20(6):395-400. doi: 10.5505/tjtes.2014.92331.
2. Gönültaş F, Kutlutürk K, Gok AFK, et al. Analysis of risk factors of mortality in abdominal trauma. Abdominal travmada mortaliteyi etkileyen risk faktörlerinin analizi. Ulus Travma Acil Cerrahi Derg. 2020;26(1):43-49. doi:10.14744/tjtes.2019.12147
3. Cirocchi R, Montedori A, Farinella E, Bonacini I, Tagliabue L, Abraha I. Damage control sur-

gery for abdominal trauma. Cochrane Database Syst Rev. 2013;2013(3):CD007438. Published 2013 Mar 28. doi:10.1002/14651858.
4. Göksu Afacan (September 19th 2018). Abdominal Trauma, Trauma Surgery, Ozgur Karcioglu and Hakan Topacoglu, IntechOpen, DOI: 10.5772/intechopen.76474. Available from: https://www.intechopen.com/chapters/63082
5. Yiğit E, Taş İ. The etiology of the traumatic abdominal injuries in Diyarbakır, Turkey: A 4-year retrospective analysis. Cerrahpaşa Med J. 2021;45(3):135-140.
6. Bouzat P, Valdenaire G, Gauss T, et al. Early management of severe abdominal trauma. Anaesth Crit Care Pain Med. 2020;39(2):269-277. doi:10.1016/j.accpm.2019.12.001
7. Lockey DJ, Healey B, Crewdson K, et al. Advanced airway management is necessary in prehospital trauma patients. Br J Anaesth 2014;1–6. https://doi. org/10.1093/bja/aeu412.
8. Meizoso JP, Valle EJ, Allen CJ, et al. Decreased mortality after prehospital interventions in severely injured trauma patients. J Trauma Acute Care Surg. 2015;79(2):227-231. doi:10.1097/TA.0000000000000748
9. Center for Substance Abuse Treatment (US). Trauma-Informed Care in Behavioral Health Services. Rockville (MD): Substance Abuse and Mental Health Services Administration (US); 2014. (Treatment Improvement Protocol (TIP) Series, No. 57.) Section 1, A Review of the Literature. Available from: https://www.ncbi.nlm.nih.gov/books/NBK207192/
10. Ahmadi A, Bazargan-Hejazi S, Heidari Zadie Z, et al. Pain management in trauma: A review study. J Inj Violence Res. 2016;8(2):89-98. doi:10.5249/jivr.v8i2.707
11. Holcomb JB, Tilley BC, Baraniuk S, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: the PROPPR randomized clinical trial. JAMA. 2015;313(5):471-482. doi:10.1001/jama.2015.12
12. Ford K, Menchine M, Burner E, et al. Leadership and Teamwork in Trauma and Resuscitation. West J Emerg Med. 2016;17(5):549-556.
13. Trikha V, Albert V, Kumar VS, et al. Effect of Time Lag from Injury to Surgery on the Temporal Expression of Growth Factors After Intramedullary Nailing of Isolated Fracture of Femur Shaft. Indian J Orthop. 2020;54(Suppl 1):109-115. doi:10.1007/s43465-020-00173-9
14. Tseng CH, Chen TT, Wu MY, et al. Resuscitation fluid types in sepsis, surgical, and trauma patients: a systematic review and sequential network meta-analyses. Crit Care. 2020;24(1):693. doi:10.1186/s13054-020-03419-y
15. Wiles MD. Blood pressure in trauma resuscitation: 'pop the clot' vs. 'drain the brain'?. Anaesthesia. 2017;72(12):1448-1455.
16. Coccolini F, Roberts D, Ansaloni L, et al. The open abdomen in trauma and non-trauma patients: WSES guidelines. World J Emerg Surg. 2018;13:7.
17. Miller PR, Croce MA, Bee TK, et al. Associated injuries in blunt solid organ trauma: implications for missed injury in nonoperative management. J Trauma. 2002;53(2):238-244.
18. Jansen JO, Yule SR, Loudon MA. Investigation of blunt abdominal trauma. BMJ. 2008;336(7650):938-942. doi:10.1136/bmj.39534.686192.80
19. McDonald AA, Robinson BRH, Alarcon L, et al. Evaluation and management of traumatic diaphragmatic injuries: A Practice Management Guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg. 2018;85(1):198-207.
20. Zhao ZG, Li YS, Wang J, et al. Zhonghua Wai Ke Za Zhi. 2012;50(4):299-301.
21. Brand M, Grieve A. Prophylactic antibiotics for penetrating abdominal trauma. Cochrane Database Syst Rev. 2019;12(12):CD007370.
22. Iaselli F, Mazzei MA, Firetto C, et al. Bowel and mesenteric injuries from blunt abdominal trauma: a review. Radiol Med. 2015;120(1):21-32. doi:10.1007/s11547-014-0487-8
23. Stengel D, Bauwens K, Rademacher G, et al. Association between compliance with methodological standards of diagnostic research and reported test accuracy: meta-analysis of focused assessment of US for trauma. Radiology. 2005;236(1):102-111. doi:10.1148/radiol.2361040791
24. Deunk J, Brink M, Dekker HM, et al. Predictors for the selection of patients for abdominal CT after blunt trauma: a proposal for a diagnostic algorithm. Ann Surg. 2010;251(3):512-520.

doi:10.1097/SLA.0b013e3181cfd342
25. Goldman SM, Sandler CM. Urogenital trauma: imaging upper GU trauma. Eur J Radiol. 2004;50(1):84-95. doi:10.1016/j.ejrad.2003.11.018
26. Hamada SR, Delhaye N, Kerever S, et al. Integrating eFAST in the initial management of stable trauma patients: the end of plain film radiography. Ann Intensive Care. 2016;6(1):62. doi:10.1186/s13613-016-0166-0
27. Boulanger BR, Kearney PA, Tsuei B, et al. The routine use of sonography in penetrating torso injury is beneficial. J Trauma. 2001;51(2):320-325. doi:10.1097/00005373-200108000-00015
28. Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the Extended Focused Assessment with Sonography for Trauma (EFAST). J Trauma. 2004;57(2):288-295. doi:10.1097/01.ta.0000133565.88871.e4
29. Ball CG, Kirkpatrick AW, Laupland KB, et al. Factors related to the failure of radiographic recognition of occult posttraumatic pneumothoraces. Am J Surg. 2005;189(5):541-546. doi:10.1016/j.amjsurg.2005.01.018
30. Melniker LA, Leibner E, McKenney MG, et al. Randomized controlled clinical trial of point-of-care, limited ultrasonography for trauma in the emergency department: the first sonography outcomes assessment program trial. Ann Emerg Med. 2006;48(3):227-235. doi:10.1016/j.annemergmed.2006.01.008
31. Desai N, Harris T. Extended focused assessment with sonography in trauma. BJA Educ. 2018;18(2):57-62. doi:10.1016/j.bjae.2017.10.003
32. Ward JL, Murphy SD, Lisciandro GR, et al. Comparison of curvilinear-array (microconvex) and phased-array transducers for ultrasonography of the lungs in dogs. Am J Vet Res. 2021;82(8):619-628. doi:10.2460/ajvr.82.8.619
33. Chaijareenont C, Krutsri C, Sumpritpradit P, et al. FAST accuracy in major pelvic fractures for decision-making of abdominal exploration: Systematic review and meta-analysis. Ann Med Surg (Lond). 2020;60:175-181.
34. Via G, Hussain A, Wells M, et al. International evidence-based recommendations for focused cardiac ultrasound. J Am Soc Echocardiogr. 2014;27(7):683.e1-683.e33.
35. Von Kuenssberg Jehle D, Stiller G, Wagner D. Sensitivity in detecting free intraperitoneal fluid with the pelvic views of the FAST exam. Am J Emerg Med 2003; 21: 476e8
36. Kokabi N, Raper DM, Xing M, Giuffre BM. Application of imaging guidelines in patients with suspected cervical spine trauma: retrospective analysis and literature review. Emerg Radiol. 2011;18(1):31-38. doi:10.1007/s10140-010-0901-z
37. Corwin MT, Seibert JA, Fananapazir G, Lamba R, Boone JM. JOURNAL CLUB: Quantification of Fetal Dose Reduction if Abdominal CT Is Limited to the Top of the Iliac Crests in Pregnant Patients With Trauma. AJR Am J Roentgenol. 2016;206(4):705-712. doi:10.2214/AJR.15.14770
38. Soto JA, Anderson SW. Multidetector CT of blunt abdominal trauma. Radiology. 2012;265(3):678-693. doi:10.1148/radiol.12120354
39. Marek AP, Deisler RF, Sutherland JB, et al. CT scan-detected pneumoperitoneum: an unreliable predictor of intra-abdominal injury in blunt trauma. Injury. 2014;45(1):116-121. doi:10.1016/j.injury.2013.08.017
40. Iaselli F, Mazzei MA, Firetto C, et al. Bowel and mesenteric injuries from blunt abdominal trauma: a review. Radiol Med. 2015;120(1):21-32. doi:10.1007/s11547-014-0487-8
41. Hefny AF, Kunhivalappil FT, Matev N, et al. Usefulness of free intraperitoneal air detected by CT scan in diagnosing bowel perforation in blunt trauma: experience from a community-based hospital. Injury. 2015;46(1):100-104. doi:10.1016/j.injury.2014.09.002
42. Sodickson A. Strategies for reducing radiation exposure in multi-detector row CT. Radiol Clin North Am. 2012;50(1):1-14. doi:10.1016/j.rcl.2011.08.006
43. McCollough CH, Bruesewitz MR, Kofler JM Jr. CT dose reduction and dose management tools: overview of available options. Radiographics. 2006;26(2):503-512. doi:10.1148/rg.262055138