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OPINION ARTICLES

Limitations of Ultrasound Examination in Trauma

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Abstract

Introduction: Ultrasound examination plays a significant role in the evaluation of patients with trauma and polytrauma because it is an examination that provides information for many regions and systems, such as in the case of abdominal trauma, cardio-thoracic trauma, and vascular and musculoskeletal injuries. Ultrasound examination is used to rapidly and accurately detect hemorrhages in the pericardial, pleural, and peritoneal cavities, turning it into a necessary examination in Advanced Trauma Life Support (ATLS). Ultrasound is also used in traumas such as pneumothorax, damage to parenchymal organs and abdominal cavity, as well as rib and sternum fractures.

Material and Methods: This study considered and revised a systematic review of radiology and ultrasound specialty journals and clinical textbooks, the bibliographies of all identified articles, and meta-analyses about the role of ultrasound in trauma, especially FAST. Both prospective and retrospective studies for different types of trauma, such as abdominal trauma and thoracic trauma, trauma with unique injuries and polytrauma, and blunt and penetrating trauma, were included.

Conclusions: Although a necessary noninvasive radiological examination, ultrasound has long-term limitations during trauma evaluation. Ultrasound limitations are divided into technical limitations, image quality, the inability of sonographic windows to acquire images, echogenic similarity, and lack of differentiation between structures and organs.

Keywords: limitations, ultrasound examination, trauma, FAST, polytrauma, abdominal trauma, thoracic trauma

Introduction

Trauma is the leading cause of death and disability worldwide, particularly in developing countries and in the under-45 age group [1, 2]. Overall, trauma ranks fourth and fifth as the leading cause of death in Europe and the United States, respectively.[3] Trauma-related deaths can occur at the scene, during transport to the hospital, or at the hospital. Prevention of trauma mortality is time-related and includes management of the airway, chest injuries, and control of shock and hemorrhage [2]

Advanced Trauma Life Support *(ATLS), developed by the American College of Surgeons (ACS), is a well-*accepted standard of early care for trauma patients.

Points of focus are:

- rapid and accurate assessment of trauma patients;
- appropriate resuscitation and stabilization according to the priorities of the trauma assessment
- optimal transfer when necessary.

ATLS assessment begins with an initial assessment in which life-threatening injuries are diagnosed and treated concurrently. Portable radiography of the thorax and pelvis and focused assessment with sonography for trauma *(FAST)* are frequently performed and are considered an essential adjunct to the primary assessment in *ATLS.*

The secondary assessment includes complete body examinations such as radiography, scanning, and magnetic resonance. Assessing trauma patients can be challenging because patients may have multiple injuries and may have altered or lost consciousness. History may be insufficient

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or impossible; physical examination is difficult and often suspicious. Ultrasound is ideal in the initial evaluation of trauma patients because it can accurately detect hemorrhages in body cavities, especially the pericardial, pleural, and peritoneal spaces.

Detection of hemorrhage is crucial because the leading cause of trauma-related mortality is exsanguination, particularly from abdominal trauma[1]. Ultrasound is readily available and portable and can be performed simultaneously with other life-saving procedures. It can be used as a noninvasive tool to monitor volume status and repeated as needed. Detecting internal organ injuries and fractures on ultrasound can help expedite other confirmatory testing such as X-rays and CT scans.

Focused Sonographic Assessment for Trauma – FAST

The technique was introduced in North America in the early 1990s [4], and the term focused sonography assessment for trauma (FAST) was coined. Since then, FAST has replaced diagnostic peritoneal lavage (DPL) to become the initial evaluation modality for severe abdominal trauma in most trauma centers in the United States[5]

Additionally, the use of ultrasound in trauma patients extends to the assessment of thoracic trauma (Extended FAST/E-FAST) [6], venous volume assessment inferior cava (IVC) [7, 8], and detection of fractures [9].

The role of contrast ultrasound is still under study, but it is a method promising for helping detect injuries to abdominal parenchymal organs [10].

After the patient's initial assessment and hemodynamic status, FAST takes the next step in the management algorithm of closed trauma (Fig.1), and open trauma (Fig.2). Subsequent imaging examinations and management depend on the positive or negative FAST score explained in Table 1.[11]

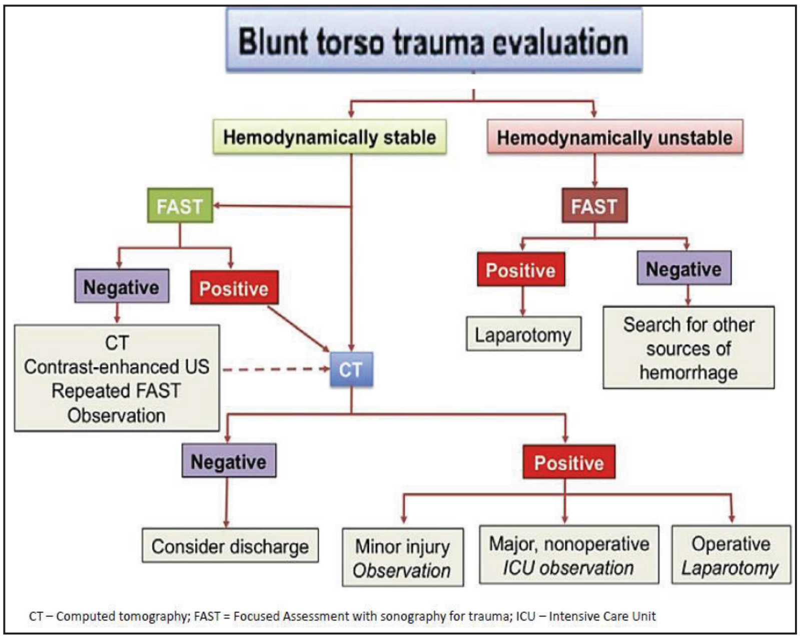

Figure 1. Suggested Algorithm for imaging and clinical management of blunt torso trauma[11]

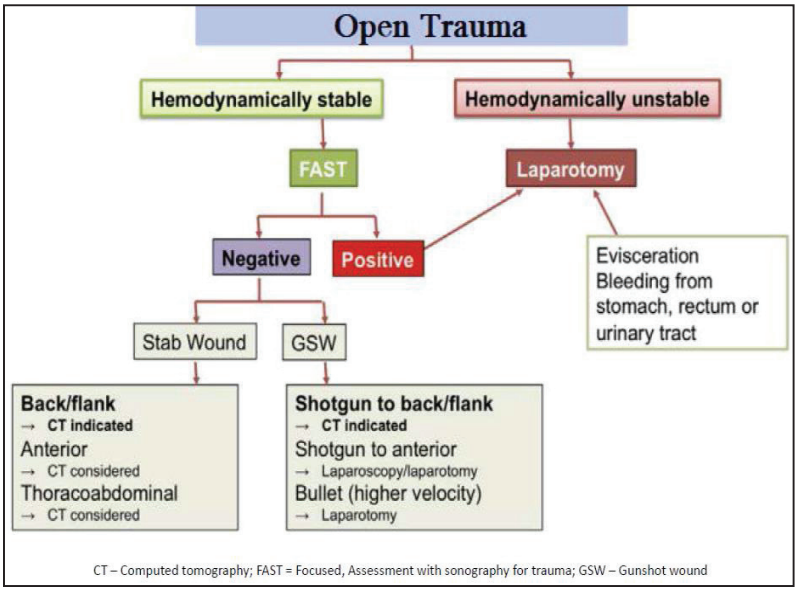

Figure 2. Suggested Algorithm for imaging and clinical management of Penetrate torso trauma[11]

Positive FAST: Presence of fluid in at least one of the three spaces—pericardial, pleural and peritoneal	Negative FAST: No evidence of free fluid in any of the three spaces—pericardial, pleural and peritoneal
Pericardial fluid	No abdominal organ injury
Hemopericardium	Parenchymal, bowel and mesenteric injury with no or minimal free fluid
Pre-existing pericardial fluid	Retroperitoneal organ injury
Pleural fluid	Pelvic and acetabular fracture
Hemothorax	
Pre-existing pleural fluid	
Peritoneal fluid	
Hemoperitoneum	
Urine (bladder injury)	
Bile (gallbladder injury)	
Bowel contents (bowel injury)	
Amniotic fluid (uterine injury during pregnancy)	
Volume resuscitation or third space loss	
Ovulation	
Peritoneal dialysis fluid	
Pre-existing ascites	

Table 1. Definitions and etiologies of true-positive and true-negative FAST [11]

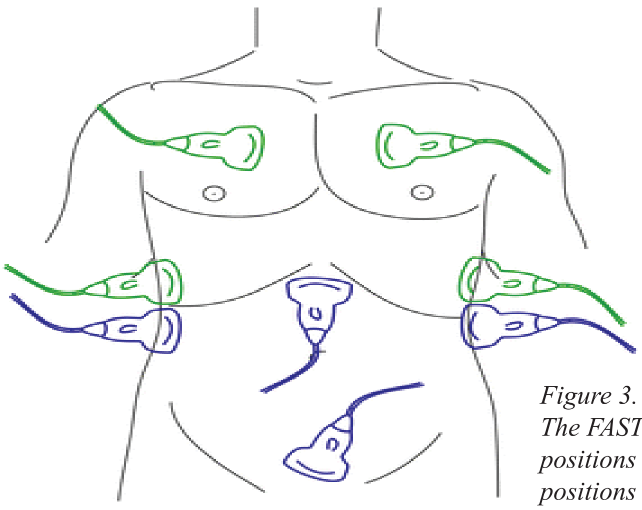

Figure 3.
The FAST and eFAST exam. The blue probes illustrate the scanning positions of the FAST exam. The green probes illustrate the scanning positions of the extended FAST exam assessing for pneumothorax and hemothorax.[12]

Limitations of the use of Ultrasound in Trauma.

Although ultrasound has many advantages, such as noninvasive screening, portability, wide availability, repeatability, and lack of ionizing radiation, several limiting factors must be considered during trauma.

Technical limitations relate to the machine, the techniques of use and the environment, the nature of the operators, and the ultrasound. Non-technical factors relate to diseases/conditions and patients.

Image quality and technique affect the accuracy of *FAST*. The most frequent causes of false-negative examinations are the improper adaptation of the device to the echogenicity spectrum of the images, as well as the measurement of the length/depth of the structures and inadequate anatomical coverage [14]

Due to difficult access and poor acoustic windows, subxiphoid pericardial and perisplenic views must be clarified. A more extended depth for the subxiphoid pericardial view or performing a long left parasternal axis to assess pericardial fluid can overcome these limitations. Small amounts of perisplenic fluid may collect higher than the spleen; therefore, images of this area should be included whenever possible. Splitting the patient to the right side may help assess the entire space.

Ultrasound may not be able to distinguish between different types of liquids. Although the free liquid in acute trauma patients is assumed to be hemorrhage, it may represent extravasation of urine (e.g., from bladder injury), bile (e.g., from gallbladder injury), food contents (e.g., from GIT injury), or pre-existing ascites.

This is especially true when dealing with clear, anechoic liquid. If the liquid creates an echo with floating debris, it may be blood mixed with food material. Also, in women of reproductive age, isolated free fluid in the recto-uterine space is likely to be physiological fluid and may not require further examination [15].

Step in the primary survey	***Potential roles for ultrasound***
A = Airway	Determine tracheal position. Confirm ETT placement and position
B = Breathing	Assess for pneumothorax and hemothorax
C = Circulation	Assess for hemoperitoneum. Assess for hemopericardium, Assess for hemothorax, [a] To guide peripheral or central venous access to [a] Assess intravascular filling
D = Dysfunction (CNS)	Assess optic nerve sheath diameter as a reflection of intracranial pressure.
E=Exposure	
Indications are widely accepted and commonly used in trauma management.	

Table 2 Steps of the primary survey and potential roles of ultrasound.[13]

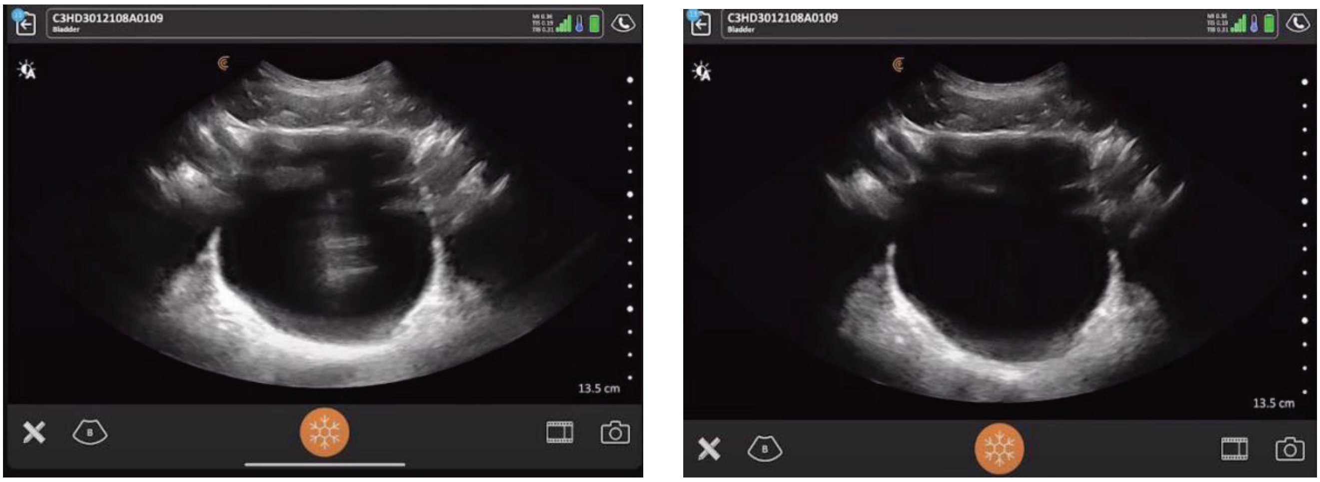

Figure 4. Urinary bladder in ultrasound examination. In the first view, artifacts such as echogenic changes are observed inside the filled bladder. The second image shows the appearance after fitting the device.

Sometimes, perinephric adipose tissue affects the dimensions of the hepatorenal spaces and splenorenal fossae, which can be confused with free liquid. Distinguishing free liquid from perinephric adipose tissue is generally straightforward because most free liquid in trauma patients is anechoic or hypoechoic compared to abdominal organs.

In addition, perinephric adipose tissue often exhibits bright reticular echo within *(Fig. 5)*. Comparative views of each kidney may be helpful for differentiation. Although the absence of a pulmonary field is highly suggestive of pneumothorax in acute trauma patients [16], it may be secondary to intubation of a lung or subcutaneous emphysema that is not clinically apparent.

The former should be suspected, especially when the pathology involves the left hemithorax, and the endotracheal tube should be checked immediately for proper positioning. Intubation often occurs on the right side, resulting in an unventilated left lung and resulting in a lack of pulmonary field being misdiagnosed as pneumothorax. Subcutaneous emphysema can be distinguished from pneumothorax by its more superficial location and characteristic E-lines. Although emphysema subcutaneous excludes the direct assessment of the pleural cavity on ultrasound, its presence in patients with open trauma should raise the suspicion of pneumothorax [17].

Pericardial liquid can be confused with pericardium, adipose tissue, or left pleural fluid. Liquid in the pericardial space is often isolated around the apex of the heart. The parasternal region likely represents pleural fluid if the liquid is focal in the back of the heart on the left side.

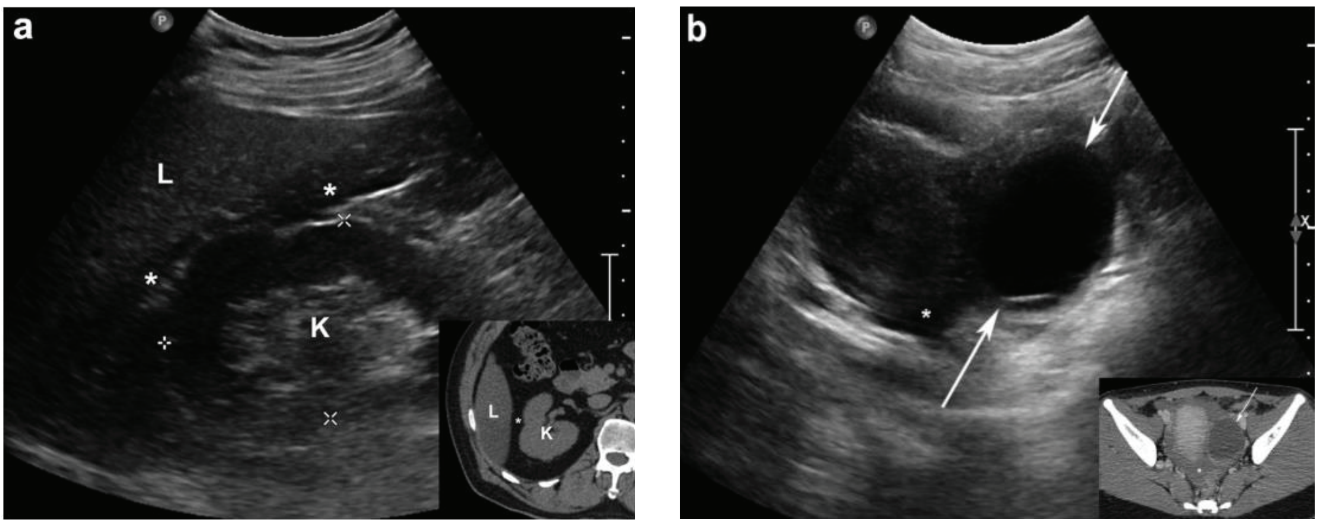

Figure 5. Mimics of hemoperitoneum on focused assessment with sonography for trauma (FAST). Perihepatic view (a) reveals a hypo-echoic band (asterisk) between the liver (L) and kidney (K). Note relatively hyper-echoic liver parenchyma. Findings represent abundant perinephric fat (asterisk) with fatty liver (inset axial non-enhanced computed tomography image with soft tissue window). Pelvic view (b) of another woman reveals a large left ovarian cyst (arrows) with small free fluid (asterisk). Complicated ovarian cystic disease can mimic or coexist with acute traumatic conditions. An axially enhanced computed tomography image with a soft tissue window (inset) confirms these findings.

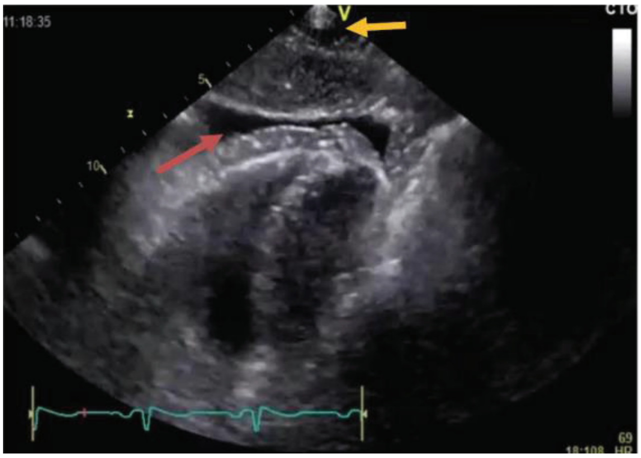

Figure 6. The red arrow indicates pericardial effusion Moreover, the yellow arrow indicates adipose tissue.

Alternatively, a focal hypoechoic area in front of the heart may represent pericardial adipose tissue in this view. Small amounts of pericardial fluid in elderly patients are close to normal and usually not clinically significant.

Pericardial liquid can be confused with pericardium, adipose tissue, or left pleural fluid. Liquid in the pericardial space is often isolated around the apex of the heart. The parasternal region likely represents pleural fluid if the liquid is focal in the back of the heart on the left side. (fig. 6)

Alternatively, a focal hypoechoic area in front of the heart may represent pericardial adipose tissue in this view. Small amounts of pericardial fluid in elderly patients are close to normal and usually not clinically significant.

In this case, a careful review of the chest radiograph, further CT, or prophylactic intercostal drainage may be indicated.

Specific pathologies, such as bullous changes and diffuse pleural thickening, can result in false-positive tests. Pneumonectomy and any cause of poor air ventilation in the lungs are also on the list of causes of pulmonary field deficiency. The pulmonary field may be difficult to assess in the upper thorax because of the small degree of motion of the pulmonary apex compared with the bases. Therefore, both hemithoraxes should be examined for comparison.

Because of its reduced diameter, the IVC may be difficult to identify in trauma patients with hypovolemic shock. Searching for the IVC through the right lobe of the liver may be a practical alternative. Tracing the IVC above the cavo-atrial junction is essential to avoid confusing the aorta with the IVC. IVC ultrasound is of limited value in intubated patients on positive pressure ventilation due to its contrast with respiration [8].

Ultrasound is limited in identifying organ damage because many minor injuries are not visualized in the ultrasound spectrum, and many organs and structures lie too deep to allow accurate ultrasound visualization. During the first 2-4 hours after trauma, fresh clots in the damaged organ (such as the liver and spleen) may have echogenicity similar to that of the parenchymal organ itself but not distinct [18]. Even if injuries are present, findings are often nonspecific, and classification of injuries may not be possible.

Ultrasound also limits the evaluation of injuries to retroperitoneal organs (e.g., kidney, pancreas, and adrenal), vascular structures, diaphragm, spine, and other bony structures. Renal lesions are often obscured on ultrasound. According to [19], renal parenchymal injuries can be identified in only 22% of patients with such injuries, and most of them are severe. The poor performance of ultrasound in detecting minor or moderate renal injuries may be due to the minimally altered acoustic architecture of the injured kidney in an acute phase of trauma. Furthermore, isolated renal injuries cause free intraperitoneal fluid in only 35% of patients.

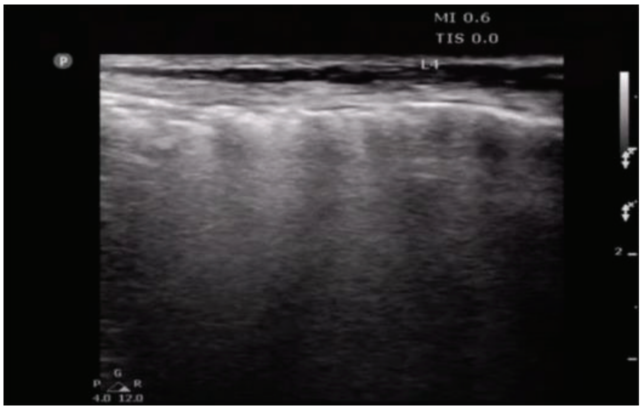

Figure 7. Ultrasound appearance of subcutaneous emphysema mimicking the ultrasound appearance of pneumothorax

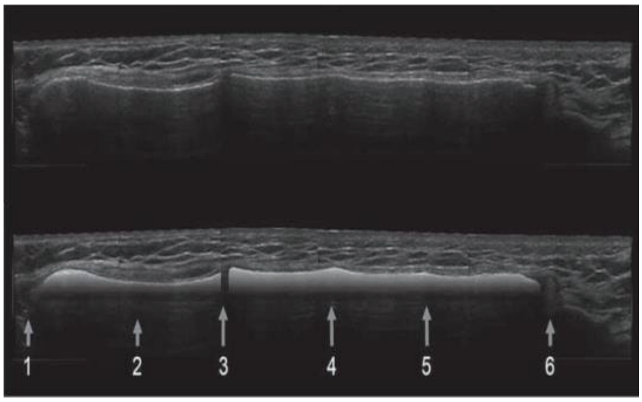

Figure 8. Ultrasound image of the sternum where the articulations with the manubrium (3) and the xiphoid process (6) mimic the appearance of a fracture.

Ultrasound diagnosis of intestinal and mesenteric injuries is challenging due to the lack of definitive and reliable findings at an early stage. In addition, extravasate liquid accumulation or hemorrhage from bowel/mesenteric injury may be minimal at the time of traumatic perforation[18, 19]

Techniques limit the accuracy of ultrasound in diagnosing free intraperitoneal air. In uncooperative or unconscious trauma patients, examination in different regions or positions may not be feasible, making it difficult to confirm the presence of pneumoperitoneum. In addition, air inside the intestine can mimic pneumoperitoneum.

Air in the pulmonary bases may protrude above the surface of the liver—however, alveolar air moves along with respiration. Intramuscular and cutaneous air in the abdominal wall can cause artifacts like free intraperitoneal air. (fig. 7)

They can be distinguished based on their origin and mobility when applying pressure. Intraperitoneal air generally does not change when transducer pressure is applied.

Although ultrasound may be more sensitive than portable radiography in detecting rib fractures, its use is hindered by long examination times and limited examination coverage.

The retro scapular ribs and the infraclavicular part of the first ribs are inaccessible by ultrasound. The examination may not be possible in dyspneic, uncooperative, unconscious, or severely traumatized patients [20]

A false-positive diagnosis of rib fracture may occur in case of heterogeneous calcification of the costal cartilage and costochondral joint [21]

Typical sternum structures may appear similar to fractures on ultrasound; thus, the images should be interpreted cautiously.

The sterno-manubrial angle and the xiphosternal junction can be misinterpreted as a fracture line (fig. 8). Incomplete fusion can also mimic a fracture line, especially in children and young adults. The presence of presternal hematoma and pain on examination are essential clues to diagnosing an actual fracture [22]. However, ultrasound can only evaluate the anterior part of the sternum; therefore, it is not accurate for classifying sternum fractures [23]

Conclusions

Although an indispensable noninvasive radiological examination, ultrasound has long-term limitations in evaluating trauma. Sonographic limitations are divided into technical limitations, image quality, the inability of sonographic windows to obtain image and echogenic similarity, and the lack of differentiation between structures and organs.

The technical limitations of ultrasound are related to the condition of the apparatus, the conditions in which the examination is performed, the condition and cooperation of the patient, and the experience of the examiner.

Free fluid from adipose tissue in the pericardium and the hepatorenal and splenorenal spaces is often not differentiated.

Assessment of the IVC's diameter and caval index may help differentiate between hypovolemic and non-hypovolemic shock in trauma patients. It may be used to monitor the response to fluid resuscitation.

Retroperitoneal organs and structures are difficult to visualize. Ultrasound examination has difficulty differentiating free fluid, whether hemorrhagic or material from the urogenital or gastrointestinal tract.

Diagnoses of rib or sternum fractures are often false-positive.

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