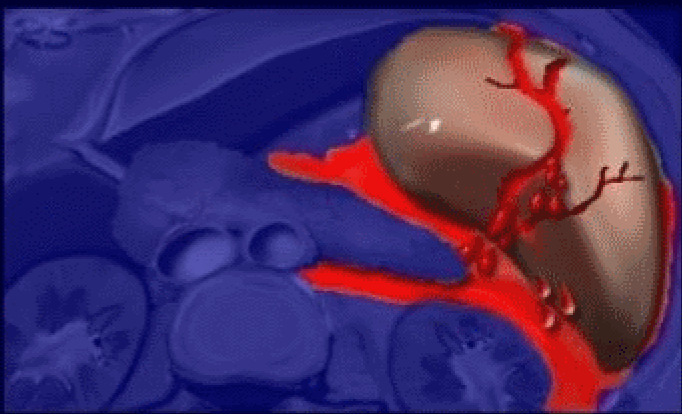
EMERGENCY SONOGRAPHY FOR TRAUMA

FAST

PROTOCOL



SONOMIR

Preface

Evaluation of patients with thoracoabdominal trauma is often a diagnostic challenge for emergency physicians and trauma surgeons. The use of ultrasound became a standard for trauma centers throughout the world. In fact, in many trauma centers bedside ultrasound has become the initial imaging modality used to evaluate the abdomen and chest in patients who present with blunt and penetrating trauma to the torso.

Bedside ultrasonography in the evaluation of trauma patients has been given name the FAST exam as a limited ultrasound examination, focusing on the detection of free fluid in abdominal, pleural and pericardial cavities, and also pneumothorax. The FAST provides the emergency team by valuable diagnostic information within several seconds or minutes allowing for rapid triage of patients with unstable hemodynamic.

Its success and growing popularity are in large part due to the fact that the examination is noninvasive and accurate and can be easily performed by emergency physicians and trauma surgeons with limited training. The FAST examination performed rapidly by the treating emergency physicians and trauma surgeons, who first face the trauma patients, allows to timely diagnosis and improves patient management, enhances patient safety, and saves lives.

This book just summarizes information about FAST exam from the best articles published in well-known electronic journals, sites and books containing the information about FAST protocol from 2000 – 2010, such as:
American Journal of Roentgenology, Radiology, British Journal of Radiology, Radiographics, Journal of Ultrasound in Medicine, The Journal of Trauma, Emergency Med. Journal, Chest, eMedicine, hqmeded.com, Trauma.org, sonoguide.com, Ultrasoundcases.info.

Emergency ultrasound O. John Ma, James R. Mateer, Michael Blaivas
Emergency radiology – Imaging and Intervention Borut Marincek, Robert F. Dondelinger
General ultrasound in the critically ill Daniel Lichtenstein
Manual of Emergency and Critical Care Ultrasound Vicki E. Noble, Bret Nelson, A. Nicholas Sutingco
Ultrasound for surgeons Heidi L. Frankel
Ultrasound in Emergency Care Adam Brooks, Jim Connolly, Otto Chan
Practical Guide to Emergency Ultrasound Cosby, Karen S.; Kendall, John L.
Chest Sonography Gebhard Mathis

This book provides a simplicity and compactness for the reader who uses emergency ultrasonography for trauma in practice and published on principles Open Medicine.

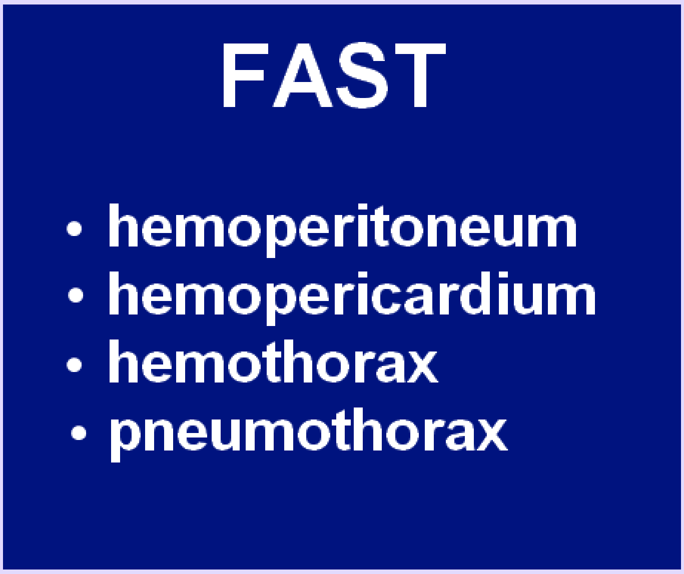
Dr.Yuliya, Ukraine, Sonologist, Mizdah General Hospital, Libya 2010
http://sonomir.wordpress.com/

Content

Emergency sonography for trauma
FAST protocol

Time-sensitive information is a cornerstone of emergency medicine. The ability to obtain and apply crucial decision-making data rapidly is paramount. Emergency ultrasound has the basic goal of improving patient care. The use of sonography in evaluating the patients with trauma has rapidly expanded in the past decade. "Trauma ultrasound" is synonymous with "emergency ultrasound." Emergency sonography at a trauma is performed as FAST protocol and is useful modality for the initial evaluation of patients with blunt or penetrating trauma.

FAST - Focussed Assessment with Sonography for Trauma

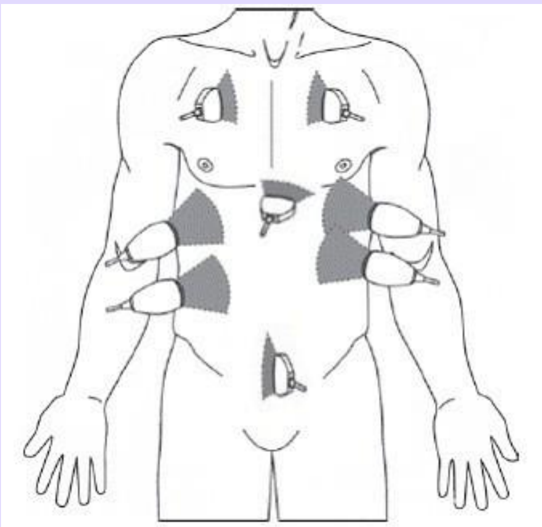


FAST (**F**ocused **A**ssessment with **S**onography for **T**rauma)

This limited ultrasound examination focused exclusively on the detection of free fluid in abdominal cavity, pleural and pericardial cavities, and also detection of pneumothorax.

Speed is important.
Examination should be performed quickly (during 3 - 3.5 minutes).

Abdominal part of the FAST examination provides a quick overview of the intraperitoneal cavity to detect free fluid, which is an indirect sign of visceral organ injury.



At FAST protocol 8 standard points are investigated:

In RUQ look for fluid in the perihepatic space and right pleural cavity.

In LUQ look for fluid in the perisplenic space and left pleural cavity.

In suprapubic area look for fluid in a pelvis.

In subcostal area look for fluid in a pericardium.

In the upper anterior chest look for pneumothorax.

Performance of the FAST protocol.

Investigation of the RUQ (Right Upper Quadrant).

Look for fluid in the hepatorenal space (Morison's pouch) and right subdiaphragmal space, and also look for fluid in the right pleural cavity.

Performance of the FAST protocol.

Investigation of the LUQ (Left Upper Quadrant).

Look for fluid in the splenorenal space and left subdiaphragmal space, and also look for fluid in the left pleural cavity.

Performance of the FAST protocol.

Subcostal (subxifoid) view.

Look for fluid in a pericardial cavity.

Performance of the FAST protocol.

Pelvic view.

Look for free fluid in a pelvis.

Performance of the FAST protocol.

Upper chest view.

Look for pneumothorax.

Why FAST

Ultrasonography is highly sensitive for detection of hemoperitoneum (as indirect sign of intraabdominal injury) but not sensitive for the identification of organ injury as source of hemoperineum. The numerous studies demonstrates that ultrasonography as method has low sensitivity (41 %) for detecting organ injuries. Even at large lacerations the parenchymal organs can appears normal at ultrasound examination. And abdominal injuries which are not associated with hemoperitoneum can be easily missed. Ultrasonography is limited and unable to show some types of injuries, including bowel and mesentery injuries, pancreatic injuries, vascular injuries, diaphragmatic ruptures, renal and adrenal injuries.

Unlike Ultrasonography, CT has ability to precisely locate intra-abdominal injuries preoperatively, to evaluate the retroperitoneum, to identify injuries that may be managed nonoperatively. CT comprises the majority of diagnostic imaging in blunt abdominal trauma and remains the criterion standard for the detection of solid organ injuries, however CT has disadvantages including: ionizing radiation, IV injection of radioiodinated contrast material, it is expensive, time-consuming, and requires that the patient be stable in order to be transported out of the ED, because the patient is less monitored during transportation and CT scanning (thus the trauma adage “death begins in radiology”).

Ultrasonography has advantages compared with DPL and CT: it is sensitive for hemoperitoneum and can be performed quickly and simultaneously with other resuscitative measures, providing immediate information at the patient's bedside, simple, noninvasive, repeatable, portable, and involves no nephrotoxic contrast material or radiation exposure to the patient, and readily available screening examination, and can be performed by non-radiologists (emergency physicians and trauma surgeons). In most medical centers, the FAST examination has virtually replaced DPL (diagnostic peritoneal lavage) as the procedure of choice in the evaluation of hemodynamically unstable trauma patients.

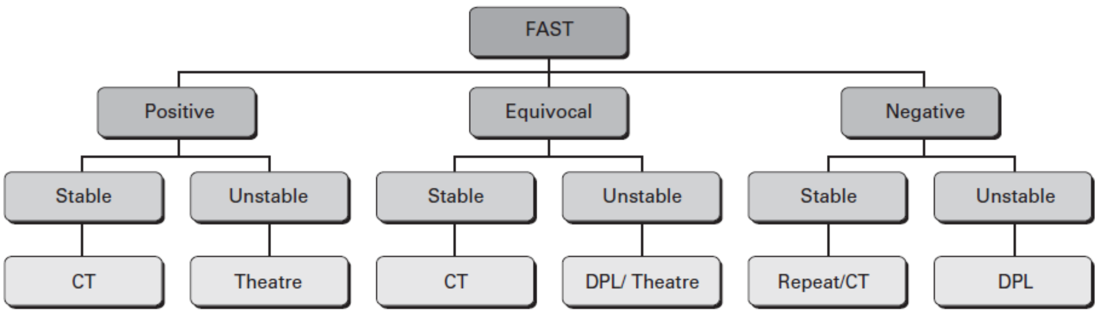
The FAST examination is based on the assumption that all clinically significant abdominal injuries are associated with hemoperitoneum. Sensitivity FAST in detecting of a free fluid in abdominal cavity is 63 - 100 % (depends on quantity of a detectable fluid and operator experience), specificity 90 - 100 %. Rozycki et al reported that ultrasound is the most sensitive and specific modality for the evaluation of hypotensive patients with blunt abdominal trauma (sensitivity and specificity, 100%).

So, FAST is effective initial triage tool to evaluate trauma victims with suspected blunt abdominal injuries, which performed rapidly in the admission area. For the unstable patient, rapid and accurate triage is crucial because delayed treatment is associated with increased morbidity and mortality. To mitigate morbidity and mortality, rapid determination of which patients with intraabdominal injuries require surgical exploration is critically important.

Hemodynamically stable patients with positive FAST results may require a CT scan to better define the nature and extent of their injuries. Taking every patient with a positive FAST result to the operating room may result in an unacceptably high laparotomy rate.

Hemodynamically stable patients with negative FAST results require close observation, serial abdominal examinations, and a follow-up FAST examination. However, strongly consider performing a CT scan, especially if the patient has other associated injuries.

Blunt abdominal trauma algorithm



Hemodynamically unstable patients with negative FAST results are a diagnostic challenge. Options include DPL, exploratory laparotomy, and, possibly, a CT scan after aggressive resuscitation.
In unstable patients with a negative FAST exam, extraabdominal sources of hypotension must be carefully ruled out (intrathoracic trauma, blood loss from extremity trauma, spinal shock, head injuries). DPL can also be performed if FAST images are not clear or difficult to obtain for technical reasons (subcutaneous air, bowel gas).

Therefore the FAST is initial screening tool for rapid triage of victims for immediate laparotomy at detecting of the hemoperitonium in patients with unstable hemodynamic and for the subsequent diagnostic tests at positive or negative FAST results in patients with stable hemodynamic.

Also ultrasonography is highly sensitive for detecting hemothorax, pneumothorax and hemopericardium, providing rapid information, and allows to emergency action at tamponade or pneumothorax.

The FAST examination is included in ATLS protocol, performing in a resuscitation area.

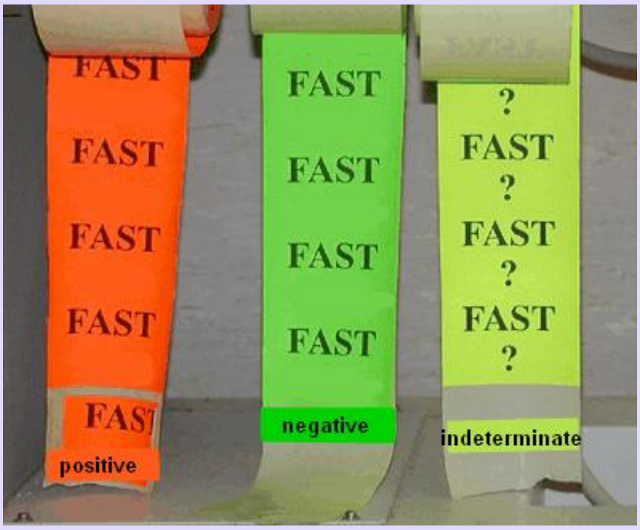
Performance of the FAST protocol during resuscitation.

FAST is performed simultaneously with physical assessment, resuscitation, and stabilization of the trauma patient.

Primary function of the radiologist or sonologist is to perform FAST, in order to evaluate for free peritoneal fluid and to exclude hemodynamically significant abdominal injuries. Speed is important because if intraabdominal bleeding is present, the probability of death increases by about 1% for every 3 minutes that elapses before intervention.

This quick study takes 3 – 3.5 minutes (2 – 2.5 minutes on searching for fluid in abdominal cavity, pericardial and pleural cavities, plus 1 minute on searching for pneumothorax). The average time to perform a complete FAST examination of the thoracic and abdominal cavities is 2 minutes to 4 minutes. At massive hemoperitonium examination only one point (pouch of Morison) allows to diagnose within several seconds.

Also important rapidity with subsequent triage of patients, especially at a large numbers of traumatically injured victims (natural disasters, terrorist attacks and military mass casualty events). To provide rapid reports that could be used instantly, can be applied colored stickers that are attached the patient's chart: red when positive for free peritoneal fluid, green when negative, and yellow when indeterminate. These are attached to the patient's chart in a clearly visible way to alert the staff as to whether the patient needs prompt further evaluation.



Rapid interpretation of the FAST result.

Red label - positive FAST

Green label - negative FAST

Yellow label - indeterminate FAST

This system is visually effective for expeditious reporting of results to all personnel involved in treating the patient in a clear and unequivocal manner. And helps for rapid triage of victims: who need for promt laporotomy and who need for immediate further evaluation (CT, MRI, DPL, angiography).

With the development of sophisticated handheld or highly portable ultrasound equipments the value of this rapid and accurate technique is becoming apparent in the pre-hospital environment (in ambulance, helicopters and planes).

Get valuable visual information at the first point of contact - reducing delays, when time is a matter of life and death.

A prehospital FAST (PFAST) may indicate abdominal injury before the patient reaches the hospital, which can increase the effectiveness of trauma management. PFAST can be performed an average of 35 minutes earlier than a FAST or CT in the emergency department. When a patient has a positive PFAST at the scene, prehospital care is minimized, allowing for quicker transport to an appropriate hospital or trauma center. In addition, the health care team at the awaiting hospital can be contacted prior to the patient's arrival, providing additional time to prepare and improving overall patient management. PFAST in remote settings using wireless and satellite transmission, can be helpful in isolated military locations and mass casualty situations. A satellite transmitter sends the ultrasound images immediately to a hospital for interpretation by a radiologist or emergency physician.

FAST history

The use of ultrasound in the evaluation of the traumatically injured patient originated in the 1970s when trauma surgeons in Europe (Germany) and Japan first described sonography for rapid detection of life-threatening hemorrhage. The German surgery board has required certification in ultrasound skills since 1988.
The experience of physicians in the United States with ultrasound in the setting of trauma came to publication in the early 1990s.

The acronym FAST, standing for “Focused Abdominal Sonography for Trauma”, or the FAST exam (as a limited ultrasound examination, focusing primarily on the detection of free fluid in abdominal cavity) appeared in a 1996 article in the Journal of Trauma, written by Rozycki. FAST rapidly developed to regions beyond the abdomen (including evaluation of the heart and the pleural spaces) and in recognition of this the term ‘Focused Assessment with Sonography for Trauma’ was accepted at the International Consensus Conference in 1997.

Ultrasound proved to be such a practical and valuable bedside resource for trauma that it received approval by the American College of Surgeons and was incorporated into standard teaching of the Advanced Trauma Life Support curriculum. The FAST exam has been included as part of the ATLS course since 1997.

Who can perform FAST

Critical condition in trauma patient requires immediate treatment for rescue of life of the patient and directly depends on rapidity of an establishment of the diagnosis. Ultrasonography is the fastest and accessible method in this situation.

FAST protocol should be performed as soon as possible. But it may be impossible in a number of institutions for the radiologist or sonologist to provide 24-hour coverage for trauma US.

Therefore researches were looked for possibility of performing FAST protocol by doctors non-radiologists, who first face the trauma patients (emergency physicians and trauma surgeons).

Performance of the FAST protocol by surgeons has begun in Germany and Japan. The researches showed, that FAST protocol (which is relatively simple in performing and interpretation of results) was successfully performed by well trained non-radiologists doctors and also results were slightly different from the results obtained by skilled radiologists or sonologists.

And now, the FAST protocol can be performed by any specialists (not necessarily by a sonographers, sonologists or radiologists), which adequately trained in this method, aiding in the immediate availability of this technique in the emergency situation.

Ability ultrasonography quickly provides clinically significant information at performance FAST protocol explains the raised popularity of this method among emergency physicians and trauma surgeons.

The American College of Surgeons has included ultrasound as one of several “new technologies” that surgical residents must be exposed to in their curriculum. Both the American College of Emergency Physicians and the Society for Academic Emergency Medicine support the use of ultrasound to evaluate blunt abdominal trauma as well. Since 2001, training in emergency ultrasound has been required for all emergency medicine residents. All physicians who will be evaluating trauma patients must become proficient in the use of trauma ultrasound.

A FAST trained military surgeon utilizing handheld ultrasound to assess a casualty with blunt abdominal trauma in a field hospital environment.

A course in FAST ultrasound has been developed for UK military surgeons who are now using the technique to assess casualties when no support from a sonographer or radiologist is available.

One study showed that 10 examinations is sufficient for successful performance of the FAST, but was overturned by subsequent studies, which demonstrated that 10 examinations are not sufficient for comprehensible results of FAST due to errors.

Therefore experience has great importance for adequate results and last researches shows that the 200 or more supervised examinations are necessary for credentialing in FAST.

Anatomical considerations

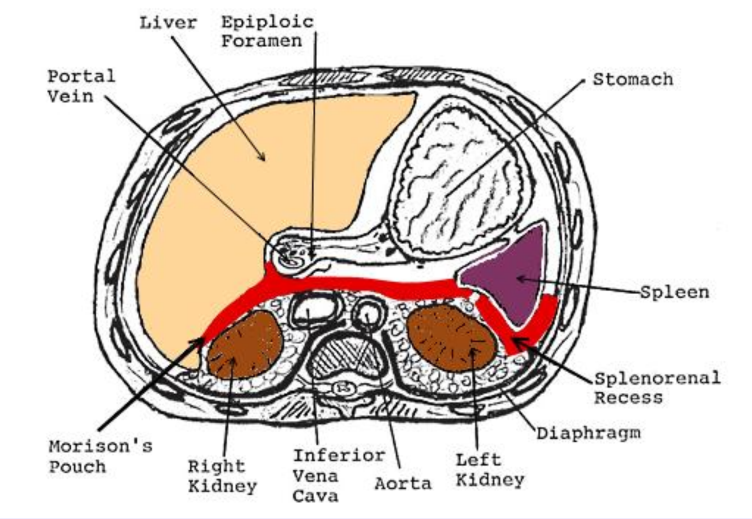
The spleen is the most commonly injured abdominal organ, occurring in one-third of all patients with blunt abdominal trauma.

After the spleen, the liver is the second most commonly injured organ in blunt abdominal trauma, occurring in approximately 20 % of all patients with blunt trauma. Injury to the right lobe is far more common than the left lobe. Injury of the posterior segment of the right lobe is more common than anterior segment. But at the combined trauma (blunt and penetrated) most often injured organ is the liver. The caudate lobe of the liver is damaged rare.

Injuries of the bowel and mesentery occurs in 5 % of patients. Usually the bowel and mesentery are injured together, but also can be isolated injured. Urinary bladder injury is not common in abdominal trauma (1.6 %). Pancreatic injuries are rare, occurring in 0.4 % of patients.

The site of accumulation of intraperitoneal fluid is dependent on the position of the patient and the source of bleeding. Hemoperitoneum starts in site of laceration, then blood flows and accumulates in dependent intraperitoneal compartments formed by peritoneal reflections and mesenteric attachments.

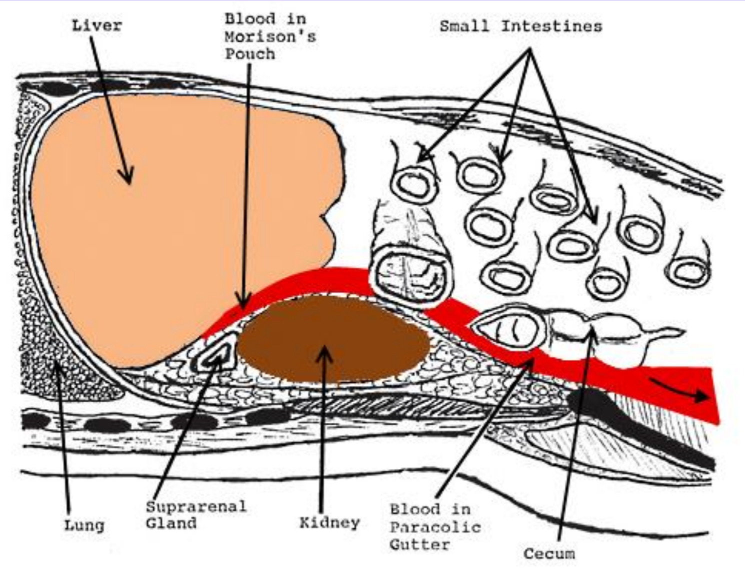
In the supine patient, free intraperitoneal fluid accumulates in 3 potential places: in hepatorenal space (Morison's pouch is the potential space between the liver and the right kidney), in splenorenal space and in a pelvis (in pouch of Douglas in women and in retrovesical pouch in men).



Transverse illustration of the upper abdomen that demonstrates the dependent compartments where free intraperitoneal fluid may collect.

The free fluid in hepatorenal pouch (Morison's pouch) and in splenorenal pouch (red spaces).

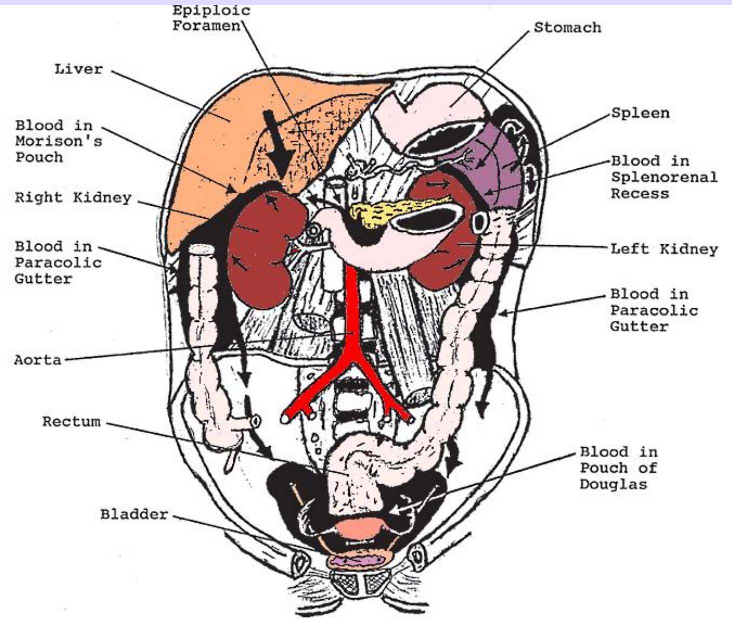
Free fluid from the lesser peritoneal sac will travel across the epiploic foramen to Morison's pouch.



Longitudinal illustration of the right paramedian abdomen which demonstrate the dependent compartments where free intraperitoneal fluid may collect.

Blood collects in Morison's pouch and then flows to pelvis through the right paracolic gutter.

Free intraperitoneal fluid in the right upper quadrant will tend to accumulate in Morison's pouch first before overflowing down the right paracolic gutter to the pelvis. In contrast, free intraperitoneal fluid in the left upper quadrant will tend to accumulate in the left subphrenic space first, and not the splenorenal recess, which is the potential space between the spleen and the left kidney. Free fluid overflowing from the left subphrenic space will travel into the splenorenal recess and then down the left paracolic gutter into the pelvis. Free fluid from the lesser peritoneal sac will travel across the epiploic foramen to Morison's pouch. Free intraperitoneal fluid in the pelvis will tend to accumulate in the rectovesical pouch in the supine male and the pouch of Douglas in the supine female.



Blood flow pattern within the abdominal cavity (black spaces, arrows).

The right paracolic gutter connects Morison's pouch with the pelvis.

Free fluid overflowing from the left subphrenic space will travel into the splenorenal recess and then down the left paracolic gutter into the pelvis.

The left paracolic gutter is more shallow than the right and its course to the splenorenal recess is blocked by the phrenicocolic ligament. Thus, free fluid will tend to flow via the right paracolic gutter since there is less resistance. In the supine patient, the most dependent area is Morison's pouch, independently from site of laceration.

Overall, however, the rectovesical pouch is the most dependent area of the supine male and the pouch of Douglas is the most dependent area of the supine female.

Large volume of blood may accumulate in a pelvis without collection of the blood surrounding a source of a bleeding.

An isolated pelvic view may provide a slightly greater yield (68% sensitivity) than does an isolated view of Morison's pouch (59% sensitivity) in the identification of free intraperitoneal fluid.

Fluid location may be helpful. Triangular or polygonal fluid collections which located centrally between bowel loops are uncommonly associated with solid organ injury and more likely to be related to bowel or mesenteric injury. Unlike liver and spleen injuries, where the fluid usually flows to pelvis on periphery (in paracolic gutters) and not accumulates centrally between bowel loops. So, detection of free intraperitoneal fluid between bowel loops raises the suspicion for bowel or mesenteric injury even in the presence of solid organ laceration.

Also it is necessary to remember, what even significant abdominal injuries can be without hemoperitonium as intraparenchymal lacerations can be without rupture of capsule.

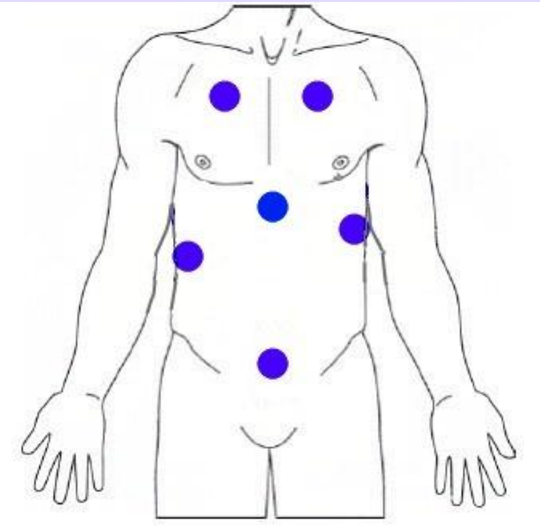
Preparation for examination

FAST is performed using abdominal probe with frequency 3.5 - 5.0 MHz.

For some parts of the extended FAST can be used high frequency probe.

But FAST is virtually can be performed by one probe for all areas of the examination.

For protection of the probe against pollution by blood at examination of trauma patients, and also protection of the patient against infections at a large numbers of traumatically injured victims, the cover or a medical glove which dresses on the probe is used, changing for each victim. A small amount of gel is put on the probe (for contact) and then covered by medical glove.



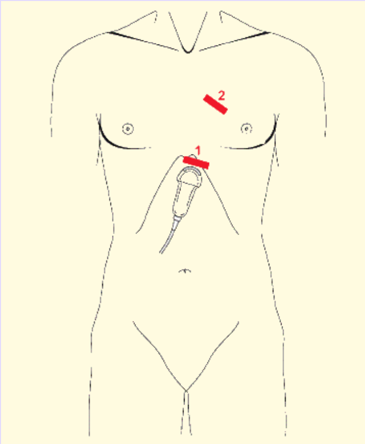
Rapid application of gel on all standard points before examination allows not to distract during scanning and shortens time of the examination.

At performing of the FAST full urinary bladder is necessary. Pelvic view is easier to obtain when the bladder is full and prior to the placement of a Foley catheter. Without a full urinary bladder as an ultrasonic window, free fluid in the pelvis is easily missed. But it is not uncommon that a Foley catheter is inserted in trauma patients to look for hematuria and monitor urinary output. If it is performed before the FAST scan, need to re-fill the urinary bladder with 200 ml saline through the Foley catheter. Beware the excessively full bladder, because a grossly distended bladder may obliterate the rectovesical pouch (or pouch of Douglas) and empty it, giving a false-negative result, thus, a partially voided study may increase sensitivity.

What look for first

The sequence of the standard points of the FAST examination is a greatly depends on the clinical scenarios. The sequence of areas of the examination in hemodynamically stable patients has little importance, because of the FAST protocol is performed quickly (within 3-3.5 minutes).

But it has huge value in hemodynamically unstable patients (with systolic pressure 90 mm Hg or less) and especially in critically ill patient without palpable pulse in the presence of cardiac electrical activity on monitor - PEA (Pulseless Electrical Activity). In such situations patients should be promptly assessed with focused echocardiography since a sonographic picture of the heart may provide an immediate understanding of the causes.

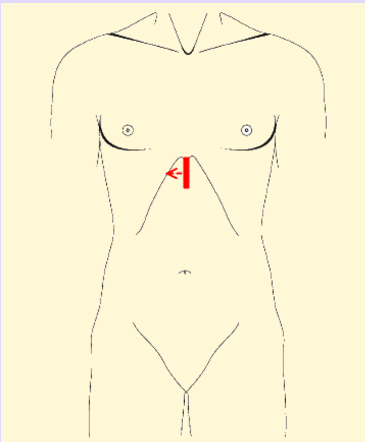


Focused echocardiography in trauma patient.
Look for pericardial effusion, filling pattern, heart rate.

Usually is used subcostal window (1) but if it is impossible to obtain quickly adequate scan, immediately should be performed parasternal scanning (parasternal long axis view) (2).

A focused assessment of the inferior venous cava (IVC) diameter is important addition to sonographic assessment of trauma patients with minimal additional time. Because size of IVC provides valuable information about hemodynamic.

The IVC is visualized through a subxiphoid or a right lateral window at the midaxillary line (depending on patient body habitus and interference of bowel gas).



IVC assessment. Subxiphoid long-axis view of the inferior vena cava.

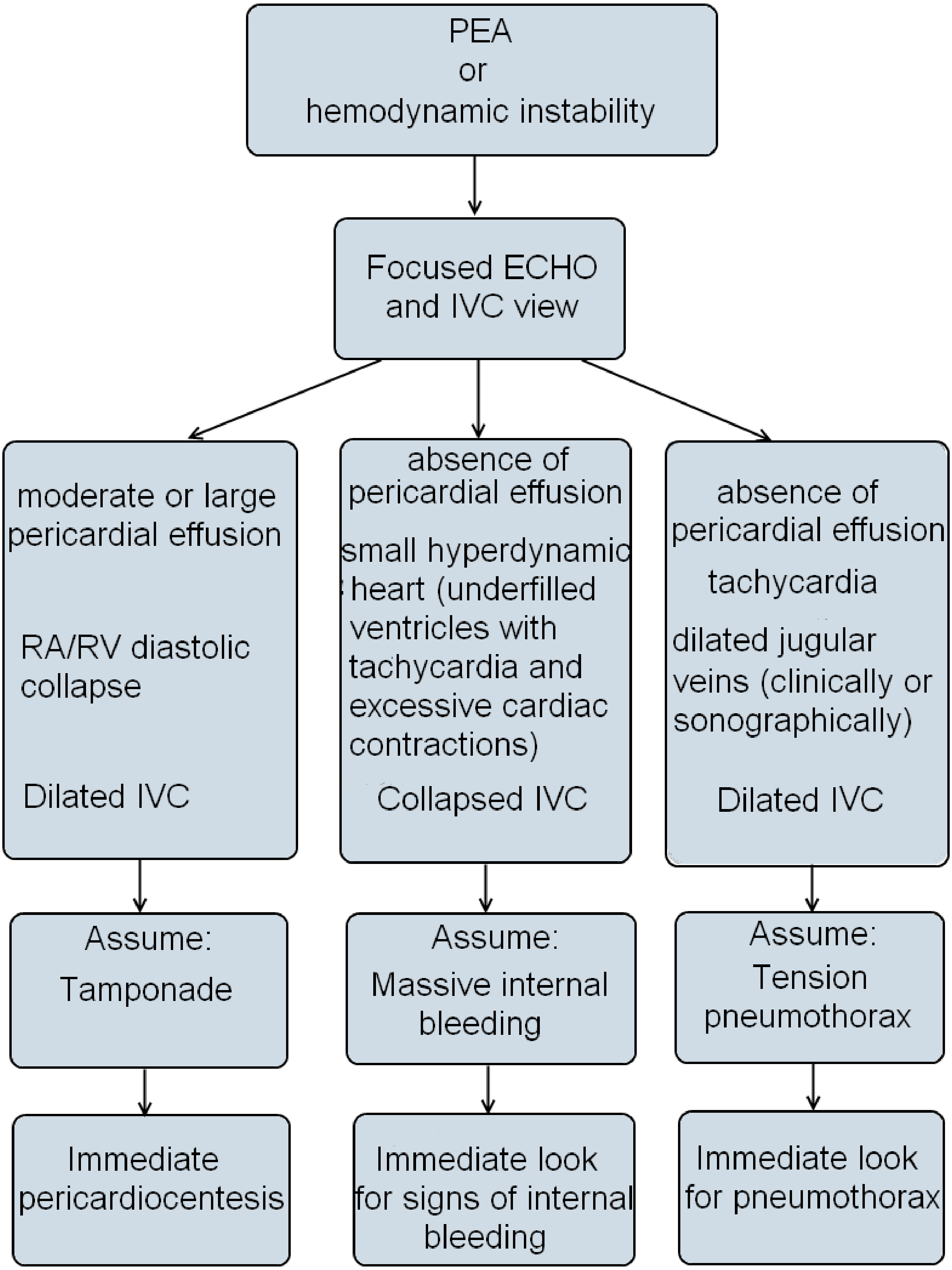
The probe is placed longitudinally in epigastric midline with beam direction slightly to the right side, to IVC appearance.
(or probe can displaced slightly to the right from midline).

Results of focused echocardiography and IVC diameter can provide quickly important information about a condition of the patient and understanding of the causes of an unstable state. Ultrasound can identify correctable causes of PEA.

3 main causes of Pulseless Electrical Activity in trauma patients:

- Tamponade of the heart
- Hypovolemic shock (at acute massive hemorrhage)
- Tension pneumothorax

Immediate Focused Echo/IVC Triage algorithm in trauma patients



The inferior vena cava (IVC) is important to evaluate because it can provide an assessment of the patient’s fluid status and right atrial pressures, representing central venous pressure.

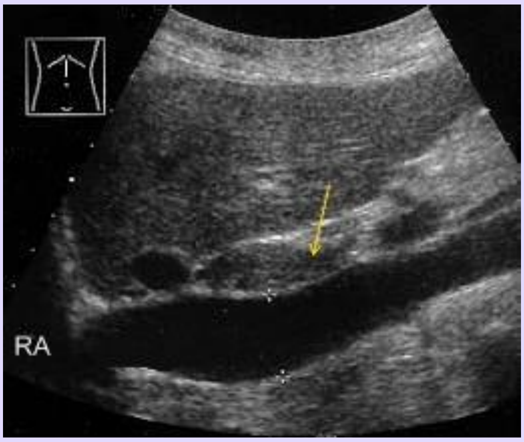
The size of the IVC provides the rapid and valuable information about pressure in the right atrium. Measuring the maximal and minimal diameter of the vein cava, reflecting changes of its diameter on inspiration and expiration (M - mode measurement is more accurate).
The IVC should collapse with inspiration (>50%) in the normal patient and suggests right atrial pressures <10 mm Hg.

Dilation of the IVC (the maximum diameter > 2 cm) with reduction of collapse at inspiration is considered evidence of elevated CVP.
Dilated IVC with collapse <50% suggests right atrial pressure >10-15 mm Hg, if dilated IVC is not collapsed right atrial pressure >15 mm Hg.
Elevation of right atrial pressure in a trauma context is characteristic for cardiac tamponade and tension pneumothorax (due to "obstruction" circulation caused by an external compression of the heart chambers).

Subxiphoid IVC view. Longitudinal scanning of IVC in supine patient.

Probe is placed longitudinally just below the xyphoid process in epigastric midline with beam direction slightly to the right side until IVC will be appear, just under caudate lobe of the liver.

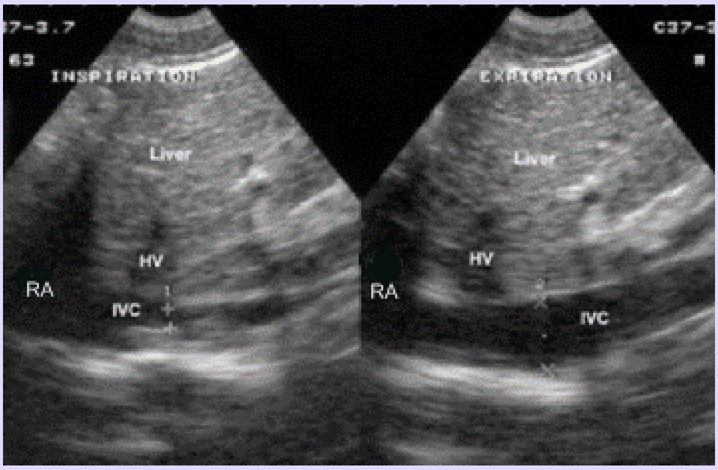
Follow the IVC up until it is seen entering the right atrium.



Anatomic markers for IVC detection are a caudate lobe of the liver (arrow), as IVC is located just under caudate lobe, and the right atrium (RA), as IVC is entranced into the right atrium (this place is easily defined because of heart motions).

The maximal antero-posterior diameter of the IVC is measured at both end inspiration and end expiration (minimal and maximal IVC diameters). These measurements are taken within 2 cm of its entrance into the right atrium.

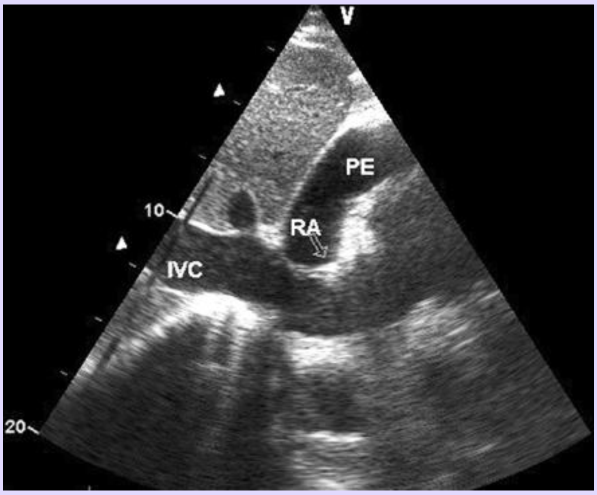
The pitfall of this view includes the misidentification of the aorta for the IVC. This can be avoided by careful attention to angulation. The aorta is to the left of the midline, while the IVC is to the right of the midline. Also the IVC is seen entering into the right atrium.



Subxyphoid window. Longitudinal scanning of the IVC.

Normally, the inferior vena cava narrows during inspiration and distends during expiration.
On the image a IVC with the maximal size 1.9 cm (at expiration) and the minimal size 0.5cm (at inspiration) – normal respiratory IVC collapse.

At IVC examination the probe marker can be directed caudally (to feet) or cranially (to head).



Subxyphoid longitudinal view.
Tamponade of the heart.
Pericardial effusion (PE) with right atrial collapse (RA, arrow).

Longitudinal scan of dilated IVC (2,6cm).
The diameter of dilated IVC was no changed at respiration.

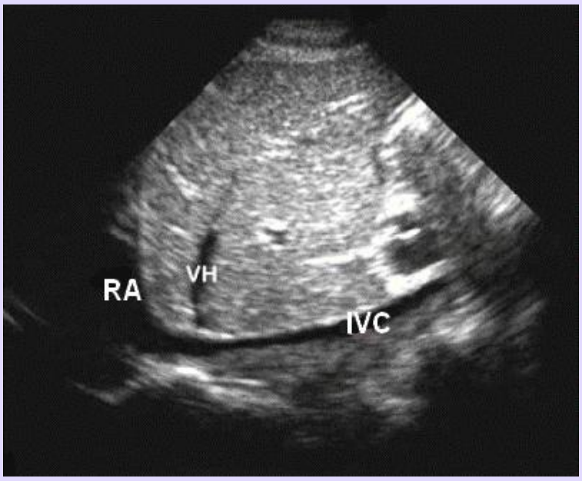
Also sonographic measurement of inferior vena cava diameter is a valuable tool in estimating fluid status. The IVC diameter is used for evaluation of central venous pressure (CVP), as an alternative, quick and noninvasive methods to assess volume status.

Collapsed IVC is accurately correlated with hypovolemia (hypovolemic shock) in trauma patients and is the reliable indicator of blood loss, even in small amounts of 450 cc.

Blaivas et al. revealed a statistically significant 5 mm decrease in IVC diameter was seen after donation of 450 cc blood in healthy donors.

So, IVC collapse is a marker of blood loss and this information helps to diagnose bleeding at blunt abdominal trauma even before detection of its source.

Hypovolemia is increasingly likely with IVC diameters less than 1 cm. This information allows quickly estimate the volume status (the patient is hypovolemic or not hypovolemic). Because not all hypotensive trauma patients are hypovolemic (frequently trauma patients with other non-volume related causes of shock are seen).

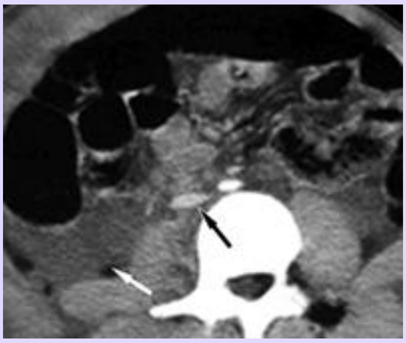


Subxyphoid window.
Longitudinal scanning of IVC.

Collapsed IVC in trauma patient with massive intraperitoneal bleeding.

Maximal diameter of IVC measuring about 0.3–0.4 cm.
Diameter is measured about 2 cm from the caval–atrial junction.

The right atrium and hepatic vein are also seen.



Flat IVC in a patient who had been involved in a traffic accident. Contrast-enhanced CT scan reveals a flattened IVC (black arrow). Gross hemoperitoneum (white arrow).

Presence of a flattened inferior vena cava ("flat cava" sign) is a strong indicator of hypovolemia (blood loss in trauma patient).

Detecting blood loss in trauma patients can often be challenging when an obvious source of hemorrhage is not readily seen.

CVP also can be estimated by sonographically evaluating the internal jugular vein, especially if the IVC view impossible to obtain. Ultrasound of the internal jugular vein is a simple examination that can be performed by a sonographer of any skill level and offers a noninvasive way to estimate CVP.

Internal jugular vein is easily seen on ultrasound.
In a patient with an elevated CVP the internal jugular vein will appear distended.
In a patient with a low CVP the internal jugular vein will appear collapsed.

FAST technique

Examination of the Right Upper Quadrant

In Right Upper Quadrant look for fluid in the perihepatic space (hepatorenal pouch and right subdiaphragmal space) and in the right pleural cavity.

Look for fluid in Morison's pouch

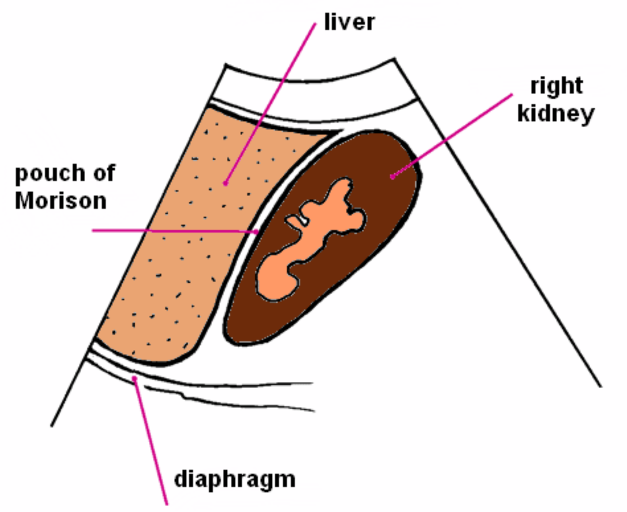
Looking for free fluid in abdominal cavity is recommend to start with a Morison's pouch, because hepatorenal pouch is the earliest and most frequent place of a blood collection at blunt abdominal trauma.

One large study (10300 patients with blunt and penetrated trauma) demonstrated, that hepatorenal pouch was positive more often, than splenorenal pouch at the isolated injury of a spleen.
Also scanning of a Morison's pouch is relatively easy and rapid.

The patient in supine position. The probe is placed in the mid-axillary line between 11th and 12th ribs, applying coronary scan with sliding by the probe (cranially or caudally and medially or laterally) for obtaining the optimal image of Morison's pouch and looking for blood in it.

Also successfully can apply longitudinal scan of the right upper quadrant in anterior-axillary line, searching for blood in Morison's pouch.

Rib shadows can cause poor acoustic window. In such situation probe should be placed between ribs (along the intercostal space).



The hepatorenal pouch (Morison's pouch) is a space between the right lobe of the liver and the right kidney, which closely adjacent to each other.

At the presence of free fluid in abdominal cavity the Morison's pouch is a potential place of fluid collection. Liver and right kidney will separated by fluid in Morison's pouch. Than more fluid than more separation of these organs.

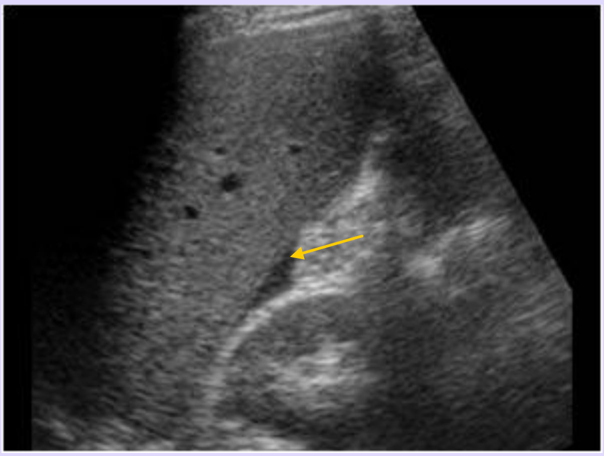
At Morison's pouch scanning must be obtained image of the right lobe of the liver and the right kidney. The attention should be focused on searching for fluid (anechoic space) between these two organs.

Correct imaging.

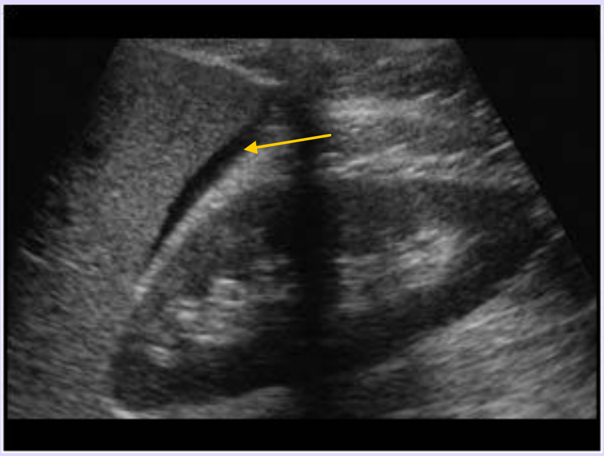
Only when liver, right kidney and a diaphragm will be together displayed on the image and well visualized, only then scan will be considered as correct.

Normally, on US image the right kidney is closely adjacent to the liver, without separation these organs by anechoic (black) space.

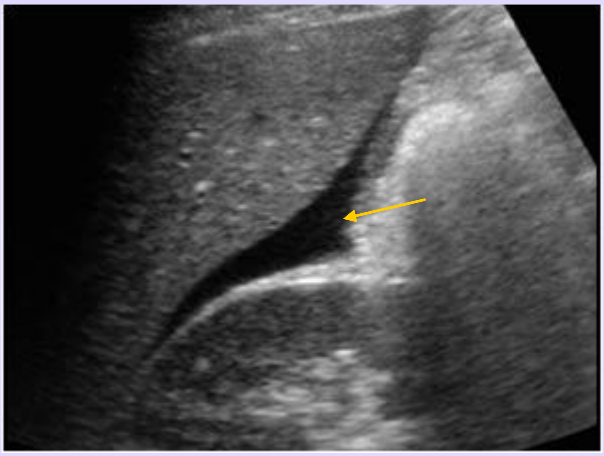
At the presence of free fluid in the Morison's pouch liver and right kidney will separated by anechoic space (from thin stripe, if small amount of fluid is present, to significant separation of these organs, if large amount of fluid is present in Morison's pouch). In cases of acute hemoperitoneum, blood appears as an anechoic space in the recess, as depicted in the images below.



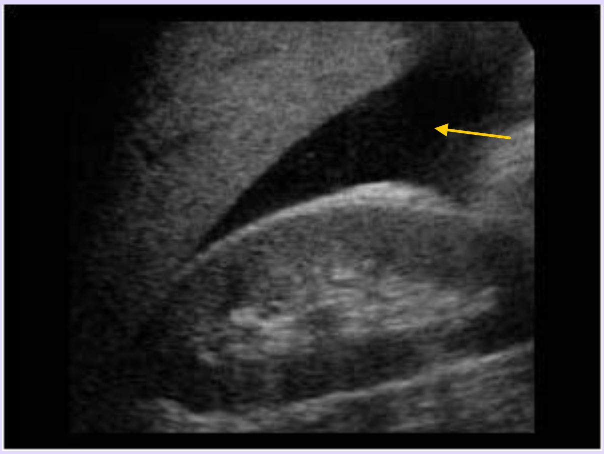
Small amount of fluid in the Morison's pouch.



Blood in the Morison's pouch as anechoic stripe between the liver and kidney.

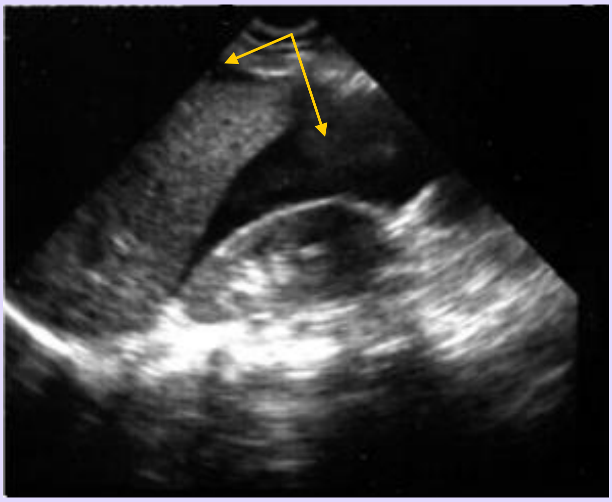


Blood in the Morison's pouch (the liver and the right kidney are more separated by anechoic fluid).



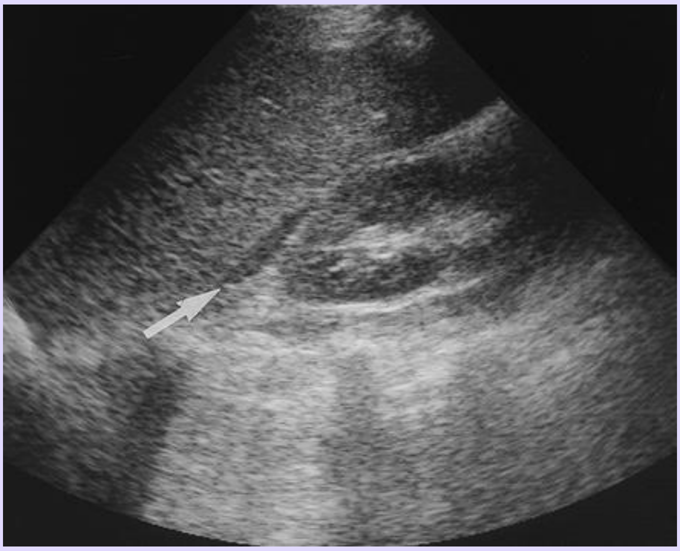
Large amount of blood in the Morison's pouch (the liver and the right kidney are markedly separated by anechoic fluid).

In critical situations, in patients with marked hemodynamic instability, the detection of fluid in pouch of Morison (as marker of hemoperitoneum) is indication for performing immediate laparotomy.



Massive hemoperitoneum.
A significant amount of the fluid surrounding a liver due to splenic laceration.

Anechoic free fluid accurately outlines pouchs of intraperitoneal cavity and contours of organs. A large amount of fluid in a pouch of Morison is easily and quickly detected, without causing difficulties in diagnose of hemoperitoneum. But difficulties can arise at small amount of fluid.

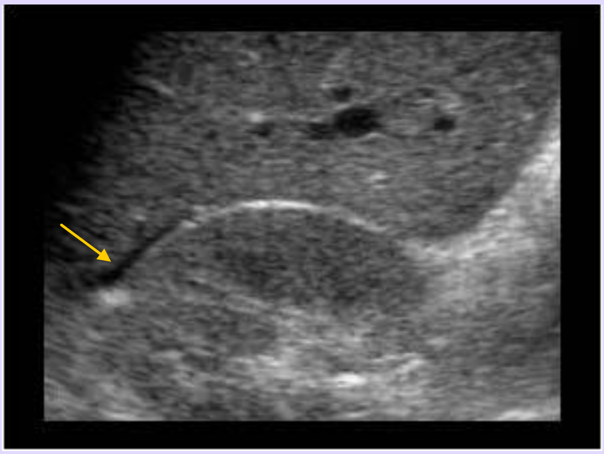


Liver laceration in a 33-year-old man involved in a motor vehicle accident.

Longitudinal scan of the right upper quadrant. The small amount of blood in the Morison's pouch (arrow).

CT was performed at the same time as the US scan and large liver laceration was detected.

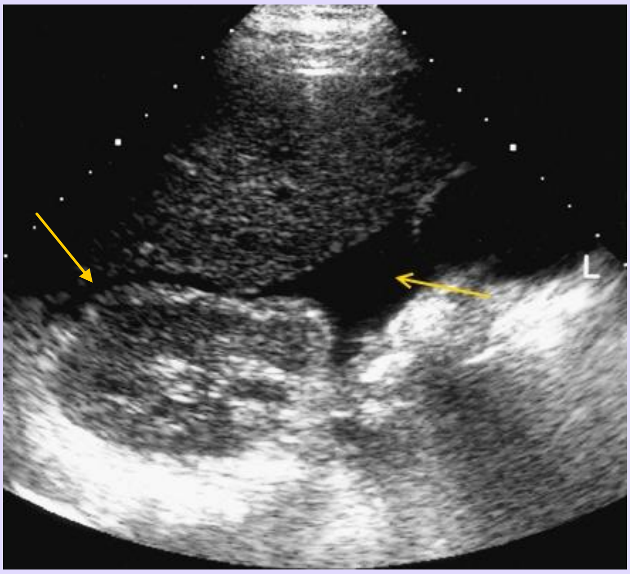
For avoiding errors, a Morrison's pouch also should be scanned with transverse plane, rotating the probe on 90 degrees. This method raises diagnostic accuracy at detection of the presence of fluid in hepatorenal pouch (especially if minimal amount of fluid is present).



Investigation of the hepatorenal pouch with transverse scanning.

The minimal amount of blood in a Morrison's pouch.

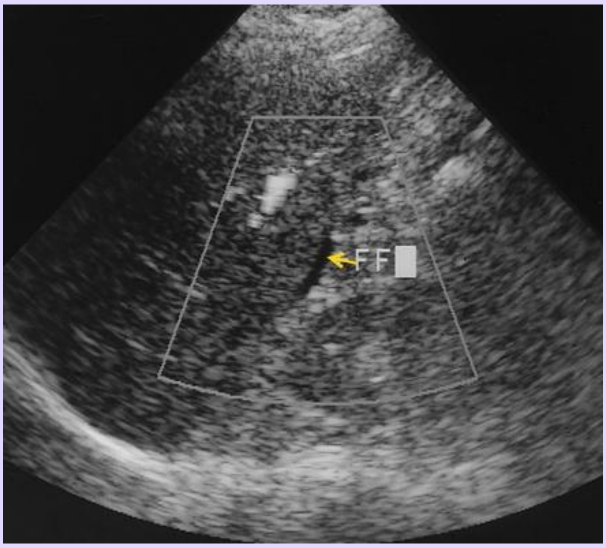
The patient with spleen rupture.
Transverse scanning of the RUQ.
The hepatorenal pouch with minimal amount of free fluid (arrow).



Hemoperitoneum.
Transverse scanning.

Free fluid in subhepatic space and a Morison's pouch.

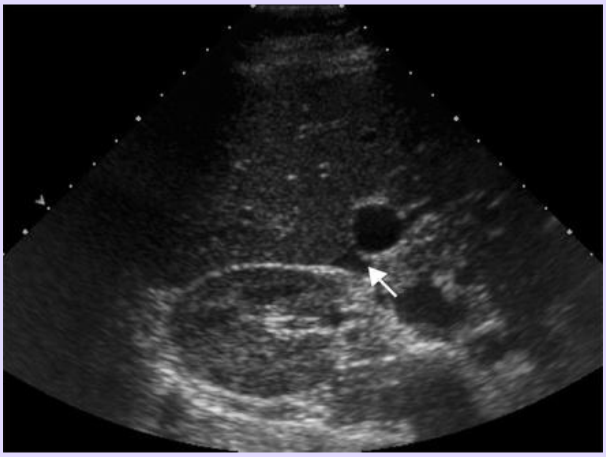
The bowel wall adjacent to the liver as thin anechoic strip (also inferior vena cava or gall bladder) should not be mistaken for free fluid.
For excluding errors, need to apply different scans, allowing to identify these structures. In such situations perpendicular scans of these structures are usually useful.



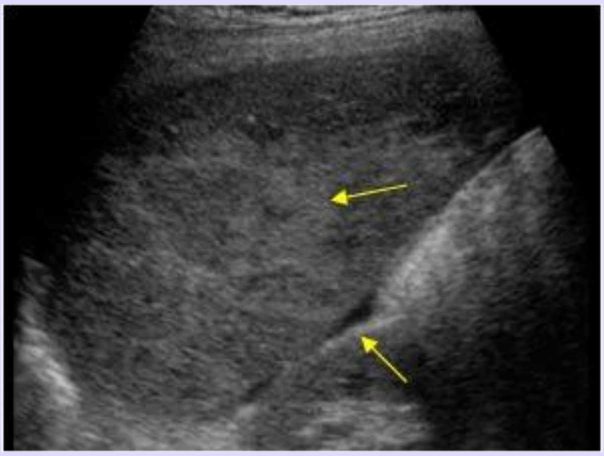
Small bowel laceration and mesenteric tear in a 72-year-old woman involved in a motor vehicle accident.
Longitudinal scanning of the hepatorenal pouch.

FF (free fluid) - a trace amount of free fluid in the Morison's pouch. Anechoic stripe representing free fluid (non vascular origin confirmed by color Doppler).

In any doubts transverse scanning of this area should be performed.



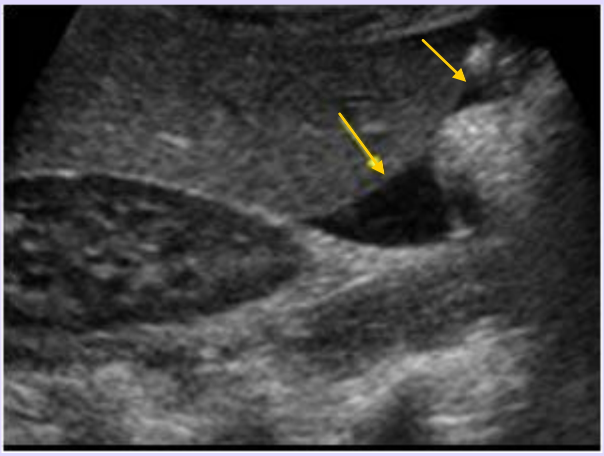
The minimal amount of blood in Morison's pouch was confirmed at transverse scanning.



Liver rupture.
Longitudinal scan of the Morison's pouch.

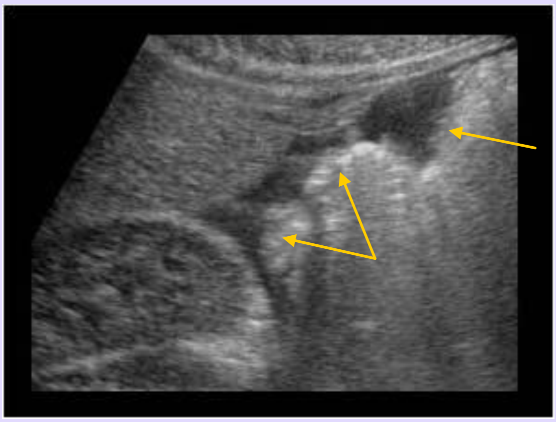
Echogenic and a heterogeneous hematoma in the liver.
The minimal amount of blood in Morison's pouch.

At searching for free fluid in RUQ also it is necessary to investigate all space surrounding the liver. Especially when in Morison's pouch free fluid is not detected.
For investigation of the space surrounding lower edge of the liver (look for free fluid in the subhepatic space) need to displace the probe mildly downwards from position of the Morison's pouch. The image of lower edge of the liver will be obtained. Then probe need to displace medially by sliding movement (with direction to the left lobe of the liver). At this time attention should be concentrated on searching for fluid surrounding the liver edges.



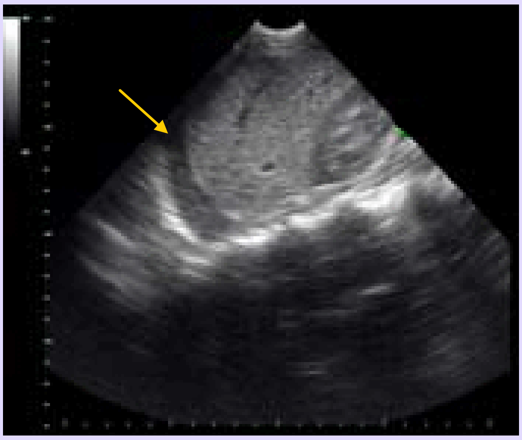
Hemoperitoneum. Blood at the lover edge of the liver.

At investigation of a pouch of Morison the free fluid was not detected, but at displacement of the probe more caudally and medially was detected the free fluid surrounding lover edge of the liver.



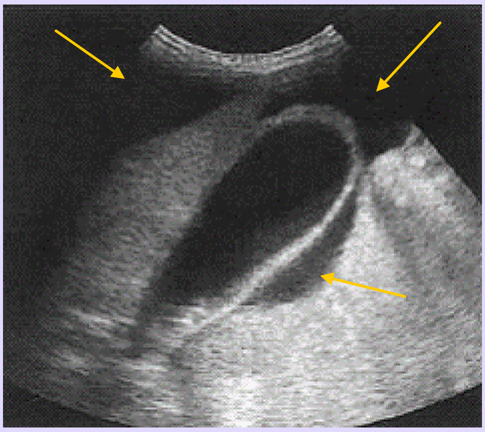
Free fluid at the lover edge of the liver (arrows).

In the same way also should be examined upper edge of the liver (look for fluid in the right subdiaphragmal space – between liver and diaphragm). The probe need to displace a little upwards from position of the Morison's pouch, and then probe need to displace medially by sliding movement (with direction to the left lobe of the liver).



Hemoperitoneum. A blood in right subdiaphragmatic space.

Anechoic space (arrow) between the upper edge of the liver and hyperechoic diaphragm.



Massive Hemoperitoneum.

A large amount of the free fluid surrounding the liver and the gall bladder.

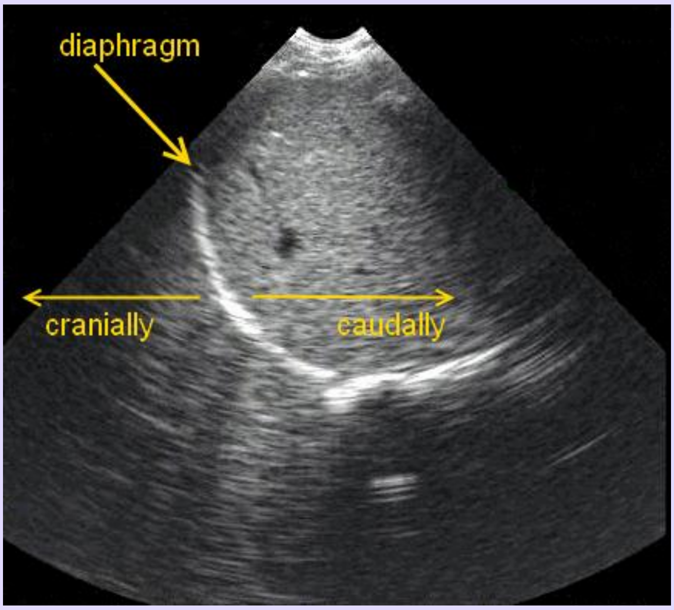
In the trauma setting, free fluid usually represents hemoperitoneum, although it may also represent bowel contents, urine, bile (due to injuries of hollow organs) or ascites.

At medical ascites (cirrhosis, heart failure) in patients with trauma FAST protocol cannot be excluded hemoperitoneum and in hemodynamically unstable patients is considered positive, stable patients with medical ascites should be evaluated with other diagnostic tests.

Look for fluid in right pleural cavity

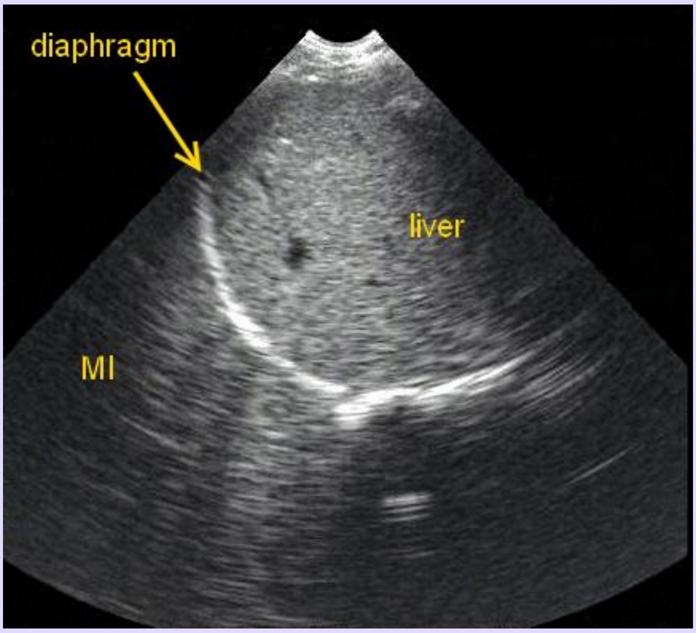
After examination of the Morison's pouch the probe must be moved mildly upwards, looking for fluid in right pleural cavity which is located above the diaphragm.

Look for fluid in right pleural cavity. Probe is moved mildly upwards from position of the Morison's pouch.



On US image diaphragm looks as hyperechoic arch and is anatomic landmark dividing abdominal cavity from a pleural cavity.
Below the diaphragm (caudally – toward the feet) is located abdominal cavity.
Above the diaphragm (cranially – toward the head) is located pleural cavity.

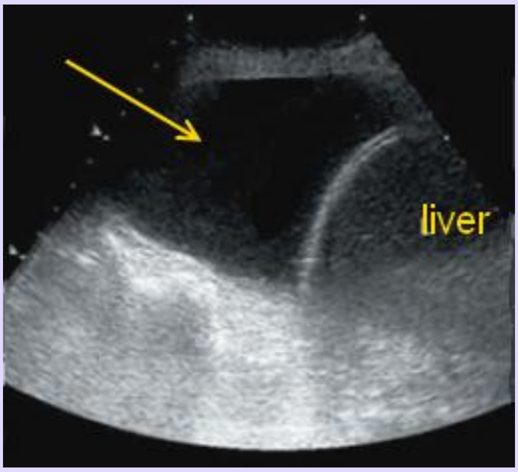
The diaphragm acts as a strong reflector of ultrasound beams and normally, mirror image of the liver projected above the diaphragm (because of a mirror artifact). At the presence of fluid in pleural cavity this mirror image disappears and anechoic space above the diaphragm is visualized.



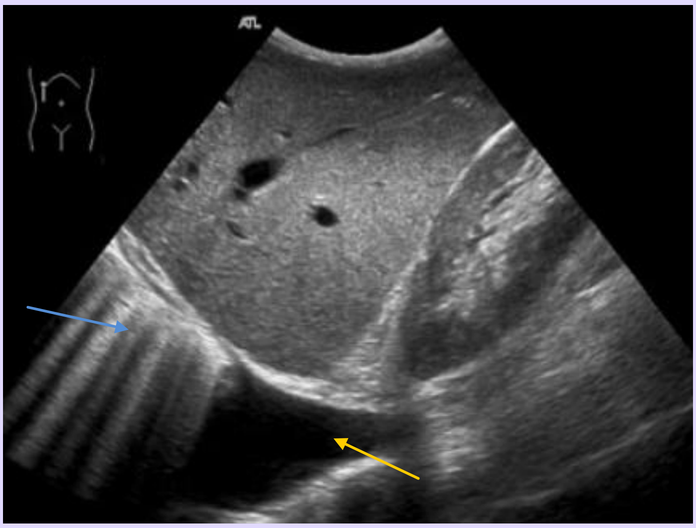
Examination of the right pleural cavity.

No hemothorax (absence of the anechoic space above the diaphragm).

MI – mirror image of the liver projected above the diaphragm.

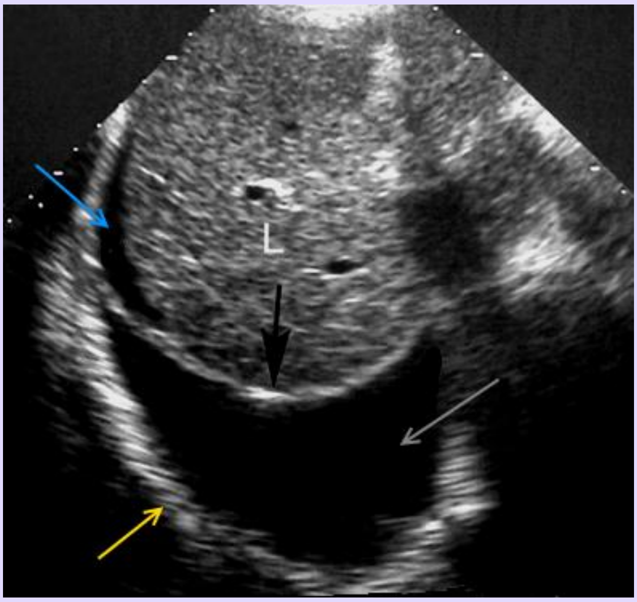


Right-sided hemothorax. Anechoic fluid (arrow) above the diaphragm (loss of mirror image).



Right-sided hemothorax – anechoic space above the diaphragm (yellow arrow).

In anechoic fluid visualized partially collapsed lung with vertical comet-tail artifacts (blue arrow).

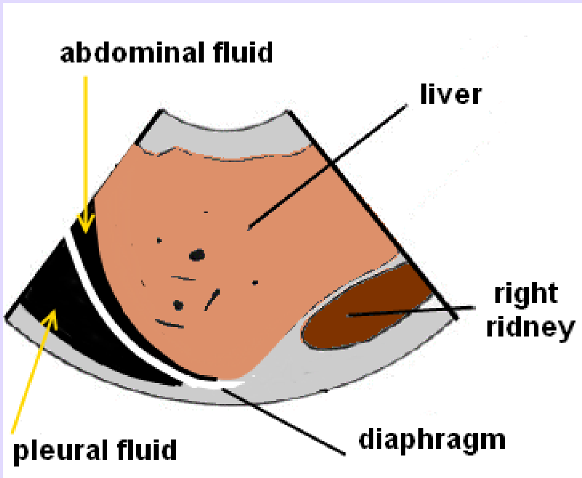


Presence of a pleural fluid can be confirmed at transverse scanning.

Transverse scan through the liver (L).

Pleural fluid (grey arrow)
Hyperechoic diaphragm (black arrow)
Chest wall (yellow arrow).

Also is present a free fluid in abdominal cavity (blue arrow)



At simultaneous presence of hemoperitoneum with right subdiaphragmal fluid and right-sided hemothorax, the fluid surrounding the liver will be visualized as anechoic space below the diaphragm, and hemothorax as anechoic space above the diaphragm.
The diaphragm will looks as hyperechoic arch dividing these spaces.

The same image will have left sided hemothorax with hemoperitoneum in left subdiaphragmal space.

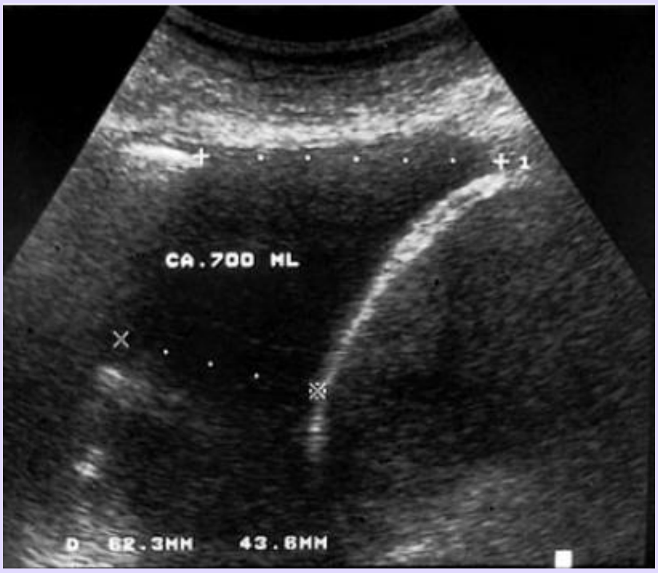
A large pleural collection (*) above the diaphragm (arrows) around the collapsed right lower lobe (arrowheads).

Also the free intra-abdominal fluid (star) below the diaphragm.

The minimum amount of a pleural fluid which can be detected at radiography in patient with upright position is 150 ml. Ultrasonography considerably surpasses radiography in revealing of a pleural fluid, with sensitivity of 100 % and specificity of 99.7 %, and can reveal minimal amount of a pleural fluid, even 5 ml.
Radiography has sensitivity of 71 % and specificity of 98.5 %, but in a prone position of patient sensitivity more decreases (43 %) and even considerable quantities of fluid can be not detected.

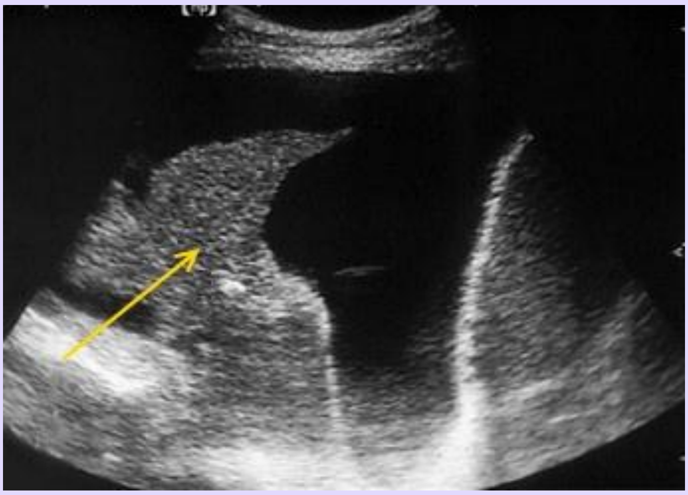
Also ultrasonography is capable to estimate volume of hemothorax.

An easy to perform method of calculation of volume of a pleural liquid is:
The total of the basal lung-diaphragm distance and the lateral height of the effusion multiplied by 70



A simple estimation of effusion volume by measuring the height of the subpulmonary effusion and the maximum height.
Estimated volume 700 ml, actual volume 800 ml.

At performance of the FAST protocol the quantity of a hemothorax is often estimated visually (mild, moderate or massive hemothorax).



Massive right-sided hemothorax - a large amount of anechoic fluid above the diaphragm.
Collapsed lung (arrow).

Examination of the Left Upper Quadrant

In LUQ look for fluid in the perisplenic space and in the left pleural cavity.

Look for fluid in the perisplenic space

The left upper quadrant free fluid is significantly associated with splenic injury. Examination of the perisplenic space is the most difficult part of the FAST protocol. The perisplenic window can be quite difficult to obtain as the spleen lies more superior and posterior than may be expected.

Unlike investigation of the right upper quadrant, left upper quadrant should be investigated along the posterior axillary line with the transducer placement one or two intercostal spaces cephalad compared to the right side.

Perisplenic probe position.

The probe is placed along the left posterior axillary line between 8 and 11 ribs.

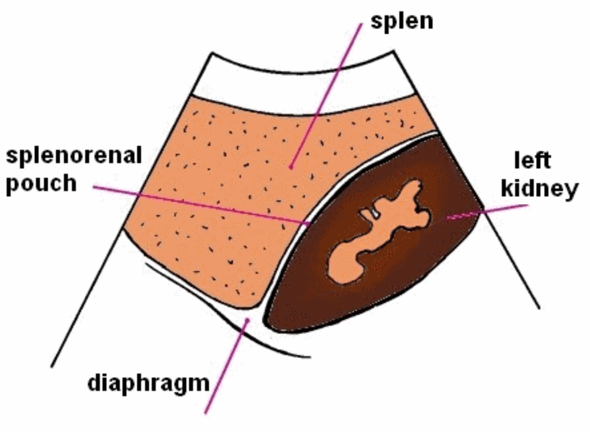
The left kidney can be used as a landmark as it will frequently be the first recognizable structure. From the left kidney view the probe should then be moved or angled cephalad (to head) to visualize the spleen and the interface between the two organs (splenorenal pouch).

Rib shadows can cause poor acoustic window. In such situation probe should be placed between ribs (along the intercostal space).

The stomach and splenic flexure of the colon are anterior to the splenorenal space and may prevent good images being obtained if they contain air. A posterior position of the probe should avoid this.

A cooperative patient may be able to improve the view by taking a deep breath. Alternatively turning the patient slightly on to their right side, if injuries allow, may be useful.

The attention should be concentrated on searching for fluid in the splenorenal pouch (between a spleen and the left kidney), but also should be estimated all perisplenic space.



The splenorenal pouch is a space between the spleen and the left kidney.

Searching for fluid must be performed in splenorenal pouch and also in all space surrounding the spleen.

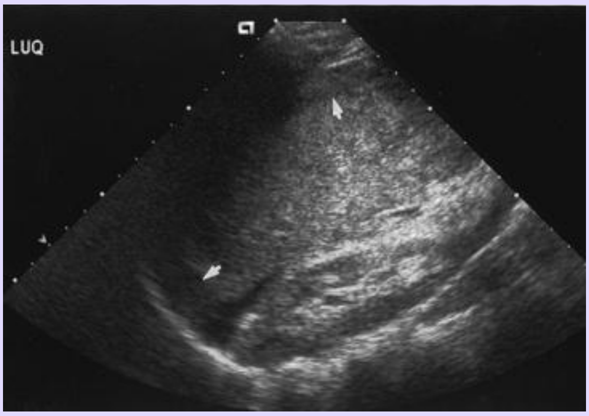
Normally the surrounding tissues of these organs are in direct contact with one another. Hemoperitoneum will seen as anechoic space between the spleen and left kidney or between the spleen and the diaphragm.

Splenorenal View.

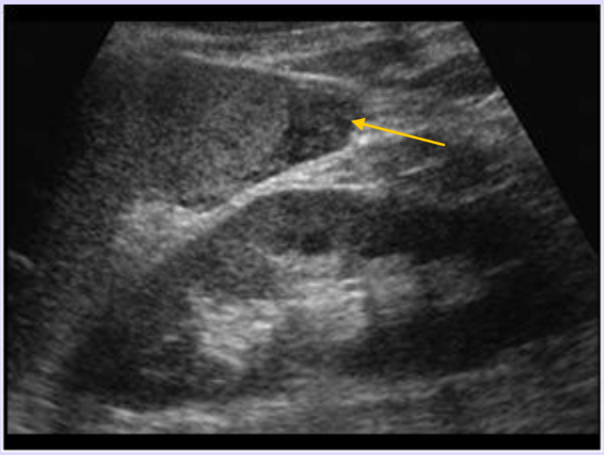
Splenic rupture.
Hyperechoic hematoma (yellow arrow) and small amount of blood in the splenorenal pouch (as anechoic strip between the spleen and the kidney (white arrow).

The posterior subphrenic space is more dependent than the splenorenal pouch, therefore free fluid is a frequently collects between the spleen and diaphragm. The probe from splenorenal view should be angled more cephalad for well visualization of the spleen and diaphragm. Left sided pleural fluid above the diaphragm can also be appreciated in this view.

But for assessment all perisplenic space the probe should be angled or moved with different positions (superiorly or inferiorly, anteriorly or posteriorly – depends from spleen location) for obtaining the desired images.

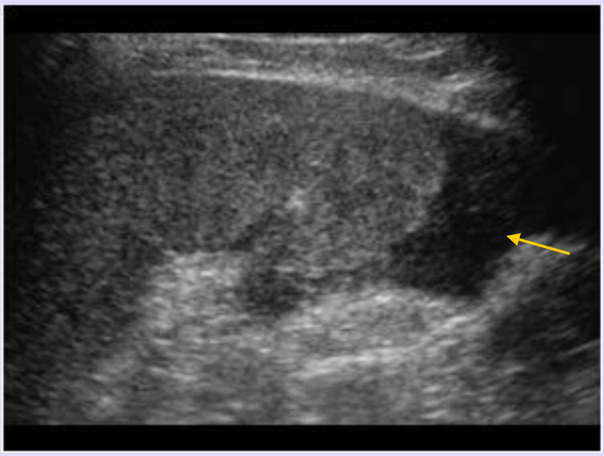


Hemoperitoneum. Splenic rupture. Anechoic fluid in left subdiaphragmatic space.



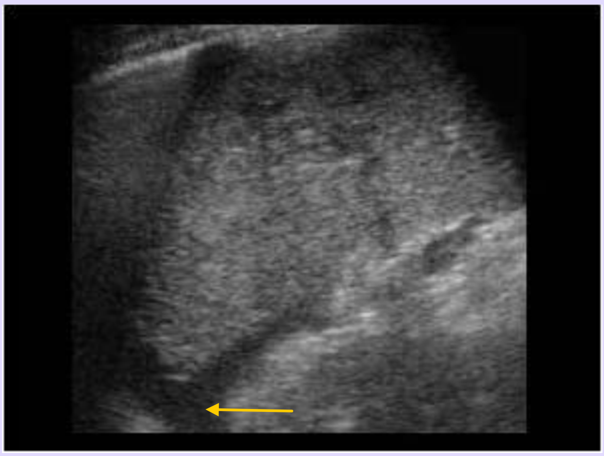
Hemoperitoneum. Splenic rupture.

Free fluid at the lower pole of the spleen. The fluid outlines the spleen edge.



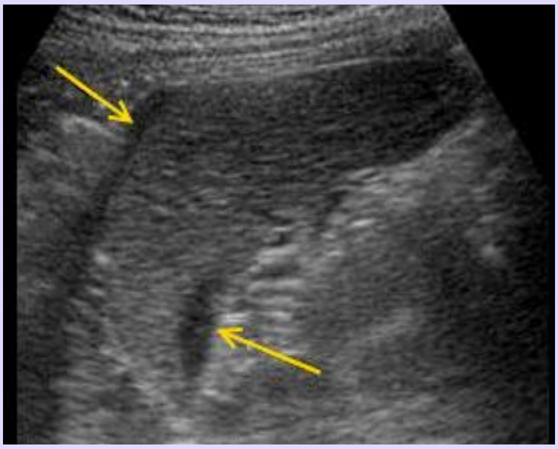
Hemoperitoneum. Splenic rupture.

Irregular lower pole of the spleen surrounded by fluid (arrow).

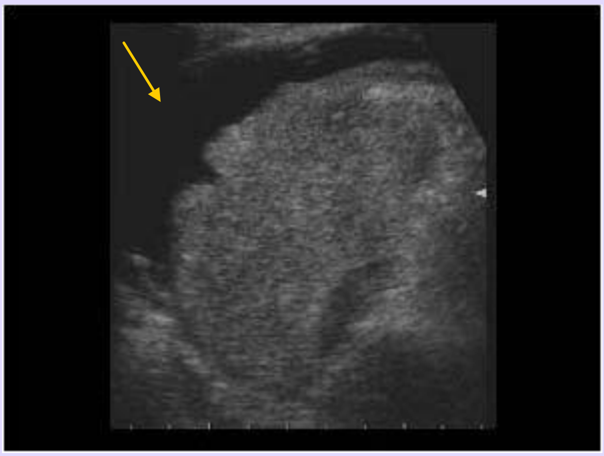


Hemoperitoneum. Splenic rupture.

Blood (arrow) surrounding the upper pole of the spleen.
Spleen is heterogeneous in echotexture.
Splenic rupture is confirmed at operation.

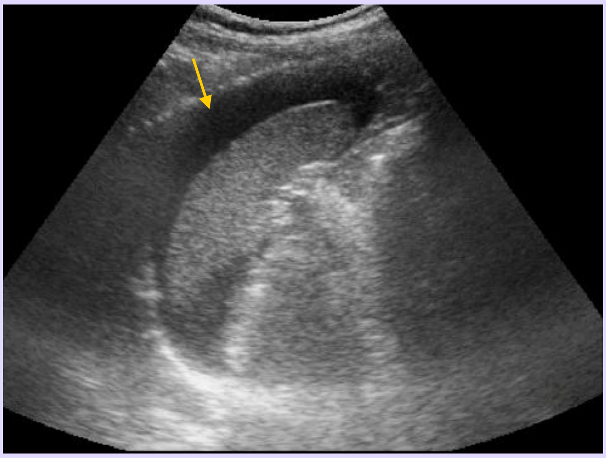


Hemoperitoneum. Splenic rupture. Fluid surrounding the spleen (arrows).



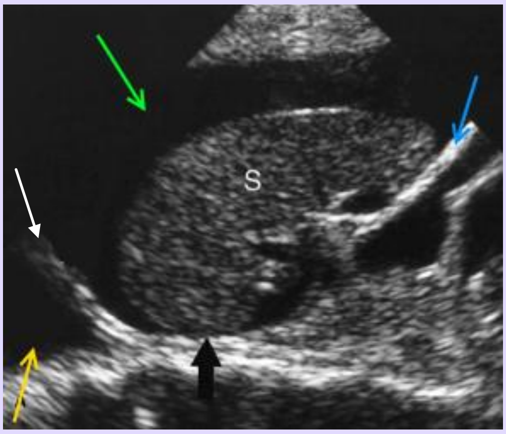
Hemoperitoneum. Splenic rupture. Blood (arrow) surrounding the spleen. It is more fluid in subdiaphragmatic space (between the spleen and the diaphragm).

Wedge-shaped defect of the spleen is also visualized.



Hemoperitonium. Splenic rupture.

Large amount of the blood surrounding the spleen.



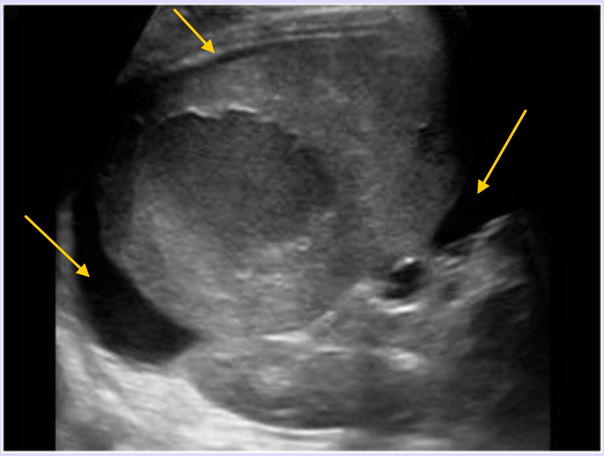
Hemoperitoneum – large amount of fluid (green arrow) surrounding the spleen (S). Fluid outlines the gastrosplenic ligament (blue arrow). Note the small bare area of the spleen (black arrow).

Also left pleural effusion (yellow arrow) is seen above the diaphragm (white arrow).

The example of splenic rupture

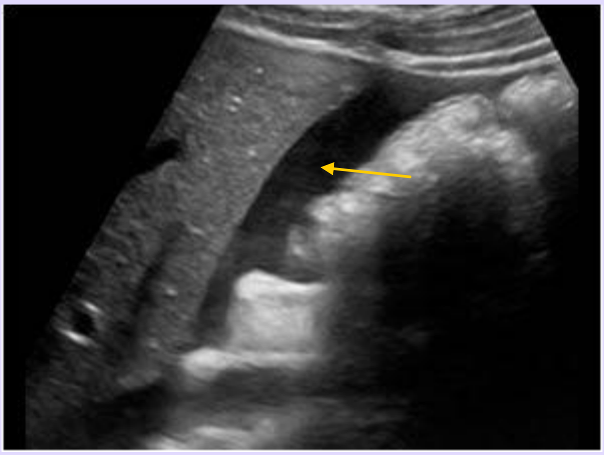
Studies demonstrates that isolated left upper quadrant free fluid, in both upper quadrants, or diffusely (fluid in LUQ, RUQ and pelvis) is significantly associated with splenic injuries. The dynamics of flow in the abdomen are of interest in that free fluid tends to flow from the left to the right upper quadrant rather than down the left paracolic gutter into the pelvis.

It can be explained that hemorrhage from the spleen first accumulates in the left and then flows to the right upper quadrant because the phrenocolic ligament acts as a relative barrier to the movement of fluid to the left gutter. Also fluid from the RUQ flows down via the right paracolic gutter to pelvis rather than toward the left upper quadrant, perhaps because of the gravity dependence of the right paracolic gutter and pelvis.



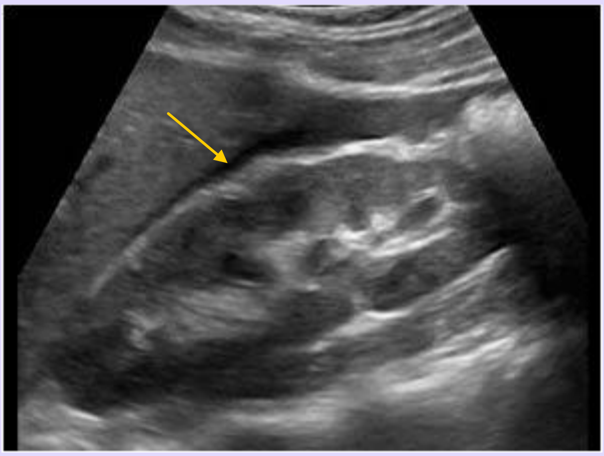
Splenic rupture.

At examination of the left upper quadrant was detected the spleen with markedly heterogeneous parenchyma, surrounded by fluid (arrows).

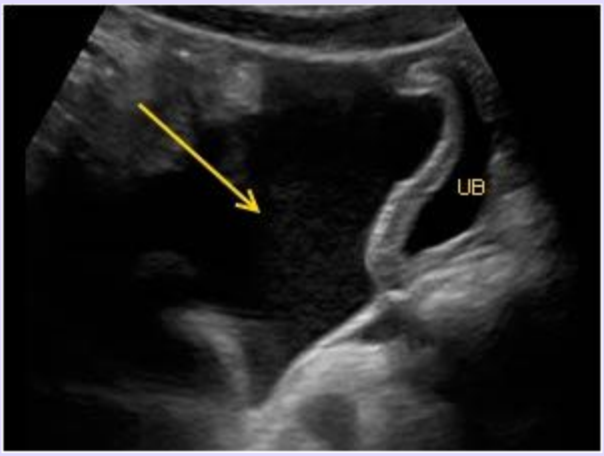


Splenic rupture.

A large amount of a fluid at the lower edge of the liver.



Splenic rupture. A fluid in the pouch of Morison.



Splenic rupture.

Longitudinal scanning of the suprapubic region. Large amount of fluid in a pelvis (arrow).

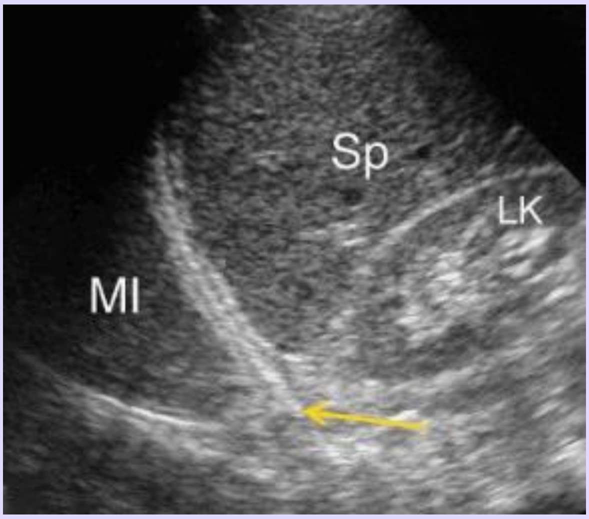
UB - urinary bladder.

Look for fluid in left pleural cavity

At searching for left sided hemothorax the probe from splenorenal view should be angled more cephalad for well visualization of the spleen and diaphragm and look for fluid above the diaphragm.
The spleen is an acoustic window at examination of the left pleural cavity. Thus, the spleen, diaphragm and the left pleural cavity which located over the diaphragm should be well visualized.

Look for fluid in the left pleural cavity. The probe from splenorenal view should be angled with beam direction more cephalad for well visualization of the spleen and diaphragm and look for fluid above the diaphragm.

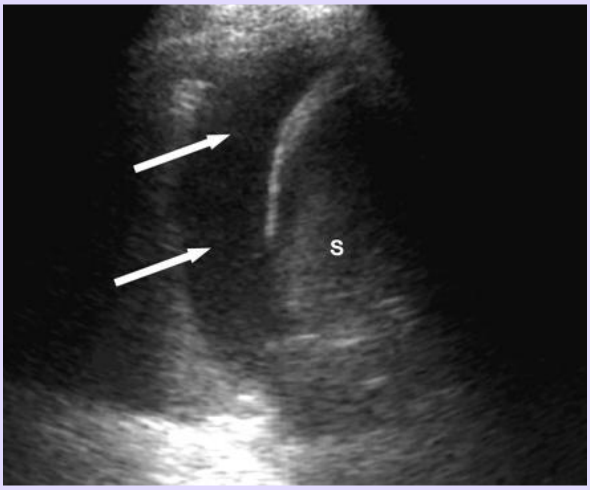
But left pleural cavity view can be difficult to obtain and the probe should be angled or moved with different positions (superiorly or inferiorly, anteriorly or posteriorly – depends from spleen location) for obtaining the desired images.



Normally, mirror image of the spleen projected above the diaphragm (because of a mirror artifact).

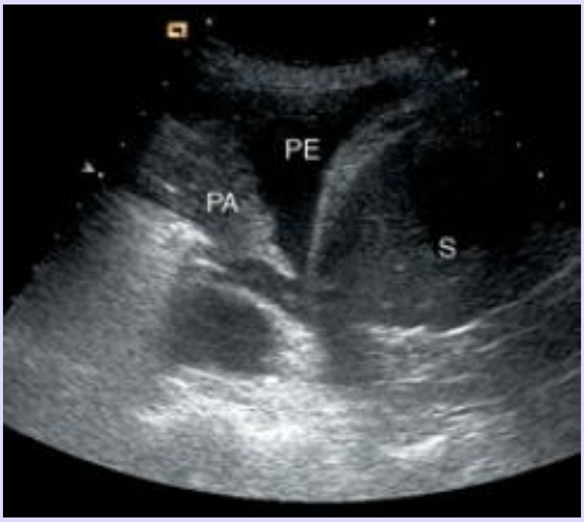
Sp – spleen
LK – left kidney
MI – mirror image
Diaphragm – (arrow).

At hemothorax this mirror artifact disappears, and replaces by anechoic space above the diaphragm representing blood in the left pleural cavity.



Left-sided hemothorax – anechoic fluid above the hyperechoic diaphragm (arrows)

S - spleen



Left-sided hemothorax - anechoic fluid above the diaphragm .

S - spleen
PE – pleural effusion
PA - pulmonary atelectasis (collapsed lung) due to a compression.

Look for free fluid in pelvis

Pelvis should be examined when the patient's bladder is full. Free fluid in the pelvis may be missed if the patient has an empty bladder. The empty or partially filled bladder is the most frequent cause of false-negative result. A full bladder act as an acoustic window to detect free fluid in pelvis.

At full bladder its walls are well visualized. The bladder wall is anatomic landmark dividing a fluid in a bladder and a free fluid in a pelvis, therefore searching for free fluid in a pelvis is performing directly behind the bladder walls.

Small amount of free fluid in a pelvis accumulates in a pouch of Douglas in women (between the uterus and rectum) and rectovesical pouch in men (between the bladder and rectum).

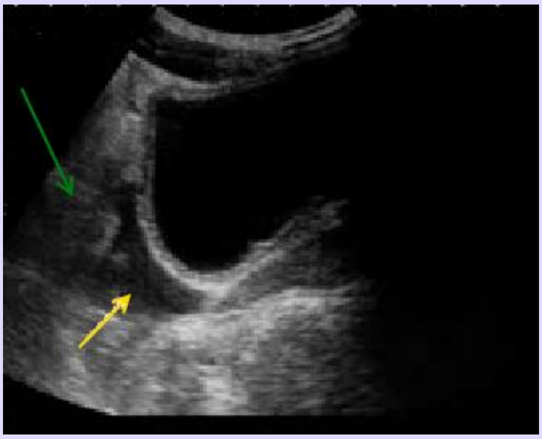
Larger amount of free fluid in a pelvis will surround a bladder. Need to obtain both transverse and longitudinal images of the bladder with searching for free fluid just behind wall of the bladder and in Douglas pouch or rectovesical pouch.

Free fluid will usually appear as anechoic or hypoechoic, but may be hypoechoic with a few internal echoes or echogenic if blood is clotted. Also in a fluid will be defined floating bowel loops.

To obtain the suprapubic view, the probe should be placed just above the pubic symphysis and directed inferiorly into the pelvis. As with all scanning applications, both transverse and longitudinal planes are critical to fully evaluate the pelvis for fluid, as there are many imaging artifacts and confusing structures that can confound the exam.

Suprapubic probe placement.

In the beginning the probe should be placed in a transverse position on 2 cm above pubis (for transverse imaging of the bladder), then turn longitudinally (for longitudinal imaging of the bladder).



Longitudinal view of the suprapubic region.

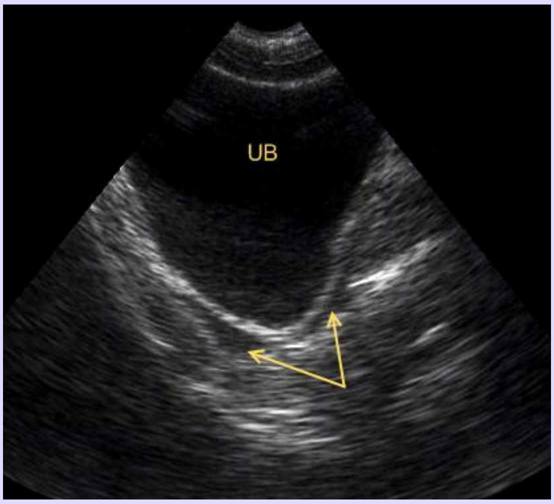
Free fluid in pelvis surrounding the wall of the urinary bladder.

Free fluid – yellow arrow.
Bowel – green arrow.

The free fluid well outlines bowel loops which are easily defined, peristalting and floating in anechoic space.

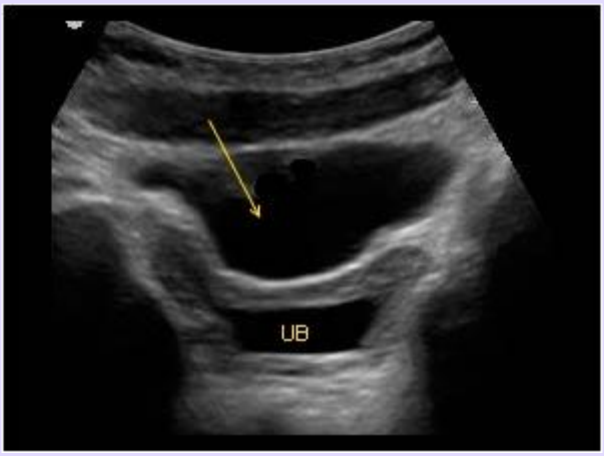
Longitudinal view of the suprapubic region.
A large amount of slightly echogenic fluid in a pelvis (clotted blood).

UB - Urinary Bladder.



Transverse view of the suprapubic region.
The minimal amount of free fluid in a pelvis.
Free fluid is noted by arrows as anechogenic space just behind the bladder wall.

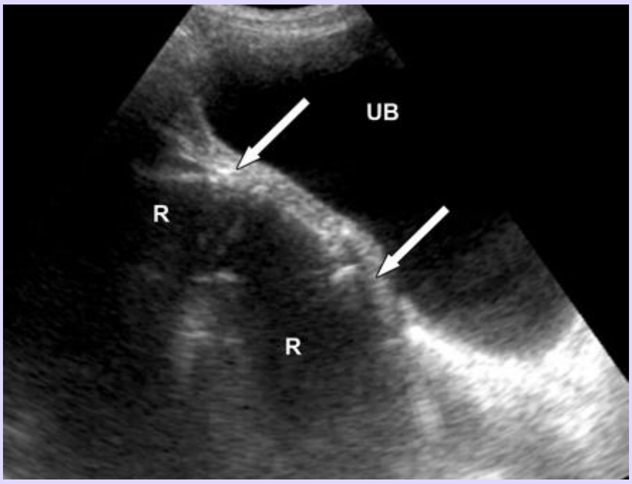
UB – Urinary Bladder.



Transverse view of the suprapubic region.
Free fluid in a pelvis (arrow) just above of the bladder.

UB - Urinary Bladder.

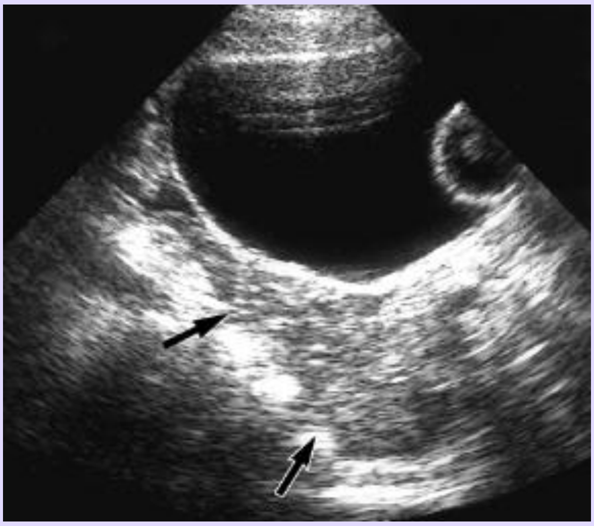
At empty bladder the collection of a free fluid in the pelvis should not be mistaken for a bladder. Unlike a urinary bladder where anechoic fluid is limited by walls, the free fluid outlines the organs with sharp angles of fluid collections. If difficulties occurs in differentiation of a free fluid from a bladder, the placement of a Foley catheter will help to identify the bladder.



Longitudinal view of the suprapubic region. Normal rectovesical pouch (arrows), the space between the rectum (R) and the urinary bladder (UB) without free fluid. The fluid-distended rectum should not be mistaken for free fluid.

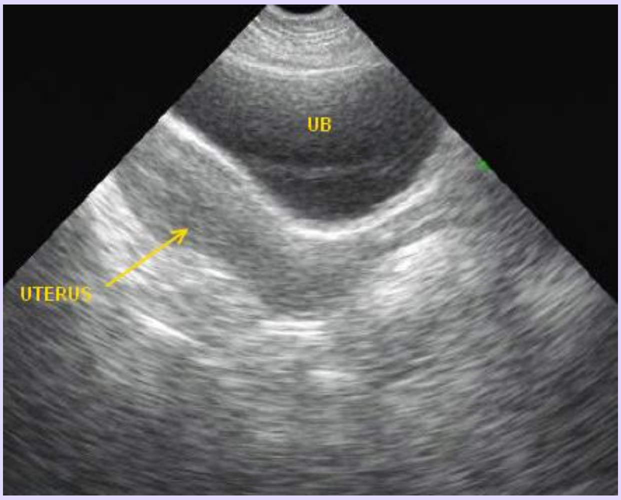
Also transverse scanning can help to determine that this structure is rectum.

Echogenic fluid or clot may be less obvious than the anechoic free fluid but should not be overlooked.



Longitudinal view of the suprapubic region reveals an isoechoic clot filling the cul de sac (arrows).

Intraperitoneal clot is usually hyperechoic relative to adjacent structures. Occasionally, however, it is isoechoic, and intraperitoneal bleeding or parenchymal injury may go unrecognized. Familiarity with the typical appearance of the peritoneal reflections and of the normal configuration of the solid organs should improve recognition of intraperitoneal clot.

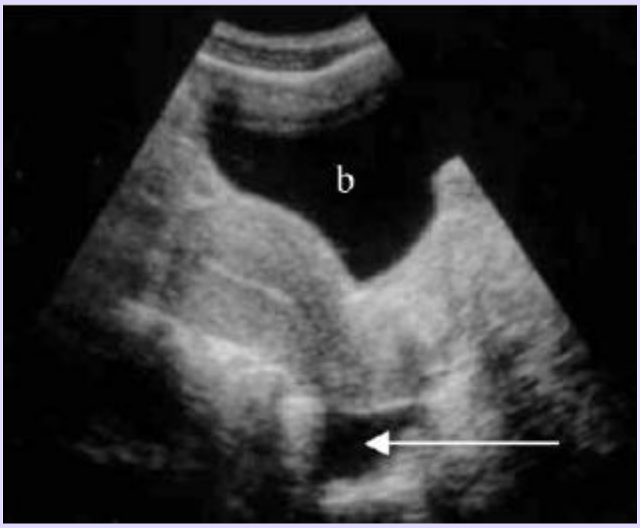


Longitudinal view of the suprapubic region.

Normal appearance of the pouch of Douglas.

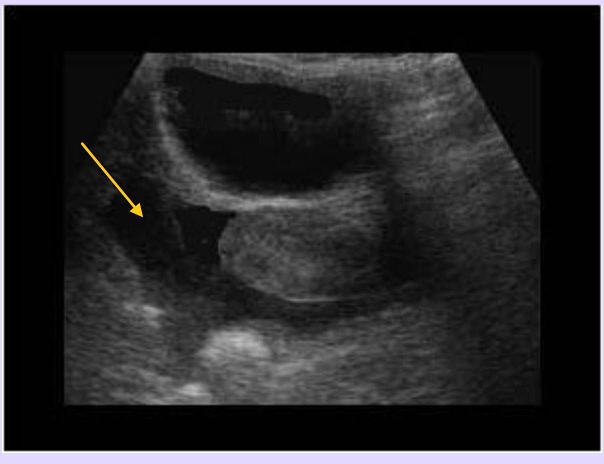
Absence of a free fluid (anechogenic space) between a uterus and a rectum.

UB - Urinary Bladder.



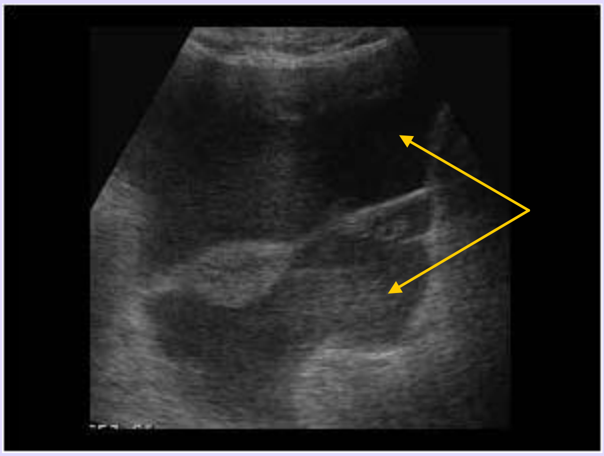
Longitudinal view of the suprapubic region. A small amount of free fluid in the pouch of Douglas (anechoic fluid collection space posterior to the uterus (arrow).

b - urinary bladder.



Longitudinal view of the suprapubic region.

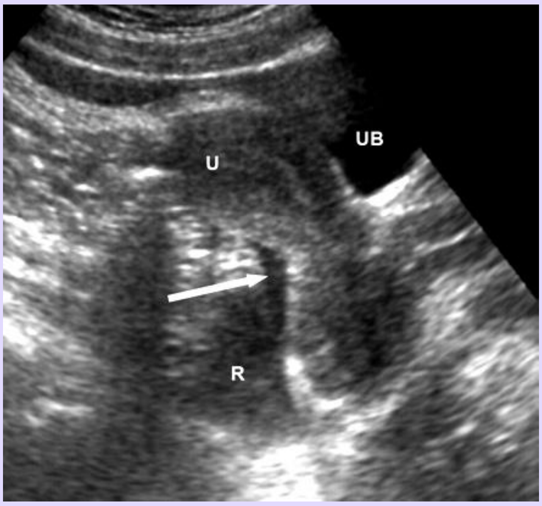
Fluid in the pouch of Douglas, surrounding the uterus (arrow).



Transverse view of the suprapubic region.
A transverse image of the uterus.

A large amount of free fluid in a pelvis (arrows) surrounding uterus.

Any quantity of fluid is considered positive, except for anechoic fluid measuring less than 3 cm in maximum antero-posterior dimension and isolated to the pelvic recesses in reproductive-age women, is considered physiologic in the absence of other suspicious findings.
Clinical observation in such situations is usually enough.



Physiological fluid in a pelvis.
Longitudinal view of the suprapubic region shows a small amount of free fluid in the pouch of Douglas (arrow).

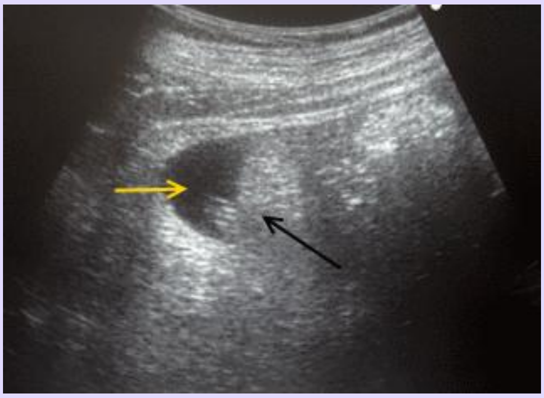
R – rectum.
U – uterus.
UB – urinary bladder.

If small amount of free fluid is detected in the pouch of Douglas which associated with fluid in any other places is considered hemoperitoneum and usually indicates on clinically considerable injuries.

After investigation upper quadrants and a pelvis should be quickly examined left and right paracolic gutters, applying transverse scanning, especially when in upper quadrants and in a pelvis the free fluid is not detected.

Paracolic gutters

The paracolic gutters are additional sonographic views that may increase the sensitivity of the standard FAST exam for the detection of peritoneal fluid. They are obtained by placing the transducer in either upper quadrant in a coronal plane and then sliding it caudally from the inferior pole of the kidney. Alternatively, the transducer can be placed in a transverse orientation.



The free in right paracolic gutter (yellow arrow) at the transverse scanning.
Bowel loops (black arrow).

Also should be examined the central part of abdomen for detection of free fluid between bowel loops, as indirect sign of bowel or mesentery injuries.

Quantity of free intraperitoneal fluid

The detectability of free fluid during the FAST examination is strongly dependent on the volume of fluid present. The quantity of free intraperitoneal fluid that can accurately be detected on ultrasound has been reported to be as little as 100 mL. The sensitivity of FAST increased with larger volumes of free fluid.

The false-negative result is often caused by early performance of FAST protocol when hemoperitoneum yet not reached detectable quantity.

Serial sonography may be useful for detecting free fluid in patients with BAT (Blunt Abdominal Trauma). If there is active bleeding in the abdomen, the amount of fluid should increase with time and would be more amenable to sonographic detection.
Studies demonstrates that the repeated sonographic examinations after 30 minutes and after 6 hours in hemodynamically stable patients with primary negative FAST, raises sensitivity of a method.

Also, the use of ultrasound as a screening test for blunt abdominal trauma not only offers the expeditious identification of hemoperitoneum but also allows for fluid quantification. Increasingly recognized that hemoperitoneum following trauma is not necessarily an indication for immediate laparotomy in stable patients. Quantifying free fluid during the early stages of assessment may improve patient selection for laparotomy.

Although US can demonstrate the extent of hemoperitoneum, communication of this information to the surgeon has been limited to the use of words such as "trace," "moderate," or "large" to describe fluid volume. To improve information transfer and assist the surgeon in decision making, a scoring system for fluid quantification was developed. Providing the surgeon with a hemoperitoneum score will help in the decision-making process (conservative or operative treatment).

Qualitative fluid scoring system is widely used. The higher the score, the higher the intra-abdominal injury rate and the greater the need for surgery.

McKenney et al. proposed a hemoperitoneum scoring system based on the antero-posterior depth of the largest fluid collection measured in centimeters plus one point for each additional area with fluid.
The depth of the largest collection plus the total additional points given equals the patient's hemoperitoneum score.

A score of greater than 3 is associated with an increased need for surgical intervention.

A score of less than 3 is more often do not need operative treatment.

Studies demonstrates that hemoperitoneum score is a more accurate predictor of the need for a therapeutic operation than initial systolic blood pressure and base deficit. And it is especially important when the unstable condition of the patient can be caused by other causes (orthopedic or neurologic) at multiple injuries.

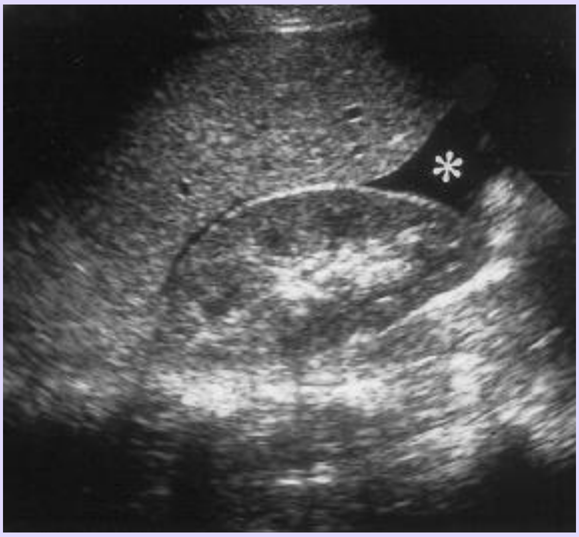
Calculation of the hemoperitoneum score.

28-year-old man after a motor vehicle crash.

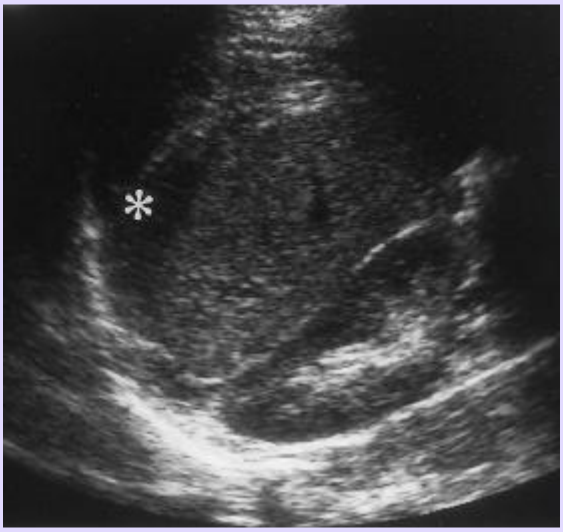
A) Longitudinal sonogram of the pelvis shows the largest collection of free fluid measured 10 cm from anterior to posterior (between calipers).

UB – urinary bladder.

Subhepatic fluid and perisplenic fluid (B and C) give two addition points, resulting in a hemoperitoneum score of 12 (10 + 1 + 1).

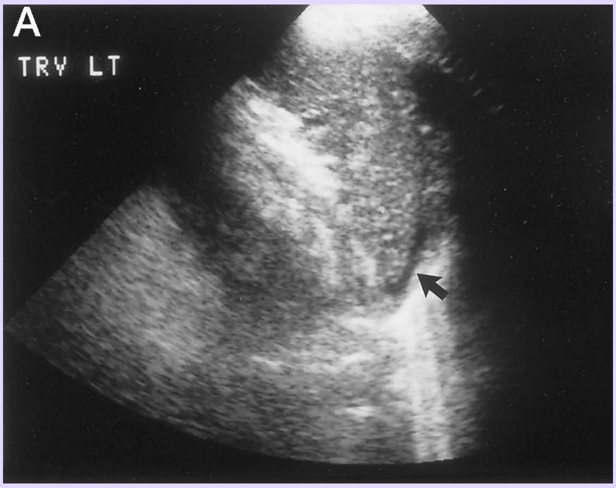


B) Longitudinal US image of the Morison pouch shows one additional site of fluid (asterisk).



C) Perisplenic fluid (asterisk), as second additional site of fluid. Also heterogeneous splenic parenchyma was detected.

Hemoperitoneum score 12 (10 + 1 + 1). Emergency splenectomy was performed.



(A) Sonogram positive for fluid in the left upper quadrant only. Transverse image of perisplenic area shows 0.3 cm of fluid (arrow). Hemoperitoneum score = 0.3.

(B) CT scan reveals a small splenic laceration (arrow) that was managed nonoperatively.

Also in practice for detecting of hemoperitoneum volume other methods are applied.

- Tiling considered a small anechoic stripe in Morison's pouch to represent about 250 mL of fluid and a 0.5-cm anechoic stripe to correspond to more than 500 mL of fluid within the peritoneum.
- The free fluid revealed in 2 or 3 pockets, corresponds approximately to 1 L of the blood.

But decision for surgical intervention depends from all factors (results of sonography, CT, systolic BP, hematocrit, clinical data).

Large amount of the free peritoneal fluid which detected at FAST examination is indication for immediate laporotomy in patients with unstable hemodynamic without performing of CT. Small amount of a fluid in patients with stable hemodynamic suspects a mild bleeding and in such situations should be performed CT, as definitive diagnostic test, which allows to diagnose not only degree of rupture, but also presence of active bleeding at extravasation of contrast material.

Look for pneumothorax

Pneumothorax represents the second most common injury, after rib fracture, in blunt chest trauma.
The diagnosis of traumatic PNX is suggested by clinical signs and is generally confirmed by standard chest radiography, usually if pneumothorax is large. At obvious clinical signs of massive pneumothorax emergency chest tube is placed without radiographic confirmation.
But a clinically silent (minimal, small) pneumothorax is difficult to diagnose by physical examination or radiographically and it often remains undiagnosed.

The detection of an occult PNX is important, because small PNX may rapidly progress to tension PTX if diagnosis is missed or delayed, especially in patients receiving mechanical ventilation. PTX may increase the mortality rate in trauma patients if it is not promptly recognized.

Thorax radiography in trauma patient is usually performed in supine position. Up to 30% of PNX are missed (occult pneumothorax) by the initial bedside antero-posterior supine chest radiograph.

In the supine trauma patient without previous pleural disease, pathologic air within the pleural space tends to rise to the anterior chest wall at the paracardiac regions and anterior costo-diaphragmatic sulci. Therefore ultrasonography is ideal for detection of anterior pneumothorax.

US is more sensitive than supine chest radiography with sensitivity of 95%-100%) for PNX detection, compared with the supine chest radiography (36%-75%).
Sometimes even massive pneumothorax can be not detected by radiography in the supine trauma patient.

US is highly sensitive and also has a high negative predictive value for the detection of traumatic pneumothorax and therefore can be an effective diagnostic tool to definitively exclude pneumothoraces in trauma patients.

Value of ultrasonography in pneumothorax detection consists in its rapidity (providing diagnosis within few minutes), especially at life-threatened conditions, such as tension pneumothorax, there is no time for radiologic confirmation.

Also US can quickly exclude pneumothorax (skilled operators can exclude pneumothorax within few seconds).

CT has excellent diagnostic accuracy. CT is the gold standard in pneumothorax detection and its volume, however cannot be performed in patients with unstable haemodynamic.

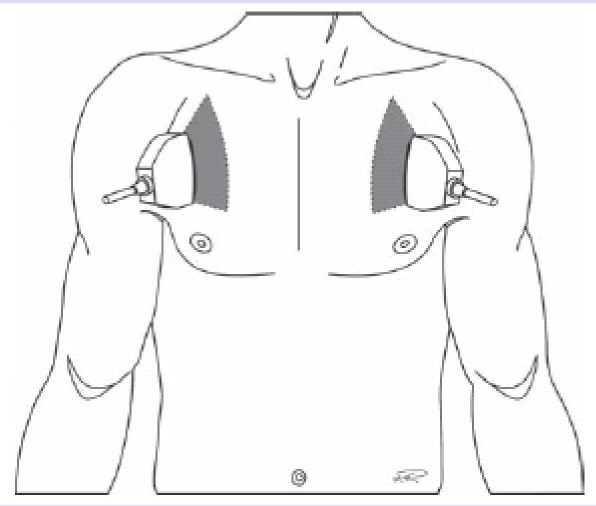
Ultrasonography is especially useful in emergency diagnosis, in which no radiographic equipment is readily available. It may occur in locations where access to traditional means of diagnostic confirmation (CT and chest radiography) is not readily available, such as remote military operations, space travel, and during natural disasters and mass-casualty situations. Newly developed US equipment includes high-quality portable units that are easily transported by hand. The use of these units can enable the assessment of thoracic trauma in many diverse environments.

Therefore sonography has a number of advantages: highly sensitive, rapid and simple method at performance and interpretation of results.

Technique

This technique is simple and for training only few examinations are required. Assessment of the chest to rapidly confirming or rule out a pneumothorax is performed by the same abdominal probe with frequency 3.5 - 5 MHz, but in presence of any doubts examination should be performed with the linear high-frequency probe (7 - 10 MHz) for best visualization of sliding of the visceral pleura.

Scanning should be performed with short depth (approximately 5 cm).

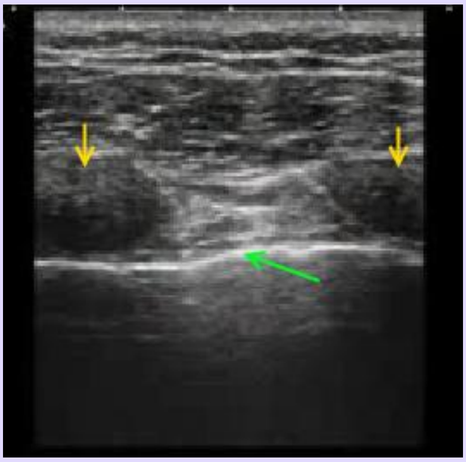


Anterior chest view for pneumothorax detection.

The transducer is placed longitudinally in the midclavicular line usually over the third and fourth intercostal spaces

The probe is placed perpendicular to the ribs in the anterior chest region for scanning 2-3 intercostals spaces in the midclavicular line (usually 3 rd - 4th intercostals spaces).

If visualization is inadequate, the probe can be rotated on 90 degrees, placing it directly in intercostal space along ribs.



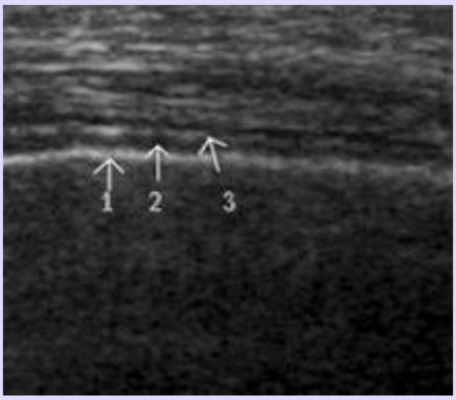
Need to obtain the cross-section image of 2 ribs with an intercostal space between them.

This scan is classic at any investigations of the pleura and lungs, because the hypoechoic ribs with posterior shadows act as fixed anatomical landmarks for rapid detection of a pleural line. Because pleural line is well defined as hyperechoic stripe located just below ribs.

Ribs (yellow arrows) with clear acoustic shadowing.
The pleural line (green arrow), A - line.

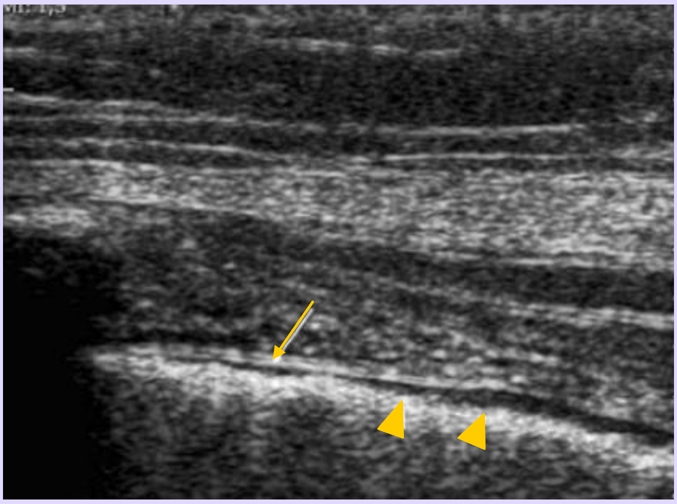
The pleural line is border between soft tissue of a chest wall and a lung and represents the parietal and visceral pleural interface.

Parietal pleura looks as hyperechoic line which located just below ribs and is motionless. Visceral pleura covering a lung is located under parietal pleura and moves (to-and-fro), synchronously with respiratory movements.



Pleural layers are accurately visualized with using high-frequency transducer (10MHz).
The visceral pleura is separated from the parietal pleura by a thin layer of pleural fluid in the pleural space.

1 - normal visceral pleura.
3 - normal parietal pleura representing thin echogenic line.
2 - pleural space representing anechoic or hypoechoic stripe between parietal and visceral pleura.



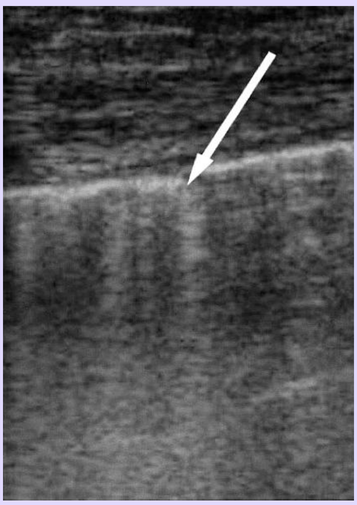
The parietal pleura is well visualized (arrow).
The visceral pleura (triangles) seems thicker and more echogenic due to reverberation artifacts on the visceral pleura/air-filled lung interface and consequently is easily visualized and identified by its movement with respiration (sliding sign). The attention should be focused on searching of sliding movement (to-and-fro) of the visceral pleura.
Should be investigated few respiratory movements.

This sliding movement of the visceral pleura is called «lung sliding». If sliding movement is revealed, pneumothorax is almost completely excluded. Absence of «lung sliding» is the basic sign of a pneumothorax.

The normal to-and-fro sliding of the visceral pleura against the stationary parietal pleura is easily visualized and is synchronized with respirations. Therefore visualization of the sliding shows that visceral pleura is not separated from parietal pleura by air.

At pneumotorax «lung sliding» is absent, because a parietal and visceral pleura separated by air. Therefore absence of the sliding indicates subparietal air collection.

Also, directly below this hyperechoic pleural line, hyperechoic vertical «comet tail» artifacts are normally visualized, named B - lines. This is a reverberation artifact that has been described as a vertical, narrow-based, echogenic band extending from the visceral pleura into the deeper portions of the imagine (laser ray-like). This is generated by the large difference in impedance between the pleura (highly reflective) and its surrounding air filled lungs. This arises from the pleural line and fans out to the edge of the screen.
In the presence of a pneumothorax, these reverberation artifacts are absent due to separation parietal and visceral pleura by air.



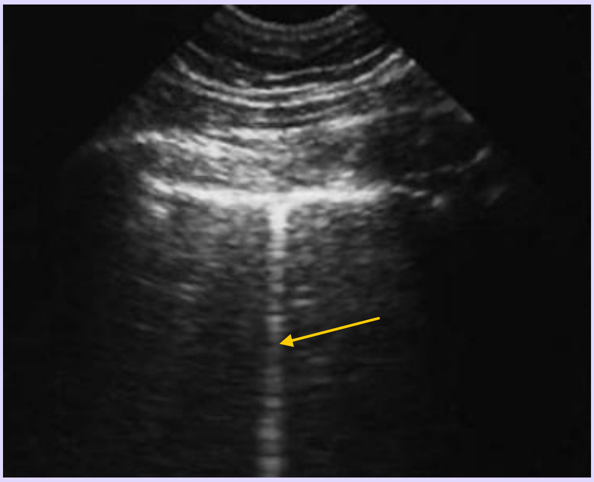
Normal lung.

B-lines vertical, comet-tail artifacts arising from the pleural line, hyperechoic and long (spreading up to the edge of the screen).

B-lines arise due to reverberation on interface between visceral pleura and air in superficial alveoles of lung.

Therefore these linear artifacts also moves (to-and-fro) together with a lung movements at inspiration and expiration, reminding a laser beam.

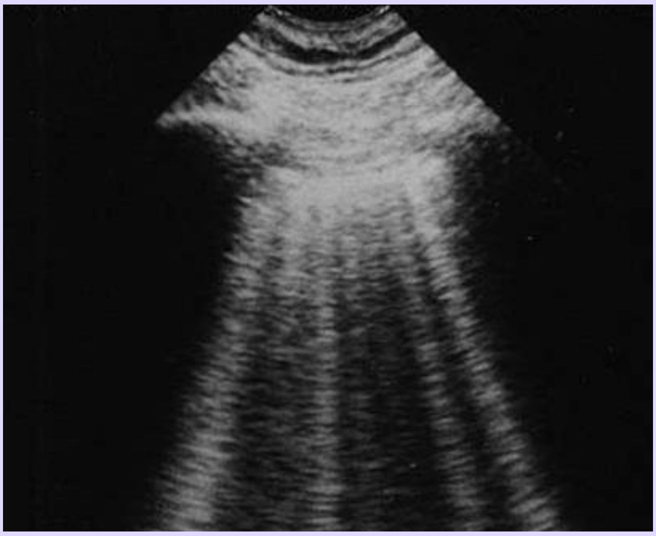
At a normal lung comet-tail artifacts can be single or multiple, but less than 7 in one intercostal space. Because significant amount of B - lines (7 and more) at a thorax trauma is a sign of a lung contusion.



Normal lung.

Single vertical «comet tail» artifact (B line).

In real time moves «to-and-fro», synchronously with «lung sliding», reminding a laser beam.



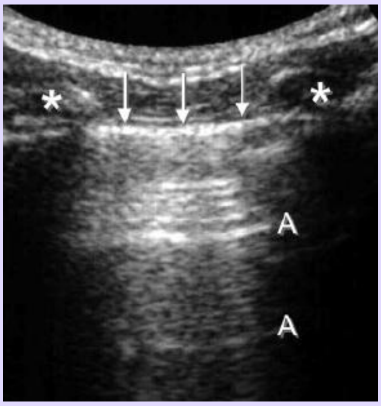
Lung contusion at a trauma.

In this example the lung contusion is represented by alveolar-interstitial syndrome (AIS) and sonogram shows multiple (7) B lines originating from a pleural line.

Short distances between vertical linear artifacts indicates their large quantity.

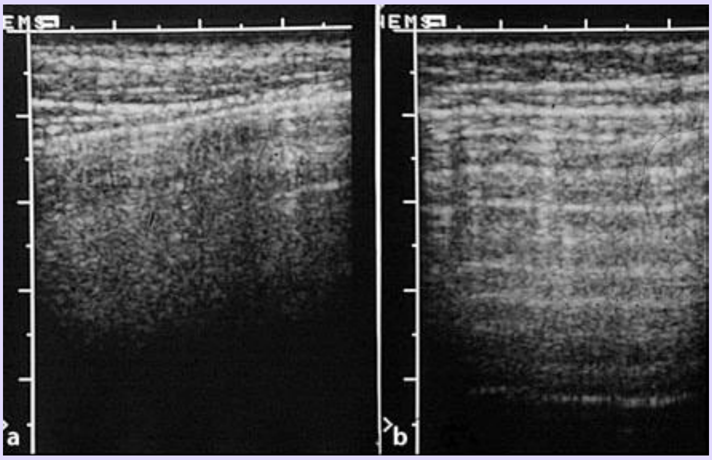
The diagnosis of pneumothorax relies on the “absence” of both the normal lung slide as well as the normal of comet-tail artifacts. The one study demonstrates that combining the absence of normal lung sliding and comet-tail artifacts has a sensitivity of 100% and a specificity of 96%. Therefore the sonographic diagnosis of the pneumothorax is based on the basic signs: absence of "lung sliding» and absence of vertical artifacts (B lines). And in the presence of these signs pneumothorax is almost completely excluded.

Also at pneumothorax present the rough, multiple horizontal artifacts originating from the pleural line (A - line). These horizontal repetitive artifacts are called A - lines.
Normally, one or more horizontal artifacts also can be visualized, but they are usually subtle and distance between repetitive A-lines strictly equal to distance from a skin to the pleural line because they are reverberation artifacts from ultrasound reflection between these two surfaces. Sometimes, normal A-lines can be rough, multiple similar to pneumothorax pattern, but presence of the lung sliding helps to exclude pneumothorax in such situations. So, A lines itself can be less helpful.



Imaging of the normal lung. The arrows show the pleural line.

Normal horizontal artifacts (A) are shown (A-lines). Ribs (asterisks).



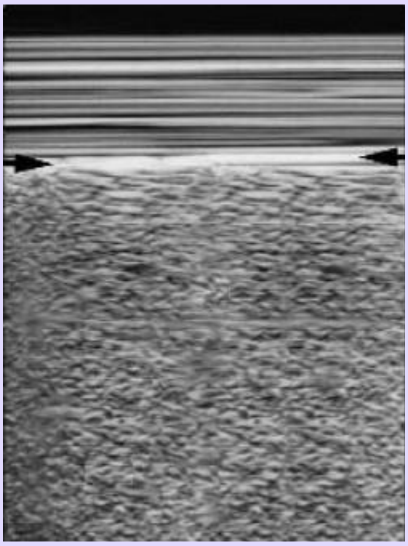
A (normal lung B-mode) – presence of lung sliding (in real time) with few subtle horizontal artifacts which are parallel to A - line. Their depth is a multiplicative of the distance between the skin surface and the pleural line.

B (pneumothorax b-mode) – absence of lung sliding (in real time) with multiples, rough horizontal artifacts which are parallel to A - line.

In doubtful cases comparison with opposite hemithorax can help to diagnose pneumothorax (if bilateral pneumothorax is not present).

Usually B-mode examination is enough for confirmation or rule out pneumothorax, but lung sliding sometimes can be subtle, therefore in doubtful cases should be performed M-mode.

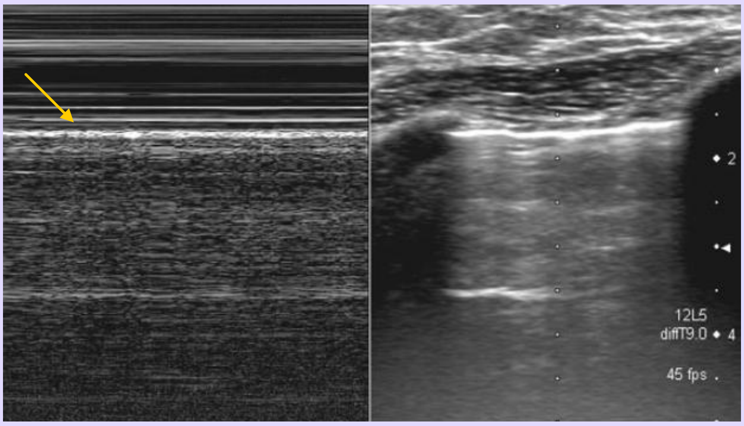
In the M-mode presence of sliding characterized by a “seashore sign”, which included motionless parietal tissue over the pleural line and a homogenous granular pattern below it.



Normal lung (M – mode)

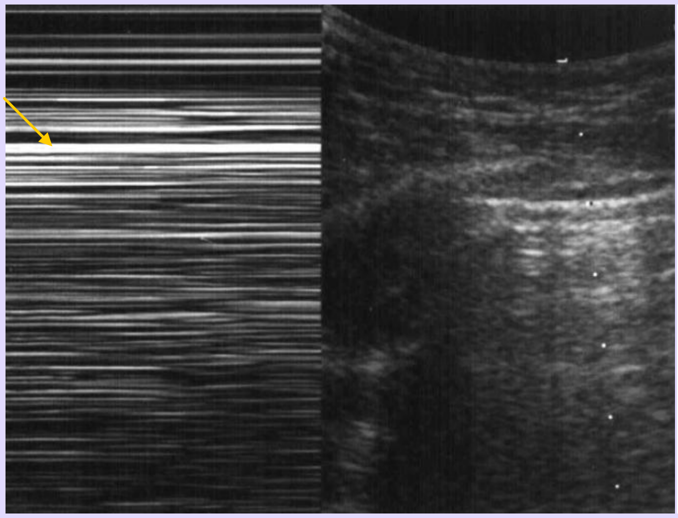
Parallel lines above the pleural line (arrows) representing the motionless parietal tissue of the chest wall (reminds the sea with silent waves).
Below the pleural line a homogenous granular pattern representing the constant motion of the underlying lung and giving the appearance of a sandy beach.
This pattern known as the «Seashore Sign».

This phenomenon, known as the “Seashore Sign” indicates normal lung sliding and excludes pneumothorax.

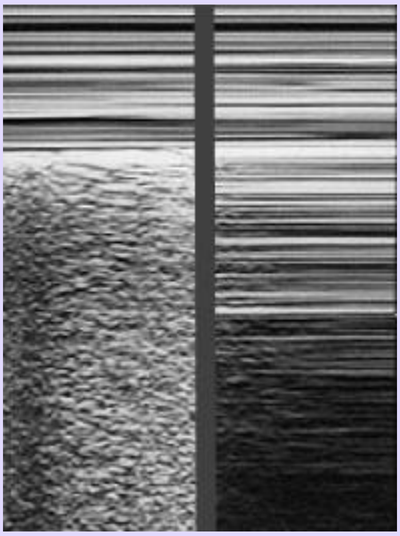


Normal US lung imaging in M-mode (left) and B-mode (right).
M-mode image demonstrates linear, laminar pattern in the tissue superficial to the pleural line (arrow) and a granular or “sandy” appearance deep to the pleural line (“Seashore Sign”).
Normally, few subtle horizontal artifacts which are parallel to pleural line also visualized.

In the case of a pneumothorax, normal sliding is absent and M-mode reveals a series of parallel horizontal lines, suggesting complete lack of movement both over and under the pleural line. This is known as the “Barcode sign”.



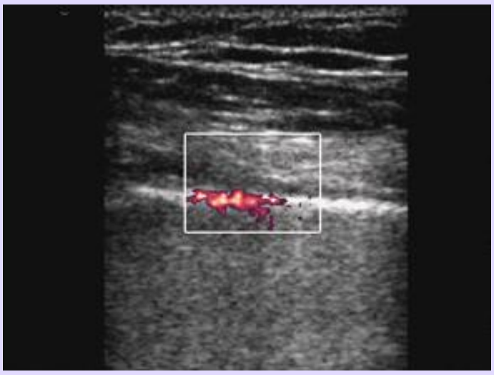
M-mode image demonstrates linear, laminar pattern in the tissue superficial to the pleural line (arrow) and a similar linear pattern deep to the pleural line.
This phenomenon, known as the «Barcode sign» indicates absent lung sliding and means the presence of pneumothorax.



Comparison of the M -mode images of the normal lung sliding with a phenomenon of «Seashore Sign» and pneumothorax with a phenomenon «Barcode sign».

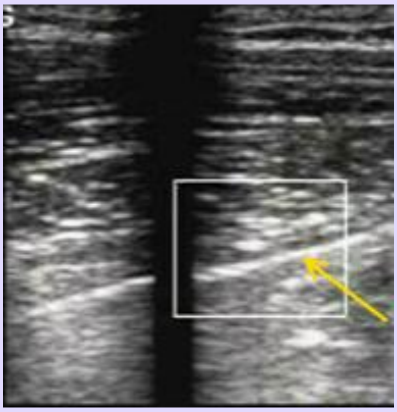
Also a Power Doppler can be used for enhancement of recognition of lung sliding.
Presence or absence of Power Doppler signals can exclude or confirm pneumothorax, because Power Doppler is very sensitive to movement.

Presence of Power Doppler signals at the pleural interface reflects respiratory movements of a lung along a pleural surface and can enhance the recognition of lung sliding. Color enhancement of the pleural line sliding with respiration is known as the «power slide».
At examination the probe should be motionless for excluding the artifacts caused by movements of the probe, which should not be mistaken for «power slide» signals.



Power Doppler of normal lung sliding.
Color Power Doppler image illustrating the presence of movement at the pleural line (power slide) – thus confirming lung sliding and excludes pneumothorax.

The color gain is low so that only movement along the pleural interface is demonstrated. Avoid setting the gain too high, as general patient respiratory motion will be detected.



Pneumothorax.
No power Doppler signals at the pleural interface (absence “power slide”) confirms pneumothorax.

The gain adjusted correctly by comparison to the normal left hemithorax

But all described above signs are indicated only on presence of pneumothorax but not about its size. Also these signs of pneumothorax do not have 100 % specificity because absence of "lung sliding» which is specific for pneumothorax, can occur at other conditions such as main stem intubation (usually the right main stem) with absence of the «lung sliding» on the opposite side, pleural adherences, bullous emphysema and advanced chronic obstructive pulmonary disease, bronchial asthma, respiratory distress syndrome, so lung sliding can be abolished in the absence of pneumothorax. Though, in a trauma context pneumothorax is most probable if the patient had no previous lung disease.

Therefore numerous researches was performed for detection of the most specific sign of pneumothorax and determination of its size by ultrasonography.

It was revealed that such sign is “Lung Point”. “Lung Point” is highly specific sign of pneumothorax (specificity 100 %).

This sign is used for confirmation of the pneumothorax and also for determination of the its size (small, moderate, massive). Information about size of the pneumothorax is important for clinical decision in the management of the pneumothorax (the drainage is necessary or not).

CT - is gold standard for detection of the pneumothorax and its size.
Earlier was considered that ultrasonography is a high-sensitive method for detection of the pneumothorax, but is unable to determine its volume. But the subsequent studies have overturned this viewpoint and recent studies shows, that localization "lung points" where lung sliding and absent lung sliding appear alternately, allows to determination of the size of pneumothorax with the accuracy similar to accuracy at CT.

For determination of the size of pneumothorax examination should be extended to lateral regions of the chest wall for detection of the point where the normal lung pattern (lung sliding with vertical B-lines) replaces the pneumothorax pattern (absent lung sliding and horizontal A-lines). This point is called the "Lung Point" and is border of pneumothorax.

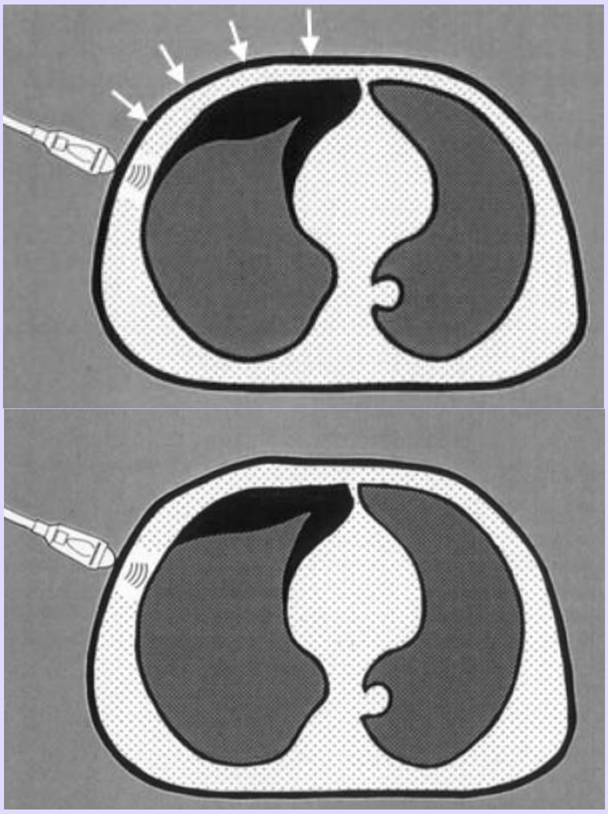
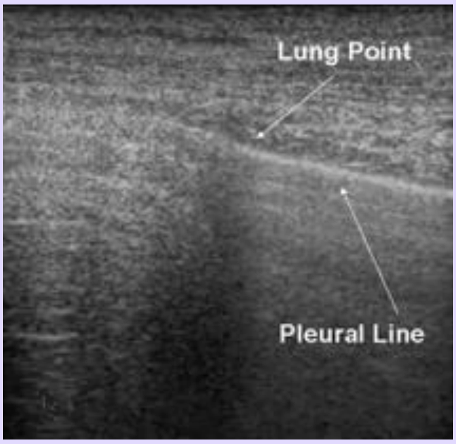


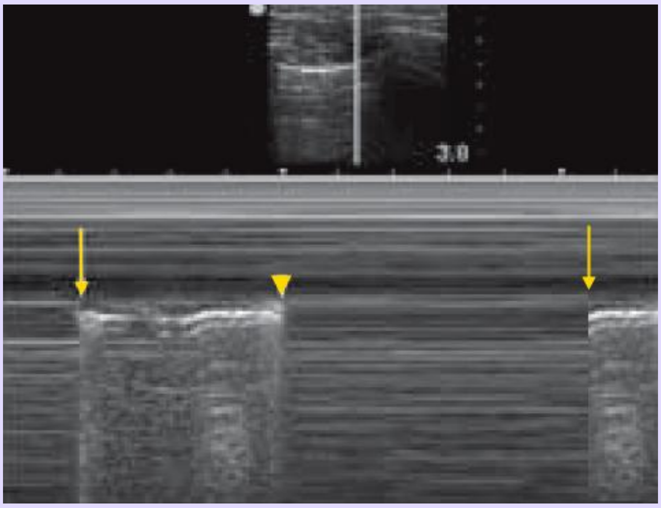
Diagram explaining the origin of the "Lung Point".

At partial pneumothorax with an incomplete lung collapse, in this place, parietal and visceral pleura are separated by air with pneumothorax pattern (absent lung sliding) while in other part pleural layers are not separated by air with normal sliding pattern .
The lung point is found at the site where partially collapsed lung is apposed to the inside of the chest wall. With careful technique, the examiner searches for the site at which the two pleural surfaces touch.
For detection of lung point the probe is moved from anterior to lateral regions of the chest wall. At the border of pneumothorax pleural layers start to contact during inspiration (lung itself is located in front of the probe, which remained motionless at the site of examination) with normal lung sliding. And during expiration pleural layers are separated again.



"Lung point" is visualized only in real time there B-mode signs of pneumothorax start to disappear during inspiration with fleeting appearance of pleural sliding at the examination of lateral regions of the chest wall (alternating pattern of pneumothorax with normal lung sliding in this boundary region).

"Lung Point" usually is well visualized in B-mode, but this sign can be confirmed or facilitate its detection, using the M-mode. Applying the M-mode, the probe must be placed motionlessly at the site of examination. On the M-image in this site will be detected alternating pattern of "Seashore sign" during inspiration with "Barcode sign" during expiration.



Alternating pattern of "Seashore sign" with "Barcode sign".
M - mode image demonstrates an alternating pattern of pneumothorax "Barcode sign" with normal lung sliding "Seashore sign". This occurs at the boundary of the pneumothorax where lung sliding is appears during inspiration and disappears during expiration.

This phenomenon, known as "Lung point", confirms the presence of pneumotorax with determination its border.

Look for pneumothorax and its size should be performed with "two-look approach".
The "first look" consists of anterior chest wall examination in standard points (longitudinal scanning of the anterior chest wall in 3 - 4 intercostal spaces on mid-clavicular line).

If pneumothorax pattern is detected, a "second-look" should be performed. The probe should be moved laterally along the chest wall and systematically assessed with transverse scans along the intercostal spaces from midclavicular (or parasternal) line to mid-axillary line to evaluate its size and location.

This technique attempts to identify the lateral extent of the pneumothorax by localizing the "Lung point" – point of chest wall where pneumathorax pattern (absent lung sliding) alternating with the normal lung pattern (normal lung sliding).

The search for the lung points (lateral limit of the retroparietal air collection) is followed through three intercostal spaces (second or third, fourth or fifth, and sixth or seventh, respectively defined as high, medium, and low sectors).

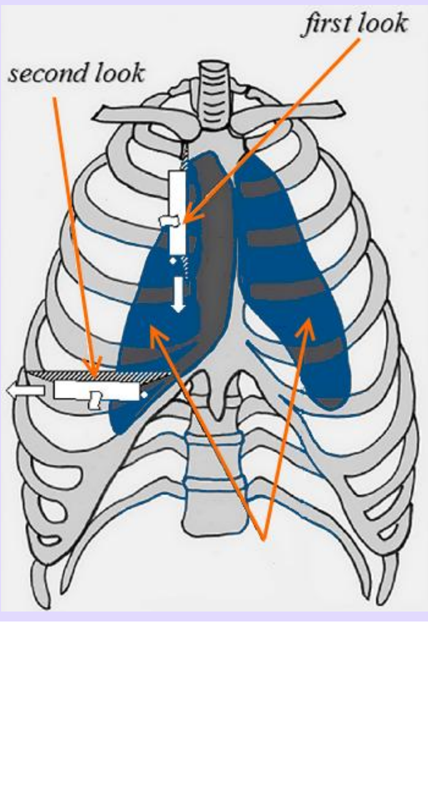
“Lung point” detection (size of pneumothorax).

Intercostal spaces should be systematically assessed from anterior to lateral parts of chest wall on the side of pneumothorax or bilaterally, if bilateral pneumothorax is present.

Appearance of lung sliding at inspiration indicates contact of visceral and parietal pleura in this place. So, the “Lung point” marks the periphery of the pleural air collection in this point.

When the patient is upright, the air collects in the apicolateral location. In fact, when the patient is in the supine position, air in the pleural space collects anteriorly and inferiorly within the anteromedial and costophrenic regions of the pleural spaces.
For physical reasons, the detection of the absence of sliding sign in the supine patient with PNX is more successful anteriorly in the parasternal line and near the diaphragm (“deep sulcus sign” area).
The finding of an immobile pleural line in the “deep sulcus sign” area allows the diagnosis of PNX, whereas the systematic research of the lung points permits the evaluation of its extent and consequently the hypothesis of its radiographic visibility.

The sonographic findings of PNX in the “deep sulcus sign” area are defined as the “ultrasonographic deep sulcus sign”. The “deep sulcus area” is the anterior thoracic area corresponding to the projection of the cardiomediastinal borders and anterior costophrenic sulcus, bounded superiorly by the second rib, inferiorly by the diaphragm and laterally by the mammary lines above and the anterior axillary lines below.



Anatomical projection of the “deep sulcus sign” on anterior chest wall.

“deep sulcus area” (blue area).

Anatomical structure – air collecting in antideclive pleural space (PNX, occult)

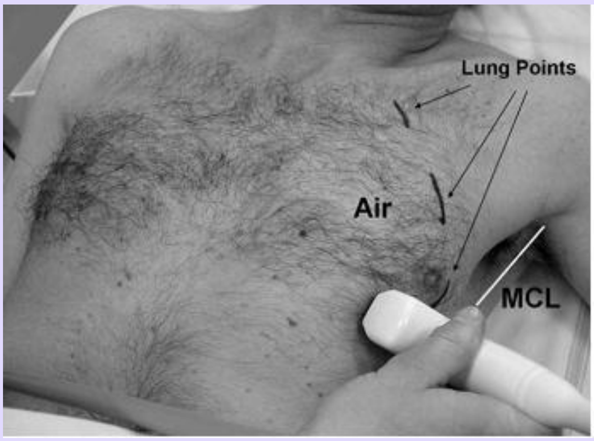
The correct position of probe during the examination is indicated. The first look is conducted by moving the probe in a longitudinal scan starting from the parasternal line (or midclavicular line): this approach provides to detect or rule out PNX. The second look is conducted by directly exploring the intercostal spaces accurately to recognize the lung point: its aim is to evaluate the size and location of PNX and to delimit the deep sulcus area.

In the supine patient with small pneumotorax pleural air is occupied anterior aspects of chest (anterior pneumothorax), while at a large pneumothorax pleural air is extended laterally (anterolateral pneumothorax).

PNXs are classified on CT images, according to Wolfman et al. (1993), as “anterior” (anterior pleural air not extending to the mid-axillary line dividing the thorax into equal anterior and posterior halves) or “anterolateral” (pleural air extending at least to the mid-axillary line).

Studies shows that anterior lung point is correlated with minimal and generally radio-occult pneumothorax. The more lateral the lung point, the more the pneumothorax is substantial. Major pneumothorax yields very posterior or absent lung point (if total collapse of lung is present).

Anterior PNXs do not requires a drainage, while anteriolateral pneumothoraxes requires a drainage.



Anterior PTX.

Pen-mark delimitation of retroparietal air collection.

MCL – mid-coronal line

Anterior PTX on CT scan with delimitation (arrow).

Pleural air does not extend to the MCL - mid-coronal line (red line).

MCL (mid-coronal line) – defined as the line that divides the thorax into equal anterior and posterior halves.

For detection of the size of pneumothorax time is required (about 3 minutes at investigation of one hemithorax), so should be performed only in patients with stable haemodynamic, if time permits.

If time is limited, it is possible to apply a method of rapid confirmation or rule out a large pneumothorax. After detection of pneumothorax on anterior chest wall in standard points on mid-clavicular line, should be investigated intercostal spaces on a mid-axillary line (from 5th to 8th), placing the probe also longitudinally for obtaining transverse scan of the intercostal spaces.

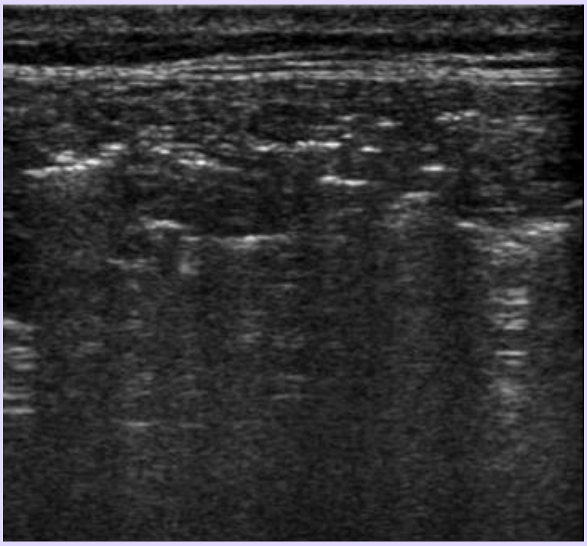
Absence of "lung sliding» and vertical artifacts (B-lines) with presence of multiple horizontal artefacts at this place indicates large pneumothorax.

But in clinically obvious massive pneumothorax decompression by chest tube placement must be performed promptly.

Subcutaneous emphysema

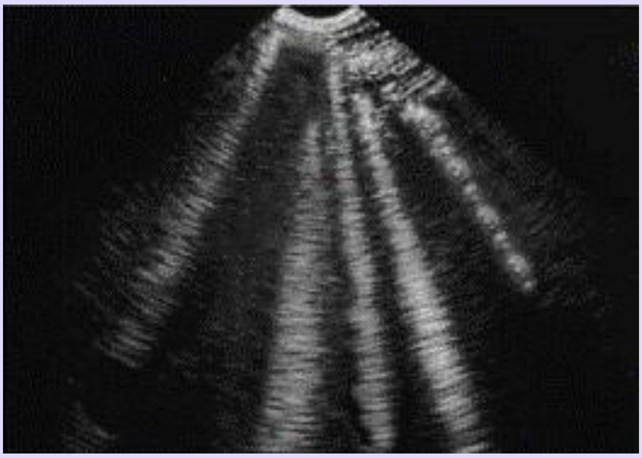
Diffuse subcutaneous emphysema can make visualization of the underlying pleural line impossible, also interfering with ultrasound diagnostic ability. However, the pressure of the probe can drive away air in some cases.
This potential pitfall is relatively unimportant in the unstable patient, as subcutaneous emphysema equates to an underlying post-traumatic pneumothorax.

Artifacts at subcutaneous emphysema (E – lines) are vertical "comet-tail" artifacts - hyperechoic lines, spreading up to the edge of the screen and very similar to B-lines.
But E – lines are originated from layers above a pleural line and distributed chaotic (from various levels in soft tissue).



Subcutaneous emphysema.

Multiple chaotic subcutaneous hyperechoic reflexions representing chaotic distribution of air bubbles in soft tissues.



Subcutaneous emphysema.

E - lines are vertical long hyperechoic lines, spreading up to the edge of the screen and originates from layers above a pleural line and distributed chaotic, not from one line.

Unlike B – lines, which are originated from a pleural line.

Searching for ribs in such situation can help to avoid this pitfall because of the pleural line is located just below ribs. Therefore, if linear artifacts originates above this level (lack the characteristic rib shadowing above) and are distributed chaotically it indicates a subcutaneous emphysema.

Diagnostic signs of pneumothorax

- **Absence of "lung sliding"**
- **Absence of vertical artifacts**
- **Rough repetitive horizontal artifacts**
- **"Lung point"**

Studies demonstrates that US is highly sensitive and has a high negative predictive value for the detection of traumatic pneumothorax and therefore can be an effective diagnostic tool to definitively exclude pneumothoraces in trauma patients.
It is rare that air does not migrate in the paracardiac regions and in the anterior costodiaphragmatic sulcuses, as in the case of pleural adherences from previous disease (posterior pneumothorax, apical septate, anterior septate can be present in such cases).

Look for fluid in pericardium

Cardiac injuries more often occurs at penetrating trauma, than at blunt trauma. Penetrating injuries to the heart have a high mortality, with more than 75% dying before reaching the hospital. In those patients reaching the hospital, stab wounds has a considerably higher survival rate (65%) than gunshot wounds (16%).

Though heart ruptures at blunt cardiac injuries occurs rarely, but mortality from these damages is very high. The majority of these patients die prior to reaching the hospital.
Of those reaching the emergency department, right atrial rupture is the most common finding. One third will have multiple chamber involvement, which is almost always fatal.

The mechanism of death is usually tamponade. Rapid diagnosis followed by early definitive treatment. Therefore rapid detection of the pericardial fluid as indirect confirmation of heart rupture, has huge value in patient survival.

Subxiphoid pericardial window has been considered the gold standard for the diagnosis of these injuries and should be performed as soon as possible after patient arrival. A positive exam would mandate immediate surgical intervention. Interval from positive diagnosis to the operating room have approximately 12 minutes.

Ultrasonography can provide a significant amount of the information about heart, but a main goal of FAST examination is identifying the presence or absence of pericardial fluid.
In a positive exam, one will see anechoic space (collection of fluid) between the heart and the pericardium

If present pericardial fluid it is need to estimate its quantity and presence or absence signs of tamponade. A positive exam would mandate immediate surgical intervention, but tamponade of the heart is most frequent cause of death at traumatic cardiac injuries and emergency punction of a pericardium and blood evacuation is required.

Pericardiocentesis is performed under permanent ultrasound guidance, usually from subcostal access, but it can be performed from parasternal or apical access depending on localization of the maximum quantity of fluid and better access. Evacuation even insignificant volume of blood (even 30 ml) can considerably improve a hemodynamic situation.

The quantity of the pericardial fluid can be estimated by measuring of width of the maximum pericardial layers separation (anechoic space between heart and pericardium) at end-diastole. But in critical situations its quantity is usually defined by visual assessment.

pericardial space separation		
Mild	**Moderate**	**Large**
< 1 cm	1 – 2 cm	> 2 cm
(100 – 250 ml)	(250 – 500 ml)	(> 500 ml)

Size is far less important than whether there are signs of tamponade.
Acute small pericardial effusion can result in tamponade if rapidly accumulated (this is true especially for traumatic or iatrogenic tamponade) while moderate and even large pericardial effusion, which accumulated gradually, can not cause considerable hemodynamic effects.

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Tamponade

The normal pressure within the pericardium is zero or negative. As the amount of fluid in the pericardium increases, the pressure rises. This increase in pressure does not allow complete relaxation of the ventricles during diastole, and filling is reduced. The pressure is at maximum during diastole and the ventricles may collapse. The right ventricle is typically affected, as it is usually at a lower pressure than the left ventricle. Because the right ventricle is impaired, there is a reduced cardiac output from the entire heart, leading to a drop in blood pressure.

Echocardiographic evidence of tamponade

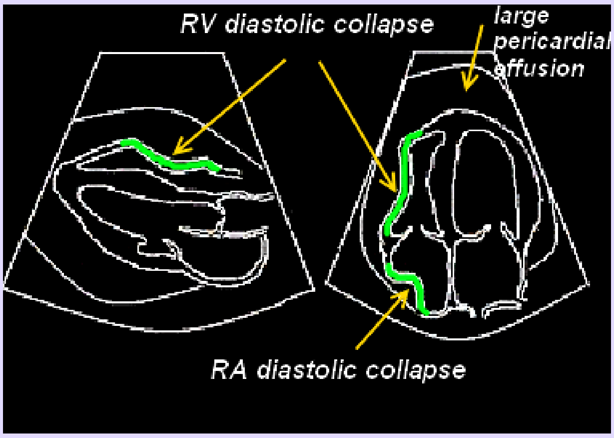
- diastolic RV collapse and/or RA collapse
- Dilated IVC (>2 cm) with inspiratory collapse of <50%
- Increasing of respiratory variations (>25%) of the transtricuspidal and transmitral flows at Doppler study.

Intrapericardial pressure is maximal during diastole and cardiac chambers can collapse. Echocardiographic part of FAST protocol is focused on the searching of any invaginations of the cardiac chambers during diastole, mainly of the right chambers (right ventricle and/or the right atrium). The collapse of the left chambers occurs much less often because of more pressure and thicker wall, than in the right chambers, therefore the right chambers of the heart collapses first.

Right Atrial Collapse.
Due to thin walls and low intracavitary pressures, the right atrium is the first cavity to be compressed with fluid accumulation in the pericardial sac. As such, right atrial collapse (inversion, invagination) is a highly sensitive sign, picking up even minimal elevations in the intrapericardial pressure. However, since it has also been described in patients with small pericardial effusion and no hemodynamic confirmation of tamponade, its specificity for clinical use is low (50 - 68 %), especially as an isolated finding.

Diastolic Right Ventricular Collapse.
Diastolic RV collapse occurs with further elevation of intrapericardial pressures. Thus, it is a more specific sign (84 – 100%), than right atrial collapse, while having a good sensitivity and signaling a more advanced degree of hemodynamic compromise, however is more late sign of tamponade.

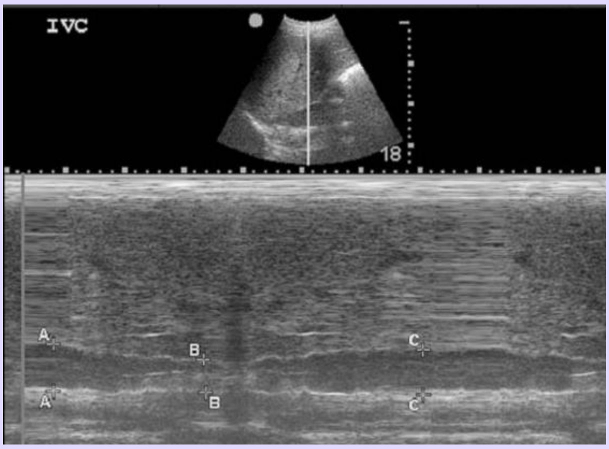
The collapse of the left chambers of the heart occurs much less often (25 %) and is highly specific a sign, but a late sign of tamponade.



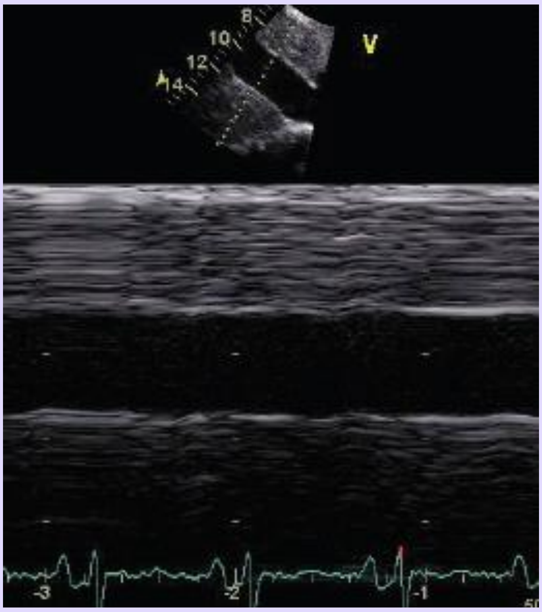
Diastolic collapse of the right chambers of the heart.

The most important echocardiographic indicators of hemodynamic significant pericardial effusion are Diastolic Right Ventricular Collapse (movement of the free wall of the right ventricle inside during diastole) and/or Right Atrial Collapse (movement of a free wall of the right atrium inside during diastole).

Dilated IVC (>2 cm) with inspiratory collapse of <50%.
Inferior vena cava plethora with decreased respiratory variations indicates high right atrial pressure.
Absence or insufficient collapse the IVC at inspiration is a highly sensitive sign of tamponade.
At tamponade the IVC is dilated (> 2 cm), without change in diameter or insignificant reduction of its size at inspiration (with inspiratory collapse less than 50%). Normally, the size of the vena cava decreases at inspiration more than 50 % (well collapsed IVC).



IVC during inspiration and expiration using M mode. Measurement B shows the inspiratory IVC diameter as compared to expiratory diameters A and C.

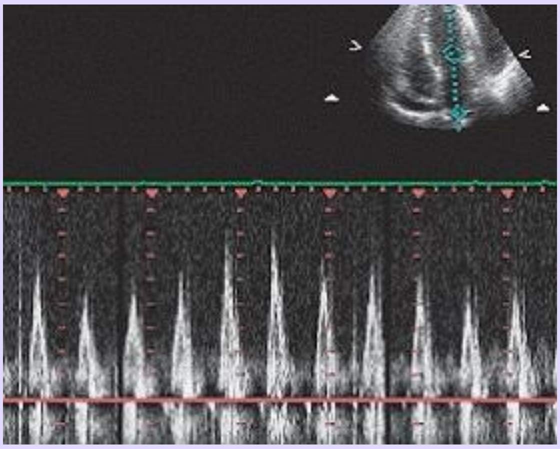


Subcostal view showing a dilated (2.5 cm) inferior vena cava without any change in diameter during respiration, indicative of elevated right atrium pressure.

This “flat” pattern can be visually identified in the two-dimensional image and clearly checked on the M-mode scan.

But the most specific echocardiographic sign of tamponade is abnormally increased respiratory variation in transvalvular blood flow velocities.

Normally, inspiration causes a minimal increase in tricuspid and pulmonary valvular blood flow and a corresponding decrease in mitral and aortic flow velocities.
Thus, in a normal subject, inspiratory variations are less than 20% and are almost invisible. With cardiac tamponade, ventricular interdependence is exaggerated, and respiratory variation is abnormally increased (more than 25 %).



The pulsed wave Doppler study of the transmitral flow shows a marked respiratory variation (which is known as "sonographic pulsus paradoxus") consistent with tamponade physiology .

At inspiration transmitral flow velocity (peak E) is considerably decreased (respiratory variation more than 25 %).

(also transtricuspidal flow velocity will increase at inspiration with respiratory variation more than 25%).

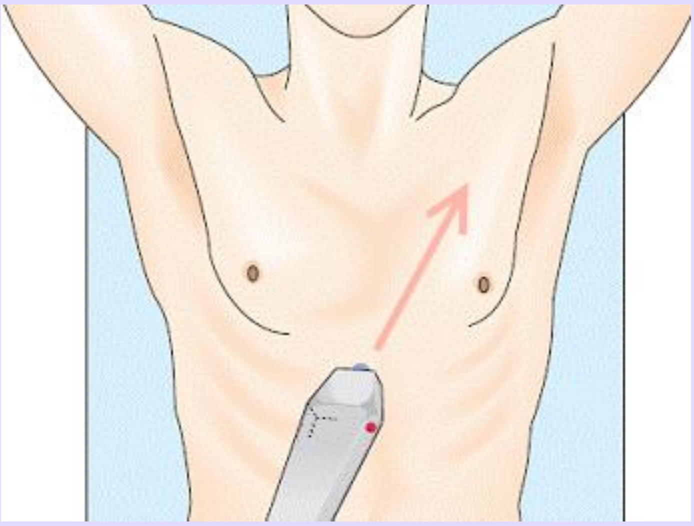
But in critical situations is no time for performing of classic investigation, therefore at the presence of the pericardial fluid during FAST examination need searching for right chambers diastolic collapse only, confirming tamponade.
In general, tamponade is not a subtle finding and should be suspected by the presence of a moderate to large pericardial effusion and hemodynamic instability.

Necessary to remember that tamponade of the heart is the clinical diagnosis. Therefore at the presence of the pericardial fluid with clinical signs of tamponade not always can be present diastolic collapse of the right chambers of the heart due to difficult interaction of the factors influencing on haemodynamic effects at pericardial effusion (pericardial relations of volume-pressure, speed of accumulation of a fluid and the volume status).

Also at the presence of the collapsed right chambers of heart can be no clinical signs of tamponade. In such situations collapsed right chambers of the heart is the indicator of haemodynamically significant pericardial effusion and it considered as threatened tamponade.

Technique of searching pericardial fluid

The subxiphoid pericardial view (Subcostal View). Looks for blood in the pericardial sac and tamponade.



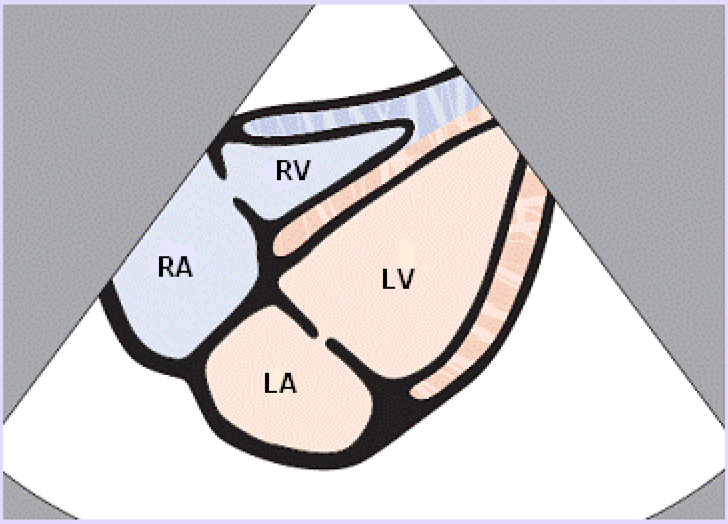
Subcostal View

The patient is supine.

The transducer is placed just below the xiphoid process and directed toward the left shoulder in a horizontal plane.

Pivot, sweep, and tilt the transducer to view all four cardiac chambers.

Identify the heart, four cardiac chambers, and surrounding pericardium.



Subcostal View

Visualized all 4 chambers of heart.
RV - Right ventricle
RA - Right atrium
LV - Left ventricle
LA - Left atrium

The right chambers are closest to the transducer and so appear more anteriorly within the imaging sector.

Scan pearls and pitfalls

- Start imaging with the depth/scale setting at its maximum (e.g., 20 to 24 cm). This should allow you to image the anterior and posterior pericardium in your initial view. Gradually decrease the depth/scale (e.g., 14 to 18 cm) to fill the entire sector image with the heart as you continue to optimize your image.

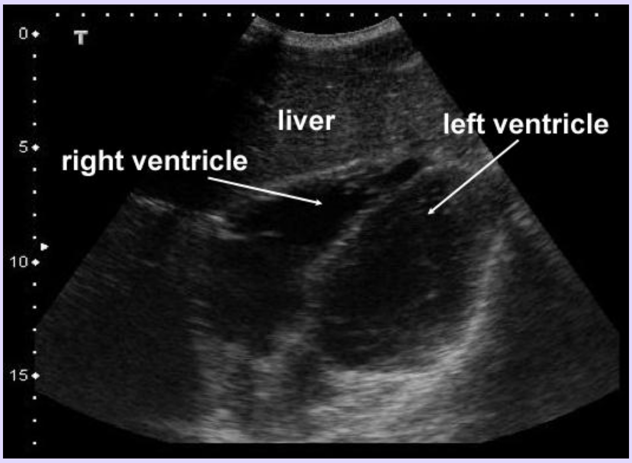
- The image must be closely scrutinized to ensure that the heart border and pericardium are clearly identified

- A frequent mistake in imaging is to direct the transducer toward the spine rather than coronally to the shoulder. You will often require less than a 30 degree angle between the transducer and the skin.

- When your view is obscured by gas, slide the transducer slightly to the patient's right subcostal region, using the liver as an echogenic window.

- If you are unable to view the heart in the subcostal window, move to a parasternal long axis view.

- Clotted blood in the pericardium may not be as obvious as unclotted blood as the contrast between ventricle and blood is reduced. This could lead to a false negative result.



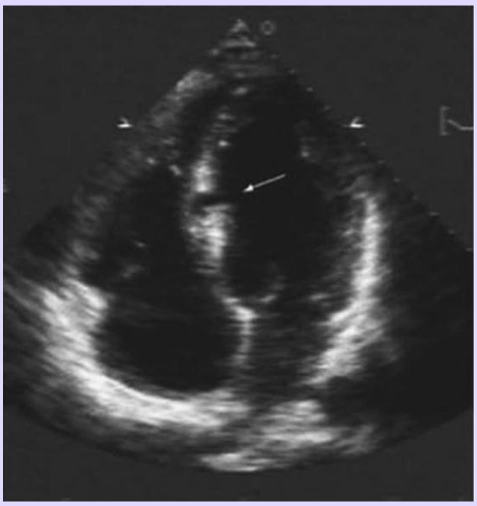
Subcostal four-chamber view.

The liver is used as ultrasound window through which to view the heart.

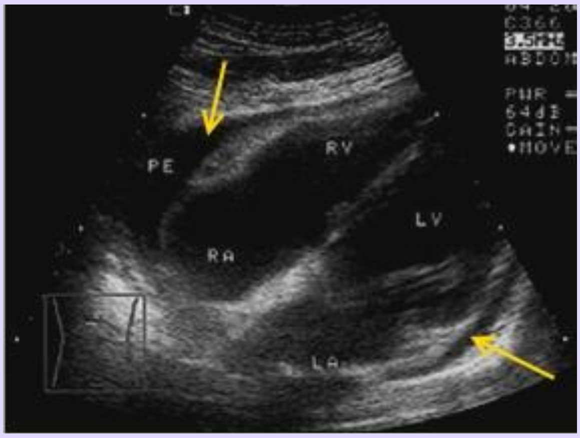
Image of normal heart without pericardial fluid (no anechoic space surrounding heart).

A pericardial effusion is visualized as anechoic or dark stripe between the (moving) walls of the heart and the bright pericardium due to separation of the pericardial layers by streaming blood at heart ruptures.

Also at ultrasound investigation sometimes can be identified site of the ruptured myocardium.



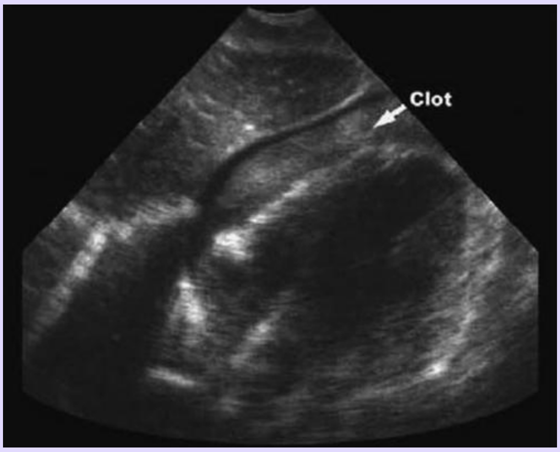
Transthoracic apical four-chamber view demonstrating incomplete transverse tear (arrow) of the interventricular septum. This image was obtained from a 50-year-old man involved in a motor vehicle crash into a tree.



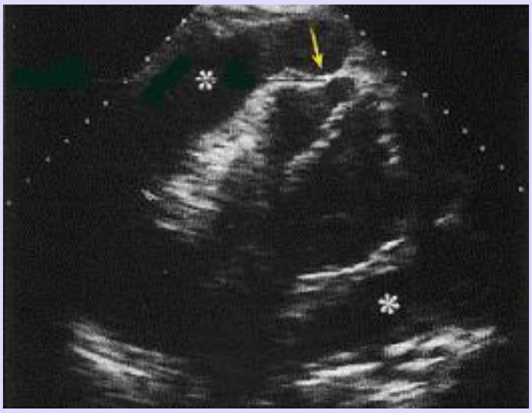
Hemopericardium.

Mild pericardial fluid is identified as an anechoic stripe surrounding the heart within the parietal and visceral layers of the bright hyperechoic pericardial sac.

Haemopericardium (the pericardial fluid in a trauma context) will looks anechoic or dark, but occasionally internal echoes representing fibrin, clot, or cardiac tissue may be present in pericardial fluid.



Subcostal four-chamber view. Clot in the pericardial space.

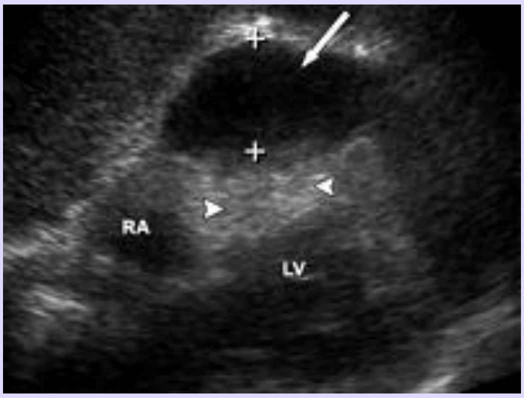


Subcostal view. Tamponade.

A significant amount of the pericardial fluid (asterisks) with a collapse of the free wall of right ventricle.

Invagination of the right ventricular wall inside during diastole (arrow).

The fluid collection in a pericardium can sometimes be localized. The localized compression of heart can cause dramatic hemodynamic effects.



Subcostal view.

The large localized pericardial fluid collection (arrow) with almost complete compression of the right ventricle (triangles).

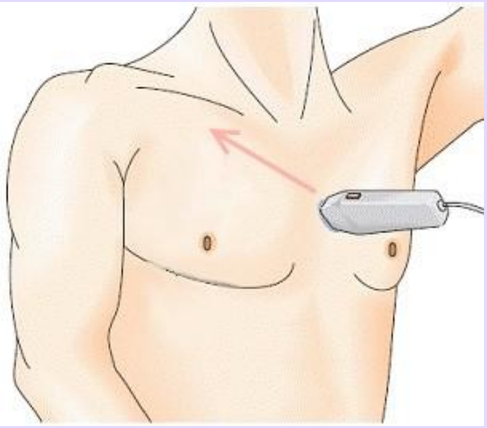
LV - left ventricle.
RA - right atrium.

If technically impossible to obtain adequate subcostal scan quickly due to narrow subcostal space, obesity, gas or pain and also in pregnant women, the transducer must be moved to parasternal view immediately, without wasting time.

Parasternal view.

Some specialists use parasternal view, as initial window, because this access quickly allows to estimate a pericardial space, as well as subcostal access or even better.

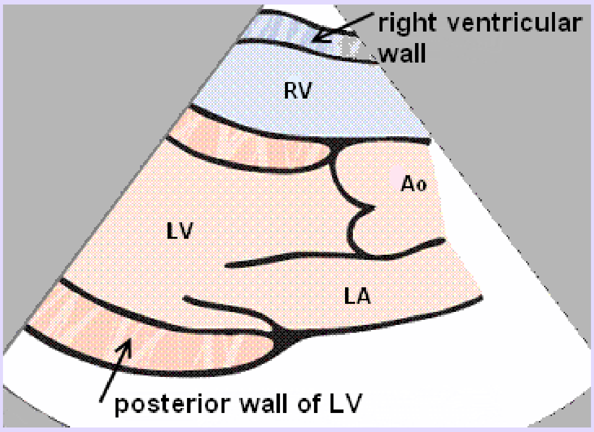
But left-sided pneumothorax or large hemothorax can cause difficulties in heart visualization from parasternal view or apical view, therefore in such cases subcostal view will be ideal.



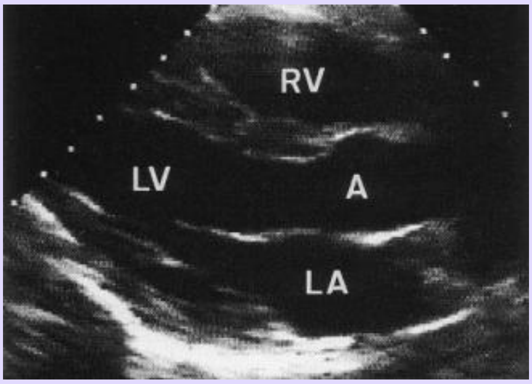
Parasternal Long-Axis View (PLAX)
(a sagittal image through the heart)

The transducer is placed in the fourth or fifth left parasternal intercostal space (just left of the sternum) with the transducer indicator directed at the right clavicle or shoulder.

If a given view is difficult to obtain, try sliding the probe cephalad or caudad one interspace or toward the sternum or midclavicular line.

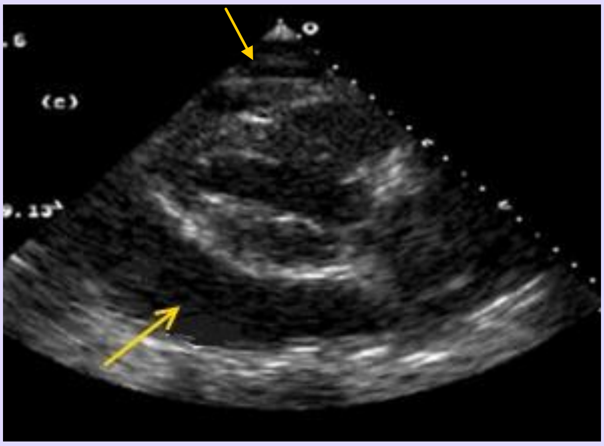


Parasternal Long-Axis View.
In this position should be visualized:
LV – left ventricle
RV – right ventricle
Ao – aorta
LA – left atrium
Aortic and mitral valves
The right ventricle is displayed at the top and the left cardiac structures below.
The FAST examination is focused only on detection pericardial fluid (anechoic space surrounding ventricular walls).



Parasternal Long-Axis View.

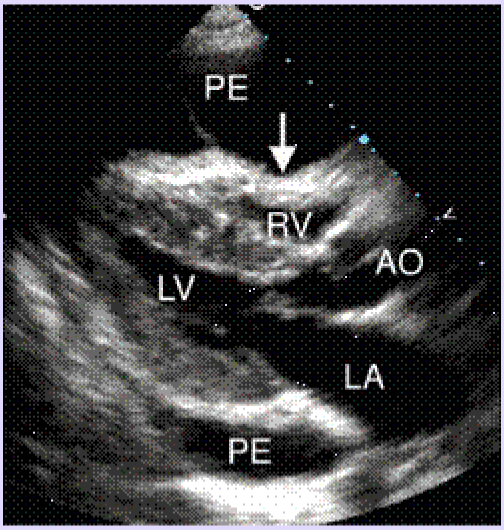
The image of normal heart, absence of the pericardial fluid behind the ventricular walls.



Parasternal Long-Axis View.

A significant amount of pericardial fluid surrounding heart.

Excessive cardiac motion up to the “swinging heart” is frequently seen in severe pericardial effusion.



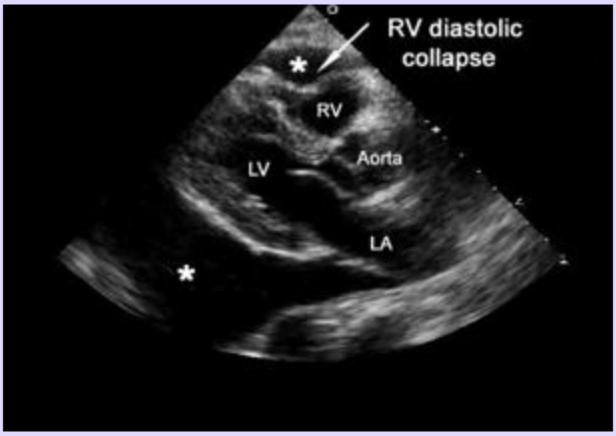
Parasternal Long-Axis View.

Tamponade (significant amount of pericardial fluid with RV diastolic collapse).

PE - pericardial fluid, surrounding heart.

RV diastolic collapse (arrow)

The fluid is more surrounding a RV wall than a LV wall.



Parasternal Long-Axis View.

Tamponade (a significant amount of pericardial fluid with RV diastolic collapse).

Pericardial fluid surrounding heart (asterisks)
RV diastolic collapse (arrow)

The fluid is more surrounding a LV wall than a RV wall.

Pitfalls

A pericardial fat can be hypoechoic or contain grey level echoes, but usually have anecoic appearance similar to a pericardial fluid and should not be mistaken for pericardial fluid. However, the pericardial fat is almost always located anterior to the right ventricle and is not present posterior to the left ventricle.

The Parasternal Long-Axis View is ideal to distinguish a pericardial fluid from anterior pericardial fat.

In the beginning fluid is accumulated behind a posterior wall of the left ventricle (due to gravitation). If amount of the fluid reaches about 100 ml it starts to surround heart, filling all pericardial space.

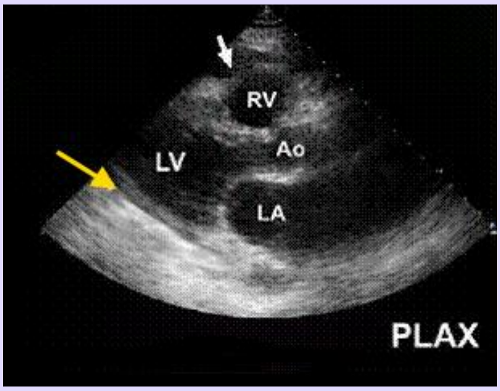
So isolated anechogenic space anterior to the right ventricle is pericardial fat and should not be confused with pericardial fluid.

In Parasternal Long-Axis View is well visualized pericardial fluid behind a posterior wall of the left ventricle, even insignificant amount.

Therefore, if at Parasternal Long-Axis View visualized anechoic space anterior to the right ventricle without of the anechoic space (fluid) behind a posterior wall of the left ventricle it represents pericardial fat.

If the anechoic space is visualized behind a posterior wall of the left ventricle it represents pericardial fluid.

At M-mode using through the left ventricle also well visualized anechoic zone behind the left ventricle (a small amount of fluid (<5 mm) may be present within the dependent pericardium, but is usually considered to be physiologic when it is visualized during systole only).

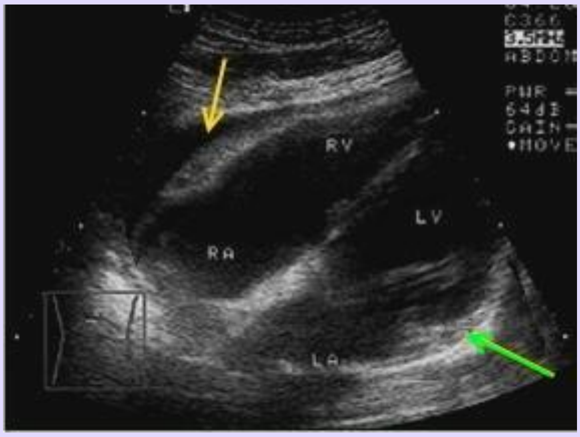


Parasternal Long-Axis View.

The anechoic space anterior to the right ventricle (white arrow) without visualization of the anechoic space behind a posterior wall of the left ventricle (yellow arrow) represents pericardial fat.

Though the localized collection of a fluid only anterior to the right ventricle sometimes can occurs.

The most frequent false-positive result at performing the FAST exam by not skilled sonographers or emergency physicians is detection of the anechoic space anterior to the right ventricle in the Subcostal View.

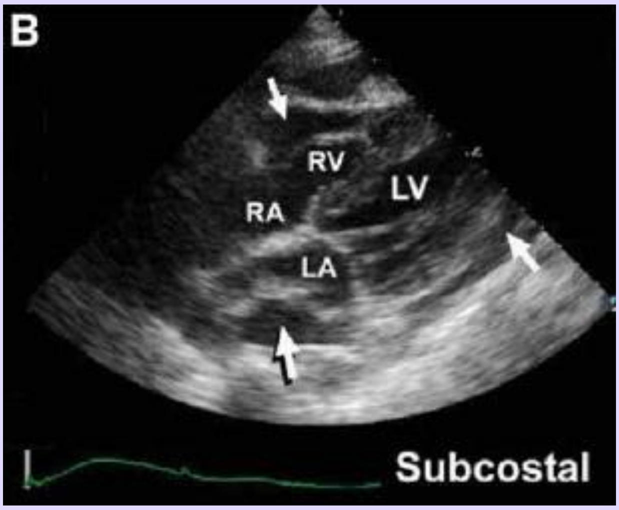


Subcostal View.

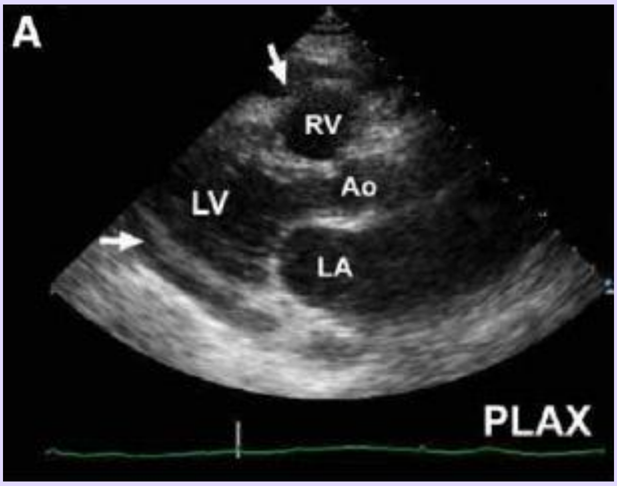
The anehoic space anterior to the right ventricle (yellow arrow) with absence of the anehoic space behind a lateral wall of the left ventricle (green arrow) is a frequent normal appearance representing pericardial fat.

For error excluding (at any doubt) should be applied the alternative window (Parasternal Long-Axis View) in which absence of the fluid behind a posterior wall of the left ventricle excludes pericardial effusion and confirms pericardial fat.

Also Parasternal Long-Axis View is ideal for confirmation of the presence of pericardial effusion, detecting in subcostal positions, especially in doubtful cases.



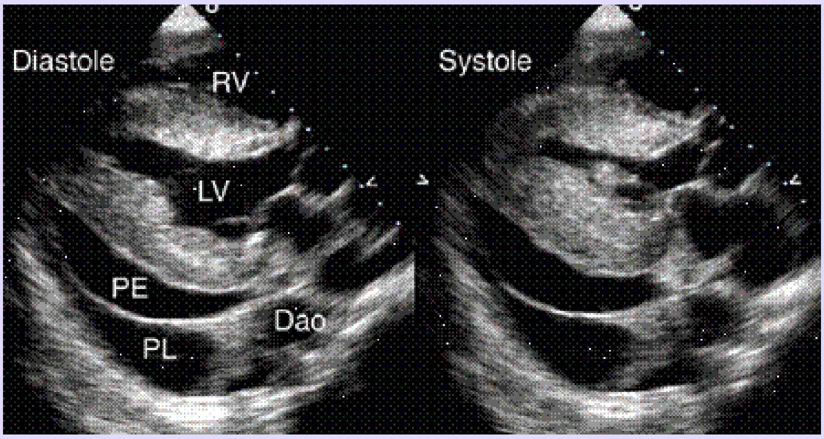
At subcostal window is visualized pericardial fluid surrounding heart (arrows).



The pericardial fluid was confirmed at Parasternal Long-Axis View.

Fluid behind a posterior wall of the left ventricle strongly confirms presence of fluid in pericardium.

Also in Parasternal Long-Axis View the left sided pleural effusion can be visualized.
A left-sided pleural effusion can have a very similar appearance to that of a pericardial effusion. Differentiation is by the location of the fluid relative to the aorta. On the parasternal long axis view a pericardial effusion will finish just anterior to the descending aorta. A pleural effusion will lie posterior to the aorta. If pericardial and pleural effusions exist side by side, the interface of the layers will be visible.

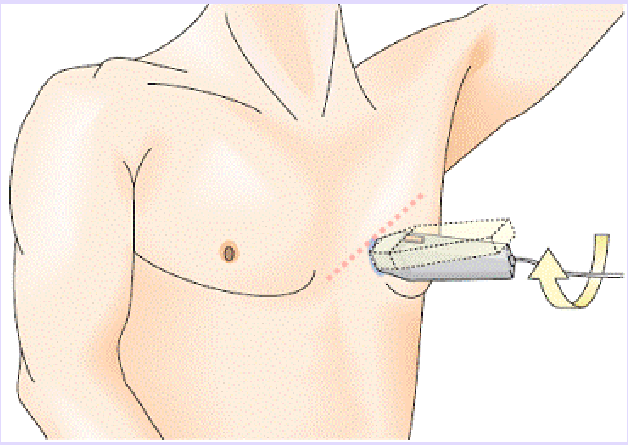
	Parasternal Long-Axis View. Pericardial and pleural effusions exist side by side. The interface of the layers is visualized as hyperechogenic strip. PE - pericardial effusion is finished just anterior to the descending aorta (Dao). PL- pleural effusion (the presence of the fluid posterior to the descending aorta)

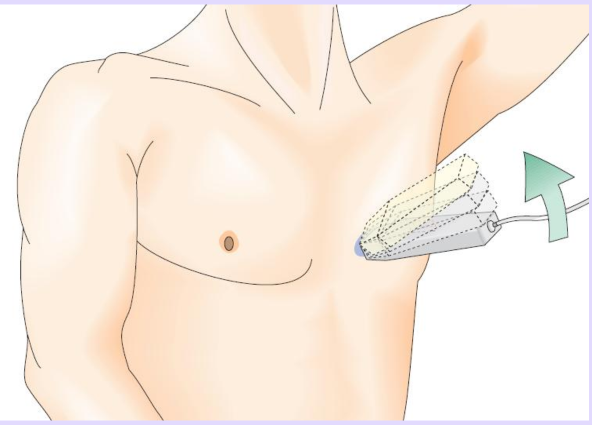
Lung can often be demonstrated within a pleural effusion.
At a significant amount of pericardial fluid heart will seem floating while in the presence of a pleural fluid heart will seem fixed.
Also application of the alternative ultrasound scan can help to differentiate pericardial fluid from the pleural fluid.

Alternative windows

At the FAST protocol usually Subcostal View or Parasternal Long-Axis View is used, but in any cases of doubt alternative windows should be performed such as Parasternal Short-Axis View and Apical View.

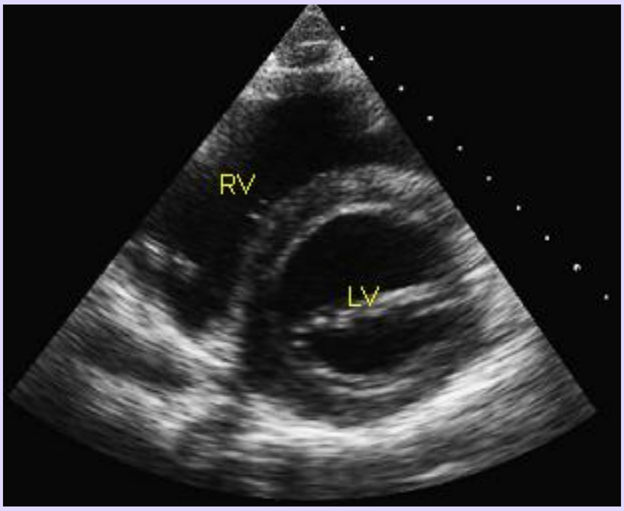
	Parasternal Short-Axis View. The parasternal position of the short axis of the heart is perpendicular to parasternal positions of the longitudinal axis of the heart.

	Parasternal Short-Axis View. From the parasternal long-axis position, rotate the transducer 90 degrees clockwise (to the patient's left) or place the transducer in the fourth or fifth left parasternal intercostal space in a line connecting the left clavicle/shoulder and the right hip. A cross-section of the heart will be received at the level of the aortic valve (base of the heart).



Slightly tilting the plane of the ultrasound beam caudally with a beam direction to a heart apex will be received cross-section scans of the heart (from the base of the heart to the apex).

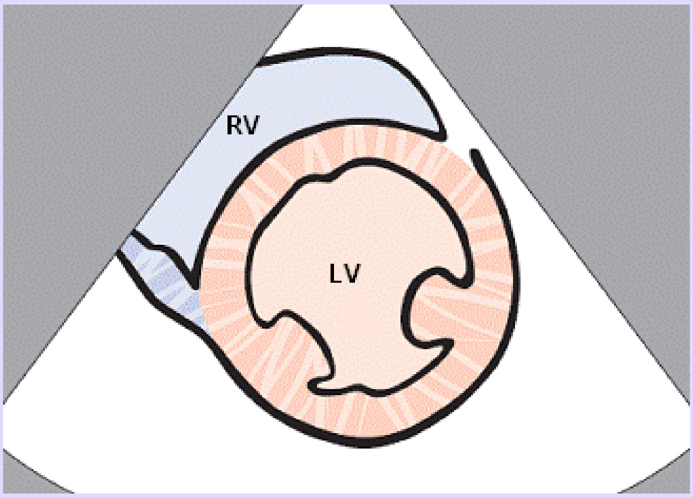
At the FAST examination parasternal short-axis view is usually obtained with the image plane at the level of the mitral valve or papillary muscles.



Parasternal Short-Axis View.
Cross-section scan of the normal heart at the level of the mitral valve. The motion of the mitral valve resembles the mouth of a fish as it opens.

No pericardial fluid surrounding ventricles.

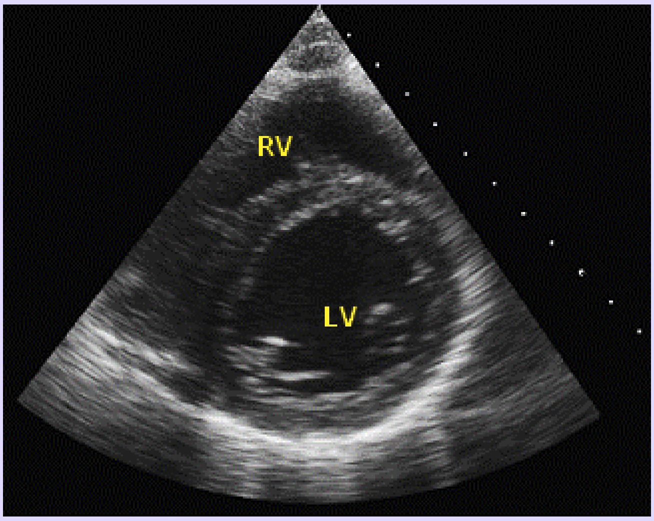
LV – left ventricle (circular)
RV – right ventricle (crescent-shaped)



Parasternal Short-Axis View at the level of the papillary muscles.

Identify the left ventricle (circular), right ventricle (crescent-shaped), and surrounding pericardium.

At the presence of pericardial fluid anechoic space will be surrounded ventricles.
LV – left ventricle
RV – right ventricle

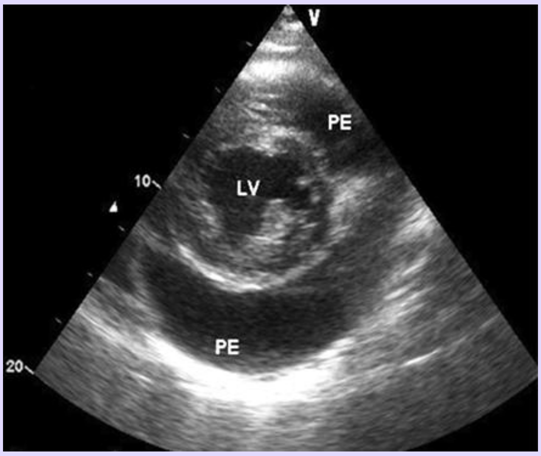


Parasternal Short-Axis View.

Cross-section scan of the normal heart at the level of the papillary muscles.

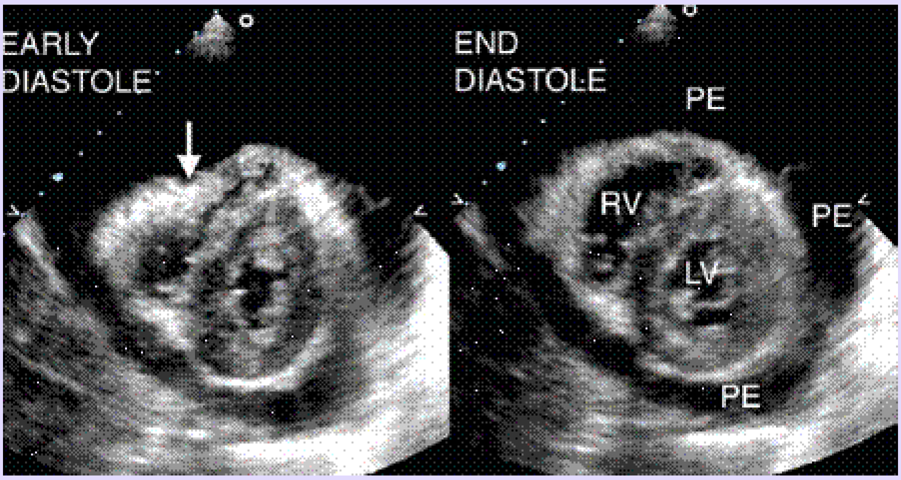
No pericardial fluid surrounding ventricle.

LV – left ventricle (circular)
RV – right ventricle (crescent-shaped), and pericardium



Parasternal Short-Axis View at the level of the papillary muscles.

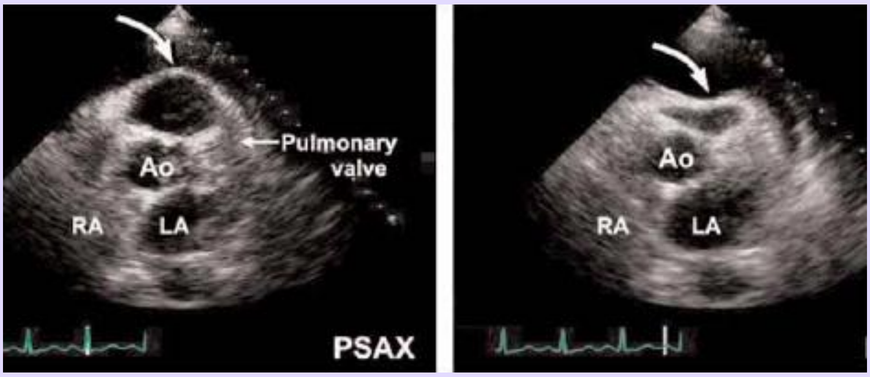
A significant amount of the pericardial fluid (PE) surrounding heart.



Parasternal Short-Axis View.

Tamponade.
A significant amount of the pericardial fluid with diastolic collapse of the free right ventricular wall (arrow), the collapse is observed in early diastole.

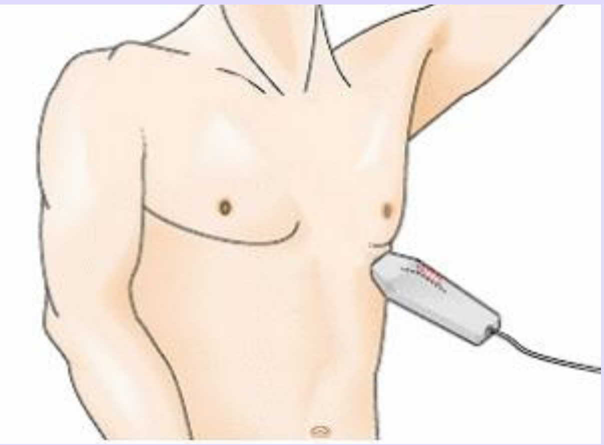
PE – pericardial effusion.



Parasternal Short-Axis View at level of the aortic valve (Ao)

The diastolic compression of the outflow tract of the right ventricle.

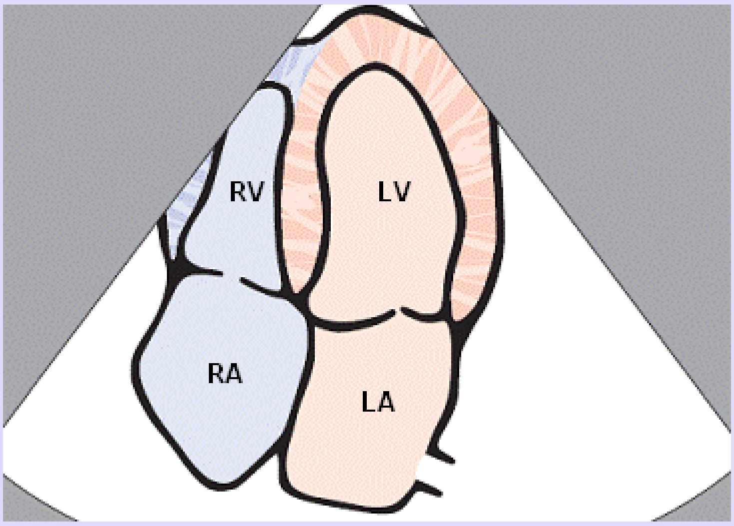
Apical Four-Chamber View (A4C)
Apical View also can be used as alternative window at the FAST examination for detection of pericardial fluid.



Apical Four-Chamber View (A4C)

The transducer is placed over the cardiac apex with the beam directed toward the right clavicle/shoulder in a plane coronal to the heart. The transducer indicator is directed toward the left axilla.

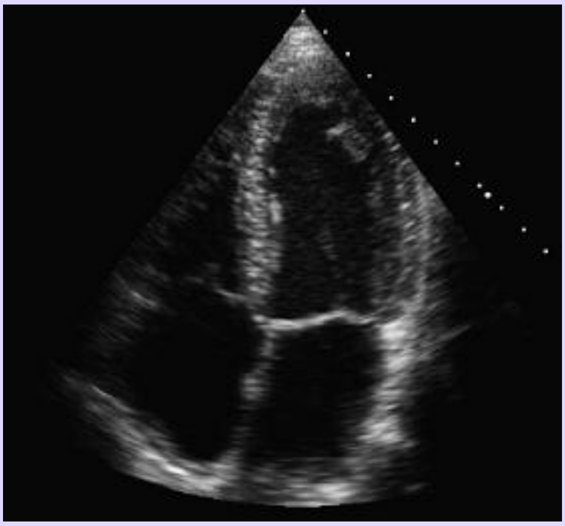
Identify the left ventricle, right ventricle, left atrium, right atrium, and surrounding pericardium.



Apical Four-Chamber View.
Visualized all 4 chambers of the heart.

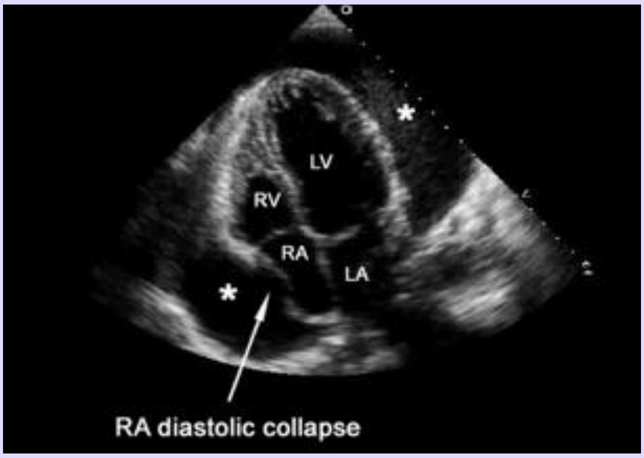
RV - Right ventricle
RA - Right atrium
LV - Left ventricle
LA - Left atrium

The upper half of the image shows both ventricles, beneath them are the right and left atria. The ventricles and atria are separated by the mitral and tricuspid valves.
The septal wall is in the center.



Normal Apical Four-Chamber View.

All 4 chambers of heart without pericardial effusion are visualized.

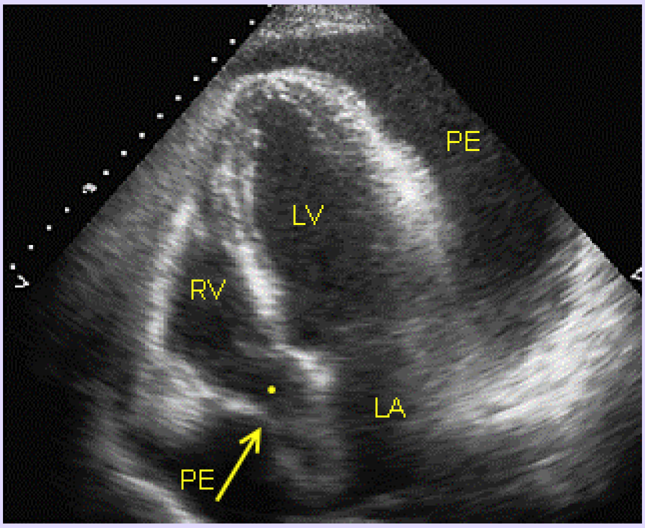


Apical Four-Chamber View.

Tamponade.

A significant amount of pericardial fluids (asterisk) with a collapse (invagination) of a free wall of the right atrium (arrow).

Collapsed the right atrium is reduced in size (RA).



Apical Four-Chamber View.

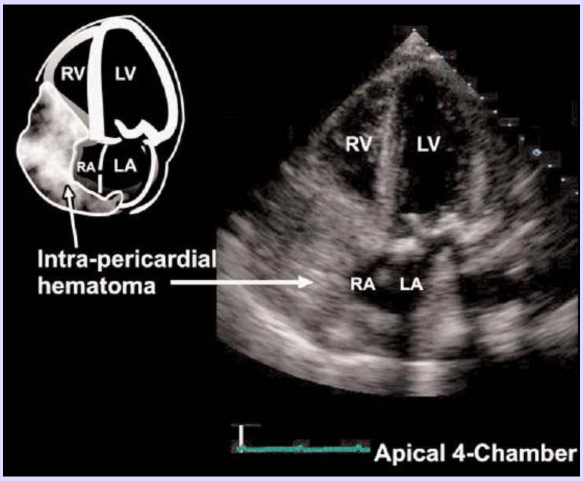
Tamponade.

The marked collapse of the wall of right atrium (arrow).

Collapsed small the right atrium (point).

A significant amount of pericardial effusion (PE).

Except searching of a compression of cardiac chambers, also need looking for echoic structures in pericardial cavity, represented by blood clots.



Apical a four-chamber view.

Large echogenic intrapericardial hematoma in the areas of the right chambers of the heart.

The right chambers of the heart are small due to compression.

Pericardiocentesis

Pericardiocentesis should be echocardiographic guided. Echo scanning allows the examiner to detect the largest collection of pericardial fluid in closest proximity to the transducer, thereby identifying the ideal entry site and so different approach is used to identify the area where the pericardial space is widest and closest to the chest wall and perform the tap at that site. Parasternal and apical approach may be used, which involves a more direct anatomic approach to the heart than the subxiphoid approach. Excellent results are reported with this method, the parasternal and apical windows being by far the most frequently used.

At subcostal approach the needle oriented in the general direction of the left shoulder. Imaging from the subxyphoid area with the transducer draped in a sterile cover will confirm the best direction for the largest pericardial space from this position, while at the same time avoiding a transhepatic tract. The distance from the skin to the pericardium and the orientation of the transducer should be mentally noted and the needle should be inserted as attempting to prolong the central axis of the transducer. A good technique is to position a finger parallel to the transducer and then use it to guide the needle. When a needle tip reached pericardial fluids the second operator aspirated blood by syringe while the first operator strictly supports needle position under constant ultrasound control on the monitor.

Echocardiographic guided pericardiocentesis using subcostal access.

In the given example the needle is completely visualised in the liver parenchyma at a puncture of the pericardial cavity.

Direct transthoracal access using parasternal window.

The probe is placed in parasternal position at site of the greatest fluid collection in pericardial cavity and the most direct access.

The diagnosis of hemopericardium sometimes can be difficult, therefore in any case of doubt the more qualified specialist should be called to the aid. In poor or inconclusive images, transesophageal echocardiography should always be performed in patients with stable hemodynamic and clinical suspicion on cardiac injury.

Cardiac Contusion

Blunt cardiac injury has been defined as the presence of wall motion abnormalities detected by echocardiography, including either, or both, ventricles, following nonpenetrating chest trauma. The left anterior descending coronary artery, tricuspid valve, and right ventricle are the most commonly injured structures due to their proximity to the chest wall.
Patients with significant chest trauma (multiple rib fractures, pulmonary contusions, hemothorax, major intrathoracic vascular injury) have an estimated 13% incidence of significant blunt cardiac injury. Patients with blunt cardiac injury may present with a wide spectrum of signs and symptoms ranging from asymptomatic to severe cardiac compromise. Arrhythmias and conduction defects are the most common complications of blunt cardiac injury. There are many reasons why a patient with blunt chest trauma may be hypotensive, hypoxic, tachycardic, or in heart failure.

Current trauma guidelines recommend an admission ECG for all patients with suspected blunt cardiac injury. Hemodynamically stable patients with a normal ECG require no further workup for blunt cardiac injury, as the risk of serious complications is minimal. If the admission ECG is abnormal, the patient should be admitted for continuous ECG monitoring for 24 to 48 hours. Echocardiography should be used for patients with hemodynamic instability of unclear etiology, an abnormal ECG, or cardiac arrhythmias with documented risk of blunt cardiac injury. Repeat echocardiography in patients with blunt cardiac injury will often show normalization of wall motion abnormalities.

Earlier echocardiographyc investigation was performed only by specialists in echocardiography, but now intensive training of emergency physicians and trauma surgeons allows to perform Emergency Echocardiography as limited echocardiography investigation focusing on the detection urgent pathology of the heart and understanding of the causes of haemodynamic instability of the patient (not only at a trauma, but also at other critical conditions).

Blunt abdominal trauma at pregnancy

About 7% of pregnant patients sustain an accidental injury sometime during pregnancy. The greatest frequency of injuries is in the third trimester.

Motor vehicle accidents are the most common cause of injuries (approximately two-thirds of cases) and 24% of pregnant patients with major injuries do not survive. The most common intraabdominal injuries is placental abruption and splenic injuries, followed by liver and bowel injuries. Uterine rupture occurs in 0.6% of cases and is almost always secondary to major trauma, the rate of fetal death in this situation approaches 100%.

The fetus is well protected against injury from blunt trauma because it is encased in a fluid-filled structure. The major cause of fetal death is maternal death. The fetal death rate approaches 80% in cases of maternal shock. In cases of trauma in pregnancy, the primary consideration is saving the mother's life, without which fetal death is inevitable.

The mother should be kept in the left lateral decubitus position during the third trimester to prevent vena caval obstruction. The pregnant patient must be adequately and rapidly evaluated by US in supine position, performing FAST as rapid screening of the maternal abdomen for free fluid. After initial attention to the mother, US should be used as rapidly as circumstances permit to investigate fetal cardiac activity and placental integrity. US is an excellent imaging modality for assessment of fetal viability and placental separation.

Fetal cardiac activity should be assessed for presence and rate as bradycardia (HR less than 120 beats per minute) is a marker of fetal distress caused by poor perfusion or hypoxia (due to maternal shock, hypoxia, placental abruption or rupture of the uterus). Blood may be shunted away from the fetus before the mother exhibits obvious signs of hypotension. If fetal bradycardia develops (heart rate less than 110 beats per minute), an immediate cesarean section becomes mandatory.

Such injuries as a minor slip or fall can lead to fetal death, usually due to incomplete or complete separation of the placenta. Therefore, monitoring of the fetal HR and assessment of placental integrity is essential in the emergency department regardless of the severity of the injury.

It is axiomatic that one must monitor the pregnant patient and her fetus in the emergency department for at least a few hours even in cases of minor trauma. In cases of major trauma, the patient and fetus should be hospitalized and monitored for at least 24 hours.

CT is frequently the study of choice in major trauma at pregnancy**.** In situations in which the patient's life can be saved, the necessary diagnostic procedures should be performed without hesitation, because radiation exposure has smaller threat in comparison with danger of the missed maternal trauma. In critical cases, CT, especially spiral CT, is often used to rapidly provide the broadest diagnostic potential in the shortest time, especially in cases of head trauma. Angiography for active bleeding and embolization may be needed in life-threatening situations.

Limitations of FAST

US is useful for diagnostic imaging in patients with trauma, but it has some limitations:

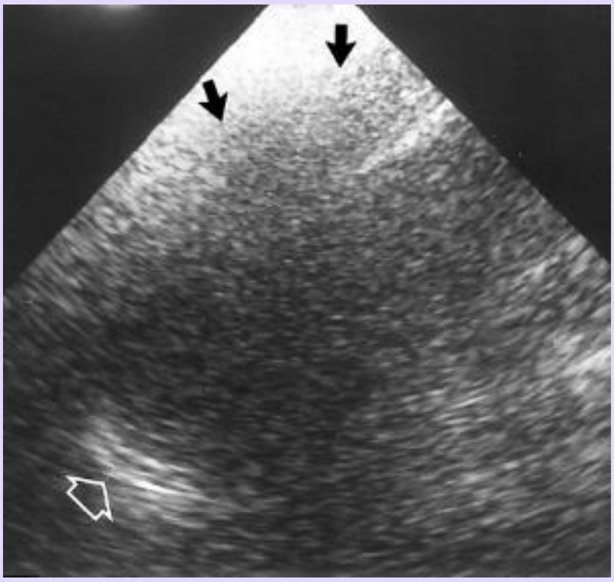
One drawback of US in the setting of major trauma is the limited availability of space and access to the patient in the emergency setting. Unless the patient is fully undressed, the sonographer has difficulty reaching all the regions of interest. Moreover, because the need to perform other diagnostic evaluations (physical examination, blood sampling, or electrocardiography) may be as urgent as the need for imaging, the sonographer often must compete with or maneuver around colleagues from other departments for access to the patient.

Patient movement during the examination is another issue: In some cases, the patient is uncooperative or aggressive with the medical staff. The chest and abdominal wall movements during resuscitation make it difficult to obtain accurate images.

Contamination of the patient with blood, dirt, or other substances is likely to complicate the imaging evaluation. In patients with penetrating trauma, dressing material and foreign bodies may obstruct access to the patient or may obscure part of the anatomy at US.

Patient obesity may make it difficult to obtain satisfactory results at US. In the obese patient, use of a 2-MHZ transducer may be adequate for the exclusion of intraperitoneal fluid.

The presence of subcutaneous emphysema can precludes adequate US examination. Subcutaneous air from a pneumothorax that dissects inferiorly may collect over the liver or spleen and prevent adequate imaging of the affected portion of the abdomen. This may be particularly evident in the left upper quadrant, where the spleen provides only a small acoustic window that can easily be obscured by air.



Subcutaneous emphysema in a 40-year-old man with a left pneumothorax.
On a suboptimal longitudinal US image of the left upper quadrant, the spleen is not visualized. Open arrow indicates the diaphragm, solid arrows indicate the region of the spleen.

If any area is not completely imaged at FAST, the US examination should be considered incomplete and CT or diagnostic peritoneal lavage should be performed.

Old US machines or handheld devices can provide limited resolution. Also, in the trauma suite there is usually bright ambient light, which is necessary for physical examination or resuscitation but which limits the visibility of the US monitor.

US is strongly operator dependent. The more experienced operators, the higher sensitivity of FAST. The definition developed by the FAST consensus conference specifies that 200 or more supervised examinations must be performed to attain a sufficient skill level to perform FAST reliably.

FAST examination is valuable tool for detecting hemoperitoneum but is inadequate for the exclusion of organ injuries. Inclusion of assessment of the organ parenchyma, awareness of the limitations and potential pitfalls of US, and close interaction with the surgical team will reduce the risk of missed injury.

Clinical value of FAST results

Abdominal part of the FAST is focused only on looking for free fluid in abdominal cavity without assessment of parenchymal organs, because sensitivity of method for detecting visceral injuries is low.

The clinical value of a positive FAST is clear. A positive test helps rapid identification of patients who require immediate exploratory laparotomy if they are hemodynamically unstable and who require definitive assessment of the abdomen with CT if they are hemodynamically stable.

The clinical value of a negative US scan is not clear and the treatment of patients with negative findings at screening US is controversial. Injuries may be missed in patients with negative US scans, including clinically important injuries that require intervention, if the diagnosis is based on the presence of intraperitoneal fluid alone. Because negative sonographic findings do not entirely exclude free fluid and may miss organs injuries if hemoperitoneum is not present.

In some centers, negative findings at US are routinely confirmed with repeat US or CT or another test. In other centers, negative findings at US are confirmed in select cases on the basis of clinical suspicion for missed injury.

In order to enhance the sensitivity of sonography for the detection of intraperitoneal injuries, some investigators, mainly from Europe and Asia, have advocated to perform, rather than FAST, a complete abdominal sonography study by a well-trained operator to depict both free fluid and parenchymal injuries. Injuries of solid organs, particularly the liver and spleen, consist of hyperechoic, hypoechoic, or mixed (both hyper- and hypoechoic) lesions. The presence of free intraperitoneal gas suggests the presence of perforation of a hollow organ. Assessment of the IVC and heart can be helpful, because IVC collapse with hyperdynamic heart indicates hypovolemia as marker of blood loss, it is especially helpful in cases if hemoperitoneum is not present.
Also Contrast enhanced ultrasound (CEUS) is able to safely demonstrate organ rupture, even before hemoperitoneum.

US findings must be interpreted in the context of clinical findings. Certain clinical findings mandate additional testing despite negative screening US findings, including persistent pain, decreasing hematocrit levels, abdominal wall ecchymosis, hemodynamic instability. Hematuria and fractures of the lower ribs, lumbar spine, and pelvis may also warrant additional tests.

Studies demonstrates that hematuria and fracture of the lower ribs, lumbar spine, or pelvis are objective predictors of missed abdominal injury in patients with blunt abdominal trauma and negative findings at initial screening with US, and such patients may benefit from additional screening with computed tomography. These objective predictors should be assessed immediately after the patient’s arrival in the resuscitation suite.

The patients with these predictors for missed injury (high-risk patients) should be screened immediately with CT rather than US. Patients who have no predictors for missed abdominal injury (low-risk patients) should be screened with US and need not undergo CT or diagnostic peritoneal lavage, both of which involve a risk of associated complications. Patients with negative US scans should be admitted and observed at least 12–24 hours, because various predictors of missed abdominal injuries may evolve over time.

Studies demonstrates that combination of negative US findings and negative clinical observation virtually excludes abdominal injury in patients who are admitted and observed for at least 12–24 hours, and confirmation with other tests is unnecessary.

But some investigators, mainly from US, have advocated to perform CT as definitive diagnostic test after negative FAST result, or even CT as a primary diagnostic study in stable patients. Because negative US scan by itself is not adequate to exclude occult injury or even significant injuries, also US is operator dependent. Operator experience plays an important role with regard to the diagnostic yield, however, even in experienced hands, sonography appears not sufficiently reliable to rule out organ injuries. CT remains the gold standard for abdominal trauma assessment.

Not only is ultrasound not accurate for evaluating retroperitoneal hemorrhage or bowel injuries, but it also cannot be relied upon to grade the severity of organ injury, detect active bleeding, or isolate injury to a single organ.
Detecting hemoperitoneum or predicting the need for laparotomy are significant diagnostic endpoints for the emergency physician, but it is also important to determine the extent of specific organ injury. Recently this has become even more relevant as many surgeons are managing

splenic and liver injury nonoperatively. In most centers indications for laparotomy are currently based on CT grading of organ injury.

These limitations of ultrasound are in competition with the fact that access, speed, and accuracy of CT scanning has increased significantly in recent years. Therefore, in trauma centers, where timely access to high-speed CT scanners is not limited, there is little sound evidence for ultrasound supplanting CT scan in the diagnostic evaluation of the stable blunt abdominal trauma patient. Trauma management incorporating FACTT (focused assessment with computed tomography in trauma) enhances a rapid response to life-threatening problems and enables a comprehensive assessment of the severity of each relevant injury.

Currently total-body CT (foot to head scan) is the preferential method in trauma centers, associated to its indiscriminate and liberal use. CT-related complications are increased risk of cancer and neprotoxicity and in case of extreme age patients, these frets should be kept in mind.

Unfortunately, unlimited access to abdominal CT scanning is not always available. Trauma centers may be presented with multiple stable patients requiring CT scanning and ultrasound may be used to triage which, and in what order, patients should be scanned. As well, patients can present with blunt abdominal trauma to hospitals where there is limited or no access to a CT scanner.

So, which type of study should be performed: US (including repeated US, clinical observation with selection of patients for CT or other diagnostic tests) or CT as primary study in patients with stable hemodynamic depends on clinical scenarios and institutions predilection.

Additional examinations at FAST

In the acute trauma situation, ultrasound can, in experienced hands, demonstrate more wide applications, expanding ultrasound examination on dependency of clinical scenarios, if time permits. All the components of the Extended FAST requires a significant amount of experience and practice.

Look for pneumoperitoneum

Recently some specialists in FAST protocol includes detection of pneumoperitoneum, as indirect confirmation of hollow viscus rupture. Since sonography has the same sensitivity and specificity in revealing of free gas in abdominal cavity, as well as radiography.

Sonography is able to reveal pneumoperitoneum in volume 5 ml and some investigations shows the better sensitivity of sonography than radiography in detection of intraperitoneal free air.

CT is the gold standard in detection of pneumoperitonium, its localization and volume, but since for the majority of patients sonography is an initial method of investigation, so this method is very valuable for rapid diagnosis of intraabdominal injuries (hollow viscus rupture) in patients with unstable hemodynamic.

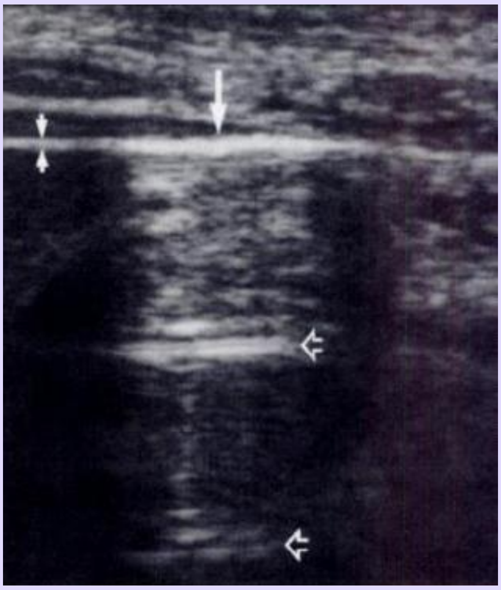
Normally, parietal peritoneum on the sonographic image looks as thin echogenic line located below a muscular layer and a preperitoneal fat of the abdominal wall.
Below this echogenic line visualized intraabdominal organs sliding «to-and-fro» synchronously with respiratory movements, also are visible peristaltic bowel loops.

Therefore peritoneal line which is looking as thin echogenic strip, is well visualized on interface between anterior abdominal wall and moving structures of the abdominal cavity.

At pneumoperitoneum the bubbles of gas are produced a sonographic appearance of focal enhancement and thickening of the peritoneal stripe (at the level of parietal peritoneum).

The EPSS (Enhanced Peritoneal Stripe Sign) is a reliable and accurate sonographic sign for the diagnosis of pneumoperitoneum with sensitivity and specificity about 100%.

Pneumoperitoneum on ultrasound is typically identified as a prominent hyperechoic peritoneal stripe with reverberation artifacts. In the right upper quadrant, pneumoperitoneum is seen as echogenic lines or spots with posterior ring-down or comet-tail artifacts between the anterior abdominal wall and the liver, but sometimes can be without artifacts (if presence tiny bubbles of gas).

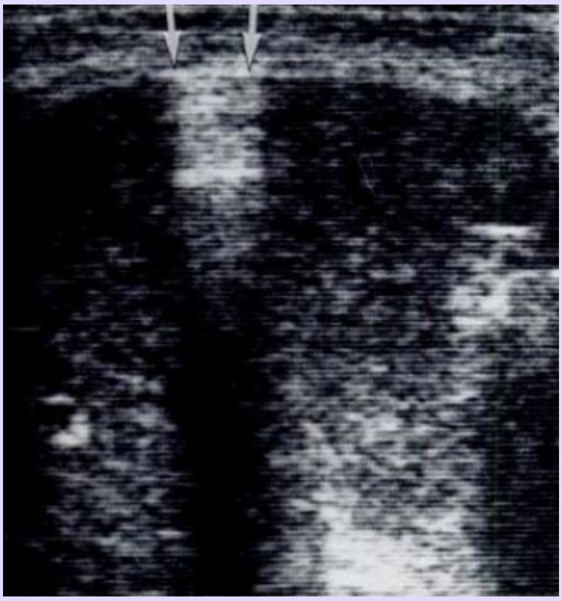


A specific sign of pneumoperitoneum is enhancement of the peritoneal stripe (peritoneal line looks much more echogenic and thicker than normal peritoneal line).

Sonogram of the right upper quadrant shows area of enhancement of the peritoneal stripe (large arrow) representing intraperitoneal air with multiple horizontal reverberation artifacts (ring-down artifacts).

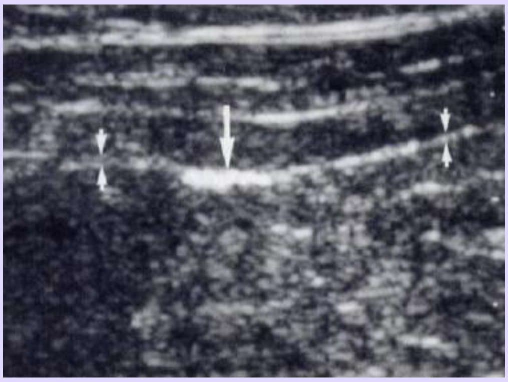
Ring-down artifact produces multiple parallel lines of similar length (open arrows).

Note normal adjacent peritoneal stripe (small arrows).



Pneumoperitoneum with posterior reverberation artifact.

Prominent hyperechogenic peritoneal stripe with corresponding horizontal reverberation artifacts between the surface of the liver and the abdominal wall.



Free intraperitoneal air.

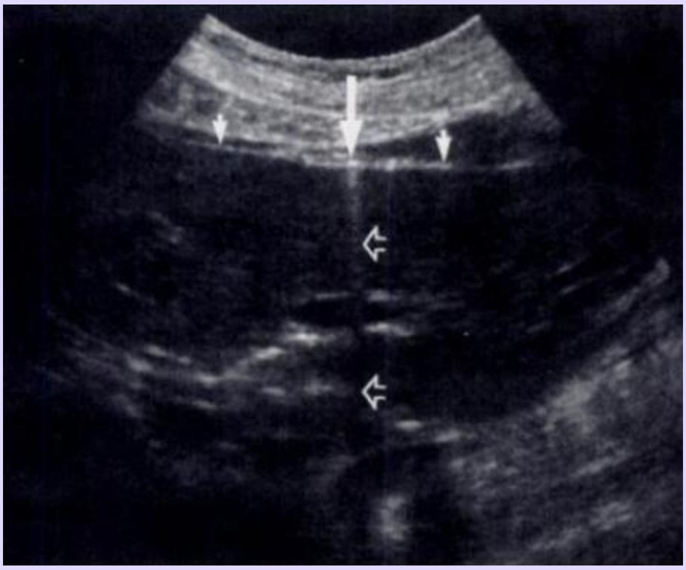
Enhancement of peritoneal stripe without posterior artifact (large arrow) representing tiny bubbles of intraperitoneal air.

Note normal adjacent peritoneal stripe (small arrows).

At pneumoperitonium gas can be visualized in any part of abdomen, but the most frequent and better intraperitoneal gas is visualized in epigastric area and in the right upper quadrant.

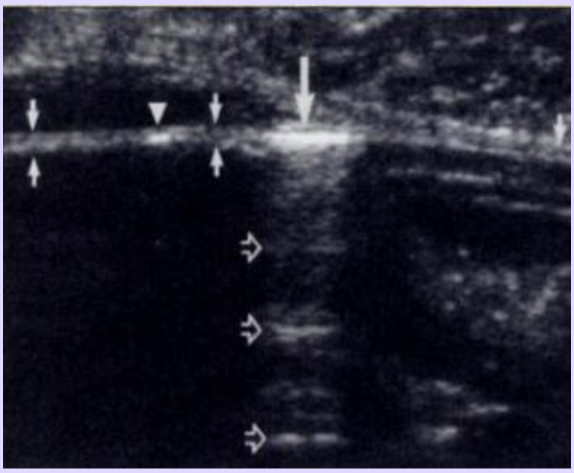
When assessing the abdomen for evidence of pneumoperitoneum, attention must be paid to technique. The patient should be scanned in the supine with attention concentrated on the epigastrium and right upper quadrant. The initial probe position is in the right paramedian epigastric area (or midline) in the longitudinal direction (for air searching between the left liver lobe and anterior abdominal wall). Then probe should be gradually displaced in right upper quadrant, the anterior and right lateral aspects of the liver are scanned in each position (for air searching between the right lobe of the liver and anterior abdominal wall).

Pneumoperitoneum will be visualized as echogenic lines or spots with posterior ring-down or comet-tail artifacts between the anterior abdominal wall and the liver. Ring-down artifact produces multiple parallel horizontal lines of similar length, whereas these lines gradually decrease in length in comet-tail artifact.



Longitudinal scan in the right upper quadrant.

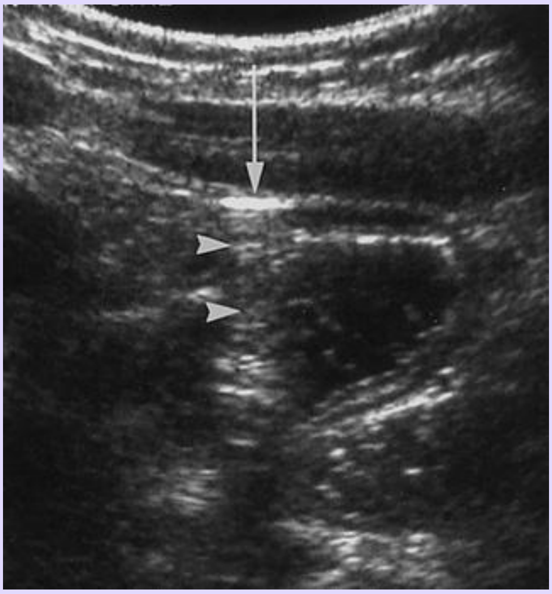
Between anterior abdominal wall and liver surface visualized a focal enhancement of peritoneal stripe (large arrow) representing tiny bubbles of intraperitoneal air with a linear reverberation artifact (comet-tail artifact). Comet-tail artifact (dirty shadowing artifact) – open arrows.
Note normal adjacent peritoneal stripe (small arrows).



Pneumoperitoneum – peritoneal stripe enhancement (large arrow) associated with multiple horizontal reverberation artifacts (open arrows) and focal enhancement of the peritoneal stripe (arrowhead) without associated posterior artifact representing small bubble gas.

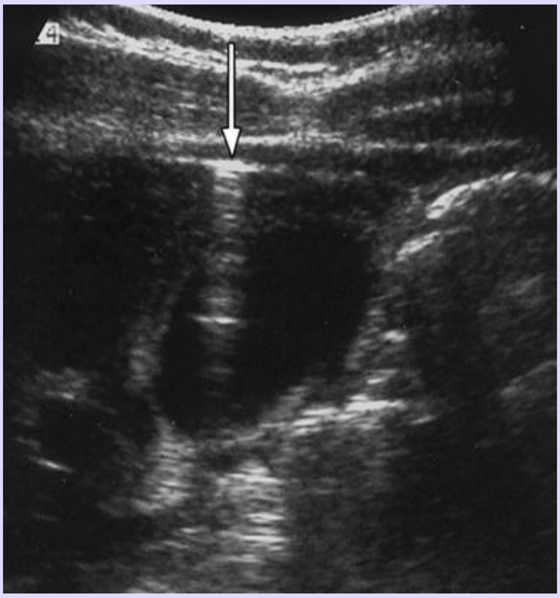
Normal peritoneal stripe (small solid arrows).

An important sign of the pneumoperitoneum is "shifting phenomenon" whereby free air shifts from the anterior to the lateral aspect of the liver as the patient turned from the supine to the left lateral decubitus position.



Pneumoperitoneum (fig 1)

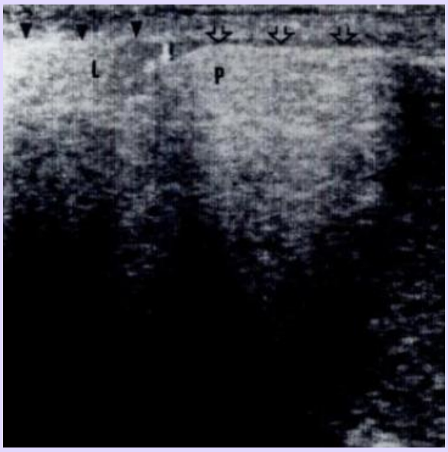
Sagittal upper midline US image obtained with the patient supine shows a small area of enhancement of the peritoneal stripe (arrow) with ring-down artifact (arrowheads).



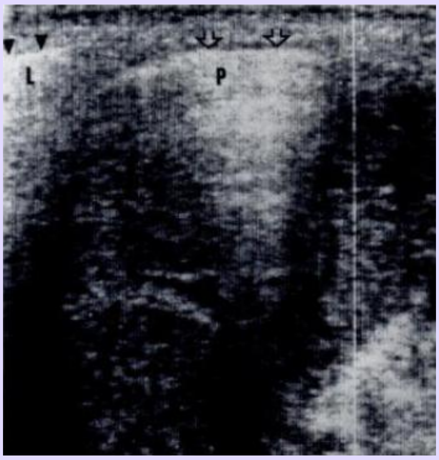
Pneumoperitoneum (fig 2)

Sagittal US image of the right upper quadrant, obtained with the patient in the left decubitus oblique position, shows that the area of enhancement of the peritoneal stripe (arrow) has moved anterior to the liver – “shifting phenomenon”.

In some patients, it may be difficult to differentiate pulmonary air from free intraabdominal air in the right upper quadrant, as the appearance produced may be that of a continuous line of reverberation. Lee et al described a technique whereby the patient is evaluated during inspiration and expiration. The pulmonary and pneumoperitoneal reverberation artifacts overlap during inspiration but appear separate at expiration.

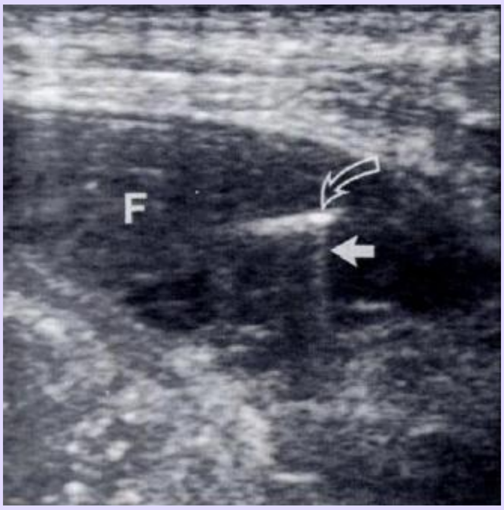


Effect of inspiration and expiration on detection of pneumoperitoneum.
Sonogram A made on inspiration shows pneumoperitoneum (P, open arrow) overlapped by lung (L, arrowheads).



Sonogram B made on expiration shows lung (L, arrowheads) separated from pneumoperitoneum (P, open arrow).

Also US sign of pneumoperitoneum in patients with free abdominal fluid is the presence of air bubbles within the fluid. They appear as floating echogenic foci with reverberation artifacts.



Free fluid with pneumoperitoneum.

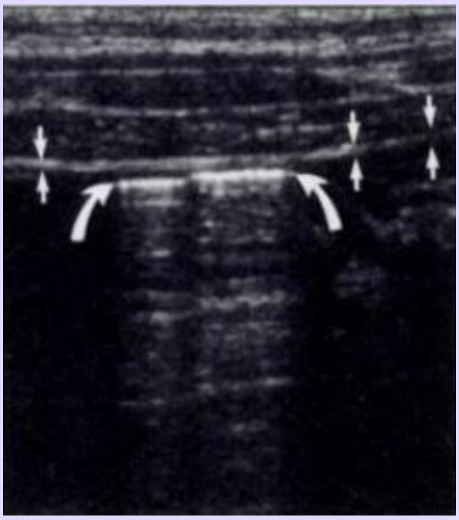
Pneumoperitoneum – the hyperehogenic focus representing a bubble gas (curved arrow) with a linear reverberation artefact (comet-tail artifact) distal to gas bubble detected in a free fluid (F).

comet-tail artifact (white arrow)

And may appear as floating echogenic foci in free fluid.

Free air may be detected anywhere in the abdomen as obvious enhancement of the peritoneal line and thus can be distinguished from adjacent intraluminal gas.

Intraluminal gas is associated with a normal overlying peritoneal stripe, whereas the free intraperitoneal air associated with an enhanced, thickened peritoneal stripe.

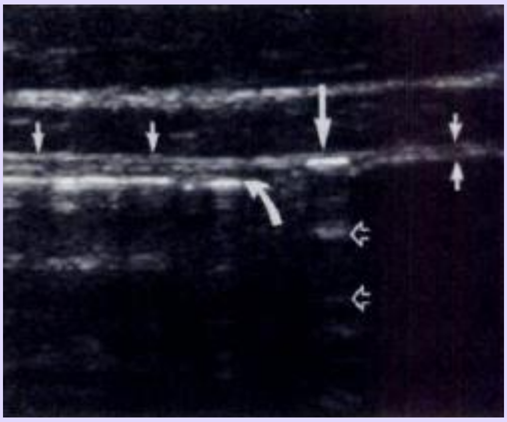


Intestinal gas echo.

Intraluminal bowel gas (curved arrows) always associated with more superficial peritoneal stripe (small arrows).

Intraluminal bowel gas is located always under peritoneal line.

Between peritoneal line and bowel gas visualized hypoechoic or anechoic thin strip representing bowel wall.



Free intraperitoneal gas – enhancement of peritoneal stripe (large straight arrow) associated with multiple reverberation artifacts (open arrow).

Note adjacent intraluminal bowel gas (curved arrow) with more superficial peritoneal stripe (small solid arrows).

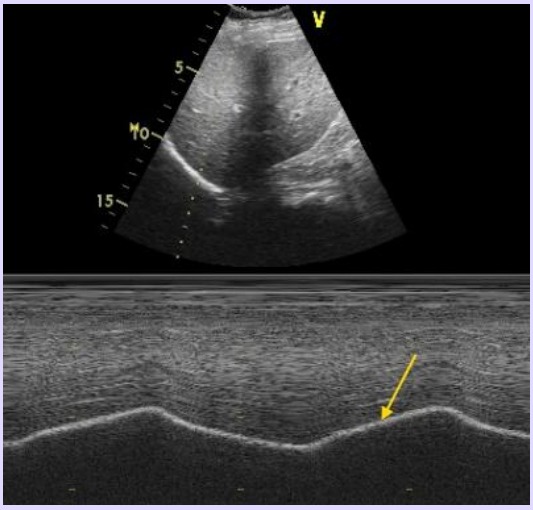
In doubtful cases the “shifting phenomenon” can help to differ free air from intraluminal air (as the patient turned from the supine to the left lateral decubitus position thus will be visualized rapid displacement of free air unlike intraluminal air).

A massive pneumoperitoneum can cause unexpected difficulty in obtaining of any images of abdominal organs and should not be mistaken for significant amount of intraluminal gas (this is similar to a situation at marked pneumothorax when unexpected difficulty at attempt to obtain heart images from transthoracal access). But absence of more superficial echogenic peritoneal stripe will help to diagnose pneumoperitoneum.

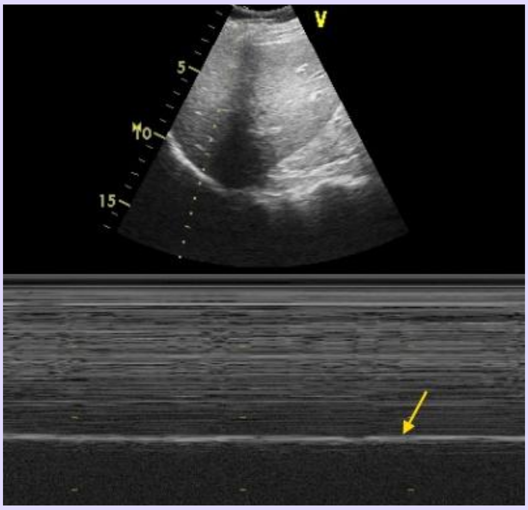
Recently was reported about a new sonographic technique (the scissors maneuver) for detection of intraperitoneal free air superficial to the liver. The maneuver consists of applying and then releasing slight pressure onto the abdominal wall with the caudal part of a parasagittaly oriented linear-array probe. The sensitivity and specificity values of sonography and radiography were identical in this study; sensitivity was 94% and specificity was 100% for both imaging modalities. Thus sonography is an effective tool in the diagnosis of pneumoperitoneum, with sensitivity and specificity equal to those of radiography. The scissors maneuver may be a useful adjunct for improving the diagnostic yield of sonography.

Focused Sonography in diaphragmatic injury

Blaivas et al describe using M-mode to diagnose diaphragmatic injury. Normally, the diaphragm moves synchronously with respiratory movements and becomes fixed after injury.



The image demonstrates normal diaphragmatic movement in M-mode during the respiratory cycle.



The image illustrates the loss of diaphragmatic movement.

Fixed M-mode image correlate with diaphragmatic injury.

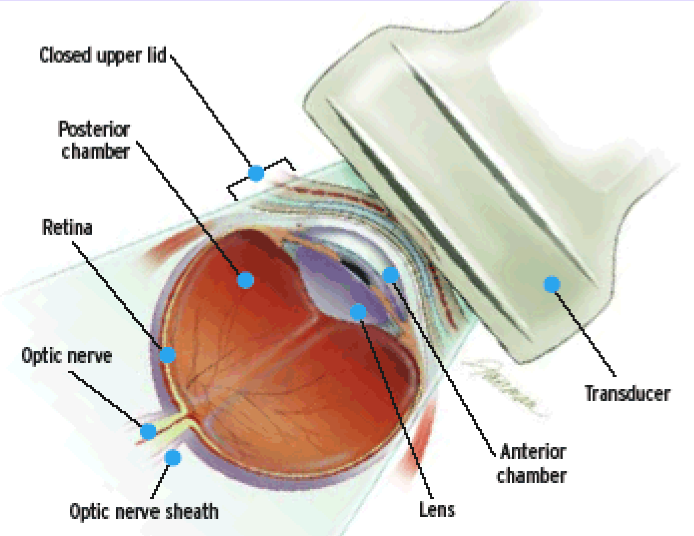
Focused Ocular Ultrasound

The resuscitation of serious closed head injuries demands the early identification of intracranial hemorrhage causing elevated intra-cranial pressure (ICP) amenable to surgical intervention. While ICP monitoring is recommended in patients with decreased Glasgow Coma Scale (<8) and an abnormal CT scan, hemodynamic instability from associated injuries requiring operative intervention can result in significant delays in both imaging and monitor insertion. As such, attempts have been made to develop a rapid, noninvasive method of ICP assessment.

Bedside ocular ultrasound for measuring optic nerve sheath diameter (ONSD) has been recently proposed as a portable noninvasive method to rapid detection of increased intra-cranial pressure (ICP) in patients with head trauma.

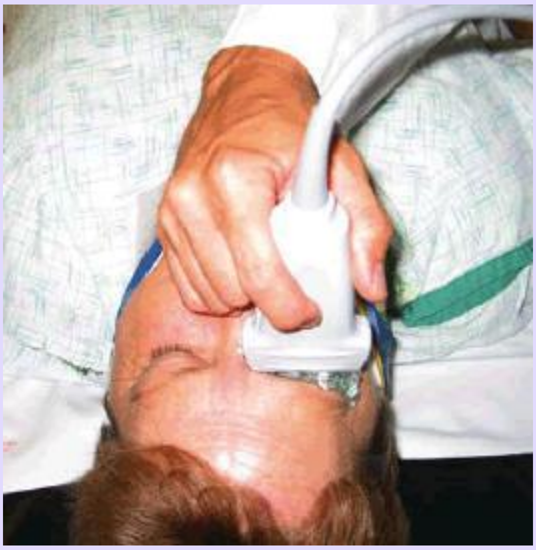
Ultrasonography of the optic nerve sheath gives the clinician an objective measurement to assess for elevated intracranial pressure and this technique parallels the concept of papilledema as a marker for increased ICP. However, optic nerve ultrasonography is arguably easier to perform and more quantifiable than the presence or absence of papilledema.

This procedure is strongly supported by anatomy and physiology, and can be used as a screening method for patients with suspected elevated ICP.



The optic nerve sheath is a direct extension of the dura. The perineural sheath travels from the brain to each orbit and communicates pressure from the CSF.

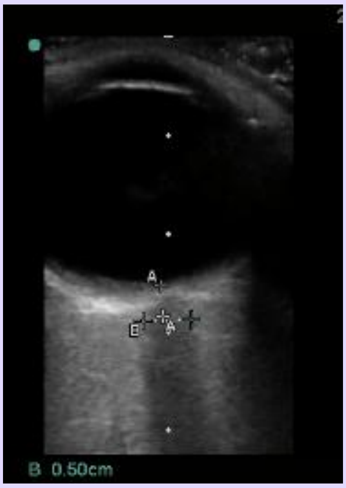
Therefore, increased ICP is transmitted to the optic nerve, causing edema and swelling of the nerve sheath. Any intracranial process that elevates intracranial pressure (ICP) will cause the optic nerve sheath to dilate. This expansion of the nerve sheath can be measured by ultrasound.



A thick layer of gel is applied over the closed upper eyelid. A high frequency linear probe is placed gently on the patient’s closed eyelid. Depth should be adjusted so that the image of the eye fills the screen.

The optic nerve is visible posteriorly as a hypoechoic linear region radiating away from globe.
For the nerve sheath shadow to be seen, the ultrasound beam or plane needs to transect the nerve, which enters the orbit at a slight angle. With gentle rocking of the probe or moving slightly to the lateral edge of the globe, the nerve sheath will usually come into view.

The optic nerve sheath is measured 3 mm behind the globe, and the ONSD measurement is taken within the visualized sheath.
Measurements should be performed in two planes, transverse and longitudinal by rotating the probe ninety degrees, to ensure true diameters are measured.

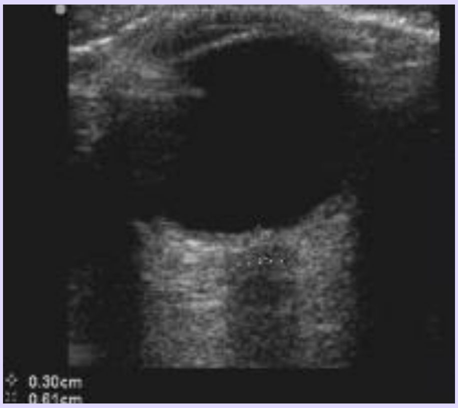


For ocular nerve sheath measurements, the dark shadow of the optic nerve should be identified posterior to the retina.

Normal optic nerve sheath diameter (D = 0.50 cm).

B - optic nerve sheath diameter (ONSD), measured 3 mm behind the globe (A-A).

Values considered normal for ONSD are less than 5 mm in adults, less than 4.5 mm in children aged 1 to 15 years, and less than 4 mm in infants. Diameters that are greater than these cutoff values indicate an elevated ICP. Measurement of >5.0 mm has been shown to correlate with elevated ICP (>20 mmHg) or evidence of increased ICP on CT scan of the head.



Dilated optic nerve sheath diameter (D = 0.61 cm) correlates with elevated ICP.

Dilated optic nerve sheath diameter (D = 0.72 cm) correlates with elevated ICP.

Optic nerve sheath diameter represents a potentially quick, noninvasive and sensitive bedside screening test for detecting raised ICP and the presence of intracranial hematoma needing surgical intervention in head injury, utilizing readily available equipment and requiring a minimal amount of training. It has all the advantages of ultrasound including being easily repeatable for dynamic changes over time.

Focused Sonography in bony injury

Ultrasound evaluation of extremity, rib, and sternal injury are valuable techniques that potentially present advantages especially in the austere and military areas, were radiography may not be readily available. Diagnosis of bony injuries may be more rapid by using ultrasound over other modalities, even plain x-rays take a significant amount of time to be performed.

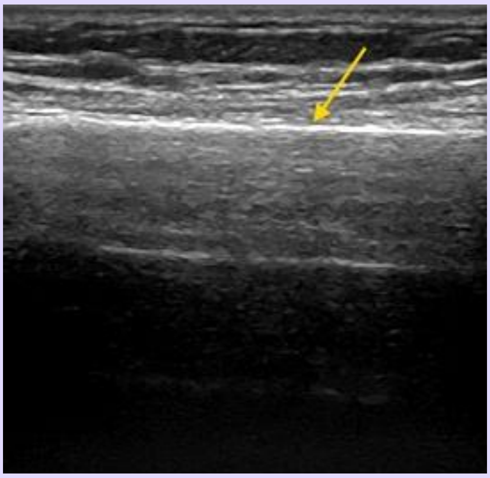
Ultrasound is used at the bedside concurrently with the overall trauma resuscitation, and may potentially limit the patient's and treating team's exposure to ionizing radiation.
Multiple long-bone fractures may be a source of shock and can be quickly confirmed at the bedside with EFAST and early detection of long-bone fractures can also aid in the early stabilization of severely injured patients.

Studies demonstrates high accuracy (overall accuracy of 94%) among both physician and para-medical clinicians in detecting long-bone fractures with minimal training.
Pitfalls in this technique include reduced accuracy with the small bones of the hands and feet, as well as great reliance on user experience.

Location	Sensitivity%	Specificity%
Forearm/arm	**92**	**100**
Femur	**83**	**100**
Tibia/fibula	**83**	**100**
Hand/foot	**50**	**100**

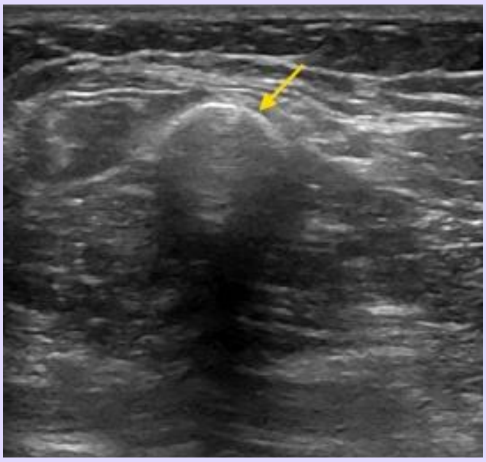
Technique

A high-frequency linear probe should be used for assessment the superficial soft tissue and bony structures. Subcutaneous tissue and muscle are readily visualized with ultrasound because they transmit sound well. Bone acts as a bright reflector, giving a strong echogenic signal with distal shadowing. The depth should be set to maximize imaging of the cortical interface. Intense wave reflection is clearly illustrated the cortical bony anatomy (readily visible as an unbroken, highly echogenic line), and making cortical disruption obvious.



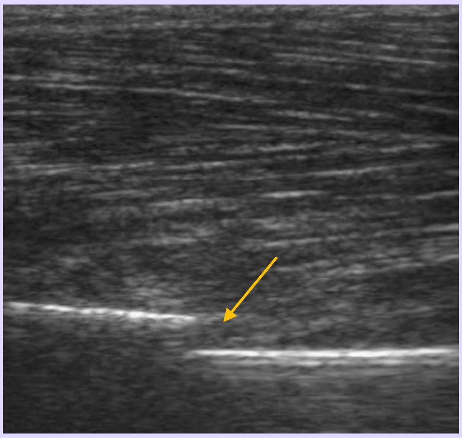
Longitudinal scan of the long bone. Normal cortical contour of bone (bright white line) – smooth and uninterrupted.

The diagnosis of long bone fractures can be made by assessing for a break in the normal cortical contour of bones.



Transverse scan of the long bone. Normal cortex (arrow) – smooth and uninterrupted.

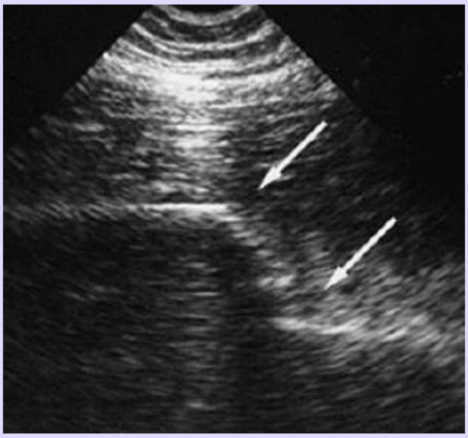
Bony fractures are evident as a break in this echogenic line, representative of a break in the cortex, or a step is detected in the bony outline when the fragment is displaced. The fracture is often associated with a localized hematoma or soft-tissue swelling.



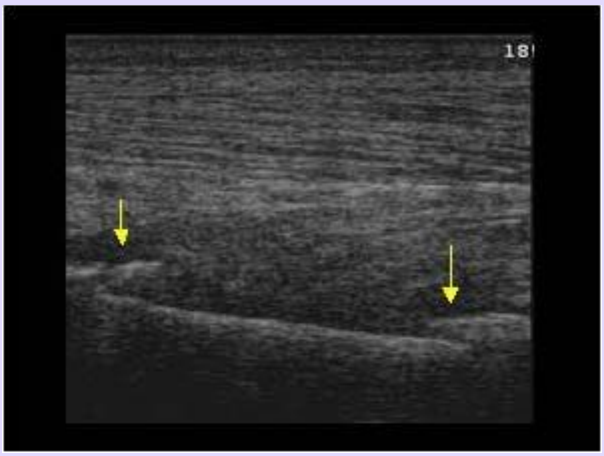
A fibula fracture with significant soft tissue swelling. Note the cortical disruption (broken bright white line) with "step" appearance.

The bone is first identified in cross-section and is initially scanned longitudinally with the probe moved slowly across the point of maximal tenderness. The cortex is assessed for irregularities, disruptions, or steps. Suspicious areas and regions of soft tissue swelling or hematoma are then further assessed in a transverse plane. Although the longitudinal view is often more useful, transverse views may also demonstrate these findings and give information as to the degree of angulation or displacement. Perform ultrasound on the contralateral side to compare the anatomy side by side if anatomy appears strange.

Probe position for femoral head.
Imaging of the femur should begin at the distal femur by placing the probe superior to the patella over the thigh laterally. The femur should first be visualized in a transverse plane to ensure proper identification, and then the probe should be rotated 90 degrees and the length of the femur scanned by moving the probe proximally. The probe should be angled at the femoral neck, with the indicator toward the pubic symphysis, to visualize the femoral neck, head, and pelvic acetabulum.

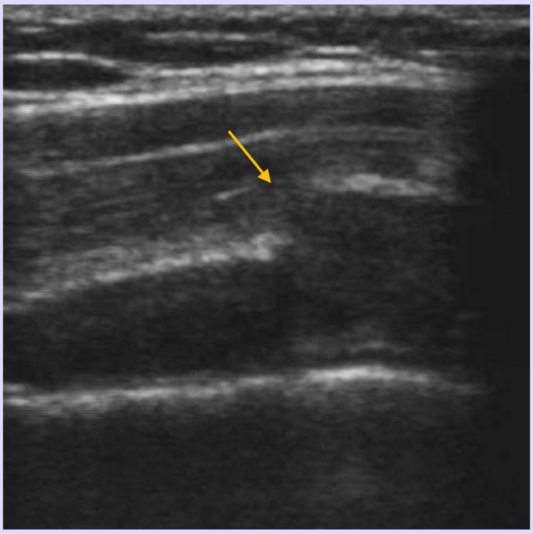


Displaced fracture of the femoral diaphysis. The proximal and distal segments are 20 mm distant, without overriding (arrows).



Comminuted fibula fracture with cortical interruption.

Comminuted fibula fracture on X-ray image.



Clavicle fracture, with cortical interruption with displacement.

Clavicle fractures are easily identified by both radiography and ultrasound. In some cases, however, ultrasound may be more advantageous. Because many of these fractures occur in children, a quick bedside diagnosis without any exposure to ionizing radiation is desirable.

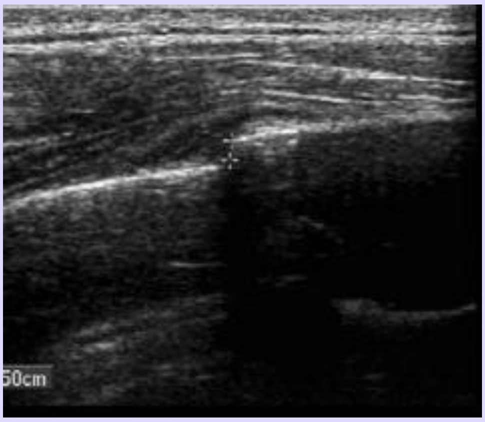
Also US may be used in the diagnosis of rib fracture. Studies have found that sonosraphy is much more sensitive than plain radiography in detecting rib and sternal fractures (up to 50–88% of rib fractures are undetected on conventional chest X-rays). Likewise, US has been shown to be more sensitive in the detection of chondral rib fractures and cartilage separations compared with chest X-rays. US can visualize the costal cartilage as well as the osseous part of the rib.

Rib fractures occur with a rate of 35–40% in thoracic trauma. The fourth through 10th ribs are the most often fractured. The rate of associated injury in patients with rib fractures is high. Potentially severe complications include:

- Pneumothorax
- Hemothorax
- Pulmonary contusion
- Flail chest
- Vascular and nerve damage (especially with trauma to the upper chest)
- Abdominal organ injury (particularly with trauma to the lower thorax).

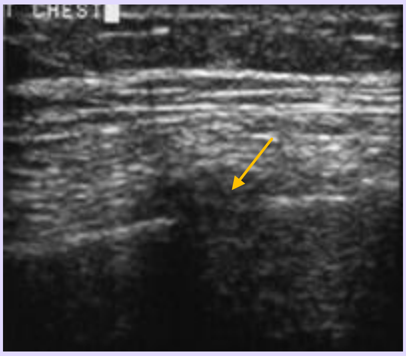
The localization of the fractured rib has a clinical significance to further evaluate a possible associated visceral injury. Fractures of the first three ribs can indicate significant trauma to the trachea, bronchi and main vascular structures and fractures of the lower ribs should arouse suspicion for a possible injury to spleen, liver, kidneys or diaphragm.

Sonography is best performed along the line of the rib and over the site of maximum tenderness.



Rib fracture with a step of 1.5 mm. This fracture could not be seen on X-rays. No accompanying hematoma above the fracture site

Traumatic rib fracture. Sonogram shows cortical disruption (arrow) and hematoma formation (arrowheads).



When a normal rib is scanned along its long axis, the anterior cortex appears as a smooth, continuous echogenic line. In this example of an acute rib fracture, a visible gap with loss of continuity of the anterior cortex of the rib is seen. A small, hypoechoic hematoma bridges the gap.

The imaging of a rib fracture with US is not a complicated procedure, and can be performed by the clinicians as well. However, examination has a number of disadvantages: time-consuming, depending on the operator's skills and may be inaccessible for the subscapular ribs and the infraclavicular portion of the first rib, which are uncommon sites for rib fractures. In addition, large breasts and obesity may also limit the optimal detection of rib fractures.

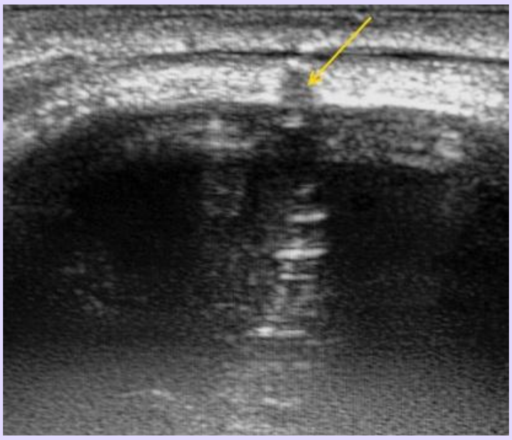
The choice of which test to use in a patient with a suspected rib fracture greatly depends on the clinical scenarios. In stable patients with penetrating or major chest or abdominal trauma, CT is the study of choice. It provides the most information about associated injuries, and accurately detects rib fractures. This helps target treatment of associated injuries, and helps identify patients at higher risk, such as those with significant vascular, pulmonary, or abdominal injuries and those with a greater number of fractures.

Sternal fractures occur in up to 10% of casualties who sustain significant blunt trauma to the chest. The most frequent mechanism of injury associated with sternal fracture is a motor vehicle crash where the driver is thrown forward against the steering wheel. Sternal fractures are usually diagnosed on a lateral radiograph, however occasionally these injuries may not be visible on the X-ray film. Studies shows that ultrasound to be more accurate than radiographs with sensitivity of 90–100%.

Ultrasound assessment of the sternum should be undertaken where there is clinical suspicion of sternal injury from the mechanism of injury and appropriate tenderness on examination.

Ultrasound of sternal fracture demonstrating interruption of the cortex (arrow).

Also ultrasound can detect skull fractures. Ultrasound has 94% specificity and 82% sensitivity for detecting closed-head skull fractures. Bedside ultrasound can help identify skull fractures in children and might be a useful tool in deciding which patients need further imaging.



Ultrasound of the skull fracture (arrow).

Bedside sonography also greatly improves the success rates of emergency procedures in trauma patients. These include vascular access (placement of central venous catheters), pericardiocentesis, thoracocentesis, control of correct placement of the intubation tube.

With the advent of portable, modern equipments and the growth in experience of focussed assessment with sonography for trauma (FAST) among emergency physicians and surgeons, the complete range of applications for ultrasound diagnosis has yet to be determined.