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E-FAST

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Historical development and definition

The morbidity and mortality of patients in haemorrhagic shock are high and trauma is not the only cause. Haemorrhage can also occur in ectopic pregnancies, coagulation disorders, vascular pathologies and postoperatively. 20–40% of patients with significant abdominal trauma have normal clinical findings [(1)]. Therefore, it is clear that trauma surgeons need reliable diagnostic aids. When searching for appropriate solutions, sonography was discovered at the end of the 1970s. This was after diagnostic peritoneal lavage (DPL) and computed tomography (CT) were introduced. Ultrasound offers great advantages over the somewhat elaborate and invasive DPL and expensive CT with its associated side effects: it is simple, is performed by the attending physician at the bedside in real time, can be repeated as often as necessary, is non-invasive, does not involve radiation, needs only a minimal amount of training and is cost-effective. This technique rapidly became a standard procedure in emergency rooms. The term Focused Assessment with Sonography for Trauma (FAST) was coined at a consensus conference in 1999 [(2)]. FAST focuses on the detection of fluid in the peritoneal cavity and pericardial space, without distinguishing between blood and other fluids. As early as the beginning of the 1990s, the ultrasound examination was extended to include the detection of haemothoraces. In 2004, the term Extended FAST (E-FAST) was born following the incorporation of detection of pneumothoraces into the standard protocol [(3)]. In brief, E-FAST is a focused, rapid ultrasound examination that is easy to learn. It is performed at the bedside to answer three clinical questions [Table 1] transformed into five sonographic questions [Table 2] using information from six standard views [Figure 1]. The main purpose is to establish whether the patient has haemodynamically significant haemorrhages in the peritoneal cavity, pleural or pericardial spaces or a pneumothorax. Together with the overall clinical assessment, this information helps in taking five important diagnostic and clinical decisions [Table 3]. This means that the objective of E-FAST is not to establish whether there is any bleeding at all, nor is it performed to locate the exact source of bleeding which would involve much more complex and time-consuming investigations, but to establish whether there is ongoing bleeding which requires surgical intervention.

Table 1 Clinical questions.

Clinical questions:
➢ Does the patient have blood in their abdomen and/or thorax? ➢ Does the patient have a cardiac tamponade? ➢ Does the patient have a pneumothorax?

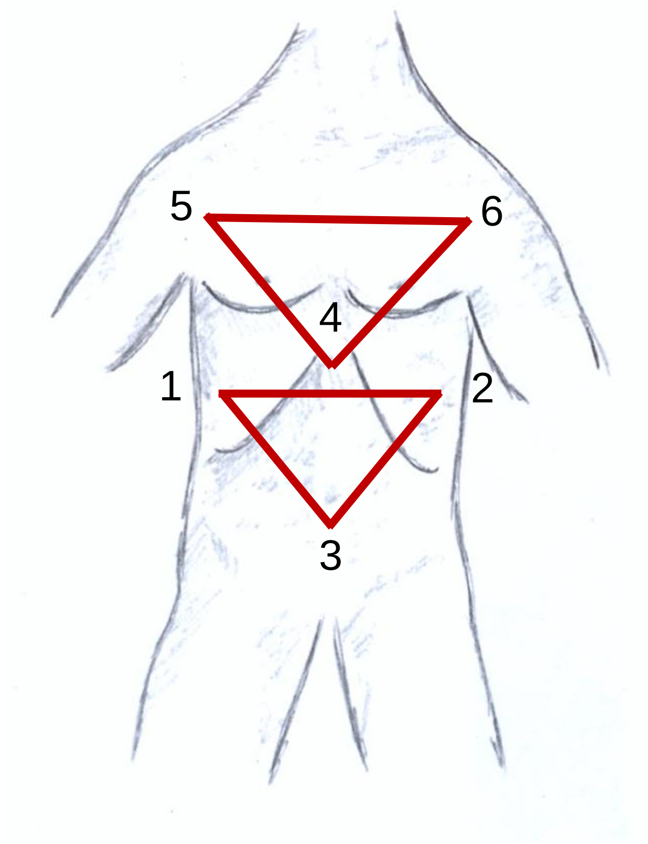
Table 2 Sonographic questions.

Sonographic questions:
➢ Is there any fluid in the peritoneal cavity? ➢ Is there any fluid in the pericardial space? ➢ Are there signs of tamponade? ➢ Is there any fluid in the pleural space? ➢ Are lung sliding, B-lines, the lung pulse and the lung point present?

Table 3 E-FAST, decision making.

E-FAST = Decision making help for:
➢ Need for immediate laparoscopy or thoracotomy ➢ Choosing the primary site of access (thorax or abdomen) ➢ Treatment of pneumothorax and haemothorax ➢ Transition to secondary survey ➢ Need for abdominal or thoracic CT

Figure 1 Standard views. Right upper quadrant (1); left upper quadrant (2); suprapubic, sagittal and transverse axis (3); subcostal cardiac, long and short axis (4); bilateral anterior longitudinal chest (5 and 6).



E-FAST has become established as an important component of the internationally recognised Advanced Trauma Life Support (ATLS) in resuscitation management. ATLS consists of two phases. The primary survey consists of life saving measures prioritised according to the diagnostic therapeutic ABCDE approach (A = Airway, B = Breathing, C = Circulation, D = Disability and E = Exposure/Environmental Control). Focussed sonography forms part of the assessment in the 'Breathing' and 'Circulation' steps. Depending on the condition of the patient, E-FAST is performed again in the secondary survey (head-to-toe examination) and after discharge from the emergency room on the observation ward. It is also indispensable when examining patients with shock of unclear origin (e.g., cardiogenic or hypovolaemic shock or haemodynamic instability), acute lower abdominal pain in women of child-bearing age and during and after cardiopulmonary resuscitation.

Investigations

Standard views – normal and pathological findings

The E-FAST investigation consists of six standard views. The prescribed sequence of view showed in Figure 1 should always be adhered to because emergency investigations are often performed under great pressure. This is the only way to ensure that no steps in the investigation are missed.

Free fluid is usually echo-free or echo-poor on an ultrasound image. A fresh haematoma, however, may on occasions be echogenic. The characteristic of free fluid is that it changes its position if the patient's position is changed. It is therefore important to identify the spaces in which free fluid may collect. Exact measurement of the amount of fluid is impossible using sonography. There are formulas, however, for different regions, which make it possible to estimate the fluid volume [(4)].

The following sections describe and discuss the six standard views [Figure 1] with comparisons of normal and pathological finding.

Position 1: Right upper quadrant

The right upper quadrant view examines the hepatorenal recess between the kidney and liver, also called Morison's pouch [Figure 2]. Free fluid is visualised as an echo-poor band between the two organs [Figure 3]. If the mean thickness of the band of free fluid in Morison's pouch is wider than 1 cm, it can be assumed that up to 1 litre of intraperitoneal fluid is present [(5, 6)]. However, free fluid in the right upper quadrant of the abdomen does not always collect in Morison's pouch. In these cases, the intraperitoneal fluid can usually be detected along the lower anterior margin of the liver.

Figure 2 Normal findings (right upper quadrant). Liver (1); kidney (2); Morison's pouch (3).

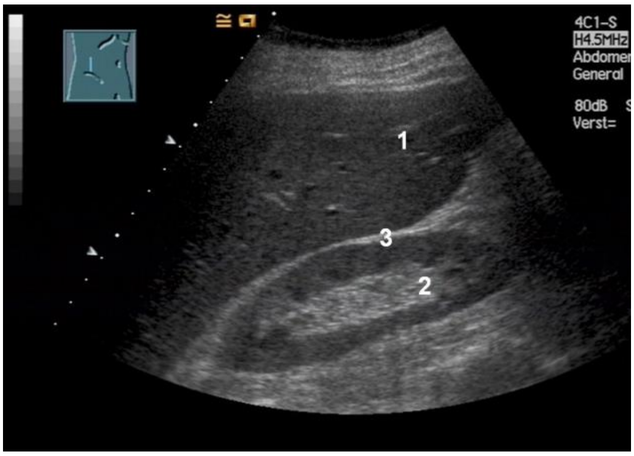
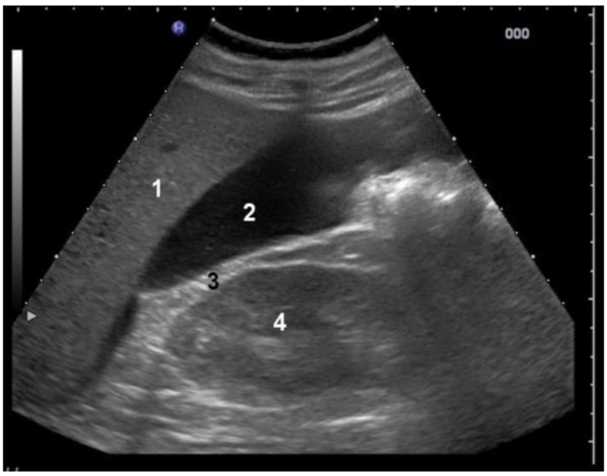


Figure 3 Free intraperitoneal fluid in Morison's pouch (right upper quadrant). Liver (1); fluid (2); fat (3); kidney (4).



By directing the probe through the liver towards the top of the diaphragm, the presence of subphrenic fluid can be excluded or visualised [Figure 4]. Gliding the probe in a craniodorsal direction to the posterior axillary line searches for fluid in the right pleural space directly above the diaphragm. When doing so, respiratory movements should be observed as when the lung is filled with air, it should slide across the liver like a curtain in the costodiaphragmatic angle [Figure 5]. Signs of fluid in the pleural space [Figure 6] are: (1) the presence of the spine sign (demonstration of the spine posterior to the pleural effusion in the supraphrenic thoracic cavity), (2) visualisation of the diaphragm (in the normally aerated lung the diaphragm cannot be seen; in the presence of a pleural effusion it appears as an echo-poor band edged with an upper and lower echo-rich border), (3) absence of the curtain sign (moving lung/air in the costodiaphragmatic angle) and (4) compression atelectasis in moderate to severe effusions [(7)]. The volumetric assessment of the amount of pleural effusions and haematomas is unreliable [Figure 6]. In order to obtain a rough estimate of the volume of the effusion in millilitres, the width of the fluid in the cross-section is measured in millimetres from the interior thoracic wall to the dorsal margin of the lung and multiplied by 20, with the procedure performed with the patient in a supine position [(8)]. The best position for drainage can also be decided at the same time.

Figure 4 Subphrenic organising haematoma of the liver (right upper quadrant). Liver (1); haematoma (2); diaphragm (3); small effusion (4).

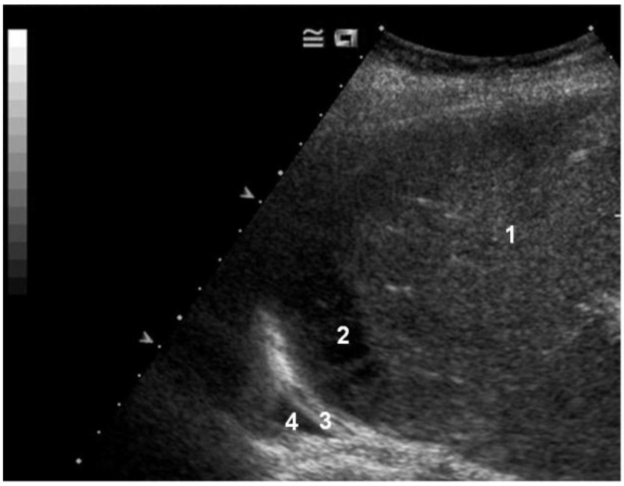


Figure 5 **Normal dorsal costodiaphragmatic angle (right upper quadrant). Liver (1); costodiaphragmatic angle (2); mirror artefact (3); adrenal gland (4); kidney (5).**

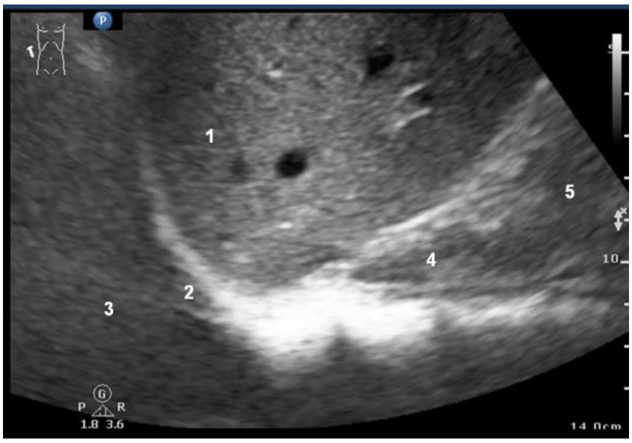
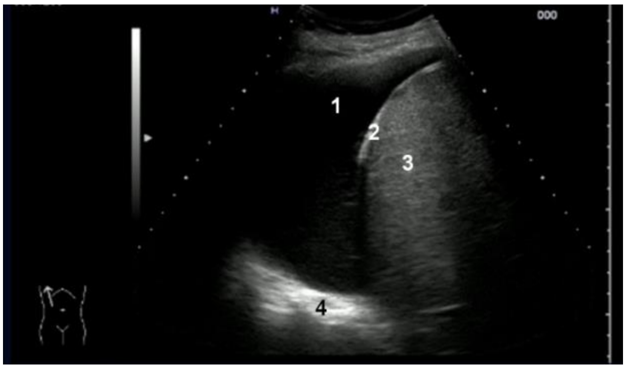


Figure 6 **Haemothorax (right upper quadrant). Haemothorax (1); diaphragm (2); liver (3); spine (4).**



Position 2: Left upper quadrant

The left upper quadrant view investigates the presence of free fluid in the perisplenic and splenorenal recess, also known as the Koller pouch [Figures 7 and 8]. To avoid missing free fluid, the splenic hilum, the spleen and the kidney should be visualised in one plane. It must be borne in mind that in cases of gastric retention, the fluid may extend to the spleen and can mimic fluid in the Koller pouch on superficial examination.

If splenic haematomas are present and are subcapsular and located along the extreme outer margin or are subphrenic, the Koller pouch may be empty [Figure 9]. Occasionally it is possible to directly visualise a ruptured spleen, although this can be quite time consuming. The best way to evaluate whether active bleeding is present is by using contrast enhanced ultrasound during the secondary ATLS survey.

Figure 7 Normal findings for Koller pouch (left upper quadrant). Spleen (1); fat in the Koller pouch (2); kidney (3); costodiaphragmatic angle (4).

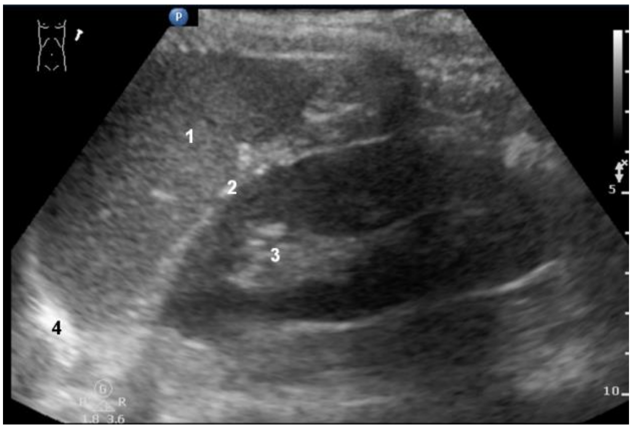


Figure 8 Small amount of free fluid in the Koller pouch (left upper quadrant). Spleen (1); fluid (2); kidney (3).

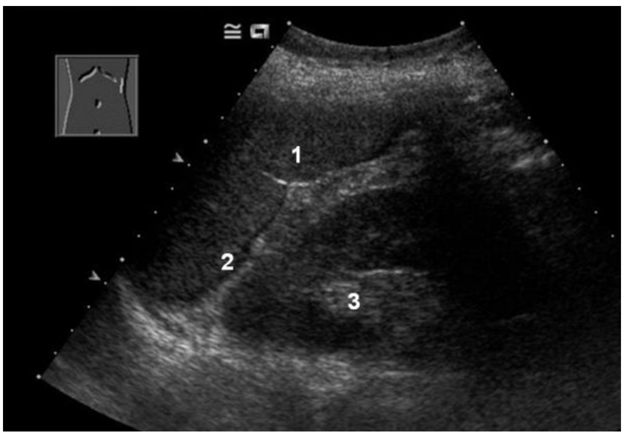
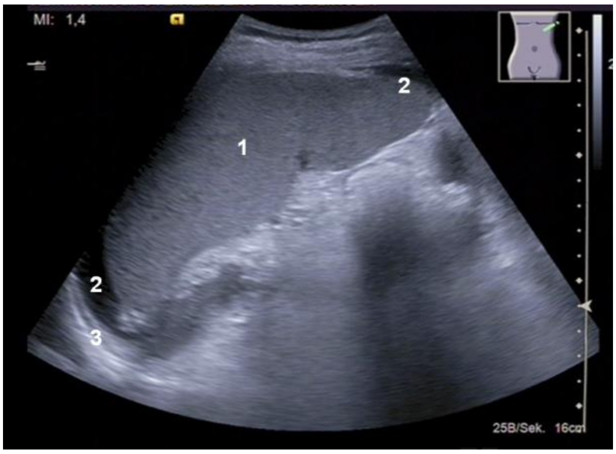


Figure 9 Subphrenic free fluid at the lower pole of the spleen (left upper quadrant). Spleen (1); fluid (2); diaphragm (3).



Similar to the view described in Position 1, the probe is also directed cranially to examine the left pleural space for free fluid. The same criteria apply as for the right side. Due to the fact that the spleen is considerably smaller than the liver, it is not always possible to achieve a good sonic window to the costodiaphragmatic angle. In such cases, in order to exclude the presence of fluid in the pleural space, the lower margin of the lung should be visualised in the posterior axillary line for respiratory-synchronous movement ('curtain sign').

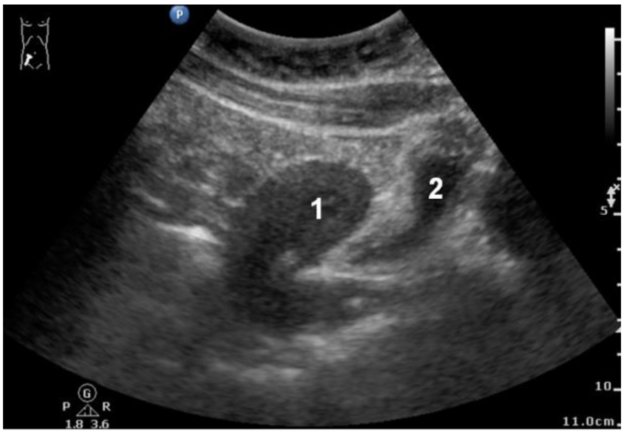
Position 3: Suprapubic pelvis

Directly above the pubic symphysis, attempts should be made to visualise the urinary bladder in the sagittal and transverse axes. In the traverse axis fluid can be missed when the angle of view (probe) is too steep. In women, the examination starts with the sagittal axis and the uterus is visualised behind the bladder. The pouch of Douglas is situated dorsal to this [Figures 10a/b]. In men, the examination starts with the transverse axis and the operator uses the prostate behind the bladder for orientation [Figures 11a/b]. Any free fluid in the pouch of Douglas [Figures 12a/b] or rectovesical pouch [Figures 13a/b] can be visualised directly in this way using the urinary bladder as a sonic window. Large amounts of fluid, when present, are found in front of, besides and behind the uterus. Difficulties occur if the bladder has been emptied or perforated. In such cases, the free fluid can sometime be visualised in the lesser pelvis with no lateral edge. The patient must have a full – or even only partially full – bladder if fluid in the lower abdomen is to be excluded. This is because if the bladder is empty, intestinal gas often impairs the imaging of the relevant structures. The status of bladder filling must therefore be documented in the patient's records.

The ellipsoid rotation equation can be used to estimate the volume of fluid in the lower abdomen, especially if the edges and shape of the body of fluid are roughly this shape. The equation is length x breadth x depth x 0.5 and with an appropriately shaped collection of fluid, the result is an acceptable estimate.

Figure 10 Normal lower abdominal findings in women (suprapubic sagittal and transverse axes). Sagittal axis (a): uterus (1); bladder (2). Transverse axis (b): bladder (1); uterus (2); rectum (3).

a



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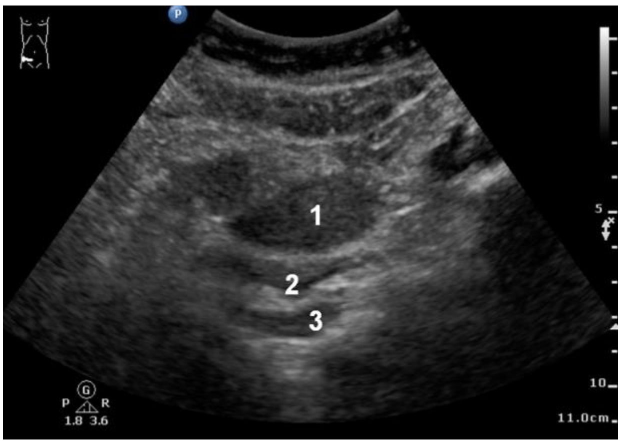
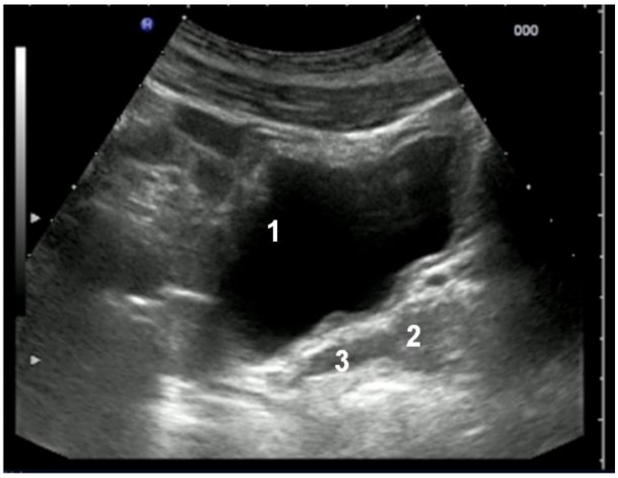


Figure 11 **Lower abdominal view in a male patient (suprapubic sagittal and transverse axes). Sagittal axis (a): bladder (1); prostate (2); seminal vesicle (3). Transverse axis (b): bladder (1); prostate (2); rectum (3).**

a



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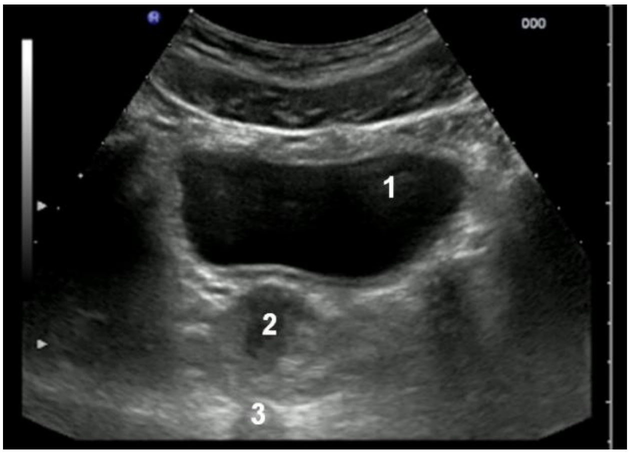
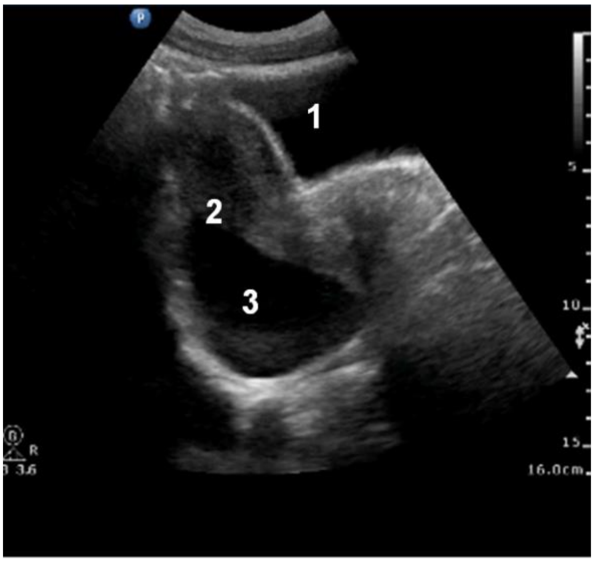


Figure 12 **Fluid in the pouch of Douglas (suprapubic sagittal and transverse axes). Sagittal axis (a): bladder (1); uterus (2); free fluid in the pouch of Douglas (3). Transverse axis (b): bladder (1); uterus (2); free fluid in the pouch of Douglas (3).**

a



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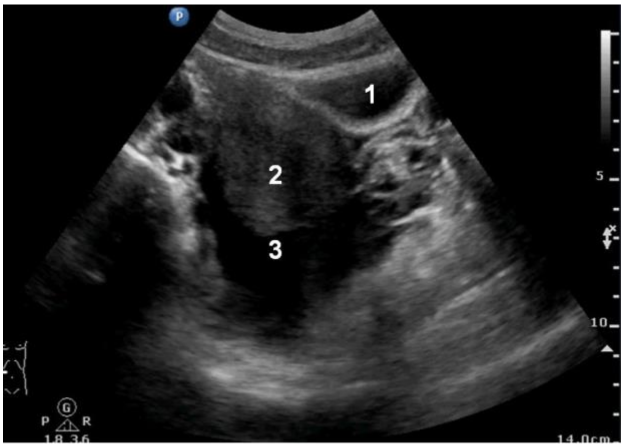
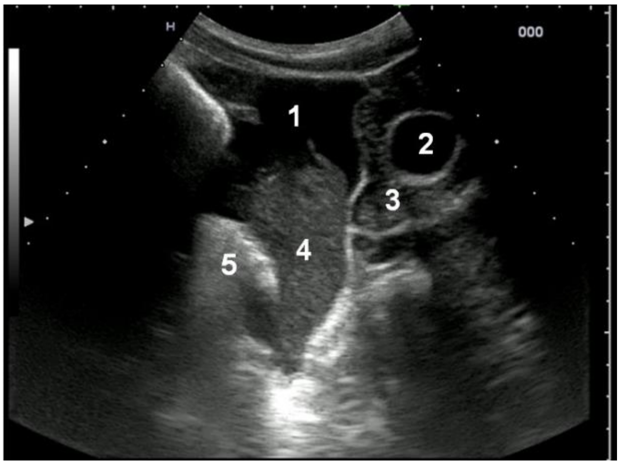


Figure 13 Rectovesical free fluid in a male patient (suprapubic sagittal and transverse axes). Sagittal axis (a): free fluid in the rectovesical pouch (1); balloon of indwelling catheter (2); bladder (3); clot in the rectovesical pouch (4); intestine (5). Transverse axis (b): free fluid in the rectovesical pouch (1); clot in the rectovesical pouch (2).

a



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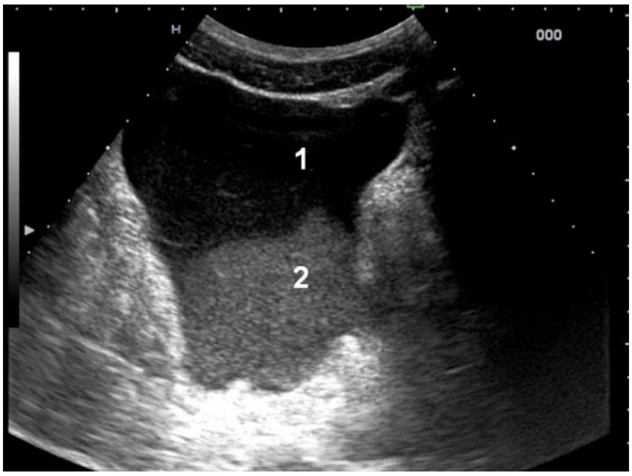


Position 4: Subcostal cardiac

The subcostal cardiac view visualises the four chambers of the heart including the pericardium [Figure 14] by holding the probe very flat and pointing it cranially behind the sternum, where the heart usually sits. In cases where the heart is not visualised with the probe in this position, the probe should be turned to the left side. This enables visualisation of a pericardial effusion. The pericardium appears as a light, echo-rich line surrounding the heart. An effusion is echo-free or echo-poor [Figure 15]. Blood and pus can be moderately echogenic, especially in cases of an organised haemopericardium. In the subcostal cardiac view, the extent of the pericardial effusion is likely to be overestimated because of the angle of the view. The haemodynamic relevance of a pericardial effusion cannot be estimated based on its size. A small, acute pericardial effusion may be very dangerous, whilst large, slowly developing chronic effusions can be well tolerated. B-mode signs for tamponade should be used to assess for haemodynamic compromise. These are inversion of the right atrium (late diastolic) and right ventricle (early diastolic). It is also worth turning the probe anticlockwise to assess the filling status and collapsibility of the inferior vena cava (this is not part of standard E-FAST).

Figure 14 Normal four chamber view of the heart (subcostal, long-axis). Liver (1); right ventricle (2); left ventricle (3).

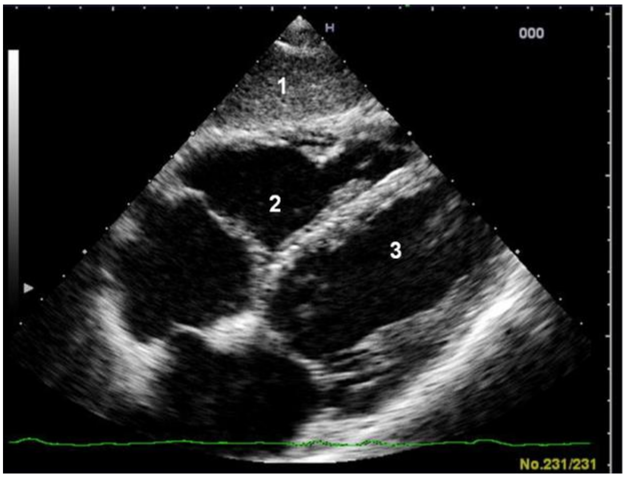
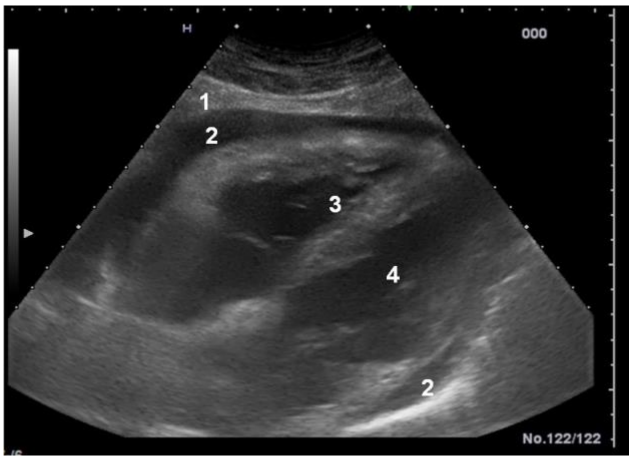


Figure 15 Haemopericardium with no signs of tamponade (subcostal, long-axis). Liver (1); pericardial effusion (2); right ventricle (3); left ventricle (4).



Using the subcostal approach to image the heart is difficult in obese patients or those who have large quantities of bowel gas. An alternative method is the parasternal approach in the long and short axes, or sometimes apical imaging of the four chambers is possible. In some cases, the operator must accept the limited views. In order not to miss focal pericardial effusions, the best image possible should be obtained, preferably with a four chamber image and two dimensional visualisations with M-mode documentation.

Epicardial fat may make diagnosis difficult (see Pitfalls section). In cases of tamponade, targeted drainage can be performed immediately under sonographic guidance so that complications including myocardial puncture are avoided.

Positions 5 and 6: Bilateral anterior chest

The examination is conducted with the patient supine. The starting point is the highest area, which usually the third or fourth intercostal space between the parasternal and the mid-clavicular lines. Air rises up to this point if it is not trapped elsewhere. First the longitudinal axis is investigated to locate the rib shadows and the respiration-dependent pleural reflex in the intercostal space. This approach also enables the less experienced operator to be sure that they have located two rib shadows, the intercostal musculature and the deeper seated pleural line. The focus is placed on the pleural line, and the respiration-synchronous sliding sign is observed. If lung sliding can be demonstrated, then a pneumothorax is not present. In cases where no lung sliding is seen, further signs such as B-lines and the lung pulse [Figure 16] are searched for. Absence of these indicates the presence of a pneumothorax. The lung pulse and lung sliding can be documented with M-mode or colour-Doppler. The most definite evidence of a pneumothorax is the lung point. This is the transition point between the inflated lung and the pneumothorax. The lung point is respiration-synchronous [Figure 17]. If the criteria for a pneumothorax are present with the probe in the starting position, it is slid laterocaudally to look for the lung point.

Lung sliding may be absent if pleural adhesions are present. Respiratory excursions are limited in the presence of severe chronic obstructive pulmonary disease and lung sliding may not always be demonstrable. To exclude a pneumothorax, therefore, all four criteria must be fully investigated and the two sides of the chest must always be compared.

Figure 16 Normal findings for the pleura and lung (anterior interpleural view). Pleural reflex (1); B-line (2).

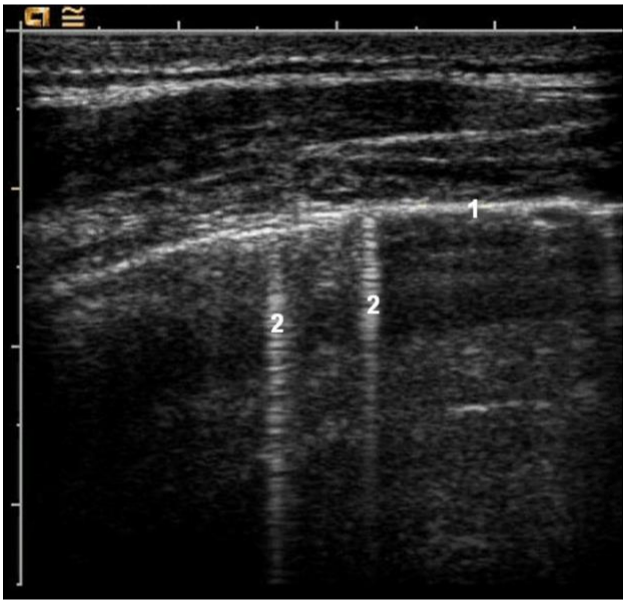
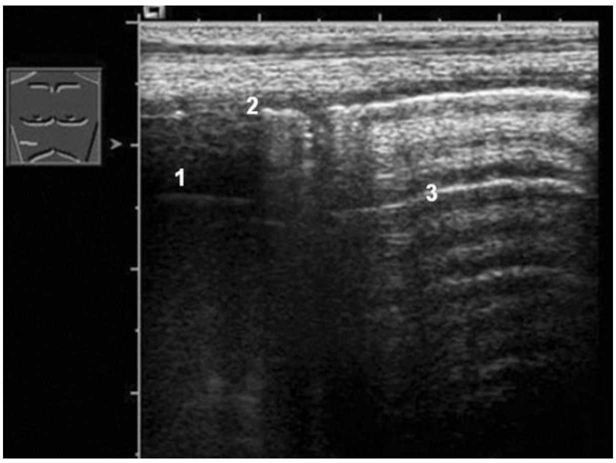


Figure 17 Lung point with a pneumothorax (anterior interpleural view). Normal lung (1); lung point (2); pneumothorax (3).



Pitfalls

Although E-FAST is easy to perform and is simple in terms of diagnostic sonography, ambiguous findings and the wrong interpretation of findings can lead to incorrect diagnoses. This section describes the most important pitfalls that lead to false-positive and false-negative findings.
Ovarian cysts, infiltration of bleeding into cystic ovaries and endometrial cysts can lead to misleading results.

False-negative findings

Peritoneal cavity

Small amounts of free fluid in the peritoneal cavity can be missed on ultrasound. Depending on the site and the position of the patient, estimates of missed fluid range between 30 ml and >600 ml. However, if all standard views are properly investigated the threshold to detect free fluid lies at about 200 ml [(9)]. If initially a small amount of blood is present and bleeding persists, the detection rate can be increased by repeating the investigation.
Organised blood in the peritoneal cavity is complex hyperechogenic and can be mistaken for intraperitoneal fat.

Pericardium

In cases where there has been penetrating trauma to the heart, it is possible that no pericardial effusion will be present as the blood can flow directly from the ruptured pericardium to the pleural space [(10)]. In these cases, if the patient's condition is unstable emergency thoracotomy is still indicated.

Haematothorax

Coagulated blood is complex hyperechoic and can be mistaken for lung consolidation.

Pneumothorax

Movements of the transducer can mimic the lung pulse sign. Artefacts caused by the presence of subcutaneous air may also be mistaken for lung sliding. Finally, the lung pulse may be confused with internal thoracic artery pulsation.

False-positive findings

Peritoneal cavity

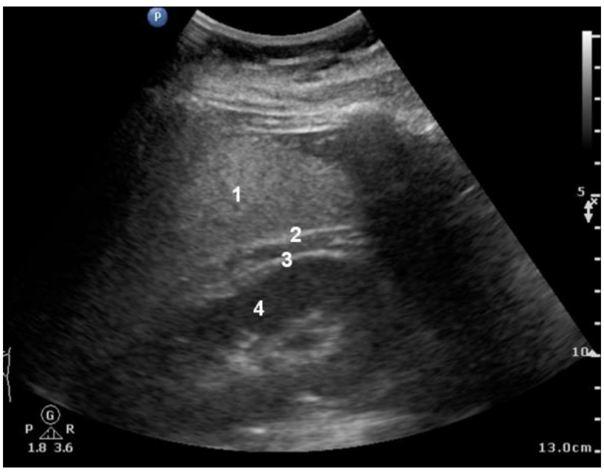
Ascites, urine and intestinal contents

Urine and leaked intestinal contents are difficult to distinguish from blood. With ascites, however, additional sonographic signs are usually found including cirrhosis of the liver, liver metastases, right heart failure or gallbladder pathology. If there is any doubt, this can be clarified by ultrasound guided needle aspiration.

Double-line sign

Echo-poor fat in Morison's pouch can mimic fluid. The 'double-line sign' is used to distinguish between the two [(11)] [Figure 18]). Fat has two echo-rich lines on either side, one along the liver and the other along the kidney. This echo-rich line directly along the liver is generally not present with free fluid in the hepatorenal recess [Figure 18].

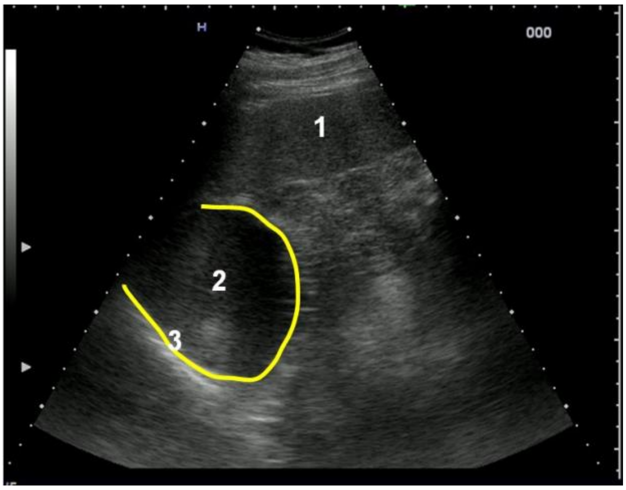
Figure 18 Double line sign in Morison's pouch (right upper quadrant). Liver (1); margin of the liver (2); margin of the kidney (3); kidney (4).



Gastric fluid sign

When examining the left upper quadrant of the abdomen, the operator needs to know how to differentiate between fluid in the stomach and free intraperitoneal fluid. Usually, free fluid collects either subphrenically or between the spleen and the kidney, resulting in an echo-poor band. Gastric contents are generally oval, surrounded by an echo-rich edge (stomach wall) and often contain food residue (light, floating internal echoes) [(12)] [Figure 19].

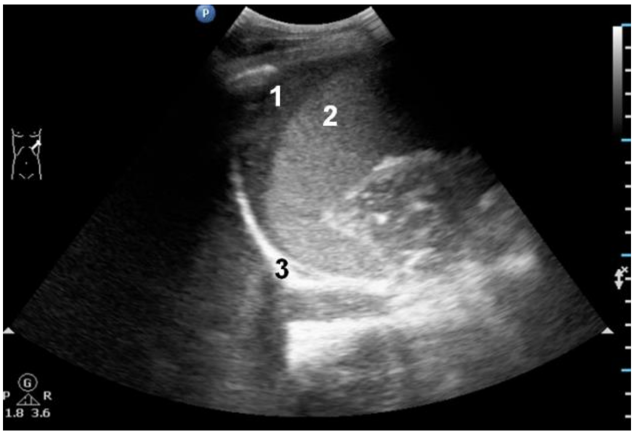
Figure 19 Gastric fluid sign (left upper quadrant). Lower pole of spleen (1); stomach contents (2); stomach wall (3).



Kissing liver

When examining the left upper quadrant of the abdomen, if the left lobe of the liver is touching the spleen, it can be somewhat echo-poorer than the spleen because of anisotropy and can be mistaken for free peritoneal fluid. To avoid this pitfall, the operator should amplify the gain so that liver tissue is easier to identify, position the probe anteriorly or turn on the colour Doppler to visualise the liver vessels [Figure 20].

Figure 20 Kissing liver (left upper quadrant). Liver (1); spleen (2); pleural reflex (3).

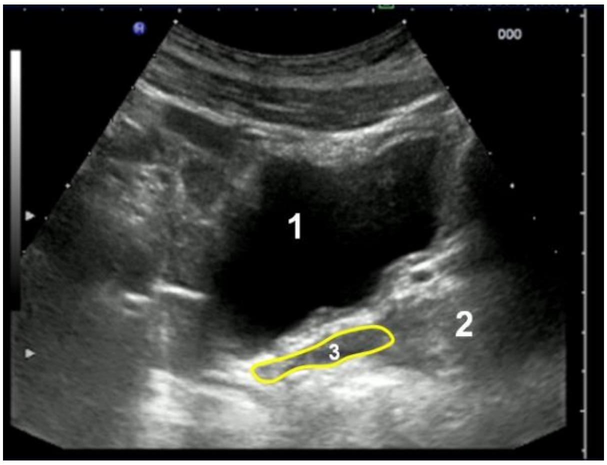


Seminal vesicle

In men, a large seminal vesicle can mimic fluid. However, free intraperitoneal fluid is never found besides or directly above the prostate gland, but more cranially and next to or above the bladder [Figures 21a,b].

Figure 21 Seminal vesicle (in suprapubic sagittal axis) (a). Bladder (1); prostate (2); seminal vesicle (3). Seminal vesicle (in suprapubic transverse axis) (b). Bladder (1); prostate (2); seminal vesicle (3).

a



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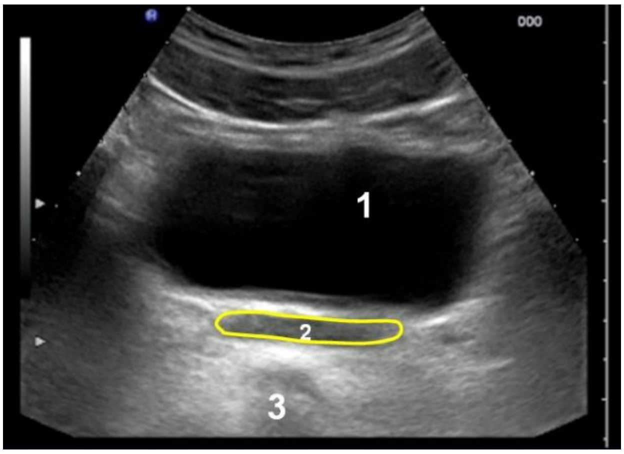
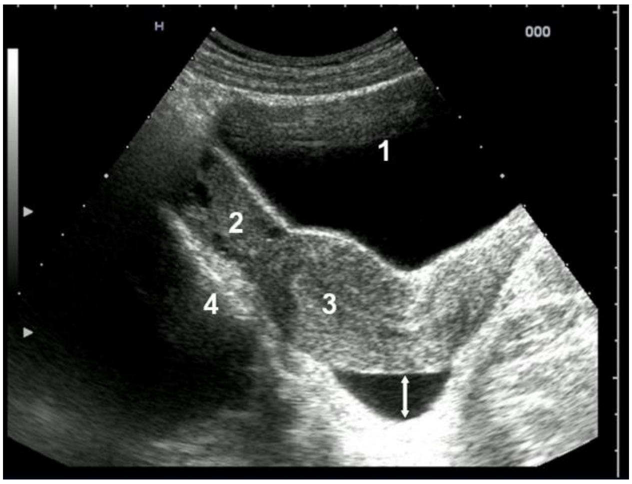


Independent of the menstrual cycle, free fluid in the pouch of Douglas can be normal and is seen in 30–40% of women of childbearing age. If the antero-posterior volume has a diameter of more than >3 cm, or there are internal echoes and/or the collection of fluid spreads above or beside the bladder, then this finding is pathological. Physiological fluid in women of childbearing age [(13)] [Figure 22].

Figure 22 Physiological fluid in the pouch of Douglas in (suprapubic sagittal axis). Bladder (1); ovary (2); uterus (3); intestine (4). ⇳ = Antero-posterior diameter 2.1 cm.



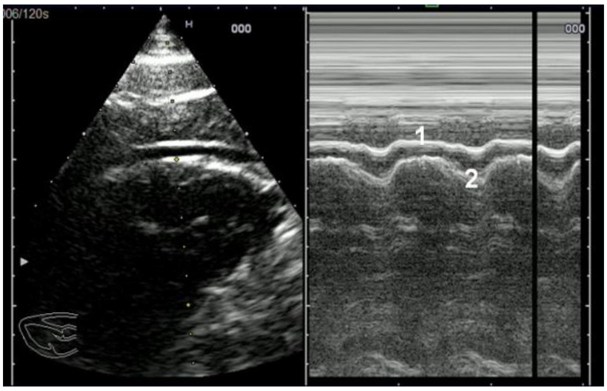
Pericardial space

Epicardial fat

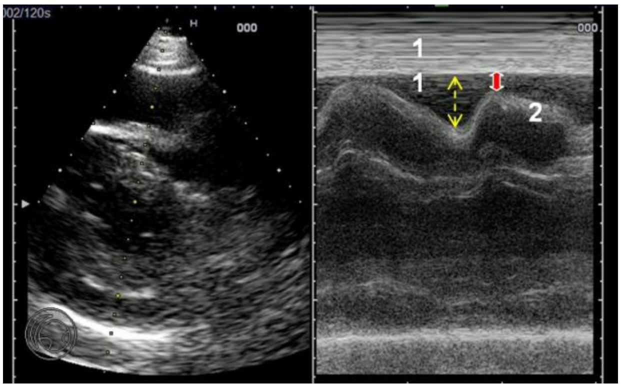
Echo-poor epicardial fat can be mistaken for a pericardial effusion. M-mode is used to distinguish between the two. Fat produces wave-like movement across the whole width of the band, whilst with fluid there is a decrease in diastole and an increase in systole. In addition, fat has a granular echotexture and occurs only above the right ventricle, i.e. it does not surround the whole heart [Figure 23a,b].

Figure 23 Epicardial fat (subcostal long-axis) (a). Parietal pericardium with parallel movement (to the right) (1); visceral pericardium (2). Pericardial effusion with collapsed right ventricle/signs of tamponade (subcostal short-axis) (b). The systolic (yellow arrow) and diastolic interval (red arrow) are also indicated.

a



b



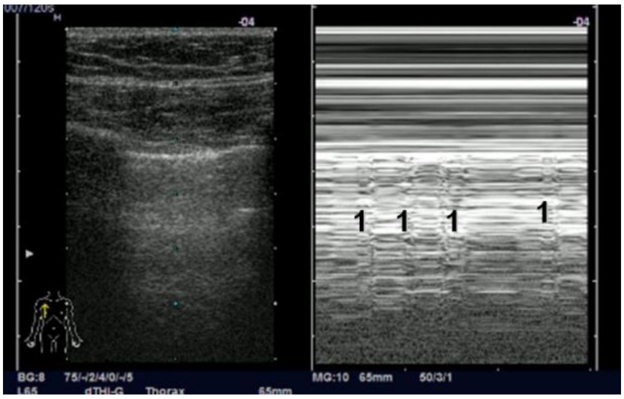
Pleural effusion

It is possible to misdiagnose intraperitoneal fluid with fluid above the diaphragm.

Pneumothorax

Lung sliding, B-lines and the lung pulse (transmission of cardiac pulsation via the pulmonary tissue to the pleura, visualised in M-mode) [Figure 24] or colour Doppler are convincing signs that a pneumothorax is not present. If they are absent, it is highly likely that a pneumothorax is present. Absence of lung sliding, i.e. the visceral and parietal pleura do not slide against each other, can be caused by bullous disease, pleural adhesions, pleurodesis, hyperinflation and endobronchial intubation. The lung pulse can also be missing in bullous lung disease, inflammatory pleural adhesions and following pleurodesis. On the other hand, absence of a lung-point can be a sign of a complete pneumothorax.

Figure 24 Lung pulse in M-mode (anterior longitudinal chest). Lung pulse (referred activity of the heart) (1).



Pearls and tips

Avoidance of false-negative findings

Serial scans in the presence of persistent bleeding

There is no international standard for this at present. We recommend a repeat scan if the haemodynamic state of the patient deteriorates or if findings are unclear or uncertain, and in all cases before discharge from the emergency room [(14)].

Patient positioning

The Trendelenburg position and the right lateral decubitus position significantly increase the detection rate of fluid in Morison's pouch.

More abdominal windows

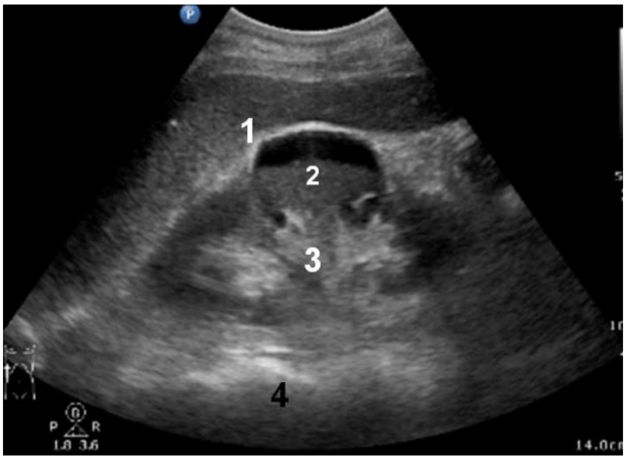
Although they are not part of the standard protocol, the left and right subphrenic views are the most sensitive way of detecting fluid in non-intubated patients. The sensitivity can also be increased by scanning the caudal edge of the liver, along the length of the left and right paracolic recesses and in between intestinal loops.

Perisplenic fluid cannot always be demonstrated in the Koller pouch, but sometimes occurs in the subcapsular or subphrenic regions or at the caudal pole.

Avoidance of false-positive findings

If positive findings are present in the abdomen, all standard views should be fully investigated. The operator should observe for pulsation and peristalsis in all investigations. Colour Doppler can be of assistance, which shows whether there is fluid in the stomach, intestines, gallbladder or great vessels. Renal cysts should be completely visualised and viewed in two planes [Figure 25]. When it is unclear whether the fluid seen is blood or an alternative such as ascites or urine, a simple ultrasound-guided aspiration can clarify the diagnosis.

Figure 25 Cortical cyst of the kidney in Morison pouch's (right upper quadrant). Liver (1); cyst (2); kidney (3); spine (4).

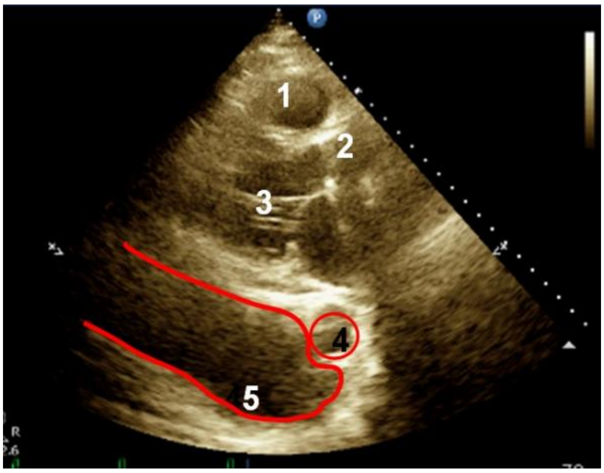


Differentiation between a pericardial effusion and a left-sided pleural effusion

The ideal position is the parasternal long-axis. Fluid between the atrium and the transversally imaged descending aorta is pathognomic of a pericardial effusion. If it spreads dorsally from the descending aorta, a pleural effusion is present [Figure 26a, b].

Figure 26 Differential diagnosis – pleural or pericardial effusion (parasternal long-axis view). Pleural effusion (a). Right ventricle (1); ascending aorta (2); left ventricle (3); transverse descending aorta (4); pleural effusion dorsal to the aorta (5). Pericardial effusion (b). Anterior pericardial effusion (1); right ventricle (2); ascending aorta (3); left ventricle (4); posterior pericardial effusion ventral to the descending aorta (5); transverse descending aorta (6).

a



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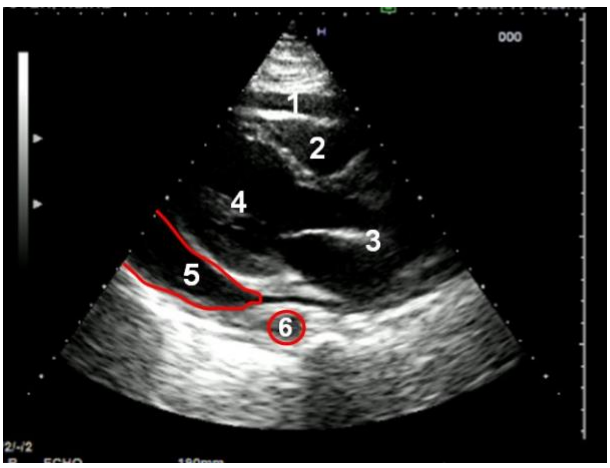


Differentiation between haemoperitoneum and haemothorax

If the diaphragm is visualised (echo-poor band edged with an upper and lower echo-rich border), the patient has a haemothorax. If all that can be visualised is an echo-rich reflex, the fluid is intraperitoneal.

Pneumothorax

The operator should not feel restricted to using visualisation of lung sliding to confirm or reject the presence of a pneumothorax. The additional criteria of the lung pulse and lung point considerably increase reliability.

The sonographic diagnosis of a pneumothorax must always be followed by a chest x-ray or a CT scan in order to confirm and quantify the findings. A small pneumothorax does not always need drainage but does need monitoring. The only exception for immediate decompression without imaging is when a tension pneumothorax is present.

Technique

The spleen and splenorenal recess often lie very dorsally and cannot be accessed ventrally.

An alternative to the subcostal view for visualisation of the heart is the parasternal long-axis view. Parts of the investigation may be difficult in obese patients and those with large amounts of bowel gas. In such cases, attempts should be made to expel the intestinal gas or use non-standard views for visualisation. An empty bladder impairs investigation of the lower abdomen. Gas in the intestine may impair visualisation of the target structures.

Clinical applications

Objectives and indications

Case history and clinical assessment do not provide reliable results for the diagnosis of intraperitoneal and intrathoracic injuries. We are therefore reliant on diagnostic investigations. In such cases, because the attending physician is ‘blind’, it would be helpful for them to have a look inside the torso. This can be done with ultrasound, although it does have limitations. Unlike CT, the aim of E-FAST is not to identify specific lesions and sources of bleeding, but rather to identify signs of bleeding and injuries to internal organs, i.e. fluid (blood) in the peritoneal cavity and pleural and pericardial spaces. It is not possible to distinguish between blood and other fluids with ultrasound, therefore the following principle applies: fluid is blood until proven otherwise.

When diagnosing a pneumothorax, the absence of normal findings (no lung sliding, no B-lines and no lung pulse) is only an indirect sign for the presence of a pneumothorax. The lung point is a positive sign and is rarely false positive.

In summary, E-FAST does not claim to be able to detect all internal injuries in the region of the torso, especially if they are small. The aim of the investigation is to identify immediately life-threatening intraperitoneal and/or intrathoracic bleeding and pneumothoraces that require surgical treatment, in the context of the accompanying clinical findings. The ultrasound investigation is performed to support the physician in deciding whether to perform an emergency laparotomy or thoracotomy. What makes it all the more important to have this supporting information is that at present, patients with intraabdominal and intrathoracic injuries rarely undergo surgery and are generally treated conservatively. However, if the right time for surgical haemostasis is missed the outcome may be fatal. E-FAST also assists in deciding whether to perform pleural or pericardial drainage, whether to pass from the primary to the secondary survey and whether abdominal or thoracic CT is indicated [Table 2].

However, E-FAST is only indicated if it is expected to have a significant effect on further management. This means that E-FAST should not be performed in patients in which it is clear that urgent surgery is required unless it is expected to provide essential additional information. Table 4 summarises the indications.

Table 4 Indications for E-FAST.

Indications:
➢ Trauma patients with: • Shock

- Dyspnoea/hypoxia
- Pain or clinical findings in the chest and/or abdomen
- Decreased Glasgow Coma Score/requiring intubation
- High ventilation pressure
- Suspected internal injuries

➢ Postoperative after (trauma) surgery
➢ Shock of unclear origin
➢ Women of childbearing age with acute lower abdominal pain
➢ During and after cardiopulmonary resuscitation

Interpretation

Positive E-FAST

E-FAST is used to visualise small amounts of free intraperitoneal, intrapleural and intrapericardial fluid. It is not intended to detect the type of fluid (in cases of doubt, aspiration under ultrasound guidance must always be performed) or the source of bleeding. The interpretation and the practical conclusions drawn from the E-FAST findings are only valid in the context of all accompanying clinical findings. They can assist the physician in answering five clinically important questions which will help in making decisions regarding further diagnostic steps and management decisions:

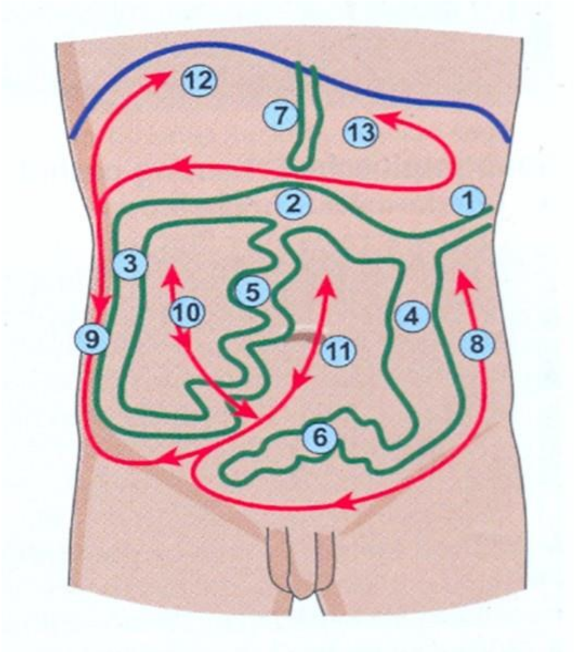
1. Is the fluid blood and if so, is it indirect evidence of organ injury?
2. Is immediate surgical haemostasis necessary, can the patient wait or is a CT scan needed?
3. If surgery is necessary, what should be opened first, the abdomen or the chest?
4. In cases of haemopericardium, is temporary drainage indicated (i.e. to buy some time) or would this lead to delays in performing necessary definitive management such as pericardiotomy?
5. Is a chest X-ray or CT needed in order to decide on whether intervention is needed in the management of a pneumothorax or haemothorax?

Negative E-FAST

A negative E-FAST does not exclude the presence of intraabdominal or intrathoracic injuries. A negative E-FAST also does not rule out the presence of retroperitoneal or mediastinal injuries. Patients with a moderate to high likelihood of torso injury should therefore undergo repeated E-FAST examinations, CEUS or a CT scan. Unfortunately there is no scoring system to objectively assess the probability of injury in an individual. This assessment depends entirely on the clinical experience of the treating physician.

To be able to interpret the presence of fluid in the peritoneal cavity, an awareness of the anatomy and pathophysiology of this region is necessary [Figure 27] [(9)]. The mesenteric folds divide the peritoneal cavity into the supramesocolic and inframesocolic spaces. The inframesocolic space is divided into a right and left inframesocolic and paracolic space plus the pouch of Douglas in women and the rectovesical pouch in men. The supramesocolic space, above the transverse colon, is connected to the inframesocolic space via the right paracolic recess. On the left side, this connection is usually prevented by the phrenicocolic ligament. The falciform ligament separates the supramesocolic space into two chambers. Fluid can only circulate along the caudal margin of the falciform ligament.

Figure 27 Anatomy of the peritoneal cavity. Intraperitoneal anatomy and flow: phrenicocolic ligament (1); transverse mesocolon (2); ascending mesocolon (3); descending mesocolon (4); root of mesentery (5); sigmoid mesocolon (6); falciform ligament (7); left paracolic space (8); right paracolic space (9); right infracolic space (10); left infracolic space (11); right supracolic space (12); left supracolic space (13). (Strunk H. Klinikleitfaden Sonographie Common Trunk. Urban & Fischer. With kind permission of the Publisher).



The lowest points of the peritoneal cavity are Morison's pouch and the pouch of Douglas in women and the rectovesical pouch in men. The distribution of intraperitoneal fluid depends, however, not only on anatomy, gravity and site of a lesion, but also on respiration, which has a major influence on the intraperitoneal pressure gradient and the distribution of fluid. For example, spontaneous breathing creates a pressure gradient in the direction of the subphrenic space as a result of inspiratory expansion of the thorax. These physiological conditions mean that fluid is most often found subphrenically and there even in very small quantities. The pressure gradient runs in the opposite direction in the intubated patient, i.e. in the direction of Morison's pouch and the lesser pelvis.

A knowledge of the peritoneal anatomy and pathophysiology helps when searching for very small amounts of blood. The most likely sites are the right anterior subphrenic region and the pelvic region [(15)]. The site where the blood collects may provide some indication of the source of bleeding.

Diagnostic-therapeutic algorithm

The procedure is divided into three algorithms [Figures 28 and 29] based on the questions sonography is performed to answer.

Figure 28 FAST Algorithm – blunt trauma (modified after Jehle D. ACEP 2001).

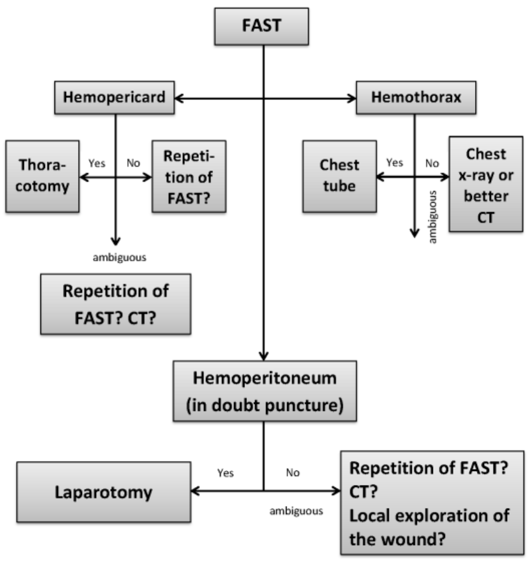
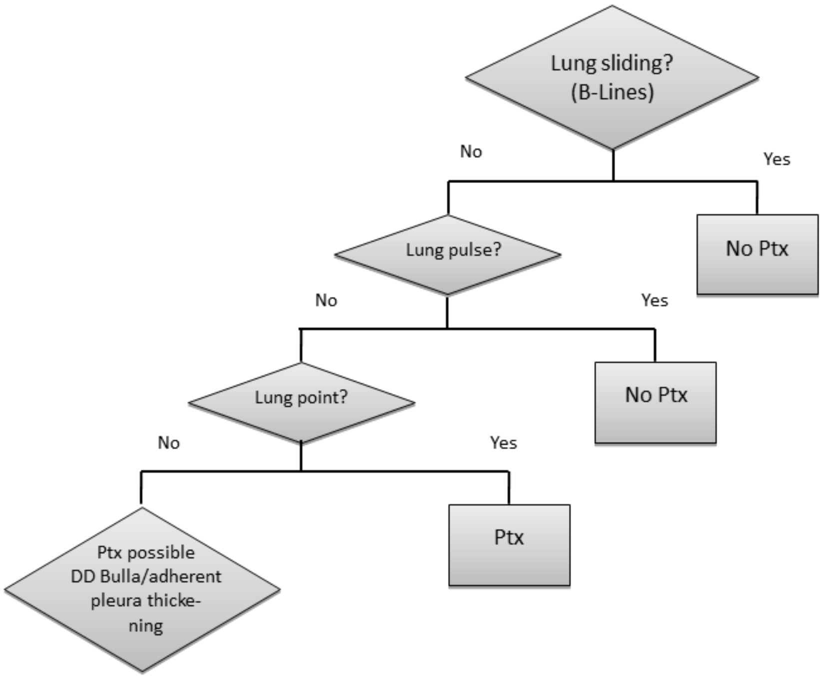


Figure 29 E-FAST Component. Ptx = Pneumothorax.



Evidence

The evidence supporting the use of E-FAST or FAST is summarised in the next three sections [(16)].

Abdominal FAST

In the literature, the sensitivity for detecting the presence of intraabdominal injuries is between 63 and 99% and the specificity is between 88 and 93% [(9)]. This wide variability is due to differences in study design, ultrasound protocols, outcomes measured (fluid, injuries to organs, laparotomy etc.), gold standards (surgery, CT, clinical course etc.), training and experience of the operator, quality of clinical examinations and whether the E-FAST was repeated.

Only a few studies have evaluated the true objectives of abdominal E-FAST. Its main objectives are to help the physician with two decisions: (1) does the patient need immediate lifesaving surgery and (2) does the patient need further imaging with a CT scan or serial ultrasounds. This is also the reason why a much quoted meta-analysis [(17)] and a Cochrane review [(18)] led to conclusions that are of no benefit in everyday clinical practice. The objectives of these studies are of little relevance to the practising physician. For example, the meta-analysis claims that abdominal FAST is unable to rule out intraabdominal injuries with adequate certainty. The Cochrane review claims that there is no evidence for the use of ultrasound based clinical investigations in patients with suspected blunt abdominal trauma. Both papers, by the same group of authors, miss the point which is that currently abdominal injuries are generally treated conservatively, the primary survey in an emergency is not the time to be looking for tiny amounts of fluid or small and even trivial injuries. What the practical physician wishes to know is whether emergency surgery is necessary because even the slightest delay increases mortality [(19)]. Two papers published by Melniker show that this objective can be achieved with abdominal FAST [(20, 21)].

Pleural and pericardial FAST

The pleural FAST is superior to chest X-ray in detecting pathologies with a sensitivity of 41–94% and a specificity of 94–100% versus 33–75% respectively 94–99% [(22, 23)]. Only a few papers have been published on FAST and the detection of haemopericardium. They report sensitivities of 56–100% and specificities of 87–100% [(22)]. The low sensitivity of 56% is due to the fact that, with additional pericardial lesions, blood from myocardial injury leaks into the pleural space.

E-FAST

Ultrasound has a sensitivity of 68.1–91.8% and a specificity of 97–99.5% for the detection of pneumothoraces. This is greatly superior to that of chest X-ray with 29.4–55 % respectively 98.4–100% in the supine patient [(23)]. As a result of this high detection rate, even occult pneumothoraces can be discovered, the clinical significance and consequences of which are often unclear.

Essentials and tips

The E-FAST examination is part of the primary ATLS survey and plays a major role in triage and in the diagnosis and management of trauma patients [(24)]. Although the abdominal FAST exam is commonly used and has acceptable sensitivity for the detection of free intraperitoneal fluid, it has poor sensitivity for the diagnosis of injury to solid organs and gastrointestinal injuries and underestimates the severity of solid organ injuries [(25)]. This makes it especially challenging in cases of negative FAST scans. It raises the question: what is the value of a negative FAST? Given these problems, it is recommended to use the FAST scan for a quick overview, a 'first look', not for a definite diagnosis [(25)] and to try to expand its application to examine additional views, the retroperitoneum and to search for free intraperitoneal air.

Adult abdominal FAST

- The abdominal FAST has a reasonable sensitivity to detect free intraperitoneal fluid (69–98%) [(26)], but it may underestimate injuries and their severity, especially in stable adult patients without detectable free fluid [(25)]. The practitioner should also be aware that the false negative rate seems to be higher in patients with Injury Severitiy Score (ISS) > 25 [(27)], in patients with severe head injury and minor abdominal injuries [(30)], haematuria, lower rib fractures, lumbar spine and pelvic fractures [(28)] and in penetrating trauma.

- In cases of a negative FAST scan and where there is no urgency to perform a CT scan, the inclusion of additional sonographic views (subphrenic, caudal edge of liver, paracolic gutter, between intestinal loops) and the repetition of FAST can increase the sensitivity.
- FAST has a high specificity in identifying free fluid (94–100%) [(26)]. This can be increased by ultrasound-guided aspiration.
- The detection of solid organ injury is neither sensitive nor specific and the sensitivity for gastrointestinal injury is very low, but can be increased by performing serial scans within 12–24 hours [(24)].
- The reported sensitivity in penetrating abdominal trauma is highly variable, but specificity is high [(24)].

Positive FAST

- A patient with persistent haemodynamic instability despite adequate volume replacement and treatment of coagulopathy requires immediate intervention.
- Semi-stable and stable patients should undergo a CT scan and in selected cases CEUS for better definition of the injury.

Negative FAST

A negative FAST scan has the potential for an unacceptable false negative rate.

- A CT scan is indicated for patients with severe head injuries (ISS>25), symptomatic abdominal trauma, haematuria, lower rib fractures, lumbar spine and pelvic fractures and penetrating trauma (the alternative is wound exploration).
- In all other stable patients with a low probability of intraabdominal injury a CT scan is not necessary.
- Patients with moderate to high likelihood for trauma injury should undergo serial FAST examinations, CEUS or a CT scan. For advanced sonographers, obtaining additional views, examining the retroperitoneum and searching for free intraperitoneal air during the secondary survey could increase the accuracy. Proof of this concept has not yet been obtained.

Paediatric abdominal FAST

- The sensitivity for the abdominal FAST (free fluid caused by injury) is 50–81% and the specificity is 95–97% [(29)].
- Approximately 26–34% of children with intraabdominal injuries present without a haemoperitoneum [(29)].

Positive FAST

- A child with persistent haemodynamic instability despite adequate volume replacement and treatment of coagulopathy requires immediate intervention.
- Semi-stable and stable patients should undergo serial examinations, CEUS or CT scan for better definition of the injury. CT scan increases the detection of retroperitoneal and gastrointestinal injuries. The risks of abdominal CT including radiation exposure, contrast administration and the need for sedation [(29)] must be taken into consideration.

Negative FAST

- A negative FAST scan cannot reliably rule out the presence of an intraabdominal injury.
- In stable patients with a low probability of intraabdominal injury a CT scan is not indicated.
- Patients with a moderate to high probability of intraabdominal injury should undergo serial FAST examinations, CEUS or a CT scan. As mentioned above, additional views, an examination of the retroperitoneum and searching for free intraperitoneal air have the potential to decrease the false negative rate.

Haemothorax

- Lung ultrasound is superior to chest x-ray in detecting haemothoraces.
- In our opinion, the wide variability in operator accuracy depends mainly on degree of training.

- Inadequate training is often responsible for three common pitfalls: the examiner does not search for the spine sign, does not apply criteria to identify the diaphragm and clotted blood is mistaken for lung consolidation.
- The diagnostic performance can be significantly improved when the operator looks carefully for the presence of the four sonographic signs of pleural effusions.

Haemopericardium

- Patients with pericardial effusions and penetrating trauma need surgical exploration.
- Patients with pericardial effusions and blunt trauma need a CT scan and formal transthoracic or preferably transoesophageal echocardiography.
- Cardiac trauma such as myocardial wall, coronary artery, valve and thoracic aorta injury are not always associated with a pericardial effusion. As a consequence, the absence of a pericardial effusion cannot exclude cardiac injury.
- In patient that have sustained penetrating trauma presenting without a pericardial effusion but with a left sided haemothorax, cardiac surgery still needs to be considered. If a gross lesion is present in the pericardium, it may have a connection to the left pleural cavity and the effusion will drain into it.
- In patients where there is a high suspicion of cardiac injury despite the absence of a pericardial effusion, a CT scan as well as formal transthoracic or preferably transoesophageal echocardiography should be performed.

Pneumothorax

- The patient should always be examined in supine position.
- Presence of either lung sliding, B-lines or lung pulse exclude a pneumothorax and the presence of a lung point reliably confirms the presence of an incomplete pneumothorax.
- A negative scan rarely needs confirmation with a chest x-ray. To try to avoid false-negative results, the whole antero-lateral chest needs to be examined systematically and caution taken not to misinterpret short vertical artefacts as B-lines
- In stable patients the entire antero-lateral chest should be scanned. A positive exam will always be followed by chest x-ray or CT scan to confirm and quantify the pneumothorax. In unstable patients only check the most superior area of the chest and in the absence of

lung sliding, B-lines and lung pulse proceed immediately to decompression without performing chest x-ray or CT scan.

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