

College of Emergency Medicine of South Africa
Use of Bedside Emergency Ultrasound in South African Emergency Departments
Part 2 – Emergency Ultrasound Resource Document

A provisional policy statement by the Emergency Ultrasound Subcommittee of the College of Emergency
Medicine of South Africa

The authors of this document consist of the following members of the subcommittee:

Mike Wells BSc(Med).Hons, MBBCh, Dip PEC(SA)¹

Stevan Bruijns MBChB, Dip PEC(SA), MPhil²

1. Division of Emergency Medicine, University of the Witwatersrand
2. Joint division of Emergency Medicine, Universities of Stellenbosch and Cape Town

Corresponding Author:

Dr M Wells

+27 11 724 2113/ +27 82 491 0369

mike@casualty.co.za

PO Box 773, Glenvista, Johannesburg, South Africa 2058



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Acknowledgements:

The Emergency Ultrasound Subcommittee would like to acknowledge:

The College of Emergency Medicine of South Africa for providing the infrastructure to produce and publish this document.

The American College of Emergency Physicians (ACEP)¹, the Australasian College for Emergency Medicine (ACEM)² and the College of Emergency Medicine of the United Kingdom for their kind permission to use their emergency ultrasound policy documents as reference in order to produce this document. This resource document has been adapted and modified, in parts, from their policy documents. As a result this document does not necessarily reflect the views of these organisations.



Glossary:

AAA, Abdominal aortic aneurism

AHA, American Heart Association

CEM(SA), College of Emergency Medicine of South Africa

CPR, Cardiopulmonary resuscitation

CVC, Central venous catheter

DVT, Deep venous thrombosis

ED, Emergency department

EFAST, Extended Focused Assessment by Sonography in Trauma

ERC, European Resuscitation Council

EUS, Emergency ultrasound

ILCOR, International Liaison Committee on Resuscitation

PEA, Pulseless electrical activity

Rocking, Angling probe parallel to the scan plane

Sliding, Gliding probe over skin, also called skiing

SMA, Superior mesenteric artery

Tilting, Angling probe perpendicular to the scan plane, also called fanning

Introduction

The CEM(SA) has developed this document to assist clinicians in the use of EUS in the ED. This is not an exhaustive text on the various applications of EUS, but is meant to guide the emergency physician by providing core knowledge, insights and resources for the successful integration of EUS into the clinical management strategies of critically ill or injured adults and children presenting to the ED. It also contains a bibliography of the most recent literature relevant to the use of EUS in the ED.

General Principles

1. EUS should never interfere with the emergency management of a patient by delaying resuscitative treatment. When performed during cardiac arrest, minimise interruptions in chest compressions and provide high quality cardiopulmonary resuscitation (CPR).
2. EUS does not replace good clinical judgement – it is a tool to be used by the clinician as part of the management plan. The interpretation of the findings is determined by the insight and experience of the provider.
3. EUS is not a substitute for formal ultrasound examinations performed by radiologists, but a limited, goal-directed examination to answer a binary question (yes/no) to assist in the management of an unstable patient.
4. EUS must be used to answer a binary question (yes/no). For example, when scanning the abdomen, asking “*What intra-abdominal injury is present?*” is not the correct question. EUS cannot exclude any form of intra-abdominal injury and the assumption that a negative abdominal scan excludes intra-abdominal injury might lead to patient harm. The correct question would be, “*Is there free fluid in the abdomen?*”
5. Indeterminate scans and suboptimal images are common and over-interpretation thereof is discouraged. Unless good images are obtained, the findings of the scan should not be included in the decision-making process.
6. Serial scans are encouraged: EUS is non-invasive and further scans might add additional information.
7. Involve other specialities early – unstable trauma patients will need an urgent trauma surgical consultation; or may require a formal ultrasound by a radiologist in the ED.
8. Where indicated, infection control policies should be adhered to.



Training

It has been clearly shown that emergency physicians can acquire the skills to accurately and efficiently perform various emergency ultrasound techniques.⁴⁻²⁴ The CEM(SA) has, similar to the systems used in the United Kingdom and Australasia, elected to adopt a system of credentialing that requires the candidate to:

1. Successfully complete an online quiz,
2. Attend an accredited training course,
3. Perform a total of 65 logged scans and
4. Pass a formal assessment.

There is sufficient evidence to suggest that this system is an effective method for clinicians to achieve and demonstrate competency in basic EUS.

Extended Focused Assessment by Sonography in Trauma (EFAST)^{15, 22, 25-143}

1. Overview

The EFAST (or trauma ultrasound) is used to evaluate the peritoneal, pericardial or pleural spaces in anatomically dependent areas by combining several separate focused ultrasound examinations of the chest, heart, abdomen and pelvis. The examination also includes an assessment of the anterior aspect of the chest for the detection of pneumothorax. The primary indication for this application is to identify pathologic free fluid as a result of injured organs or structures. EFAST is performed at the bedside to assess for haemopericardium, haemothorax, haemoperitoneum or other abnormal fluids such as urine or bile. Free fluid is regarded as a marker of injury and not the injury itself. Since certain important traumatic conditions such as hollow viscus injury, mesenteric vascular injury, and diaphragmatic rupture may cause minimal haemorrhage, it can easily be overlooked by EUS. Also, EUS can not differentiate between different types of pathological fluid such as urine and blood. These characteristics of EUS have implications for management of patients in whom these injuries are a consideration. The EUS is performed as an integral component of trauma resuscitation. Other diagnostic or therapeutic interventions may take precedence or may proceed simultaneously with the EUS evaluation. It is a clinically focused examination, which, in conjunction with historical and laboratory information, provides additional data for decision-making. It attempts to answer specific questions about a particular patient's condition. Where other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses; EUS is non-invasive, can be rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialised technical personnel and the risk in administration of contrast agents and radiation. EUS exams can be repeated as frequently as is clinically indicated. These advantages make it a valuable addition to diagnostic resources available in the care of patients with the time-sensitive and/or emergent conditions associated with torso trauma.

In addition, EUS is suitable for use in major incidents where it can be used to rapidly triage multiple victims. It can be performed with portable equipment on a patient with spinal immobilisation. It is also useful in remote or difficult clinical situations such as aeromedical transport, wilderness rescue,

expeditions and battlefield settings. EUS can also be utilised to demonstrate free fluid such as ascites, pleural and pericardial effusions from a non-traumatic origin and even spontaneous pneumothorax. Although this may be helpful in practice, this document is concerned only with the use of EUS in so far as rendering time-critical intervention.

2. Indications

EFAST is indicated to rapidly evaluate the torso for evidence of free fluid in the peritoneal, pericardial, and pleural cavities suggestive of injury and to assess for the presence of pneumothorax. Figure 1 gives guidance on EUS and its role in advanced trauma life support. Depending on local resources and policies this algorithm may require amendment in order to meet the local needs.

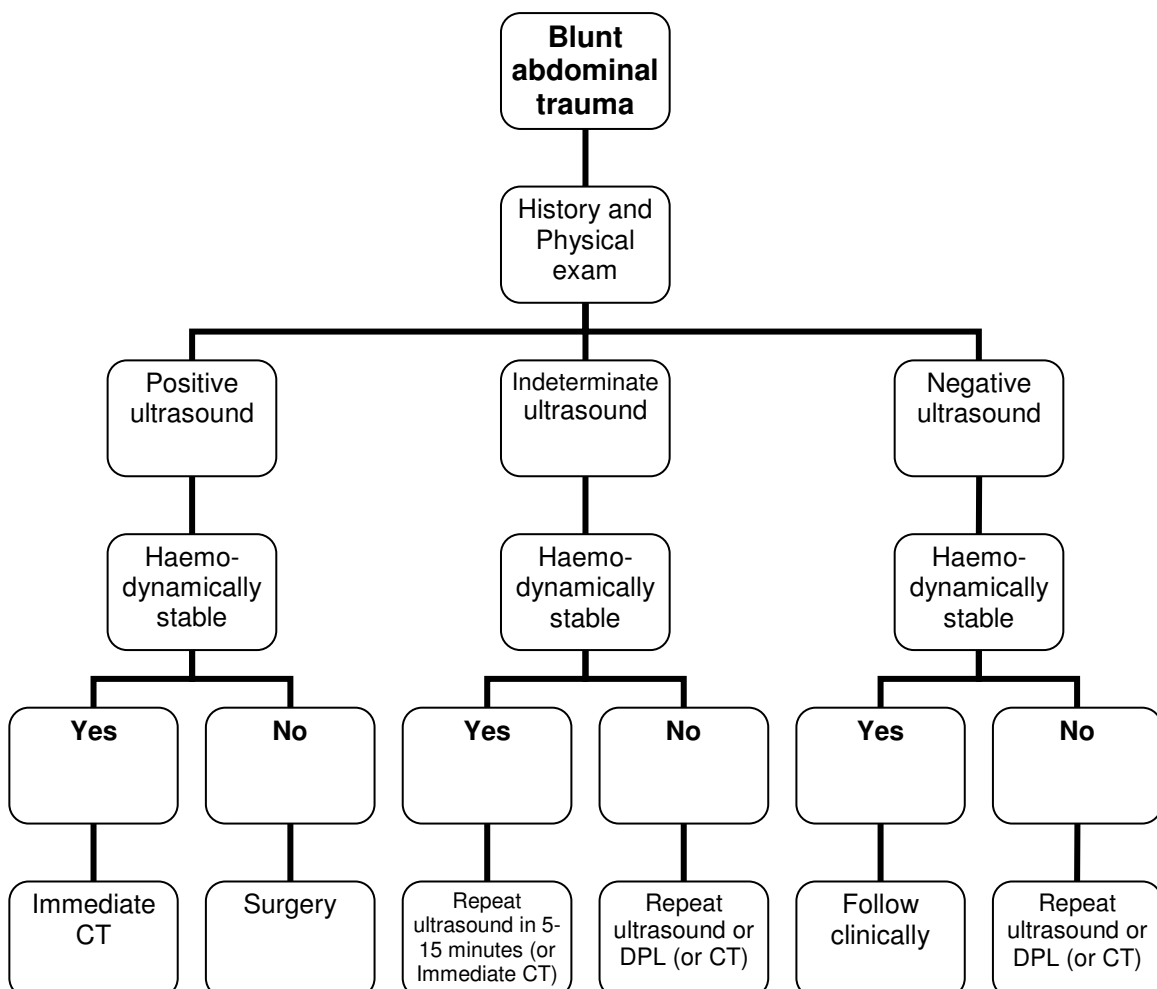


Figure 1. EUS and its role in advanced trauma life support

There are no absolute contraindications to EUS in trauma. There may be relative contraindications based on specific features of the patient's clinical situation, e.g. extensive abdominal or chest wall trauma. The need for immediate laparotomy is often considered a contraindication to the EFAST; however, even in this circumstance, EUS evaluation for pericardial tamponade or pneumothorax may be indicated prior to transfer to the operating room.

3. Limitations

EFAST is a single component of the overall resuscitation attempt. Since it is a focused examination, EUS does not profess to identify all abnormalities or injuries resulting from trauma to the torso. EUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. If the findings of the EUS are equivocal, additional diagnostic testing may be indicated. EUS in trauma may be technically limited by bowel gas, obesity, and subcutaneous emphysema. Trauma EUS is likely to be less accurate in paediatric patients, patients with other reasons for free fluid such as prior diagnostic peritoneal lavage, ascites, ruptured ovarian cyst, or pelvic inflammatory processes.

4. Pitfalls

- When bowel gas or other technical factors prevent a complete or adequate exam, these limitations should be identified and documented. This may mandate further evaluation by alternative methods.
- Most studies show that peritoneal free fluid is not identified by EUS until at least 500 ml is present. Thus, a negative exam does not preclude early or slowly bleeding injuries. Some injuries may not give rise to free fluid and may therefore easily be missed by EFAST. These include contained solid organ injuries, mesenteric vascular injuries, hollow viscus injuries, and diaphragmatic injuries. As patients are likely to be stable, serial EUS or alternative methods could be deployed.
- Non-traumatic fluid collections such as ascites or pleural and pericardial effusions may be mistakenly ascribed to trauma. A comprehensive history with associated clinical findings, as well as the sonographic features of the free fluid, may suggest such conditions.

- EFAST does not specifically identify most solid organ injuries and does not identify retroperitoneal haemorrhage.
- A negative trauma EUS is not accurate in excluding intra-abdominal injury after isolated penetrating trauma.
- Blood clots form rapidly in the peritoneum. Clotted blood has sonographic qualities similar to soft tissue and may thus be overlooked.
- Perinephric fat may be mistaken for haemoperitoneum.
- Fluid in the stomach, bowel, gallbladder or seminal vesicles may be mistaken for haemoperitoneum.
- A small haemothorax may be missed in the supine patient.
- Epicardial fat pads, pericardial cysts, and the descending aorta can be mistaken for free fluid in the evaluation of the pericardium.
- Patients with peritoneal or pleural adhesions with significant haemorrhage may not develop free fluid in the normal locations.
- In the suprapubic view, posterior acoustic enhancement caused by the bladder can result in pelvic free fluid being overlooked. Gain settings should be adjusted accordingly.

5. Qualifications and responsibilities of clinicians using EUS

Information provided through an EFAST form the basis of immediate decisions about further evaluation, management, and therapeutic interventions and is therefore ideally performed by the emergency physician. That said clinicians of a variety of medical specialties may perform the EFAST examination if they have been appropriately credentialed (for example surgeons and physicians).

Due to the time-critical and dynamic nature of traumatic injury, emergent interventions may be mandated by the diagnostic findings of EUS examination. For this reason, EFAST should be performed as soon as possible (usually minutes) following the decision that the patient needs a sonographic evaluation.. The clinician performing the EFAST is ultimately responsible for the decisions influenced by the said clinician's interpretation of the EUS.

6. Specifications for performance and interpretation

EFAST is performed simultaneously with other aspects of resuscitation. The transducer is placed systematically in each of 6 general regions with known windows to the peritoneum, pericardium and pleural spaces for detection of fluid, pneumothorax and other sonographic abnormalities. The precise location of these regions varies slightly between patients and is used as a means to identify the potential spaces where pathological collections of free fluid are known to collect. The transducer is placed in each of the regions consecutively and then tilted, rocked, slid and rotated to optimise the image of the relevant structures. The ultrasound images obtained are interpreted in real-time as the exam is being performed.

The EFAST examination evaluates 4 general regions or views for free fluid and 2 views for assessment for pneumothorax. The order in which the regions are examined may be determined by clinical factors such as the mechanism of injury or external evidence of trauma. Since best evidence have shown that the single most likely site for free fluid to be identified is the right upper quadrant, many practitioners start with this view, and then progress in a clockwise rotation through the subxiphoid, left upper quadrant, and suprapubic views. As with other EUS, the potential spaces being examined should be scanned methodically in real-time through all tissue planes. If possible, they should be evaluated in at least two orthogonal directions. Identification of the potential spaces in a single still image or plane is likely to result in early injuries, or those with small volumes of free fluid, being overlooked. Serial EFAST scans may be performed in response to changes in the patient's condition, to check for the development of previously undetectable volumes of free fluid or for purposes of ongoing monitoring, as indicated clinically.

- Right upper quadrant view (right flank, perihepatic or Morison's pouch view):

Four potential spaces for the accumulation of free fluid are examined in this region: the pleural space, the subphrenic space, the hepatorenal space (Morison's pouch), and the inferior pole of the kidney, which is a continuation of the right paracolic gutter. In this region, the liver usually provides a sonographic window for all four potential spaces. If the liver margin is sufficiently low, the probe can be placed in a subcostal location in the mid-axillary line. Cooperative patients may facilitate this by being asked to "take a deep breath and hold" while the four potential spaces are examined. In the majority of patients the liver does not afford an adequate window with a subcostal probe position, so

an intercostal approach is necessary. The probe should be positioned in a location between the mid-axillary and posterior axillary lines with the probe indicator orientated superiorly. If a clear image is not obtained it may be necessary to place the transducer in an intercostal space in order to minimise rib shadowing, with the plane of the probe parallel to the ribs. This plane is about 45 degrees counter-clockwise from the long axis of the patient's body. The probe indicator, by convention, is always directed toward the head (the vertebral end) of the rib. By rocking the probe superiorly, the subhepatic space and the right pleural space may be visualised for fluid. Abnormal fluid collections in the pleural space are visualised as anechoic or hypoechoic collections above the diaphragm. Rocking inferiorly allows visualisation of Morison's pouch and may show the inferior pole of the right kidney. In many patients, bowel gas is interposed between the liver and the inferior pole of the kidney, necessitating a more posterior approach to visualise this space. Gain settings should be adjusted so that the diaphragm and renal sinus fat appear white, and known hypoechoic structures (such as the inferior vena cava, gallbladder, or renal vein) appear black. Trendelenberg position may increase the sensitivity of the ultrasound exam for abnormal fluid in the right upper quadrant.

- The pericardial view (subcostal or subxiphoid view):

To examine the pericardium, the left lobe of the liver in the epigastric region is most commonly used as a sonographic window to the heart. The heart lies immediately behind the sternum, so that it is necessary, in a supine patient, to direct the probe in a direction toward the left shoulder that is almost parallel with the horizontal plane of the stretcher. This requires firm downward pressure, especially in patients with a protuberant abdomen, in order to obtain a view posterior to the sternum ("under" the sternum) in the supine patient. Both sagittal and transverse planes may be used. The transverse plane is easier to use, especially in obese patients, since it requires less compression of the abdominal wall to obtain adequate views. The potential space of the pericardial sac is examined for fluid both inferiorly (between the diaphragmatic surface and the inferior myocardium), and posteriorly. In some patients, a subxiphoid view is not possible due to anterior abdominal trauma, or body habitus. In this case, other routinely used cardiac windows such as the parasternal long and short axis views may be used. The parasternal views are typically obtained using the third, fourth, and fifth intercostal spaces, immediately to the left of the patient's sternum. For the parasternal long

axis view the probe marker is directed to the patient's left hip (approximately 4-o'clock). In this view the aortic outflow and left atrium will be on the right side of the screen as it is viewed and the cardiac apex will be on the left side of the screen. Alternately, the probe may be directed to the patient's right shoulder (approximately 10-o'clock). This will provide a view that is reversed 180 degrees from that seen in cardiology texts, but is consistent with orientation in the rest of emergency ultrasound, with the apex (a leftward structure) on the right side of the screen as it is viewed. In this probe position the orientation will appear very similar to the subxiphoid view, only slightly higher so that the aortic outflow tract is seen instead of the right atrium. If the transducer is rotated clockwise through 90 degrees from the parasternal long-axis view (or anticlockwise from the alternate long axis view), the short-axis view is obtained. In this probe position the right ventricle will appear at the top of the screen with the interventricular septum and left ventricle below. By rocking or tilting the probe in the intercostal spaces, images can be obtained from the apex of the left ventricle inferiorly up to the aortic root superiorly. The potential space of the pericardial sac is examined for fluid both anterior and posterior.

- Left upper quadrant view (left flank or the perisplenic view):

Four potential spaces are sonographically explored, analogous to the right upper quadrant view: the pleural space, the subphrenic space, the splenorenal space, and the inferior pole of the kidney, which is a continuation of the left paracolic gutter. This view can make some use of the spleen as a sonographic window, but, being so much smaller, it provides a much more limited window than the liver on the right. For this reason the posterior intercostal approach described for the right upper quadrant is utilised extensively in the left upper quadrant. In order to avoid the gas-filled splenic flexure and descending colon it is usually necessary to place the probe on the posterior axillary line or even more posteriorly. Hold the probe, with the probe indicator directed superiorly, and allow the hand to rest on the stretcher. This positions the probe sufficiently posteriorly for good visualisation. If good images are not obtained it may be necessary to orientate the probe parallel to the ribs. This requires that, on the left, the probe is rotated approximately 45 degrees clockwise from the long axis of the patient's body. As is the case on the right side, the probe indicator, by convention, is always directed toward the head (the vertebral end) of the rib. Angulation superiorly allows visualisation of

the left pleural space. As on the right, the pleural spaces are investigated for evidence of haemothorax by looking for anechoic or hypoechoic collections above the diaphragm. In order to visualise the inferior pole of the left kidney and the superior extent of the left paracolic gutter, it is usually necessary to move the probe one to three rib spaces in a caudal direction. In each rib space, the probe is systematically tilted and rocked through all planes in a search for free fluid.

- Pelvic or suprapubic view (pouch of Douglas, retrovesical or rectovesical view in the male and retro-uterine or recto-uterine view in the female):

This space is the most dependent peritoneal space in the supine position. A full bladder is ideal to visualise the potential spaces in the pelvis, but adequate views can often be obtained with a partly filled bladder. When the bladder is empty, large volumes of anechoic or hypoechoic free fluid may still be seen; however, it is not possible to reliably rule out the presence of smaller amounts of free fluid. The probe is placed in the transverse plane directly superior to the pubic bone. This maximises the sonographic window afforded by the bladder. The probe is tilted from inferior to the dome of the bladder in a systematic manner through all tissue planes. The probe may be rotated 90 degrees clockwise into the sagittal plane for additional visualisation of the bladder and pelvic peritoneum. Gain settings usually need to be decreased in this view to account for the posterior acoustic enhancement caused by the fluid-filled bladder. A semi-seated position may increase the sensitivity of the ultrasound exam for abnormal fluid in the pelvis though this is arguably not always achievable in the trauma patient.

- Anterior pleural views:

In non-collapsed lungs, the anterior visceral and parietal pleura are intimately apposed, and slide past one another during respiration. Absence of identifiable pleural sliding is indicative of separation of the parietal–visceral pleural interface by interposed gas, i.e. pneumothorax. Similarly, the absence of the comet tail artefact supports the diagnosis of pneumothorax. Comet tail artefact arises from the pleural line and spreads down toward the lower edge of the screen. In the supine position, the anterior pleura are examined by sliding the probe in a sagittal plane between the intercostal spaces between the clavicle and diaphragm. The approximate midclavicular line is used on both sides. If



pleural sliding and comet tail artefact are absent, the probe can be positioned in the midaxillary line or more posteriorly to obtain a rough estimate of the size of the pneumothorax. It is necessary to adjust frequency, depth, focus and gain settings to optimally image these superficial structures.

7. Documentation

The EFAST is interpreted by the clinician as it is performed and then used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure and an interpretation of the findings: is there peritoneal, pleural or pericardial free fluid and is there a pneumothorax? Clinicians should endeavour, if the situation allows, to at least electronically store images as part of medical record keeping. This should be done in accordance with local clinical governance requirements.

8. Equipment

Generally, a curvilinear abdominal or phased array cardiac ultrasound probe at frequencies of 2.0-5 MHz with a mean of 3.5 MHz will be used for an adult and 5.0 MHz for children and smaller adults. A small footprint may facilitate scanning between the ribs. A depth of field of up to 25 cm may be required in order to adequately visualise deeper structures in the right upper quadrant in large patients. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

Abdominal Aortic Aneurysm (AAA) emergency ultrasound^{70, 144-159}

1. Overview

Ultrasound has been shown to be accurate in identifying aneurysms of the abdominal aorta. In most cases EUS is used to identify or exclude the presence of infrarenal AAA. In some cases EUS of the abdominal aorta can also identify the presence of suprarenal AAA. Patients in whom AAA is identified also need to be assessed for free intraperitoneal fluid. EUS evaluation of the aorta occurs in conjunction with other EUS applications and other imaging and laboratory tests. It is a clinically focused examination, which, in conjunction with the patient history and laboratory information, provides additional data for decision making. It attempts to answer specific questions about a particular patient's condition. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses; EUS is non-invasive, can be rapidly deployed and does not entail removal of the patient from the resuscitation area. Furthermore EUS avoids the delays, costs, specialised technical personnel, the administration of contrast agents and the harmful potential of radiation. These advantages make EUS a valuable addition to available diagnostic resources in the care of patients with time-sensitive or emergency conditions such as acute AAA.

2. Indications

EUS for the rapid evaluation of the abdominal aorta is indicated when a patient presents with syncope, hypovolaemic shock and/ or anaemia associated with abdominal or back pain. The abdominal aorta is assessed from the diaphragmatic hiatus to the aortic bifurcation for evidence of AAA and for intraperitoneal free fluid if AAA is identified. There are no absolute contraindications to abdominal aorta EUS. There may be relative contraindications based on specific features of the patient's clinical situation.

3. Limitations

EUS of the aorta is a single component of the overall and ongoing resuscitation. Since it is a focused examination EUS does not identify all abnormalities or diseases of the aorta. EUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture.

Additional diagnostic testing may be indicated if the findings of the EUS are equivocal. Examination of the aorta may be technically limited by obese habitus, bowel gas or abdominal tenderness.

4. Pitfalls

- When bowel gas or other technical factors prevent a complete systematic real-time scan through all tissue planes, these limitations should be identified and documented. Such limitations may mandate further evaluation by alternative methods.
- A small aneurysm does not preclude rupture. A patient with symptoms consistent with ruptured AAA and an aortic diameter ≥ 3.0 cm is highly suggestive for this diagnosis.
- The absence of free intraperitoneal fluid does not rule out acute AAA. Most acute AAAs presenting to the ED do not have free peritoneal fluid as the aorta is mostly a retroperitoneal structure. The presence of retroperitoneal haemorrhage cannot be reliably identified by EUS.
- Presence of AAA does not necessarily mean ruptured AAA, but should be considered among the differential diagnoses if clinically suspicious.
- While most aneurysms are fusiform, extending over several centimetres of aorta, saccular aneurysms are confined to a short focal section of the aorta, making them easily overlooked. This may be avoided by methodical, systematic real-time scanning through all tissue planes.
- Oblique or angled cuts exaggerate the true aortic diameter. Scanning planes should be obtained that are either exactly aligned with, or at exact right angles to, the main axis of the vessel. With a tortuous or ectatic aorta “longitudinal” and “transverse” views should be obtained with respect to the axis of the vessel in order to avoid artefactual exaggeration of the aortic diameter.
- Large para-aortic nodes may be confused with the aorta and/or AAA. They usually occur anterior to the aorta, but may be posterior, displacing the aorta away from the vertebral body. They can be distinguished by an irregular nodular shape, identifiable in real-time. If colour flow Doppler is utilised nodes will not demonstrate luminal flow.

5. Qualifications and responsibilities of clinicians using EUS

EUS of the aorta provides information which forms the basis of immediate decisions about further evaluation, management, and therapeutic interventions and is therefore ideally performed by an emergency physician. That said clinicians of a variety of medical specialties may perform the abdominal aorta EUS assessment if they have been appropriately credentialed (for example surgeons).

Due to the time-critical and dynamic nature of ruptured AAA, emergent interventions may be mandated by the diagnostic findings of EUS of the aorta. For this reason, EUS of the aorta should occur as soon as the clinical decision is made that the patient needs a sonographic evaluation. Clinicians should render a diagnostic interpretation in a time frame consistent with the management of acute AAA, as outlined above. The clinician performing the EUS is ultimately responsible for the decisions influenced by the said clinician's interpretation of the EUS.

6. Specifications for performance and interpretation

Ultrasound images should be obtained simultaneously with other aspects of resuscitation, to demonstrate the abdominal aorta from the diaphragmatic hiatus to the bifurcation. The aorta is most easily identified and most accurately measured in the transverse plane following identification of the vertebral body. The aorta is a circular structure identified as tubular in real-time adjacent to the left anterior surface of the vertebral body. The abdominal aorta extends from the diaphragmatic hiatus to the bifurcation. The surface anatomy corresponding to these points are the xiphoid process (T12) and the umbilicus (L4). The celiac artery originates approximately 2-centimetre below the diaphragmatic hiatus and the SMA 2-centimetre below the celiac artery. The renal arteries lie directly below the SMA. The SMA can therefore be used as a landmark to identify the infrarenal aorta.

If possible, the probe is held at right angles to the skin and slid from the xiphoid process down the abdominal midline to the umbilicus, providing real-time systematic scanning through all planes from the diaphragm to the bifurcation. The probe is then rotated 90 degrees and real-time images are obtained of all longitudinal planes by rocking and sliding the probe. In the subxiphoid area the liver often provides a sonographic window. A co-operative patient may be asked to take a deep breath, which augments this window by lowering the diaphragm and liver margin. Frequently, gas in the transverse colon obscures

the midsection of the aorta in a roughly 5-centimetre band between the xiphoid process and the umbilicus. This precludes a systematic sliding movement of the probe from xiphoid to umbilicus. In order to circumvent the gas-filled transverse colon, it is necessary to use a rocking/ tilting technique in the windows above and below this sonographic obstacle. This may give rise to a slightly exaggerated measurement of the AP aortic diameter because the scanning plane is not completely at right angles to the tubular axis of the aorta. However, it is necessary to use this technique since it often allows for real-time systematic scanning through all planes of the abdominal aorta, and will diminish the possibility of missing a small saccular aneurysm. After a systematic real-time scan in transverse planes, the aorta should be scanned longitudinally. In this view, abnormalities in the lateral walls may be missed, but focal abnormalities in the anterior or posterior walls and absence of normal tapering are more easily appreciated. If bowel gas and/or obesity interfere with visualisation of the aorta in the anterior midline, the emergency physician should use any probe position that affords windows of the aorta. In particular, two additional windows can be used. First, in the right midaxillary line intercostal views using the liver as a window can sometimes provide images of the aorta. To optimise this approach, the patient may be placed in a left decubitus position. On this view the aorta will appear to be lying “deep” to the inferior vena cava. Second, the distal aorta can sometimes be most easily visualised with the probe placed in a left para-umbilical region. The aorta is measured from the outside margin of the wall on one side to the outside margin of the other wall. The maximum aortic diameter should be measured in both transverse and longitudinal planes. For technical reasons, when scanning in the transverse plane, the anterior and posterior walls are usually more sharply defined than the lateral walls, allowing for more precise measurements in this direction. However, due to the fact that many AAAs have larger side-to-side than AP diameter, measurements are obtained in both directions when possible. If an AAA is identified, evaluation of the peritoneal cavity for free fluid (using the approach of the EFAST) should be made. If a high clinical index of suspicion persists despite a normal EUS exam of the aorta, an attempt may be made to evaluate the iliac arteries for aneurysm.

7. Documentation

As with EFAST, EUS of the aorta are interpreted by the treating clinician as it is performed and then used to guide contemporaneous clinical decisions. Such interpretations should be documented in the



medical record. Documentation should include the indication for the procedure and an interpretation of the findings: is there an AAA and if so is there free peritoneal fluid? Clinicians should endeavour, if the situation allows, to at least electronically store images as part of medical record keeping. This should be done in accordance with local clinical governance requirements.

8. Equipment

Curvilinear abdominal or phased array ultrasound probes can be utilised. A 2 - 5 MHz multi-frequency transducer is ideal. The lower end of this frequency range may be needed in larger patients, while the higher frequency will give more detail in thin patients. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

Focused Emergency Echocardiography in Resuscitation (FEER)^{16, 20, 28, 187, 202, 205, 216, 228-248}**1. Overview**

The primary application of FEER concerns peri-resuscitative care. The examination identifies the etiologies of PEA and asystole in the order of frequency and ease of reversal (hypovolaemia and an obstruction to cardiac outflow which is pulmonary embolism, cardiac tamponade and pneumothorax). Evidence suggests that the presence of sonographically identifiable cardiac kinetic motion is more often associated with return of spontaneous circulation than when cardiac kinetic motion is absent. As CPR should not be interrupted for prolonged periods, a FEER has to fit in such a way that chest compressions are resumed within a reasonable time. Recording a short video loop of more than three seconds is therefore helpful. Depending on the device, the clinician can resume the video loop for review purposes while CPR continues and show it to any colleague that may arrive later. Another option is to record an M-mode picture, which allows for the analysis of wall movement, pericardial effusion or enlarged right ventricle, in one picture.

2. Indications

FEER is indicated for rapid evaluation of cardiac structures during active CPR for the causes of PEA, profound bradycardia-asystole, pacemaker-ECG and early detection of a return to spontaneous circulation.

The need for immediate thoracotomy is often considered a contraindication to a FEER; however, even in this circumstance, a FEER evaluation for pericardial tamponade or pneumothorax may be performed before surgical expertise arrives.

3. Limitations

EUS of cardiac structures plays only a part of the overall resuscitation attempt. The clinician who wishes to perform a FEER should first endeavour to deliver optimal CPR as described by the AHA, ERC and ILCOR. The importance of good quality CPR cannot be overemphasised and should not unnecessarily be interrupted. As a focused examination, EUS of cardiac structures during resuscitation does not

identify all abnormalities or diseases of the heart. EUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. Examination of the heart may be technically limited by obese habitus, ongoing CPR or chest wall abnormalities (congenital and acquired).

4. Pitfalls

- The standard sequence to obtain an echocardiogram is parasternal-apical-subxiphoid in a patient who is turned onto the left side. However, a patient undergoing CPR is normally in a supine position and artificial ventilation is likely. Evidence indicates that in this situation the heart is easier to access in the sequence subxiphoid-parasternal-apical.
- The FEER examination for non-expert sonographers requires simplification in the context of a time-dependent investigation. It does not claim absolute quantitative accuracy. Therefore, it uses a semi-quantitative measurement of myocardial function.
- Non-traumatic fluid pericardial collections may be mistakenly ascribed to cardiac tamponade. A comprehensive history with associated clinical findings, as well as the sonographic features of the free fluid, may suggest such conditions.
- Blood clots form rapidly in the pericardium. Clotted blood has sonographic qualities similar to soft tissue and may thus be overlooked.
- Epicardial fat pads, pericardial cysts, and the descending aorta can be mistaken for free fluid in the evaluation of the pericardium.
- Patients with pericardial or pleural adhesions with significant haemorrhage may not develop free fluid in the normal locations.

5. Qualifications and responsibilities of clinicians using EUS

A FEER provides information which forms the basis of immediate decisions about further evaluation, management, and therapeutic interventions and is therefore ideally performed by an emergency physician. That said clinicians of a variety of medical specialties may perform a FEER assessment if they have been appropriately credentialed (for example physicians, cardiologists or surgeons).

Due to the time-critical and dynamic nature of cardiac arrest, emergent interventions may be mandated by the diagnostic findings of a FEER. It is however of the utmost importance that high quality CPR is not unnecessarily interrupted for protracted periods. For this reason, a FEER should either occur during the initial assessment or after five cycles of high quality CPR. Clinicians should render a diagnostic interpretation in a time frame consistent with the management cardiac arrest. The clinician performing a FEER is ultimately responsible for the decisions influenced by the said clinician's interpretation of the EUS.

6. Specifications for performance and interpretation

High quality CPR as described by the AHA, ERC and ILCOR should be initiated as soon as cardiac arrest is confirmed.

- Preparation:

Whilst CPR is in progress the clinician who will perform the FEER should prepare for the examination by removing clothing from the patient, preparing the ultrasound device and applying gel to the probe. The resuscitation team is then signalled that the clinician is ready to perform the echocardiogram. The FEER is performed during a rhythm check and should continue for no longer than ten seconds. A member of the team is asked to time the interruption.

- Performing EUS:

During the final chest compressions the patient's xiphoid is palpated and the probe placed about 2 cm, slightly below and to the right of the xiphoid in a flat (10 degrees) angle to obtain a glimpse of the ventricles. On discontinuation of chest compression, the probe must be positioned and calibrated as fast as possible to gain a four-chamber view from the subxiphoid window. The ventricles, atria, and valves should ideally be visualized in one view and a description of the real-time observation should be reported directly to the rescue team. CPR should recommence after ten seconds irrespective of whether the examination had been completed. If the subxiphoid view fails, the parasternal long or short view should be used next. The apical four-chamber view is only used if necessary. It is advisable to delay the subsequent examinations with at least five CPR cycles to ensure good quality chest compressions. Recording a short video loop or an M-mode picture aids

post hoc analysis when CPR has been resumed. Based on these findings the treatment plan should be clearly communicated to the resuscitation team.

The alternative views:

The parasternal views are described elsewhere. Images may include the entire left ventricular cavity, the right ventricle, the papillary muscles, the mitral valve, the aortic outflow tract, the aortic valve, the aortic root and the left atrium, all in cross-section. The view at and immediately below the mitral valve may be particularly helpful for determining overall left ventricular systolic function.

The apical four-chamber view is usually obtained by placing the probe at the point of maximal impulse (PMI) as determined by physical exam. The position can be found in the fifth intercostal space and inferior to the nipple; however, this location is subject to individual variation. The clinician should also bear in mind that an impulse will be absent during cardiac arrest. This is why this view is used as a last resort during cardiac arrest. The probe is directed up along the axis of the heart toward the right shoulder, with the marker oriented towards the patient's right or 9-o'clock, which is towards the ceiling in a supine patient. The apex of the heart is at the centre of the image with the septum coursing vertically also in the centre of the screen. The left ventricle and left atrium will be on the right side of the screen, and the right ventricle and atrium will be on the left side of the screen. This view demonstrates both the mitral and tricuspid valves and gives a clear view of the relative volumes of the two ventricular cavities, the motions of their free walls, and the interventricular septum. The clinician should be aware of the difference between the various presets and the impact this has on orientation. The presets commonly used are explained in Table 1.

Ultrasound Preset	Echocardiography/ Cardiac	Abdomen/Pelvis
Machine/probe location	To the patient's left	To the patient's right
Monitor indicator	Right side of the image	Left side of the image
Subcostal	Probe marker directed to the patient's left flank	Probe marker directed to the patient's right flank
Apical four-chamber	Probe marker directed to the left side & probe aimed to right shoulder	Probe marker directed to the right side & probe aimed to right shoulder
Parasternal long	Probe marker directed to the patient's right shoulder (10 o'clock)	Probe marker directed to the patient's left hip (4 o'clock)
Parasternal short	Probe marker directed to the patient's left shoulder (2 o'clock)	Probe marker directed to the patient's right hip (8 o'clock)

- PEA causes and their echocardiographic signs

The echocardiographic signs of hypovolaemia are an underfilled right ventricle, hyperkinetic left ventricular wall motion, and close ventricular walls (so-called kissing trabecular muscles). Suspicion is confirmed by slightly angulating the probe when held in the transverse subxiphoid orientation in an inferior direction to allow visualisation of the inferior vena cava at the diaphragm using the liver as an acoustic window. A flat IVC (less than 5mm) suggests hypovolaemia. The diameter of inferior vena cava is an accurate variable to estimate hypovolaemia in the emergency department and may be a useful extension to the FEER examination.

The echocardiographic finding of engorged right chambers with flattened left ventricle suggests a haemodynamically significant pulmonary embolism (Acute Cor Pulmonale). As it takes an obstruction of 30% of the pulmonary arterial bed before signs of PE are visible on echocardiography, absence of these signs does not exclude pulmonary embolus.

The EUS finding of cardiac tamponade and pneumothorax is described elsewhere. Integration of a FEER into the advanced life support algorithm is shown in Figure 2.

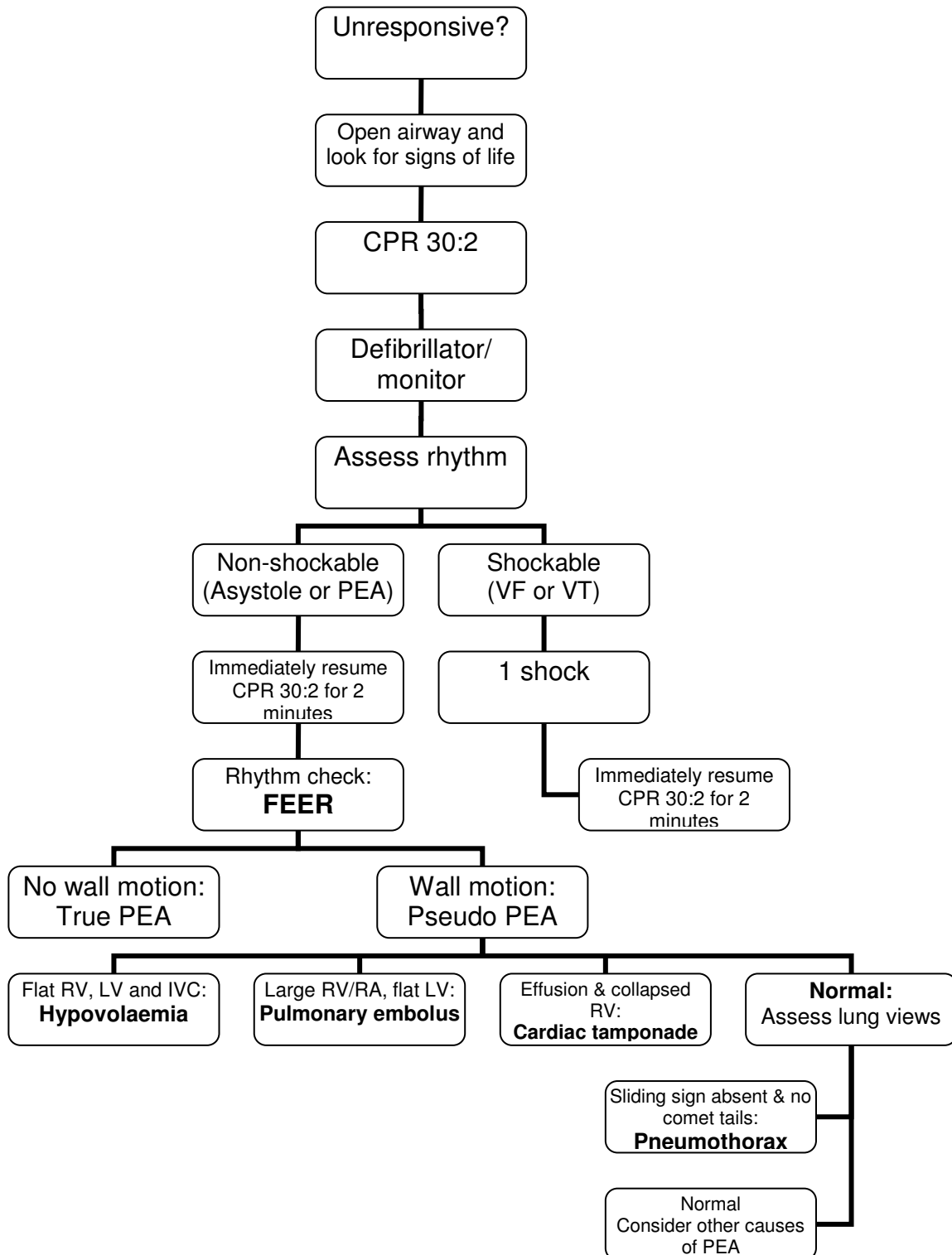


Figure 2. Integration of a FEER into the advanced life support algorithm



7. Documentation

The echocardiograph is interpreted by the treating clinician as it is performed and then used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure and an interpretation of the findings. Clinicians should endeavour, if the situation allows, to at least electronically store images as part of medical record keeping. This should be done in accordance with local clinical governance requirements.

8. Equipment

A phased array cardiac ultrasound probe at frequencies of 2.0-5 MHz is used. The small footprint facilitates scanning between the ribs. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

Deep Venous Thrombosis (DVT) emergency ultrasound^{4, 19, 20, 46, 114, 160-177}

1. Overview

The primary application of venous EUS is in evaluation of deep venous thrombosis (DVT) of the proximal lower limbs. Venous EUS differs in two fundamental aspects from the “Duplex” evaluation performed in a vascular laboratory or by radiologists. Firstly, its anatomic focus is limited to two specific regions of the proximal deep venous system. Secondly, its sonographic technique consists primarily of dynamic evaluation of venous compressibility in real-time. This approach to lower limb proximal venous EUS is often referred to as “compression ultrasonography”. Since B-mode (gray-scale) equipment is widely available, and because substantial scientific evidence supports the use of limited compression ultrasonography, this guideline is focused on the evaluation of proximal lower limb DVT using this technique. It is recognised that many emergency physicians have access to equipment with colour flow and Doppler capabilities, and are experienced in its use. It is likely that they will augment their venous EUS with this technology. Lower limb venous EUS is performed and interpreted in the context of the entire clinical picture. It is a clinically focused examination, which, in conjunction with patient history and laboratory information, provides additional data for decision-making. It attempts to answer specific questions about a particular patient’s condition. EUS of the lower limbs does not identify all abnormalities or diseases of the deep venous system. If the findings of lower limb venous EUS exam are equivocal, further imaging or testing may be needed.

2. Indications

Evaluation for acute proximal DVT in the lower limbs.

3. Limitations

EUS of the lower limb deep venous system is a single component of the overall and ongoing evaluation. Since it is a focused examination EUS does not identify all abnormalities or diseases of the lower limb veins. EUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. If the findings of the EUS are equivocal, additional diagnostic testing may be indicated. A prior history of DVT may limit the utility of EUS. The chronic effects of DVT are highly

variable in extent, location, timing and morphology. A completely normal venous EUS exam is likely to exclude both acute and chronic DVT. However, the interpretation of abnormal findings in patients with a history of prior DVT may be outside the scope of a lower limb venous EUS examination. Examination can be limited by obesity, local factors such as tenderness, sores, open wounds, or injuries and the patient's ability to cooperate with the exam.

4. Pitfalls

- A non-compressible vein may be mistaken for an artery, leading to a false negative result.
- An artery may be mistaken for a non-compressible vein, leading to a false positive result.
- Large superficial veins may be mistaken for deep veins. This pitfall is more likely in obese patients and those with occlusive DVT causing distension in the collateral superficial veins. Depending on the compressibility of the vein, this can lead to both false positive and false negative results.
- While thrombus may be directly visualised on examination, it is frequently isoechoic to unclotted blood and failure to see echogenic clot should not be used to exclude DVT.
- Inguinal lymphadenopathy may be mistaken for a non-compressible common femoral vein.
- Failure to arrange for repeat venous evaluation in patients with suspicion for isolated calf or distal DVT.
- Failure to consider the possibility of iliac or inferior vena cava obstruction as a cause for pain or swelling. While colour flow and Doppler techniques may identify the presence of these conditions, they are beyond the usual scope of the EUS exam.
- A negative scan for a lower limb DVT does not rule out the presence of pulmonary embolism.
- Not recognising that the superficial femoral vein is part of the deep venous system. This sometimes confusing terminology has resulted in some authorities referring to the superficial femoral vein as simply the femoral vein.

5. Qualifications and responsibilities in the performance and interpretation

Limited compression ultrasound of the venous system provides information that is the basis of immediate decisions concerning the patient's evaluation, management, and therapy. Because of its direct bearing

on patient care, the rendering of a diagnosis by venous EUS represents the practice of medicine, and therefore is the responsibility of the treating clinician. Due to the potential for life-threatening complications arising from acute DVT, emergent interventions may be mandated by the diagnostic findings of the EUS exam. For this reason, EUS exam should occur as soon as the clinical decision is made that the patient needs a sonographic evaluation. A variety of medical specialists may perform a lower limb limited compression exam. Training and credentialing should be in accordance with specialty or organisation specific guidelines. Clinicians should render a diagnostic interpretation in a time frame consistent with the management of acute DVT, as outlined above.

6. Specifications for performance and interpretation

Emergency ultrasound for the diagnosis of DVT evaluates for compressibility of the lower limb deep venous system with specific attention directed towards the common femoral and popliteal veins. For the purposes of lower limb EUS, the proximal deep veins of the lower limb are those in which thrombus poses a significant risk of pulmonary embolisation. These include the common femoral, superficial femoral and popliteal veins. It is important to note that the superficial femoral vein is part of the deep system, not the superficial system as the name suggests. Conversely the deep femoral (profunda femoris) vein is not considered to be a source of embolising thrombi, and is therefore not included in the evaluation for DVT. In the proximal leg, the popliteal vein is formed by the confluence of the anterior and posterior tibial veins with the peroneal vein approximately 4-8 cm distal to the popliteal crease. Continuing proximally, the popliteal vein becomes the superficial femoral vein as it passes through the adductor canal approximately 8-12 cm proximal to the popliteal crease. The superficial femoral vein joins the deep femoral vein to form the common femoral vein approximately 5-7 cm below the inguinal ligament. Prior to passing under the inguinal ligament to form the external iliac vein, the common femoral is joined by the great saphenous vein (a superficial vein) merging from the medial thigh. In relation to the companion arteries, the popliteal vein is superficial to the artery. The common femoral vein lies medial to the artery only in the region immediately inferior to the inguinal ligament. The vein abruptly runs posterior to the artery distal to the inguinal region.

- Femoral vein. Gel is applied to the groin and medial thigh for a distance of a few centimetres distal to the inguinal crease. Filling of the common femoral vein might be augmented by placing a small

bolster under the knee resulting in slight (about 10 degrees) hip flexion or positioning the patient in the reverse Trendelenberg position (30° head down). Mild external rotation of the hip (30 degrees) may also be helpful. The vein and artery may have almost any relationship with one another, although the vein is frequently seen posterior to the artery. Distinction of the two vessels may therefore depend on size (the vein is usually larger), shape (the vein is more ovoid) and compressibility. If colour-flow or Doppler is utilised characteristic signatures can help with differentiation. Compressive evaluation of the vessel commences at the highest view obtainable at the inguinal ligament. Angling superiorly, a short section of the distal common iliac vein might be scanned. Systematic scanning, applying compression every centimetre or so, should be continued to the bifurcation of the common femoral vein into its superficial and deep branches and 1 – 2 cm beyond, since branch points are particularly susceptible to thrombosis. If difficulty is encountered in following the common femoral vein to the bifurcation, or in clearly identifying the two branching vessels, techniques to optimise the angle of interrogation should be used. In equivocal cases, comparison with the contra lateral side may be helpful.

- Popliteal vein. The patient can be placed in either a prone or decubitus position. In the latter case, the knee is flexed 10 – 30 degrees, and the side of the leg being examined should be down. If the patient is prone, placing a bolster under the ankle to flex the knee to about 15 degrees facilitates filling of the popliteal vein. Again, reverse Trendelenberg positioning promotes venous filling. Gel is applied a few centimetres proximal and distal to the popliteal crease. The vein usually lies superficial to the artery. Both vessels lie superficial to the bony structures, which can be used as landmarks to anticipate the depth of the vessels. If difficulty is encountered in identifying the terminal branches of the popliteal vein, it is possible that the patient has one of the common variants of venous anatomy. In the absence of clear anatomic identification of the termination of the popliteal vein, the major venous structures should be imaged to a few centimetres below the popliteal crease. In equivocal cases, comparison with the contralateral side may be helpful.

The sonographic evaluation is performed by compressing the vein directly under the transducer while watching for complete apposition of the anterior and posterior walls. If complete compression is not attained with sufficient pressure to cause arterial deformation, obstructing thrombus is likely to be

present. To facilitate the identification of the veins and test for compression, they need to be distended. This is accomplished by placing the lower limbs in a position of dependency preferably by placing the patient on a flat stretcher in reverse Trendelenberg. If the patient is on a surface where this is not possible, the patient should be placed semi-sitting with 30 degrees of hip flexion. A linear array vascular probe with a frequency of 6 – 10 MHz and width of 6 – 8 cm is often ideal. Narrower transducers may make it harder to localise the veins and to apply uniform compression. For larger patients, a lower frequency or even an abdominal probe will facilitate greater tissue penetration.

7. Documentation

In performing venous EUS, images are interpreted by the treating clinician as they are acquired and are used to guide contemporaneous clinical decisions. Image documentation should be incorporated into the medical record. Documentation should include the indication for the procedure, the views obtained, a description of the structures studied and an interpretation of the findings. Limitations of the exam and impediments to performing a complete exam should be noted. The written report of the venous EUS should document the presence of complete, partial or absent collapse in each vein examined. Whenever feasible, images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Since the compression EUS is a dynamic test, repeated multiple times over the lengths of the common femoral vein and popliteal vein, it is not practical in the emergency setting to obtain a still image record of each site evaluated with and without compression. If still image records are obtained for documentation, one or more representative images of each vein, reflecting the key findings with and without compression, should be recorded.

8. Equipment

A linear array vascular probe with a frequency of 6 – 10 MHz and width of 6 – 8 cm is often ideal. Narrower transducers may make it harder to localise the veins and to apply uniform compression. For larger patients, a lower frequency or even an abdominal probe will facilitate greater tissue penetration. Colour or power Doppler capabilities may be of assistance in localising venous structures. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

Central Venous Catheter (CVC) insertion with emergency ultrasound^{6, 11, 18, 20, 37, 50, 60, 85, 86, 149, 174, 175, 178-}

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1. Overview

Ultrasound has been shown to be helpful in determining patency of vascular structures and with the placement of central lines as well as peripheral lines. Various international organisations have highlighted ultrasound guided central lines as a key intervention that should be implemented immediately into twenty-first century patient care. This focus on patient safety will promote procedural ultrasound as it enables trained operators to decrease complications and increase the first-time success of line placement. These ultrasound examinations are performed at the bedside to identify vascular anatomy and guide direct visualisation and cannulation of vessels. The advantages of procedural ultrasound includes improved patient safety, decreased procedural attempts, and decreased time to perform procedures in patients whom the technique would otherwise be difficult. It is important to recognise that procedural ultrasound is a method to identify relevant anatomy and pathology before proceeding with invasive procedures while aiding the accurate execution and minimising procedural complications. Procedural ultrasound is an adjunct to emergency care.

2. Indications

EUS is useful to identify central venous structures, their relative location and their patency in facilitating placement of central venous catheters, and peripheral venous and arterial access and catheterisation in adults and children

3. Limitations

Procedural ultrasound is an adjunct to care. No modality is absolutely accurate. Procedural ultrasound should be interpreted and utilised in the context of the entire clinical picture. Procedural ultrasound may be technically limited by obese habitus or subcutaneous air.

4. Pitfalls

- Needle localisation and its associated artefact must be visualised before continuing with any procedure. The short axis transverse (out-of-plane) approach allows only a cross section of the needle to be visualised by the ultrasound beam and may lead to errors in depth perception of the needle. The long axis orientation (in-plane approach) allows the operator to trace the entire path and angle of the needle from the entry site at the skin and is preferred when this transducer orientation is possible.
- It is important to identify a vessel by multiple means before attempting cannulation. The difference between veins and arteries can be determined by compressibility (veins compress), shape (arteries tend to be circular in transverse view, with muscular walls) and flow dynamics if Doppler is available and/or utilised. Many times abnormal structures can be compared to adjacent tissue or to the other normal side. If questions persist about the sonographic appearance of a structure, another imaging modality may be warranted.

5. Qualifications and responsibilities in the performance and interpretation

A variety of medical specialists may perform procedural ultrasound. Training and credentialing should be in accordance with specialty or organisation specific guidelines.

6. Specifications for performance and interpretation

Ultrasound can be used to both localise the relevant anatomy and pathology before executing the procedure in a sterile manner, or with sterile probe covers and real-time assessment. All invasive procedures should employ standard sterile techniques to diminish the risk of infection. A high frequency ultrasound probe is placed over the anatomy of interest in both a sagittal and transverse plane. The probe should be initially placed at the primary window and then be tilted, rocked and rotated to allow for real-time imaging of the area involved. This may take more time with difficult windows, challenging patients or other patient priorities. Interpretation should be done at the bedside immediately with performance of the real-time examination.

Ultrasound guidance or ultrasound-assisted procedures can be performed using either of two accepted techniques:

- **Static:** Anatomic structures are identified and an insertion position is identified with ultrasound. The procedure then proceeds as it would without ultrasound and is not performed with the transducer imaging the patient through key components of the procedure.
- **Real-Time:** The ultrasound transducer is placed in a sterile covering and the key components of the procedure are performed with simultaneous ultrasound visualisation during the procedure (e.g. using ultrasound to visualise a needle entering a vessel).

7. Documentation

Procedural ultrasound requires documentation of the ultrasound-assisted procedure. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Whenever feasible, images should be stored as a part of the medical record and in accordance with facility policy requirements. Given the often emergent nature of such ultrasound procedures, the timely delivery of care should not be delayed by the archiving of ultrasound images.

8. Equipment

Multiple probes can be used yet high frequency (7.0-12 MHz) linear array transducers work best to image superficial and vascular structures. Portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.



Additional information

Prehospital and aeromedical emergency ultrasound.^{45, 80, 213-221}

Airway management.^{76, 80, 81, 221-227}

Echocardiography and EUS during cardiopulmonary resuscitation.^{16, 20, 28, 187, 202, 205, 216, 228-248}

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