American College of Emergency Physicians®
ADVANCING EMERGENCY CARE

POLICY STATEMENT

Approved October 2014

Emergency Ultrasound Imaging Criteria Compendium

Revised October 2014

Originally approved April 2006

Emergency Ultrasound Imaging Criteria Compendium

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ACEP Emergency Ultrasound Imaging Criteria:

Aorta

1. **Introduction**

   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound studies (EUS) of the abdomen and retroperitoneum in patients suspected of having an acute abdominal aortic aneurysm (AAA).

   Ultrasound has been shown to accurately identify both aneurysmal and normal abdominal aortas. 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 or of distal dissection. If thoracic aortic aneurysm or proximal dissection is suspected, these may be detected using transthoracic techniques or may require additional diagnostic modalities. 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 historical 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, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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/Limitations**

   a. Primary
      i. The rapid evaluation of the abdominal aorta from the diaphragmatic hiatus to the aortic bifurcation for evidence of aneurysm.

   b. Extended
      i. Abdominal aortic dissection
      ii. Thoracic aortic dissection
      iii. Intraperitoneal free fluid in the event that AAA is identified
      iv. Iliac, splenic, and other abdominal artery aneurysms

   c. Contraindications
      i. There are no absolute contraindications to EUS of the abdominal aorta. There may be relative contraindications based on the patient's clinical situation.

   d. Limitations
      i. 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. If the findings of the EUS are equivocal additional diagnostic testing may be indicated.

      ii. Examination of the aorta may be technically limited by
         – Obese habitus

- Bowel gas
- Abdominal tenderness
- Abdominal dressings

e. Pitfalls

i. While most aneurysms are fusiform, extending over several centimeters 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 in both transverse and longitudinal sections.

ii. When bowel gas or other technical factors prevent a complete systematic real-time scan in orthogonal planes, these limitations should be identified and documented. Such limitations may mandate further evaluation by alternative methods, as clinically indicated.

iii. A small aneurysm does not preclude rupture. A patient with symptoms consistent with acute AAA and an aortic diameter greater than 3.0 cm should undergo further diagnostic evaluation.

iv. The absence of free intraperitoneal fluid does not rule out acute AAA as most acute AAAs presenting to the ED do not have free peritoneal fluid.

v. The presence of retroperitoneal hemorrhage cannot be reliably identified by EUS.

vi. If an AAA is identified, it still may not be the cause of a patient's symptoms.

vii. The presence of free intraperitoneal fluid with an AAA, does not necessarily mean that the aneurysm is the source of the fluid.

viii. 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.

ix. Off-plane longitudinal images and transverse images not obtained at the level of maximal dilatation will underestimate the true diameter of the vessel.

x. 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 artifactual exaggeration of the aortic diameter.

xi. 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 color flow Doppler is utilized, nodes will not demonstrate high-velocity luminal flow.

xii. Longstanding thrombus within an AAA may become calcified and mistaken for bowel outside the aorta, thereby obscuring the aortic walls and preventing recognition of the aneurysm. Gain should be adjusted so that blood within the lumen of the vessel appears anechoic (ie, black).

3. Qualifications and Responsibilities of the Clinician Performing the Examination

EUS of the aorta provides information that is the basis of immediate decisions about further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by EUS represents the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of acute 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 to evaluate the patient with ultrasound.

Physicians of a variety of medical specialties may perform EUS of the aorta. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute AAA, as outlined above.

4. Specifications for Individual Examinations

a. General – Simultaneously with other aspects of resuscitation, ultrasound images are obtained demonstrating the abdominal aorta from the diaphragmatic hiatus to the bifurcation.

b. Technique

i. Identification. The aorta is most easily identified and most accurately measured in the transverse plane. The transverse image of the vertebral body is identified. In this plane, the normal aorta is a circular, hypoechoic structure identified adjacent to the left anterior surface of the vertebral body.

ii. Real-time scanning technique.

1. Overview. The abdominal aorta extends from the diaphragmatic hiatus to the bifurcation. The surface anatomy corresponding to these points are the xiphoid process and the umbilicus. If possible, the probe is held at right angles to the skin and slid from the xiphoid process inferiorly 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 images are obtained in the longitudinal plane by rocking or sliding the probe from side-to-side.

2. Details of technique. In the subxiphoid region, the liver often provides a sonographic window. A cooperative 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-centimeter band inferior to the margin of the liver. This may preclude an uninterrupted and/or complete visualization of the aorta. In order to circumvent the gas-filled transverse colon, it may be necessary to use a fanning technique in the windows above and below this sonographic obstacle. Alternatively, applying downward constant pressure with the probe, in conjunction with peristalsis, may dissipate bowel gas.

   After a systematic real-time scan in transverse plane, 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.

3. Additional windows. If bowel gas and/or truncal obesity interfere with visualization 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 an acoustic window

may provide alternate images of the aorta. To optimize 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 visualized with the probe placed in a left paraumbilical region.

Evaluation of the ascending aorta, aortic arch, and descending aorta for dissection or aneurysm can be performed using parasternal and suprasternal windows. These are discussed in the "Cardiac" criteria.

4. Measurements. The aorta (and other abdominal arteries) are measured from the outside margin of the wall on one side to the outside margin of the other wall. In most instances, the anterior and posterior walls are usually more sharply defined, so an antero-posterior measurement is most precise. However, since many AAAs have larger side-to-side than antero-posterior diameters, measurements are obtained in both directions when possible. The maximum aortic diameter should be measured in both transverse and longitudinal planes.

5. Additional technical considerations. – If an AAA is identified, evaluation of the peritoneal cavity for free fluid (using the approach of the Focused Assessment by Sonography in Trauma) should be made.

5. Documentation

In performing EUS of the aorta, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications

Curvilinear abdominal or phased array ultrasound probes can be utilized. A 2.0 – 5.0 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 those with low body mass index. Both portable and cart-based ultrasound machines may be used.

7. Quality Control and Improvements, Safety, Infection Control and Patient Education

Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Cardiac

1. Introduction

The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound studies (EUS) of the heart in patients suspected of having emergent conditions where cardiac imaging may influence diagnosis or therapy.

The primary applications of cardiac EUS are in the diagnosis or exclusion of pericardial effusion, cardiac tamponade and the evaluation of gross cardiac function. Increasingly, evaluation of the right ventricle and aortic root are considered integral parts of focused cardiac EUS, and evaluation of the inferior vena cava for fluid status may be considered part of the cardiac exam. Cardiac EUS is an integral component of patient evaluation and/or resuscitation. 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. Other diagnostic or therapeutic interventions may take precedence or may proceed simultaneously with the cardiac EUS evaluation. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses, EUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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 cardiac disease. In addition, cardiac EUS is an integral component of the trauma EUS evaluation.

2. Indications/ Limitations

a. Primary
   i. Detection of pericardial effusion and/or tamponade

   ii. Evaluation of gross cardiac activity in the setting of cardiopulmonary resuscitation

   iii. Evaluation of global left ventricular systolic function

b. Extended
   i. Gross estimation of intravascular volume status and cardiac preload.

   ii. Identification of acute right ventricular dysfunction and/or acute pulmonary hypertension in the setting of acute and unexplained chest pain, dyspnea, or hemodynamic instability.

   iii. Identification of proximal aortic dissection or thoracic aortic aneurysm.

   iv. Procedural guidance of pericardiocentesis, pacemaker wire placement and capture.

c. Contraindications
   There are no absolute contraindications to cardiac EUS. There may be relative contraindications based on specific features of the patient's clinical situation.

d. Limitations
   i. Cardiac EUS 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 heart. 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.

   ii. Cardiac ultrasound is capable of identifying many conditions beyond the primary and extended EUS applications listed above. These include but are not limited to: assessment of focal wall motion abnormalities, diastolic dysfunction, valvular abnormalities, intracardiac thrombus or mass, ventricular aneurysm, septal defects, aortic dissection, hypertrophic cardiomyopathy. While these conditions may be discovered when performing cardiac EUS, they are typically outside of the scope of focused cardiac EUS and should typically undergo appropriate consultant-performed imaging for confirmation or follow-up.

   iii. Cardiac EUS is technically limited by:

1. Abnormalities of the bony thorax

2. Pulmonary hyperinflation

3. Massive obesity

4. The patient's inability to cooperate with the exam

5. Subcutaneous emphysema

e. Pitfalls

i. When technical factors prevent an adequate examination, these limitations should be identified and documented. As usual in emergency practice, such limitations may mandate further evaluation by alternative methods, as clinically indicated.

ii. The measured size of a pericardial effusion should be interpreted in the context of the patient's clinical situation. A small rapidly forming effusion can cause tamponade, while extremely large slowly forming effusions may be tolerated with minimal symptoms.

iii. Clotted hemopericardium may be isoechoic with the myocardium or hyperechoic, so that it can be overlooked if the examining physician is expecting the anechoic of most effusions.

iv. Sonographic evidence of cardiac standstill should be interpreted in the context of the entire clinical picture.

v. Cardiac EUS may reveal sonographic evidence of right ventricular strain in cases of massive pulmonary embolus sufficient to cause hemodynamic instability. However, a cardiac EUS may not demonstrate the findings of right ventricular strain and a normal EUS does not exclude pulmonary embolism.

vi. Evidence of right ventricular strain may be due to causes other than pulmonary embolus. These include acute right ventricular infarct, pulmonic stenosis, and chronic pulmonary hypertension.

vii. Small or loculated pericardial effusions may be overlooked. As with other EUS, the heart should be scanned through multiple tissue planes in two orthogonal directions.

viii. Pleural effusions may be mistaken for pericardial fluid. Evaluation of other areas of the chest usually reveals their characteristic shape and location.

ix. Occasionally, hypoechoic epicardial fat pads may be mistaken for pericardial fluid. Epicardial fat usually demonstrates some internal echoing, is not distributed evenly in the pericardial space, and moves with epicardial motion.

x. The descending aorta may be mistaken for a posterior effusion. This can be resolved by rotating the probe into a transverse plane.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Cardiac EUS provides information that is the basis of immediate decisions about further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by cardiac EUS represents the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of cardiac disease, emergent interventions may be mandated by the diagnostic findings of EUS examination. For this reason, cardiac EUS should be performed as soon as the clinical decision is made that the patient needs a sonographic evaluation.

Physicians of a variety of medical specialties may perform focused cardiac ultrasound. Training should be in accordance with specialty or organization-specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute cardiac disease, as outlined above.

4. Specifications for Individual Examinations

a. General - Images are obtained and interpreted in real time without removing the patient from the clinical care area. Images are ideally obtained in a left-semi-decubitus position, although the clinical situation often limits the patient to lying supine. Images may be captured for documentation and/or quality review. Recording of moving images, either in video or cine loops, may provide more information than is possible with still cardiac EUS images. However, capturing moving images may be impractical in the course of caring for the acutely ill patient.

b. Technique

i. Overview

Both patient habitus and underlying pathological conditions affect the accessibility of the heart to sonographic evaluation. For example, patients with causes of pulmonary hyperinflation (eg, emphysema or intubation) are likely to have poor parasternal windows, while patients with abdominal distension or pain may have an inaccessible subcostal window. For this reason, familiarity in evaluating the heart from a number of cardiac windows and planes increases the likelihood of successful EUS performance and interpretation.

ii. Orientation

Cardiologists have traditionally used an alternate image orientation convention from general ultrasound and other EUS applications. In this cardiology convention, the probe indicator corresponds to the right side of the screen as it is viewed, rather than the left of the screen for a general or EUS convention. Since reversing the screen for certain images and/or parts of an EUS exam can be time-consuming and confusing, especially under the emergent conditions typical of cardiac EUS, most emergency physicians have adopted the convention of not adjusting the screen orientation. Throughout this document, this EUS convention will be followed to obtain the views described, and the emergency physician will not need to reverse the orientation of the screen. The approximate orientation of the probe marker in the various classic cardiac views is described in terms of a clock face where 12 o'clock is directed to the head, 6 o'clock is directed to the feet, 9 o'clock is directed to the patient's right, and so on.

iii. The primary cardiac views

Throughout the following discussion "windows" refer to locations that typically afford sonographic access to the heart. Conversely, "views" refer to cardinal imaging planes of the heart, defined by specific structures that they demonstrate. In the following discussion, typical surface anatomical locations are described for the cardiac windows, but these are subject to significant individual variation based on the location and lie of the heart. The emergency physician should focus on identifying the key features of the primary cardiac views, regardless of the window where the probe needs to be positioned to obtain them.

1. Subcostal four-chamber view (subxiphoid)
   This view is obtained by placing the probe just under the rib cage or xiphoid process with the transducer directed towards the patient's left shoulder and the probe marker directed towards the patient's right (9-o'clock). The liver is used as a sonographic window. The heart lies immediately behind the sternum, so that it is necessary, in a supine patient, to direct the probe in a plane that is almost parallel with the horizontal plane of the stretcher. This requires firm downward pressure, especially in patients with a protuberant abdomen. Structures imaged in the subcostal four-chamber view include the right atrium, tricuspid valve, right ventricle, left atrium and left ventricle. The pericardial spaces should be examined both anterior and posterior to the heart. By scanning inferiorly, the inferior vena cava may also be visualized as it drains into the right atrium. This can help with orientation, as well as giving information about the patient's preload and intravascular volume status.

2. Parasternal long axis view
   This view is typically obtained using the third, fourth, and fifth intercostal spaces, immediately to the left of the patient's sternum. Structures imaged on this view include the pericardial spaces (anterior and posterior), the right ventricle, the septum, the left atrium and left ventricular inflow tract, the left ventricle in long axis, the left ventricular outflow tract, the aortic valve, and the aortic root.

   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 subcostal view, only slightly higher so that the aortic outflow tract is seen instead of the right atrium.

3. Parasternal short axis view
   This view is obtained by directing the marker in an approximately 8-o'clock direction. By rocking the probe in these interspaces, images can be obtained from the apex of the left ventricle inferiorly up to the aortic root superiorly. Intervening structures which can be identified, all in cross-section, 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. The view at and immediately below the mitral valve may be particularly helpful for determining overall left ventricular systolic function.

4. Apical four-chamber view
   This view is obtained by placing the probe at the point of maximal impulse (PMI) as determined by physical exam. Normally this is in the fifth intercostal space and inferior to the nipple, however this location is subject to great individual variation. 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 center of the image with the septum coursing vertically in the center 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.

iv. Secondary cardiac views

1. Subxiphoid short axis view
   This view is obtained by placing the probe in the same location as the subxiphoid four-chamber view, but rotating the probe marker 90 degrees clockwise into a cephalad direction at 12-o'clock. This provides a short axis view of the right and left ventricles. With side to side rocking motion, a longitudinal view of the inferior vena cava emptying into the right atrium can be seen.

2. Venous windows
   The inferior vena cava (IVC) may be traced by following hepatic veins in a subcostal window. Comparing the maximal IVC diameter in exhalation with the minimal IVC diameter in inhalation may provide a qualitative estimate of preload. Collapse of 50 - 99% is normal; complete collapse may indicate volume depletion and <50% collapse may indicate volume overload, pericardial tamponade and/or right ventricular failure.

3. Suprasternal notch view
   This view is obtained by placing the probe in the suprasternal notch, directed inferiorly into the mediastinum. The marker is usually directed obliquely between the patient's right and anterior since this is the plane followed by the aortic arch as it crosses from right anterior to left posterior of the mediastinum. A bolster under the patient's shoulders with the neck in full extension will facilitate this view used to visualize the aortic arch and great vessels.

4. Apical two chamber view
   This view is obtained by rotating the probe clockwise 90 degrees from the apical four chamber view, so that the probe marker is directed in a cephalad direction or 12-o'clock. This allows visualization of the anterior and inferior left ventricular walls as well as the mitral and aortic valves. This view is infrequently utilized in the cardiac EUS.

v. Relationship of the cardiac views
Several of the cardiac views provide images of the same planes of the heart from different angles. This is true of the following pairs of views: the parasternal long axis and apical two-chamber views; the apical four-chamber and sub-xiphoid four-chamber views; and the parasternal short axis and the subxiphoid short axis views.

c. Key components of the cardiac EUS evaluation

i. Evaluation of pericardial effusion. Pericardial effusion usually appears as an anechoic or hypoechoic fluid collection within the pericardial space. With inflammatory, infectious, malignant or hemorrhagic etiologies, this fluid may have a more complex echogenicity. Fluid tends to collect dependently, but may be seen in any portion of the pericardium. Very small amounts of pericardial fluid can be considered physiologic and are seen in normal individuals. A widely used system classifies effusions as none, small (< 10 mm in diastole, often non-circumferential), moderate (circumferential, no part greater than 10 mm in width in diastole), large (10-20 mm in width), and very large (>20 mm and/or evidence of tamponade physiology).

ii. Echocardiographic evidence of tamponade. Diastolic collapse of any chamber in the presence of moderate or large effusion is indicative of tamponade. Hemodynamic instability with a moderate or large pericardial effusion, even without identifiable diastolic collapse, is suspicious for tamponade physiology. A dilated non-collapsible IVC in the presence of pericardial effusion is also suspicious for tamponade physiology.

iii. Evaluation of gross cardiac motion in the setting of cardiopulmonary resuscitation. Terminal cardiac dysfunction typically progresses through global ventricular hypokinesis, incomplete systolic valve closure, absence of valve motion, absence of ventricular motion, and finally culminating in intracardiac gel-like densities. The lack of mechanical cardiac activity, or true cardiac standstill, demonstrated by EUS has the gravest of prognoses. The decision to terminate resuscitative efforts should be made on clinical grounds in conjunction with the sonographic findings.

iv. Evaluation of global cardiac function. Published investigations demonstrate that emergency physicians with relatively limited training and experience can accurately estimate cardiac ejection fraction. Left ventricular systolic function is typically graded as normal (EF>50%), moderately depressed (EF 30-50%), or severely depressed (EF<30%).

5. Documentation

In performing EUS of the heart, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications

A phased array cardiac transducer is optimal, since it facilitates scanning through the narrow intercostal windows, and is capable of high frame rates, which provide better resolution of rapidly moving cardiac structures. If this is not available, a 2-5 MHz general-purpose curved array abdominal probe, preferably with a small footprint, will suffice. The cardiac presets available on most equipment may be activated to optimize cardiac images. Doppler capability may be helpful in certain extended emergency echo indications but is not routinely used for the primary cardiac EUS indications. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. Quality Control and Improvements, Safety, Infection Control and Patient Education

Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Kidney and Bladder

1. Introduction

The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound studies (EUS) of the kidneys and bladder in patients suspected of having diseases involving the urinary tract.

Emergency ultrasound of the kidneys and urinary tract may identify both normal and pathological conditions. The primary indications for this application of EUS are in the evaluation of obstructive uropathy and acute urinary retention. The evaluation of perirenal structures and the peritoneum for perirenal fluid is considered in the criteria for trauma EUS.

EUS of the kidneys and urinary tract occurs as a component of the overall clinical evaluation of a patient with possible urinary tract disease. 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. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses, EUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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 renal colic and urinary retention.

2. Indications/Limitations

a. Primary
   i. The rapid evaluation of the urinary tract for sonographic evidence of obstructive uropathy and/or urinary retention in a patient with clinical findings suggestive of these diseases.

b. Extended
   i. Causes of obstructive uropathy
   ii. Causes of acute hematuria
   iii. Causes of acute renal failure
   iv. Infections and abscesses of the kidneys
   v. Renal cysts and masses
   vi. Gross bladder and prostate abnormalities
   vii. Renal trauma

c. Contraindications: No absolute contraindications exist. Contraindications are relative, based on specific features of the patient's clinical condition.

d. Limitations
   i. EUS of the kidney and urinary tract 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 urinary tract. 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.
   ii. Examination of the kidneys and collecting system may be technically limited by:

1. Patient habitus including obesity, paucity of subcutaneous fat, narrow intercostal spaces
2. Bowel gas
3. Abdominal or rib tenderness
4. An empty bladder

e. Pitfalls

i. When bowel gas or other technical factors prevent a complete real-time scan through all tissue planes, the limitations of the examination should be identified and documented. As is customary in emergency practice, such limitations may mandate further evaluation by alternative methods, as clinically indicated.

ii. Hydronephrosis may be mimicked by several normal and abnormal conditions including dilated renal vasculature, renal sinus cysts, and bladder distension. Medullary pyramids may mimic hydronephrosis, especially in young patients.

iii. Presence of obstruction may be masked by dehydration.

iv. Absence of hydronephrosis does not rule out a ureteral stone. Many ureteral stones, especially small ones, do not cause hydronephrosis.

v. Patients with an acutely symptomatic abdominal aortic aneurysm may present with symptoms suggestive of acute renal colic.

vi. Both kidneys should be imaged in order to identify the presence of either unilateral kidney or bilateral disease processes.

vii. The bladder should be imaged as part of EUS of the kidney and urinary tract. Many indications of this EUS exam are caused by conditions identifiable in the bladder.

viii. Variations of renal anatomy are not uncommon and may be mistaken for pathologic conditions. These include reduplicated collection systems, unilateral, bipartite, ectopic and horse-shoe kidney.

ix. Renal stones smaller than 3 mm are usually not identified by current sonographic equipment. Renal stones of all sizes may be missed and are usually identified by the shadowing they cause as their echogenicity is similar to that of surrounding renal sinus fat.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

EUS of the kidneys and urinary tract provides information upon which immediate decisions for further evaluation, management and interventions are based. Rendering a diagnosis by EUS impacts patient care directly and qualifies as the practice of medicine. Therefore, performing and interpreting EUS is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of many conditions of renal pathology, emergency interventions may be undertaken based upon findings of the EUS exam. For this reason, EUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam.

Physicians of a variety of medical specialties may perform renal ultrasound examinations. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute renal pathology, as outlined above.

4. Specifications for Individual Examinations

a. General. An attempt should be made to image both kidneys and the bladder in patients with suspected renal tract pathology undergoing EUS. In addition, hydronephrosis and urinary retention are frequently unsuspected causes of abdominal pain and may be recognized in the course of other abdominal or retroperitoneal EUS examinations.

b. Technique

i. Identification. The kidneys are more easily identified in their longitudinal axis. They are paired structures that lie oblique to every anatomic plane and at different levels on each side. Their inferior poles are anterior and lateral to their superior poles. Both hila are also directed obliquely. Orientation is defined with respect to the axes of the organ of interest (longitudinal, transverse, and oblique), rather than standardized anatomic planes (sagittal, coronal, oblique and transverse). The long axis of the kidney approximates the intercostal spaces and longitudinal scans may be facilitated by placing the transducer plane parallel to the intercostal space. By convention, the probe indicator is always toward the head or the vertebral end of the rib on both the right and left sides. Transverse views of the kidneys are therefore usually also transverse to the ribs, resulting in prominent rib shadows that may make visualizing the kidneys more difficult unless a small footprint or phased array probe is available. Transverse views are obtained on both sides by rotating the probe 90 degrees counter-clockwise from the plane of the longitudinal axis.

ii. Real-time scanning technique

1. Overview. The kidneys are retroperitoneal in location and are usually above the costal margin of the flanks in the region of the costovertebral angle. A general-purpose curved array abdominal probe with a frequency range of between 2.0 -5.0 MHz is generally used. A small footprint or phased array probe may facilitate scanning between the ribs, but may require several windows in the longitudinal plane if the kidney is long, or superficial. Images of both kidneys should be obtained in the longitudinal and transverse planes for purposes of comparison and to exclude absence of either kidney. The bladder should be imaged to assess for volume, evidence of distal ureteral obstruction and for calculi. As with other EUS exams, the organs of interest are scanned in real-time through all tissue planes in at least two orthogonal directions.

2. Details of technique. The right kidney may be visualized with an anterior subcostal approach using the liver as a sonographic window. Imaging may be facilitated by having the patient in the left lateral decubitus position or prone. Asking the patient to take and hold a deep breath may serve to extend the liver window so that it includes the inferior pole of the kidney. Despite these techniques, parts or the entire kidney may not be seen in this view due to interposed loops of bowel, in which case the kidney should be imaged using an intercostal approach in the right flank between the anterior axillary line and midline posteriorly. For this approach, the patient can be placed in the decubitus position with a bolster under the lower side with the arm of the upper side fully abducted, thus spreading the intercostal spaces. Separate views of the superior and inferior poles are often required to adequately image the entire kidney in its longitudinal plane. To obtain transverse images, the transducer is rotated 90 º counter-clockwise from the longitudinal plane. Once in the transverse plane, the transducer can be moved

superiorly and medially, or inferiorly and laterally to locate the renal hilum. Images cephalad to the hilum represent the superior pole and those caudad represent the inferior pole. The left kidney lacks the hepatic window, necessitating an intercostal approach similar to the one described above for the right flank.

The bladder is imaged from top to bottom and from side to side, in transverse and sagittal planes, respectively. While a full bladder facilitates bladder scanning, distension may be a cause of artifactual hydronephrosis and is therefore to be avoided in scanning the kidneys. Ideally, the bladder is scanned prior to voiding (and again post-void, if outlet obstruction is a consideration), and kidney scanning performed after voiding. Such ideal conditions are rarely met with the exigencies of EUS and emergency care.

3. Key components of the examination. The kidneys should be studied for abnormalities of the renal sinus and parenchyma. Under normal circumstances, the renal collecting system contains no urine, so that the renal sinus is a homogeneously hyperechoic structure. A distended bladder can cause mild hydronephrosis in normal healthy adults. Several classifications of hydronephrosis have been suggested. One that is easily applied and widely utilized is Mild or Grade I (any hydronephrosis up to Grade II), Moderate or Grade II (the calices are confluent resulting in a “bear’s paw” appearance), or Severe or Grade III (the hydronephrosis is sufficiently extensive to cause effacement of the renal parenchyma). Other abnormalities identified including cysts, masses and bladder abnormalities may require additional diagnostic evaluation. Measurements may be made of the dimensions of abnormal findings and the length and width of the kidneys. Such measurements are rarely relevant in the EUS examination.

5. Documentation
In performing EUS of the kidneys and urinary tract, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications
A curved array abdominal transducer with a frequency range of between 2.0 -5.0 MHz is generally used. A small footprint or phased array probe may facilitate scanning between the ribs. A higher frequency 5.0-7.0 MHz transducer may give better resolution in children and smaller adults. Both portable and cart-based ultrasound machines may be used, depending upon the location of the patient and the setting of the examination.

7. Quality Control and Improvements, Safety, Infection Control and Patient Education
Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Lung and Pleura

1. Introduction

The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound (EUS) studies of the chest to rule out pneumothorax and abnormal collections of pleural fluid.

Ultrasound has been shown to be helpful in the diagnosis of acute pneumothorax and is particularly sensitive for ruling out the presence of pneumothorax and pleural effusion. The ultrasound evaluation for pneumothorax examines the apposition of visceral and parietal pleura. The ultrasound evaluation for pleural effusion or hemothorax seeks to identify abnormal collections of pleural fluid. Extended applications for thoracic ultrasound include the diagnosis of abnormal interstitial lung water. Recent literature has shown that ultrasound is both sensitive and specific for interstitial lung fluid caused by congestive heart failure, volume overload, acute respiratory distress syndrome (ARDS), interstitial lung disease, and a variety of other diseases. Advantages of thoracic ultrasound are rapid deployment in critically ill patients with immediate diagnostic information without the need to transport or transfer the patient, the ability to perform the exam with portable ultrasound machines in remote or difficult clinical situations, and the ability to integrate the exam with sonographic evaluation of multiple organ systems. It is important to understand that thoracic ultrasound is a part of the resuscitative effort and is an emergent procedure. Other procedures may take precedence or may proceed simultaneously. It is not a comprehensive imaging test such as computerized tomography. The judicious use of ultrasound can add to the rapid, non-invasive, and dynamic evaluation of the critical patient.

2. Indications/Limitations

a. Primary
   i. Acute pneumothorax

   ii. Abnormal collections of pleural fluid

b. Extended
   i. Interstitial lung fluid caused by CHF and other conditions

   ii. Pneumonia

   iii. Pulmonary fibrosis

c. Contraindications
   i. Known, tension pneumothorax requiring emergent intervention

d. Relative Contraindications
   i. Significant pain in the area to be scanned

   ii. Open wounds or dressings in area to be scanned

e. Limitations
   i. Morbidly obese patients can present so much adipose tissue that adequate imaging with ultrasound is technically difficult

   ii. While bedside thoracic ultrasound is more sensitive to diagnose pleural effusion than chest X-ray, the performance of the exam is dependent on the skill level of the sonologist

f. Pitfalls

i. Absence of pleural sliding is not 100% specific for pneumothorax, as prior pleurodesis, pleural scarring, lung contusions, bronchial obstruction, and advanced bullous emphysema, may result in absence of lung sliding.

ii. The presence of pleural sliding only excludes pneumothorax immediately under the transducer. It does not rule out the presence of pneumothorax in other parts of the chest.

iii. Thoracic ultrasound does not exclude the presence of a pulmonary embolism

iv. The presence of B-lines posteriorly in the supine patient may be a normal finding.

v. The presence of interstitial lung fluid on bedside thoracic ultrasound can be caused by many disease processes. Sonographic information should be correlated with history, physical exam, and with other clinical findings.

vi. Motion of the transducer with respect to the patient's chest wall may give the impression of pleural motion, resulting in failure to identify pneumothorax.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Chest EUS is the basis of immediate decisions concerning further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by chest EUS represents the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of many causes of chest pathology, emergency interventions may be undertaken based upon findings of the EUS exam. For this reason, EUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam.

Personnel that may perform EUS of the chest include physicians of multiple specialties, ultrasound technologists, physician extenders, and emergency medical personnel. Training should be in accordance with specialty or organization specific guidelines.

4. Specifications for Individual Examinations

a. General - Chest EUS is performed simultaneously with other aspects of resuscitation. The transducer is placed systematically in each of the appropriate windows based on the clinical scenario. The ultrasound images are interpreted in real-time as the exam is being performed. If possible, images may be retained for purposes of documentation, quality assurance, or teaching.

b. Technique. Overview. The chest ultrasound examination requires little patient preparation except for positioning in the bed at an ergonomic height for the examiner. Multiple areas of the chest are scanned. A generous amount of ultrasound gel is helpful, as wide areas of the chest are evaluated. In the absence of pleural adhesions, a pneumothorax typically occurs in the most anterior aspect of the chest in a supine patient. Conversely, pleural effusions or hemothoraces tend to accumulate posteriorly in the costophrenic sulci. When evaluating a patient for pulmonary edema, the patient is often in a semi-recumbent or upright position. Experienced sonologists often perform lung and pleural exams with the transducer parallel to the ribs, but for most emergency sonologists, an orientation perpendicular to the ribs facilitates identification of the pleural line, immediately deep to the ribs, which are useful landmarks recognizable in older children and adults by distal shadowing. When evaluating the lung bases via the liver and spleen, the sonologist should identify the solid organ below the diaphragm, and the thoracic cavity superior to the diaphragm, indirectly recognizable by mirror artifact of liver (on the right) and spleen (on the left).

c. Pathologic findings
   i. Pneumothorax
      1. Anterior chest. In a trauma patient on a backboard, the anterior chest will be the most sensitive area to identify a pneumothorax. In this window, a linear array transducer is ideal, with the focal zone set at the pleural line. However, a curvilinear or phased array transducer may also be used, using their high frequency range, and with adjustment of the focal zone. The transducer is placed in the mid-clavicular line, immediately inferior to the clavicles, and the orientation marker is directed cephalad in a sagittal plane. Two ribs, with distal shadowing should be identified. The pleural line beneath the ribs should be identified. The physician should evaluate for pleural sliding or shimmering as the patient breathes, indicating that the lung is expanded with the visceral and parietal pleura directly apposed. Other findings that exclude pneumothorax under the transducer include "lung pulse" (motion of visceral pleura and lung in time with cardiac motion) and the presence of B-lines (see below). The absence of any of these findings is highly suggestive of the presence of a pneumothorax. Conversely, the presence of the "leading edge" or "lung point" sign (created by the site of transition between expanded and collapsed lung) is pathognomonic of the presence of pneumothorax. Each interspace in the mid-clavicular line should be systematically evaluated to the level of the diaphragm on both sides. At each interspace, the sonologist should anchor the probe to the patient's chest wall using his/her examining hand, in order to minimize chest wall motion, which can be mistaken for lung sliding. The movement of the pericardium should not be mistaken for either pleural sliding or the lung-point sign in the left chest. In most cases, the probe should be placed more laterally when examining the left chest in the region of the heart.

      2. Lateral chest. The technique for examining the lateral chest is identical to the anterior chest, except the physician will examine each interspace in the mid-axillary line.

      3. Posterior thorax. The technique for examining the posterior thorax is identical to the anterior chest, except the physician will examine each interspace on the patient's back. The patient is examined sitting up if possible. Ultrasound waves do not penetrate the scapulae, so these should be abducted by asking the patient to grasp the contralateral shoulder with each hand.

      4. Abbreviated exam. In critical situations, an ultrasound exam of the entire chest may not be feasible. In such circumstances, the evaluation may be limited to a single location on each anterior hemothorax. This two-point exam may identify large pnemothoraces, but miss a smaller pneumothorax.

      5. M-Mode evaluation. M-Mode can be used to help identify or to document the presence of a pneumothorax. The M-mode sampling bar is placed in the middle of the intercostal space and the resulting M-Mode tracing is evaluated over time. In the normal patient a linear pattern superficial to the pleural line is in sharp distinction to the granular pattern deep to it (the "seashore sign"). With pneumothorax, there is a horizontal linear pattern above and below the pleural line ("stratosphere sign" or "barcode sign").

   ii. Pleural effusion
      1. Evaluation of right lung base in the supine patient. Similar to the evaluation of fluid in Morrison's Pouch, the physician can rapidly identify fluid above the diaphragm. Typically, a curvilinear or phased array probe is placed in an intercostal space around the nipple line in the coronal plane or parallel with the ribs, with the orientation marker

directed cephalad. Following the identification of the kidney, liver, and diaphragm, the examiner angles or rocks the probe to evaluate above the diaphragm, using the liver as the acoustic window. Free fluid in the hemithorax will be identified as an anechoic or black area above the diaphragm. The examiner may also identify consolidated lung sitting in large pleural effusions. The examiner should be aware that B-mode ultrasound is preferred to identify the presence of pleural effusion and hemothorax.

2. Evaluation of left lung base in the supine patient. Similar to the evaluation of free abdominal fluid in the left flank, the physician can rapidly identify fluid above the left diaphragm. Typically, a curvilinear or phased array probe is placed in an intercostal space around the mid-axillary line in the coronal plane or parallel with the ribs, with the orientation marker directed cephalad. Following the identification of the spleen, liver, and diaphragm, the examiner angles or rocks the probe to evaluate above the diaphragm, using the spleen as the acoustic window. Free fluid in the hemithorax will be identified as an anechoic or black area above the diaphragm. The examiner may also identify consolidated lung sitting in large pleural effusions. This view is often more challenging secondary to the relatively smaller size of the spleen compared to the liver.

3. Evaluation in the upright patient can be performed by placing the transducer on the midscapular line in a sagittal orientation, and sliding it from the level of the liver (on the right) or the spleen (on the left) in a cephalad direction until the diaphragm and costophrenic sulcus are identified. In the normal patient, this will be recognized by the presence of pleural sliding. Abnormal fluid collections (effusion, hemothorax, empyema, etc.) appear anechoic or hypoechoic.

4. Large pleural effusions. Occasionally, a large fluid collection may be identified during the evaluation of the pleura on the anterior chest wall.

5. E-FAST. During trauma scenarios, many clinicians now include evaluation of the pleural spaces for hemothorax during the E-FAST exam. The technique is as described above for "Evaluation of the lung bases in the supine patient" (see 7.f.vi.1 above and 7.f.vi.2 above).

iii. Interstitial lung fluid

1. Undifferentiated dyspnea. There is a substantial body of literature supporting the use of ultrasound for the differentiation of intrinsic lung disease and pulmonary edema states as a cause of acute dyspnea. The ultrasound finding of relevance is the presence of widespread B-lines. These are fine reverberation artifacts that extend from the pleural line to the far field. (Traditionally, depth is set at 15 cm.) These represent accumulation of fluid within the pulmonary interstitium. Many qualitative and quantitative methods have been described to assess B-lines. One of the most widely used divides the anteriolateral thorax into eight zones. In each hemithorax, the four zones are defined approximately by the anterior axillary line (anterior and posterior) and the nipple line (superior and inferior). Scattered B-lines may be normal in the more posterior areas of lung in the supine patient, but are abnormal if found anteriorly. In general, the greater the number of rib spaces with B-lines, and the more anterior in distribution, the more specific the finding for abnormal increased interstitial lung water. If the B-lines are unilateral or more localized, a focal process such as pneumonitis is more likely. Bilateral and extensive B-lines are more likely to be due to a more generalized process such as volume overload, heart failure, or ARDS. In infants and children, the differential diagnosis of B-lines is different from that in adults, and is the subject of ongoing

elucidation. In extreme cases, the B-lines can become confluent, giving the appearance of a swinging curtain of artifact. A recent consensus conference has endorsed the use of "B-lines" to apply to the variety of terms used in the early literature on the topic including "comet tail artifacts", and "lung rockets". Ideally a small footprint curvilinear transducer is used with the focus at, or slightly below the pleural line and a 12 to 15 cm depth of field (greater depth also allows easier recognition of consolidations). If such a transducer is not available, a curved array abdominal transducer or a phased array transducer can be used. Linear array transducers (ideal for the assessment of pneumothorax) are suboptimal due to their limited depth of field. If possible, artifact-reduction technologies such as multibeam processing and tissue harmonic imaging should be turned off. The transducer should be oriented in the sagittal plane to identify two ribs and the pleural line immediately beneath the ribs. Scattered comet tail artifacts that dissipate in the far field are caused by minor irregularities in the visceral pleura are referred to as "Z-lines," and have no clinical significance. They can be distinguished from B-lines, which are multiple and do not diminish in the far-field.

5. **Documentation**
   In performing EUS of the lung and pleural spaces, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. **Equipment Specifications**
   A linear array transducer with a frequency range of 5.0 to 12.0 MHz will allow the sonologist to image the superficial pleura and its artifacts. A curvilinear or phased array probe with a low frequency range of 2.0 – 5.0 MHz can be used for the evaluation of pleural effusion and B-lines. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. **Quality Control and Improvements, Safety, Infection Control, and Patient Education**
   Policies and procedures related to quality, safety, infection control, and patient concerns should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Ocular

1. **Introduction**
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound (EUS) studies of the eye to evaluate for traumatic and non-traumatic findings.

   The use of EUS of the eye has been used for the detection of posterior chamber and orbital pathology. Specifically, ultrasound has been described to detect retinal detachment, vitreous hemorrhage, and dislocations or disruptions of structures. In addition, the structures posterior to the globe such as the optic nerve sheath diameter may be a reflection of other disease in the central nervous system.

   EUS evaluation of the eye occurs in conjunction with other EUS applications and other imaging and laboratory tests. 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. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses, EUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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 ocular complaints.

2. Indications/Limitations

a. Primary
   i. Retinal detachment (RD) with or without vitreous detachment

b. Extended
   i. Intracranial pressure indirectly via optic nerve sheath diameter measurement

   ii. Vitreous hemorrhage

   iii. Lens dislocation

   iv. Intraocular foreign body

   v. Globe rupture

   vi. Retrobulbar hemorrhage

   vii. Central retinal artery/vein occlusion

   viii. Subretinal hemorrhage

   ix. Posterior vitreous detachment (PVD)

   x. Direct and consensual light reflex

c. Limitations
   i. Patient's inability to tolerate exam secondary to eye pain

d. Relative Contraindications
   i. Open ocular trauma with leaking aqueous or vitreous humor; globe rupture. This risk may be minimized with the use of a Tegaderm and copious gel over the closed eyelid.

   ii. Periorbital wounds

e. Pitfalls
   i. Missed pathology due to visualization in only one plane or neglecting to utilize kinetic echography to visualize all quadrants and contents of the globe.

   ii. Applying too much pressure in a patient with suspected globe rupture or intraocular foreign body. In these patients a Tegaderm may be placed over the closed eyelid and copious gel applied. Scanning may then proceed using minimal or no applied pressure.

iii. Failure to differentiate retinal detachment from other pathologies such as chronic vitreous hemorrhage, PVD, or fibrinous vitreous bands.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Ocular EUS is the basis of immediate decisions concerning further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by ocular EUS represent the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of many causes of ocular pathology, emergency interventions may be undertaken based upon findings of the EUS exam. For this reason, EUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam.

Physicians of a variety of medical specialties may perform ocular ultrasound. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of ocular disease, as outlined above.

4. Specifications for Individual Examinations

a. General – The eye is examined systematically in real time in all quadrants and in at least two orthogonal directions. Evaluation of the eye for evidence of other pathologies such as lens dislocation or vitreous hemorrhage, as described in "Extended Indications," are then performed based on the clinical situation and the physician's sonographic experience. The ultrasound images are interpreted in real-time as the exam is being performed. Images may be captured for archiving and/or quality review.

b. Technique

i. Identification

1. Anterior chamber. The anterior chamber of the eye is the smaller of the two chambers. It appears in the near field and is bounded posteriorly by the iris and lens.

2. Iris. In a transverse section, the iris is usually seen as 2 horizontal hyperechoic lines flanking the lens. In a longitudinal plane, the iris is donut-shaped, hyperechoic, and changes size when light is applied.

3. Lens. Due to its density and composition, the lens is difficult to completely visualize. Usually only the anterior and posterior surfaces, represented by two gently curved inverse arcs between the horizonal lines of the iris, can be seen. Reverberation artifact may also be seen extending posteriorly from the lens.

4. Posterior chamber. The posterior chamber of the eye is the larger of the two chambers. It is located directly posterior to the iris and lens, and should be completely anechoic and without internal echoes in the absence of pathology.

ii. Real-time scanning technique

1. Overview. The ocular examination can be performed at the patient's bedside and requires little patient preparation except for positioning in the bed (supine or 20 degrees of head elevation), and a 5-12 MHz probe. If intraocular foreign body or globe rupture/perforation are suspected, a Tegaderm may first be placed over the closed lid and then a generous amount of sterile ultrasound gel applied. After the exam, the Tegaderm is gently removed and the need to wipe gel away from the eye is negated. Both eyes are insonated. The examiner should rest the examining hand on the patient's

forehead or face to avoid unnecessary pressure on the globe. Typically, the examination is begun on the affected side and scanning is performed in two planes while and the patient is asked to move their eyes in all 4 directions. This serves two purposes: 1) all quadrants may be assessed and 2) identification of certain pathologies, such as retinal detachment and vitreous hemorrhage are easier since they move with eye movement (kinetic echography).

iii. Key components of the exam. Both eyes are systematically scanned in all quadrants as described above.

1. Traumatized eye. Evaluation of the traumatized eye with ultrasound is especially helpful when swelling limits direct visualization and evaluation of the eye and surrounding structures. The contours of the posterior chamber should be perfectly circular, and particular attention is paid to the posterior surface of the posterior chamber for evidence of retinal detachment. The vitreous is examined for hemorrhage or foreign bodies. Attention should also be paid to the retrobulbar space for hemorrhage and assessment of optic nerve edema. Direct and consensual light reflex of the iris may be checked with light applied to the closed eyelid of the traumatized eye as well as the unaffected eye.

2. Non-traumatized eye. Evaluation of the non-traumatized eye is a useful adjunct to the physical exam and slit lamp exam, especially with complaints of sudden onset vision loss. Attention is again paid to the posterior chamber for evidence of vitreous detachment with or without accompanying retinal detachment or hemorrhage. If the examiner is sufficiently skilled, color and power Doppler can be used to examine blood flow if central retinal artery/vein occlusion is suspected.

iv. Pathologic findings

1. Fibrinous vitreous bands. Usually an asymptomatic bilateral finding that occurs increasingly with age, these bands are also associated with diabetic retinopathy, sickle cells, prematurity, or previous vitreous hemorrhage. Bands appear as multiple hyperechoic mobile fibers in the posterior chamber that move with eye movement. Gain setting must usually be significantly increased to see fibrinous bands.

2. Retinal detachment. A brightly echogenic line separated from the posterior globe and tethered to optic nerve is indicative of RD. This should move as the eye is taken through range of motion. Depending on the cause of the detachment, other findings such as posterior vitreous detachment, vitreous hemorrhage, or subretinal hemorrhage may also be present. RD should be easily seen at normal gain levels.

3. Vitreous hemorrhage. The sonographic appearance of vitreous hemorrhage depends on the quantity and age of the hemorrhage. A small amount of fresh hemorrhage will appear as hyperechoic flecks that move with eye movement. A greater amount of blood will tend to layer along the posterior surface of the eye and also moves with eye movement. As blood ages, it tends to coalesce as string-like bands in the posterior chamber that move with eye movement.

4. Posterior vitreous detachment. PVD occurs increasingly with age and is usually an asymptomatic process but sometimes presents with photopsia. PVD is usually seen at higher gain levels and appears as a single, delicate string-like membrane that is detached from the posterior globe and moves with eye movement. It is thinner and less echogenic than an RD and notably, should not be tethered to the optic nerve. PVD can become

more symptomatic when it causes a tear in the retina resulting in hemorrhage and a retinal detachment.

5. Subretinal hemorrhage. Appears as a shifting fluid collection along the posterior globe that is slightly more echoic than the vitreous body, and separated from it by the brightly echogenic retina.

6. Lens dislocation. Bedside ultrasound suggests a lens dislocation when the position of the lens in the affected eye to the relative position in the unaffected eye is disrupted and out of place.

7. Foreign body. Bedside ultrasound suggests an orbital foreign body when hyperechoic foreign material is appreciated in the globe when scanning in two planes. Thin-slice CT has a slightly higher sensitivity for intraocular foreign bodies, mainly because intraocular air introduced with the foreign body can hinder the view of deeper structures and pathology. All foreign bodies will appear hyperechoic with varying posterior artifact based on the composition of the foreign body itself (Metal and glass tend to produce reverberation artifact. Wood, gravel, and plastic are hyperechoic with a trailing shadow.)

8. Globe rupture. Ultrasound suggests globe rupture when the depth of the affected globe is shallow relative to the unaffected side. The globe typically loses the perfectly circular contour and vitreous hemorrhage is commonly seen in the posterior chamber. The scan is performed using a thick layer of sterile gel to avoid direct contact between probe and eyelid.

9. Retrobulbar hemorrhage. Usually appears as a hypoechoic fluid collection posterior to the globe.

10. Optic nerve edema. The intra-orbital subarachnoid space is distensible and subject to the same pressure shifts as the intracranial compartment which contains the optic nerve. In an axis perpendicular to the optic nerve 3mm behind the globe, the optic nerve sheath diameter is measured. The optic nerve should be aligned directly opposite the probe but the optic nerve sheath diameter width measured perpendicular to the vertical axis of the scanning plane. A mean optic nerve sheath diameter of < = 5mm has been suggested as the upper limits of normal in an adult with concern for increased ICP. This measurement shows high negative predictive value.

11. Central retinal artery occlusion. Ocular ultrasound suggests occlusion to the central retinal artery or vein when there is loss of color flow along the posterior globe or overlying the optic nerve (the retinal artery and vein run within the optic nerve sheath). Power Doppler should be used if color flow is not evident, and both arterial and venous waveforms should be documented in pulse Doppler mode.

12. Light response. It is possible to assess the pupil for direct and consensual light response through a closed or edematous eyelid. The iris is usually visualized in a long axis by moving the transducer to the top of the orbit in a transverse plane and fanning inferiorly while asking the patient to look at their feet. Light is then applied to either closed eyelid and the iris assessed for constriction. Measurements of pupil constriction can also be formally obtained with this method.

5. Documentation

In performing EUS of the eye, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Documentation of the ocular EUS should be incorporated into the medical record. Documentation should include the indication for the procedure, the views obtained, a description of the organs or structures identified and an interpretation of the findings. 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 examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. **Equipment Specifications**
   A high frequency linear array probe with a frequency range of 8 to 14 MHz is ideal, as this range will allow the sonographer to image the globe in detail. An endocavitary transducer with similar frequency range can also be used, and allows a sector field of view for better imaging of the retrobulbar space. B-mode imaging is preferred to avoid exposure of the eye to higher power outputs. Color-flow and Doppler modes may be used for focused evaluations of the optic nerve and retina but these examinations should be minimized.

7. **Quality Control and Improvements, Safety, Infection Control, and Patient Education**
   Policies and procedures related to quality, safety, infection control, and patient concerns should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Pelvic

1. **Introduction**
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound studies (EUS) of the pelvis in emergency patients to evaluate for evidence of acute pathology including ectopic pregnancy, ovarian cysts and tubo-ovarian abscess.

   First trimester pregnancy complications such as abdominal pain and vaginal bleeding are common presenting complaints. Ultrasound finding of a clear intrauterine pregnancy, in many instances, minimizes the possibility of ectopic pregnancy and can decrease throughput time and decrease morbidity. The scope of practice for pelvic ultrasound will vary depending on individual experience, comfort/skill level and departmental policies. However, some centers may choose to evaluate the ovaries and seek to identify tubo-ovarian abscess, fibroids, and pelvic masses.

   EUS of the pelvis occurs as a component of the overall clinical examination of a patient presenting with symptoms related to the pelvic area. It is a clinical 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. Other diagnostic tests may provide more detailed information than EUS, show greater anatomic detail, or identify alternative diagnoses. However, EUS is non-invasive, rapidly deployed, allows the patient to remain under a physician's direct care, and avoids delays, costs, specialized technical personnel, and bio-hazardous potentials of radiation and contrast agents. These advantages make it a valuable addition to the diagnostic resources available to the physician caring for patients with time-sensitive or emergency conditions such as ectopic pregnancy and other causes of acute pelvic pain.

2. **Indications/Limitations:**
   a. Primary
      i. To evaluate for the presence of intrauterine pregnancy, minimizing the likelihood of an ectopic pregnancy when modifying factors such as infertility treatment are not present.

b. Extended
   i. Ovarian cysts

   ii. Fibroids

   iii. Tubo-ovarian abscess

   iv. Ruling out ovarian torsion by ruling out cyst or mass

   v. Identifying suspected ectopic pregnancy

c. Limitations
   i. Infertility patients or others with specifically known risk factors for heterotopic pregnancy.

   ii. Assessing pelvic sonographic anatomy after vaginal-rectal surgery

   iii. Evaluation of fetal health outside of fetal heart rate determination

d. Pitfalls
   i. Ovarian torsion evaluation in the presence of ovarian, para-ovarian, tubal or para-tubal mass

   ii. Ovarian mass evaluation for presence of malignancy versus benign mass

   iii. Interstitial pregnancy

   iv. Presence of ovarian torsion due to a mass or cyst in first trimester patient with identified first trimester intrauterine pregnancy

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Pelvic EUS provides information that is the basis of immediate decisions concerning further evaluation, management, and therapeutic interventions. Because of the direct bearing on patient care, the rendering of a diagnosis by EUS represents the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of ectopic pregnancy and other pathologic conditions of the pelvis, emergency interventions may be mandated by the diagnostic findings of the EUS of the pelvis. For this reason, EUS of the pelvis should occur as soon as the clinical decision is made that the patient needs a sonographic evaluation.

Physicians of a variety of medical specialties may perform EUS of the pelvis. Training should be in accordance with specialty or organizational specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute presentations related to the pelvic area, as outlined above.

4. Specifications for Individual Examinations

a. General – Organs and structures evaluated by pelvic EUS are scanned systematically in real time through all tissue planes in at least two orthogonal directions. The primary focus of the pelvic EUS is the identification on an intrauterine pregnancy. Pelvic sonographic evaluations for other pelvic pathology, as described in “Extended Indications,” are performed based on the clinical situation and appropriate physician’s sonographic experience.

b. Technique
  i. Identification
    1. Uterus. The uterus should be examined in at least two planes, the short- and long-axis, to avoid missing important findings that may lie off midline or outside the endometrial canal, such as an interstitial pregnancy or fibroids. The uterus should be traced from the fundus to the cervix, confirming that it is actually the uterus that is being scanned rather than a gestational reaction from a large ectopic pregnancy. Fibroids, which can cause significant pain and even bleeding, should be noted. A pregnancy located less than 5 to 7 mm (exact minimum normal distance varies from reference to reference) from the edge of the myometrium is concerning for being an interstitial ectopic pregnancy.

    2. Cul-de-sac. The cul-de-sac or pouch of Douglas may contain small to moderate amounts of fluid in the normal female pelvis depending on her point in the menstrual cycle. Large amounts of fluid are abnormal but may not be tied to significant pathology. When an ectopic pregnancy is of concern, a significant amount of fluid in the pouch of Douglas raises the concern for rupture. Echogenic fluid in the pelvis may be consistent with either pus or blood.

    3. Ovaries. Each ovary should also be scanned in at least two planes, short- and long-axis. This technique should enable visualization of possible masses juxtaposed to the ovary as well as cysts located on the periphery of an ovary. In the first trimester patient with pain evaluating the ovaries may identify an unexpected cause for pain. For instance, ovarian masses, cysts, or ovarian torsion may be the etiology of a patient's pain.

    4. Fallopian tubes. The normal fallopian tube can be visualized as it originates from the cornua of the uterus. Visualization can be limited by significant bowel gas or enhanced when distended by fluid such as in hyrosalpinx or tubo-ovarian abscess.

  ii. Real-time scanning technique
    1. Overview. The pelvic ultrasound examination can be performed at the patient's bedside and when possible, immediately following the pelvic examination portion of the physical examination to limit the time a patient spends in the lithotomy position. A chaperone should also be present for all endovaginal examinations. In most instances, the transabdominal portion of the ultrasound exam should precede the transvaginal component as information regarding bladder fullness, position of the uterus, and anatomic variations can be appreciated. As well, in a certain percentage of patients, an intrauterine pregnancy will be documented, thereby minimizing the need to perform the endovaginal ultrasound exam.

    2. Transabdominal. The patient lies supine on the examination table. The transducer is placed on the lower abdomen just above the symphysis pubis and the pelvic organs are examined through a window of the distended bladder. Bladder filling is ideal when the bladder dome is just above the uterine fundus. Under distention limits visualization of the uterus and other pelvic organs. Images are obtained in sagittal and transverse planes. To optimally image the uterus, the transducer is aligned with the long axis of the uterus, which is often angled right or left of the midline cervix. The ovaries and adnexa are best seen by sliding the transducer to the contralateral side and angling back toward the ovary of interest. The transabdominal technique provides the best overview of the pelvis.

3. Transvaginal. For the transvaginal examination, optimal imaging is achieved with an empty bladder. Two possible patient positions will facilitate endovaginal scanning. In the first, the patient is supine on a stretcher or bed with her legs flexed. Folded sheets or pads are placed under her buttocks to elevate her pelvis above the examination table to allow room for transducer movement. Alternatively, the patient may be scanned on a pelvic examination table with her feet in stirrups. The probe may be placed in the vagina by the patient or the examiner. The uterus is examined entirely in two planes. When in the sagittal plane, the examiner sweeps the transducer laterally to each side to visualize the uterus in its entirety, because it is often deviated to one side. The transducer is then rotated 90 degrees counterclockwise to obtain a coronal view. The transducer can then be angled anteriorly, posteriorly, and to each side to obtain a full assessment of the uterus.

   After the sagittal and coronal planes of the uterus have been fully interrogated, other structures in the pelvis can be visualized, such as the cul-de-sac, fallopian tubes, and ovaries. The cul-de-sac is posterior to the uterus and the ovaries are located lateral to the uterus and usually lie anterior to the internal iliac veins and medial to the external iliac vessels.

5. Documentation

In performing EUS of the pelvis, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment specifications

A curved linear array abdominal transducer with a range of approximately 3.0 to 5.0 MHz as well as an endovaginal transducer with an approximate range of 6.0 to 10.0 MHz range is used for pelvic ultrasound. Color or power Doppler and pulsed wave Doppler are critical if an assessment of blood flow will be made. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination. There is no indication to interrogate the fetus with pulsed wave Doppler, therefore avoiding high-energy ultrasound in early pregnancy. Further, all pelvic ultrasound studies should be kept to a reasonably limited amount of time when sensitive tissue such as the fetus is involved.

7. Quality Control and Improvements, Safety, Infection Control, and Patient Education

Policies and procedures related to quality, safety, infection control, and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Right Upper Quadrant

1. Introduction

The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergent ultrasound (EUS) studies of the right upper quadrant (RUQ) in patients suspected of having acute biliary disease.

Abdominal pain is a common presenting complaint in the emergency department. Biliary disease is frequently a consideration among the possible etiologies. In many cases, EUS of the RUQ may be diagnostic for biliary disease, may exclude biliary disease, or may identify alternative causes of the patient's symptoms. If biliary disease is identified, EUS also guides disposition by helping to distinguish emergent, urgent, and expectant conditions.

EUS of the RUQ occurs as a component of the overall clinical evaluation of a patient with abdominal pain. 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. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses, EUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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 biliary colic or cholecystitis, as well as other causes of abdominal pain.

2. Indications/Limitations

a. Primary
   i. Identification of cholelithiasis

b. Extended
   i. Cholecystitis

   ii. Common bile duct abnormalities, including dilatation and choledocholithiasis

   iii. Liver abnormalities, including tumors, abscesses, intrahepatic cholestasis, pneumobilia, hepatomegaly

   iv. Portal vein abnormalities

   v. Abnormalities of the pancreas

   vi. Other gallbladder abnormalities, including tumors

   vii. Unexplained jaundice

   viii. Ascites

c. Contraindications
   i. There are no absolute contraindications to RUQ EUS. There may be relative contraindications based on specific features of the patient's clinical situation.

d. Limitations
   i. EUS of the RUQ 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 RUQ. 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.

ii. The primary focus of RUQ EUS is to identify or exclude gallstones. Other entities, including hepatic tumors, abnormalities of the pancreas or abnormalities of the portal system would not usually be identified by a limited and focused exam.

iii. Examination of the RUQ may be technically limited by:

1. Obese habitus

2. Bowel gas

3. Abdominal tenderness

e. Pitfalls

i. When bowel gas or other technical factors prevent an adequate examination, these limitations should be identified and documented. As usual in emergency practice, such limitations may mandate further evaluation by alternative methods.

ii. Failure to identify the gallbladder may occur with chronic cholecystitis particularly when filled with stones, or, in the rare instances of gallbladder agenesis. Failure to identify the gallbladder should warrant additional diagnostic imaging.

iii. The gallbladder may be confused with other fluid filled structures including the portal vein, the inferior vena cava, and hepatic or renal cysts or loculated collections of fluid. These can be more accurately identified with careful scanning in multiple planes.

iv. Measurement of posterior gallbladder wall thickness may be inaccurate due to layered gallstones, acoustic enhancement from bile, and closely apposed loops of bowel. Consequently, measurement of gallbladder wall thickness should be made on the anterior wall, adjacent to the hepatic parenchyma.

v. Small gallstones may be overlooked or mistaken for gas in an adjacent loop of bowel. In questionable cases, gain settings should be optimized, the area should be scanned in several planes, and the patient should be repositioned to check for the mobility of gallstones.

vi. Gas in loops of bowel adjacent to the posterior wall of the gallbladder may be mistaken for stones. Intraluminal gas can be distinguished by noting peristalsis and specifically identifying the bowel wall. Stones are characterized by anechoic shadowing and movement with patient repositioning.

vii. Small stones in the gallbladder neck may easily be overlooked or mistaken for lateral cystic shadowing artifact (edge shadows). It may be necessary to image this area in several planes to avoid this pitfall.

viii. Common bile duct stones may only be identified by the shadowing they cause.

ix. Cholesterol stones are often small, less echogenic, may float, and may demonstrate comet tail artifacts.

x. Pneumobilia and emphysematous cholecystitis are subtle findings and may produce increased echogenicity and comet–tail artifact caused by gas in the biliary tree and gallbladder wall.

xi. Polyps may be mistaken for gallstones. The former are non-mobile, do not shadow, and are adjacent and attached to the inner gallbladder wall.

xii. Gallbladder wall thickening may not represent biliary pathology, but may be physiological, as in the post-prandial state, or with non-surgical conditions such as hypoproteinemia and congestive heart failure.

xiii. The presence of gallstones or other findings consistent with cholecystitis does not rule out the presence of other life-threatening causes of epigastric pain such as aortic aneurysm or myocardial infarction.

xiv. Except for emergency physicians with extensive experience in EUS, evaluations of the liver, pancreas and Doppler examination of the portal venous system are not part of the normal scope of EUS of the RUQ.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

EUS of the RUQ provides information that is the basis of immediate decisions concerning further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by RUQ EUS represent the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of many causes of abdominal pain and biliary pathology, emergency interventions may be undertaken based upon findings of the EUS exam. For this reason, EUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam. Physicians of a variety of medical specialties may perform biliary ultrasound. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute biliary disease, as outlined above.

4. Specifications for Individual Examinations

a. General –Organs and structures evaluated in the RUQ are scanned systematically in real time through all tissue planes in at least two orthogonal directions. The primary focus of the biliary EUS examination is the identification of gallstones. Evaluation of the gallbladder for evidence of cholecystitis and examination of the liver and biliary tree, as described in "Extended Indications," are performed based on the clinical situation and the emergency physician's ultrasound experience.

b. Technique

i. Identification

1. Gallbladder. The normal gallbladder is highly variable in size, shape, axis, and location. It may contain folds and septations, and may lie anywhere between the midline and the midaxillary line. The axis and location of the porta hepatis are also highly variable. Orientation of images of the gallbladder and common bile duct are conventionally defined with respect to their axes as longitudinal, transverse, and oblique, rather than standardized anatomic planes such as sagittal, coronal, oblique and transverse.

In most cases, the gallbladder lies immediately posterior to the inferior margin of the liver in the mid-clavicular line. In some patients, the fundus may extend several centimeters below the costal margin; in others, the gallbladder may be high in the hilum of the liver, almost completely surrounded by hepatic parenchyma. In order to avoid confusing it with fluid-filled tubular structures, the entire extent of the gallbladder should be scanned in its long and short axes.

2. Common bile duct. It is usually located by following the neck of the gallbladder to the portal triad where it can be found in conjunction with the portal vein and the hepatic artery. The use of color Doppler helps identify vascular structures from the common bile duct.

ii. Real-time scanning technique
   1. Overview: A general-purpose curved array abdominal probe with a frequency range of 2.0-5.0 MHz is generally used. A small footprint or phased array probe may facilitate scanning between the ribs. As with other EUS, the organs of interest are scanned methodically through all tissue planes in at least two orthogonal directions.

   2. In most patients, the inferior margin of the liver provides a sonographic window for the gallbladder below the costal margin. In many cases, this window can be augmented by asking the patient to take and hold a deep breath. It may also be helpful to place the patient in a left decubitus position. The transducer is placed high in the epigastrium with the indicator in a cephalad orientation. The probe is swept laterally while being held immediately adjacent to the costal margin. The liver margin should be maintained within the field of view on the screen.

   3. In patients whose liver margin cannot be visualized below the costal margin, an intercostal approach is necessary. In order to minimize rib shadowing, the transducer is oriented with the plane of the probe parallel to the intercostal space and the indicator directed toward the vertebral end of the rib. This plane is about 45 degrees counter-clockwise from the long axis of the patient's body. The probe is swept laterally from the sternal border to the midaxillary line until the gallbladder is located.

   4. When the gallbladder has been located, its long and short axes are identified. In the long axis, images are obtained, by convention, with the gallbladder neck on the left of the screen, and the fundus on the right. The gallbladder is scanned systematically through all tissue planes in both long and short axis views. In many patients, a combination of subcostal and intercostal windows allows for views of the gallbladder from multiple directions and may help identify small stones, resolving artifacts, and examining the gall bladder neck.

   5. The common bile duct is most easily located sonographically by finding and identifying the portal vein and hepatic artery, which comprise the portal triad. Several techniques can be used to locate the common bile duct in addition to anatomic location. These include tracking the hepatic artery from the celiac axis, tracking the portal vein from the confluence of the splenic and superior mesenteric veins, and following the portal vessels in the liver to the hepatic hilum. In a transverse view of the portal triad, the common bile duct and hepatic artery are typically seen anterior to the portal vein. The common bile duct is usually more lateral than the hepatic artery or more to the left on the screen. It can also be distinguished by its absence of a color flow Doppler signal if this modality is employed.

iii. Key components of the exam. The gallbladder is systematically scanned with particular attention to the neck. For patients with low-lying gallbladder, the fundus may be obscured by gas-filled colon. Decubitus positioning or inhalation may help provide adequate windows in this situation. The principal abnormal finding is gallstones that are echogenic with distal shadowing. Measurement of wall thickness, if performed, is made on the anterior wall between the lumen and the hepatic parenchyma. Measurements of gallbladder size are rarely helpful in EUS, although gross increases in transverse diameter or overall size may be evidence of cholecystitis and hydrops, respectively. A qualitative assessment of the wall and pericholecystic regions should also be made, looking for mural irregularity, breakdown of the normal trilaminar mural structure, and fluid collections.

The common bile duct, like other tubular structures, is most accurately measured when imaged in a transverse plane. It is most reliable to measure the intraluminal diameter (inside wall to inside wall). Anatomically, it is preferable to measure the common bile at its largest diameter, which typically occurs extra-hepatic ally. Identification of the common bile duct in this location is best achieved with long axis visualization, rather than the transverse orientation. Becoming facile with imaging in both planes is a key element to successful measurements of the common bile duct. Evaluation of the common bile duct may reveal shadowing suggesting stones and/or comet-tail artifact suggesting pneumobilia. The question of such findings would warrant additional diagnostic testing.

iv. Pathologic findings

1. Cholelithiasis - Gallstones are often mobile (move with patient positioning) and usually cause shadowing. Optimization of gain, frequency and focal zone settings may be necessary to identify small gallstones and to differentiate their shadows from those of adjacent bowel gas.

2. Cholecystitis - This diagnosis is based on the entire clinical picture in addition to the findings of the EUS. The following sonographic findings support the diagnosis of cholecystitis.
    a. Thickened, irregular, or heterogeneously echogenic gallbladder wall is measured along the anterior surface. Thickness greater than 3 millimeters is considered abnormal.

    b. Pericholecystic fluid may appear as hypo- or an-echoic regions seen along the anterior surface of the gallbladder within the hepatic parenchyma and suggests acute cholecystitis.

    c. A Sonographic Murphy's sign is tenderness reproducing the patient's abdominal pain elicited by probe compression directly on the gallbladder, combined with the absence of similar tenderness when it is compressed elsewhere.

    d. Increased transverse gallbladder diameter greater than 5 cm may be evidence of cholecystitis.

3. Common bile duct dilatation - The normal upper limit of common bile duct diameter has been described as 3 mm, although several studies have demonstrated increasing diameter with aging in patients without evidence of biliary disease. For this reason, many authorities consider that the normal common bile duct may increase by 1 mm for every decade of age.

4. Pathologic findings of the liver and other structures are beyond the scope of the EUS.

5. Documentation

In performing EUS of the RUQ, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Documentation of the RUQ EUS should be incorporated into the medical record. Documentation should include the indication for the procedure, the views obtained, a description of the organs or structures identified and an interpretation of the findings. 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 examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. **Equipment Specifications**
   A curvilinear abdominal transducer with frequencies of 2.0-5 .0 MHz is appropriate. A small footprint curved array probe or phased array probe facilitates intercostal scanning. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. **Quality Control and Improvements, Safety, Infection Control and Patient Education**
   Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Soft tissue/Musculoskeletal

1. **Introduction**
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound (EUS) studies of soft tissue and musculoskeletal systems (ST-MSK).

   Ultrasound allows the practitioner to rapidly assess patients for pathology that is difficult or impractical to assess by other means. Primarily, ultrasound can aid in the classification of soft tissue infection, localization of foreign bodies (FB), detection of joint effusions and guidance of arthrocentesis. Secondarily, ultrasound can aid in the diagnosis of deep space infection, guidance of foreign body removal, fracture detection and reduction, and evaluation for ligament and tendon pathology. It is a clinically focused examination, which, in conjunction with history, physical examination and other imaging, provides important data for decision-making and patient care.

2. **Indications/Limitations**
   a. Primary
      i. Soft tissue: sonographic evaluation of
         1. Cellulitis versus abscess

         2. Foreign bodies

      ii. Musculoskeletal
         1. Evaluation of joint effusion

         2. Guidance of arthrocentesis

   b. Extended
      i. Soft tissue
         1. Identification of deep space infection

         2. Guidance of foreign body removal

ii. Musculoskeletal
1. Fracture detection and reduction
2. Identification of tendon/ligament injury
3. Diagnosis of tenosynovitis

c. Contraindications
i. Need for immediate operative management

d. Relative contraindications
i. Significant pain or open wounds over the area to be scanned

e. Limitations
i. Ultrasound does not replace clinical judgment, especially when emergent surgical procedures are indicated.

f. Pitfalls
i. Soft tissue

1. Infection
a. Early in the infectious course, classic sonographic findings of soft tissue infection may not be present.
b. Deep space infections may be difficult to detect secondary to inadequate penetration with higher frequency transducers and settings.
c. Abscesses typically have variable internal densities and consistencies, so sonographic appearance can also be variable.
d. The appearance of cellulitis is indistinguishable from sterile edematous tissue. In these scenarios, sonographic findings should be interpreted in the context of the clinical history.

2. Foreign body identification
a. Small FBs (< 2 mm) may be difficult to detect and require careful and methodical examination.
b. Superficial foreign bodies can also be difficult to detect since they are not typically located within the optimal focal zone of the sonographic window.
c. Confined spaces, such as web interspaces, can be difficult to image due to the contours of the transducer.
d. FBs adjacent to bone can be difficult to detect. Sonographers typically use shadowing or other artifacts as an important visual cue for presence of FB, and these may be obscured by closely adjacent bone.
e. Other echogenic material in the skin, such as air, scar tissue, ossified cartilage and keratin plugs, may produce false positive findings.

f. Although ultrasound is sensitive for the presence of a FB, this sensitivity does not reach 100%. Ultrasound cannot definitively rule-out the presence of a FB.

3. Foreign body localization and removal – see 'Ultrasound Guided Procedures" criteria.

ii. Musculoskeletal
1. Ultrasound has been shown to be highly accurate in the detection of long bone fractures. Certain fractures may be difficult to detect, including:
   a. non-displaced fractures

   b. small avulsion fractures

   c. fractures involving
      i. articular surfaces
      ii. intertrochanteric regions
      iii. hands and feet

2. Joint effusions are occasionally difficult to detect if they are:
   a. very small in size

   b. early in an infectious course

3. Ligaments and Tendons require careful and methodical evaluation since:
   a. incomplete lacerations may be difficult to visualize

   b. anisotropy may lead to misinterpretation of the sonographic images

   c. early in the infectious course, the typical sonographic findings of tenosynovitis may not be present

3. Qualifications and Responsibilities of the Clinician Performing the Examination

ST-MSK EUS is the basis of immediate decisions concerning further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by ST-MSK EUS represents the practice of medicine, and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of many causes of soft tissue-MSK pathology, interventions may be undertaken based upon findings of the EUS exam. For this reason, EUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam.

Physicians of a variety of medical specialties may perform ST-MSK ultrasound. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of ST-MSK disease, as outlined above.

4. Specifications for Individual Examinations

a. General. The ST-MSK examination can be performed at the patient's bedside and requires little patient preparation except for positioning in the bed and control of significant pain in the scanning area if present. The ultrasound probe is placed over the area of interest and imaging is performed in both sagittal and transverse planes. 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(s) 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. Comparison to the contralateral "normal" side and dynamic imaging are both critical in ST-MSK sonography.

b. Technique
   i. Identification
      1. Dermal layer. Most superficial echogenic structure encountered (deep to the stand-off pad if one is being used).

      2. Subcutaneous fat. Located deep to the dermis, this is a relatively hypoechoic layer with a reticular pattern of interspersed echogenic connective tissue.

      3. Muscle tissue. Hypoechoic striated tissue typically found in bundles.

      4. Tendons/ligaments. Hyperechoic tissue with a fibrillar appearance in the long axis. Tendons can be observed to move as the corresponding joints are passively flexed and extended. Ligaments may be more difficult to visualize at ninety degrees to the ultrasound beam and therefore may appear more hypoechoic.

      5. Blood vessels. Anechoic with a circular profile when observed in a short-axis.

      6. Bones. Bony cortices are brightly echogenic with posterior shadowing. Typically, only the most superficial surface of the bone will be visible.

      7. Nerves. Typically, hyperechoic and fibrillar in the long axis and with a honeycomb appearance in a short axis, nerves may be confused for tendons. Nerves usually do not move significantly with joint movement, and are localized in relation to vascular structures.

   ii. Real-time scanning technique
      1. Overview. A high frequency linear or hockey stick transducer is typically employed for ST-MSK ultrasound. This enables high-resolution imaging but typically limits depth of penetration to a few centimeters. Imaging may be improved with certain devices such as stand-off pads or water bath to place the item of interest central in the focal zone. The items of interest should be scanned methodically in 2 orthogonal planes.

      2. Soft tissue. The transducer is generally first dragged over an area of normal skin adjacent to the area of interest. As the transducer moves closer to the area of interest, the sonographer will carefully assess for signs of cellulitis, abscess, or cutaneous foreign body. Of particular note, when interrogating a soft tissue abscess, the application of gentle pressure will often elicit movement within the abscess cavity and liquid contents are displaced.

      3. Bones. Ultrasound is very useful for the detection of fractures and to help guide fracture reduction. In most instances, a high frequency linear array is used to evaluate bone for the presence of a fracture; however, depending on the depth of bone being visualized, a lower frequency probe may be necessary to assure adequate tissue penetration. The probe is placed in the long axis over the bone in question to visualize the hyperechoic bony cortex. The sonographer then slides the probe along the length of the bone looking for interruptions, step-offs, and angulations of the cortex. The same technique can then

be repeated in the short axis to acquire more information. In some instances, a comparison of the contralateral bone may be helpful.

4. Joint effusions: Due to the unique anatomy of individual joints, the scanning technique is variable. In general, the probe is placed in the long axis over the bone proximal or distal to the joint in question in order to visualize the hyperechoic bony cortex. Keeping the cortex in view, the probe is slid toward the joint space looking for the presence of an anechoice/hypoechoic collection representing a joint effusion. In every instance, the contralateral joint should be used for comparison. It is generally accepted that an effusion exists if there is at least a 2mm difference in the amount of fluid present in the affected joint when compared to the contralateral joint.

5. Tendons/ligaments: Ultrasound is useful for the detection of tendon and ligamentous lacerations, ruptures, and tenosynovitis. In most instances, a high frequency linear array transducer is used to evaluate the structure of interest. In addition, superficial tendons or ligaments may be better visualized with the use of a standoff or water bath technique. Visualized in long axis, tendons and ligaments appear hyperechoic and fibrillar, and move as the corresponding joint is ranged. Disruption is most easily seen in the long axis. If infection is suspected, the sonographer should assess for fluid collections surrounding the tendon, which can be seen in either axis.

iii. Key components of the exam

1. Soft tissue. The normal/unaffected skin should be scanned prior to scanning the suspected infectious region. This comparison may aid in the recognition of subtle findings suggestive of soft tissue infection. In the assessment for abscess, the sonographer should remember that different internal densities of the abscess will lead to different echogenicities in the sonographic window. Gentle pressure should be applied to elicit movement within the abscess cavity, confirming the presence of pus. Foreign bodies can be difficult to locate, but several techniques improve visualization: scanning slow and methodically, imaging in multiple planes (to detect obliquely oriented objects), utilizing a standoff pad or water bath technique for superficial objects and ideally, imaging the foreign body directly perpendicular or parallel to its long axis. Familiarity with adjacent anatomic structures will allow the discernment of foreign bodies from muscle, nerve, fascia, tendon, blood vessels, bone and subcutaneous air.

2. Bones. The identification of small bone fractures is relatively uncomplicated given the high resolution and shallow field of view of the linear transducer. When used to assess progress in fracture reduction, ultrasound coupling gel may make reduction difficult by making the surfaces slippery. The gel should be wiped away with a towel before further attempts at reduction. When examining for femur fractures, a curvilinear transducer is helpful to obtain the depth necessary for imaging deep to the thick quadriceps muscles.

3. Joint effusions. Knowledge of the sonoanatomy of the individual joints is of the utmost importance. In most instances, a high frequency linear array is used; however, in deeper joints (ie, hip, shoulder) a lower frequency probe may be needed to assure adequate tissue penetration

4. Tendons/ligaments. Tendons should be imaged from multiple angles to minimize the effect of anisotropy. This sonographic artifact is usually hypoechoic and triangular, and mimics a disruption in the tendon or ligament, but will correct as the transducer is

moved and the beam strikes the structure at 90 degrees. Tendons may also be easily identified by ranging the accompanying joint and observing for movement of the tendon.

iv. Pathologic findings

1. Cellulitis. Sonographic findings suggestive of cellulitis are non-specific but include tissue thickening, increased echogenicity of the subcutaneous tissue and reticular regions of hypoechoic edema which may yield a cobblestone-like appearance. Differentiating bands of edematous fluid from irregular collections of pus can be difficult.

2. Abscess. A subcutaneous abscess may have a variety of appearances. In general, a hyperechoic rim of edematous tissue surrounds an elliptical or spherical-shaped, hypo-echoic fluid-filled cavity which demonstrates posterior acoustic enhancement. At times, however, an abscess can be irregularly shaped, lack a clear surrounding rim and demonstrate variable degrees of internal echogenicity due to purulent material, debris, septae or gas. Color flow Doppler can help confirm the absence of flow within the cavity and may reveal a region of hyperemia surrounding the abscess. Pressure applied over the infected region may reveal mobility of the purulent material within the cavity, helping to confirm its liquid nature. Prior to drainage of an abscess, recognition of surrounding anatomic structures (blood vessels, muscles, tendons, nerves) is essential.

3. Foreign bodies. All foreign bodies appear hyperechoic but will display variable degrees of artifact. Metal and glass tend to produce reverberation artifact. Wood, gravel, and plastic are hyperechoic with a trailing shadow. Substances that have been present in the body longer than 24 hours typically have a small amount of surrounding inflammatory fluid, which appears as an anechoic halo surrounding the hyperechoic material.

4. Foreign body localization and removal. See "Ultrasound Guided Procedures" criteria.

5. Deep space infections. In order to assure adequate tissue penetration a lower frequency transducer may be needed. The diagnosis of necrotizing fasciitis with ultrasound has not been studied systematically and thus ultrasound should not be utilized to exclude this diagnosis. A number of sonographic findings suggestive of this disease have been described including thickening of the subcutaneous fascia, a fluid layer > 4 mm adjacent to deep fascia and subcutaneous gas.

6. Joint effusions. Joint effusions are easily seen by ultrasound as hypoechoic fluid collections in the joint space. The transducer is dragged along the long axis of the bone towards the articular surface. There, a V-shaped depression will be seen that is formed by the articular surface of the connecting bone. If an effusion is present this space will be filled by hypoechoic fluid collection. The precise location of the largest fluid collection may then be easily marked for aspiration.

7. Arthrocentesis. A joint effusion may be aspirated using static or dynamic visualization techniques.
   a. Static – The ultrasonographer visualizes the joint effusion and marks the overlying skin in two distinct planes noting the depth of the fluid as well as the optimal angle of entry. The probe is then removed, and the joint tapped using standard technique.

   b. Dynamic – The sonographer obtains a view of the joint effusion and under direct visualization uses the ultrasound to guide the needle into the most readily accessible fluid collection. This may be done in short or long axis depending on the site and sonographer preference.

8. Fractures.
   a. Small bone fractures: Ultrasound may be helpful in the identification of small fractures, or those not easily or practically imaged with conventional radiography. These include facial fractures, rib fractures, and nasal bone fractures. The sonographer typically first identifies the hyperechoic bony cortex. Then, the transducer is dragged along the surface of the bone in both orthogonal planes as the continuity of the cortex is carefully assessed. Since the window depth of a high frequency transducer is 1-5 cm, fractures displaced by as little as a few millimeters will typically be obvious.

   b. Long bone fractures: Ultrasound is also helpful in the identification of long bony fractures. This includes use in austere environments such as the wilderness or battlefield. It may also be useful for a quick femoral survey in the hypotensive trauma patient when other sources of bleeding are not immediately obvious and bleeding into the femoral compartment is suspected. In this setting, a curvilinear transducer is helpful to obtain the depth necessary for imaging deep to the thick quadriceps muscles.

9. Fracture reduction. Ultrasound is helpful in fracture reduction when other imaging is impractical. This is most evident during procedural sedation when quick radiographs cannot be obtained to assess the success of the procedure. The bone is intermittently assessed along sagittal, coronal, and axial planes for adequacy of reduction as the clinician attempts to bring the cortices into alignment.

10. Tendon/ligament lacerations and ruptures. The ultrasound probe is placed in the longitudinal and transverse planes over the structure of interest in an attempt to visualize partial and complete tears. Partial tears will appear as hypoechoic areas within the normal fibrillar tendon architecture, while complete lacerations and ruptures will extend through the entire length of the tendon in question. Active and passive range of motion of the tendon can help to assist in the presence or absence of pathology; scanning the contralateral body part for comparison may be useful as well.

11. Tenosynovotis. The ultrasound probe is placed in the longitudinal and transverse planes over the tendon in question in order to assess for the presence of an anechoic/hyoechoic area around the tendon representing a collection of fluid suggesting infection. In addition, infected tendons may demonstrate enlargement when compared to the contralateral side.

5. Documentation

In performing ST-MSK EUS, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Documentation of the ST-MSK EUS should be incorporated into the medical record. Documentation should include the indication for the procedure, the views obtained, a description of the organs or structures identified and an interpretation of the findings. 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 examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications

Most of the applications described in this section involve superficial structures. Thus, optimal visualization occurs with linear ultrasound transducers at frequencies of 8.0-12.0 MHz. Occasionally, a curvilinear or phased array transducer of 3.5-5.0 MHz will be necessary to evaluate deeper structures such as in cases of suspected hip effusion/septic hip joint or deep space abscess. Endocavitary probes can be used to identify abscess formation in areas such as the oropharynx. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. **Quality Control and Improvements, Safety, Infection Control, and Patient Education**
   Policies and procedures related to quality, safety, infection control, and patient concerns should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Trauma

1. **Introduction**
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners who are performing emergency ultrasound studies (EUS) of the torso of the injured patient and commonly referred to as the Focused Assessment by Sonography in Trauma (FAST) exam.

   Trauma EUS 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. Since a variety of formats and content have been advocated for the FAST exam, and because this document considers some applications of trauma ultrasonography that are beyond the scope of the FAST, this document will refer to such examinations as "Emergency Ultrasound (EUS) in Trauma," or "Trauma EUS."

   The primary indication for this application is to identify pathologic collections of free fluid or air released from injured organs or structures. Trauma EUS is performed at the bedside to assess for hemopericardium, hemothorax, hemoperitoneum or other abnormal fluids such as urine or bile, or pneumothorax. Free fluid is a marker of injury, not the injury itself. Since certain important traumatic conditions such as hollow viscus injury, mesenteric vascular injury, and diaphragmatic rupture may cause minimal hemorrhage, they can be easily be overlooked by trauma EUS. Trauma EUS also may not differentiate between different types of pathological fluid such as urine and blood. These characteristics of trauma EUS have implications for management of patients in whom these injuries are a consideration. Pneumothorax may be mimicked by lack of respiratory effort, mainstem intubation, adhesed or pleurodesed lung, or pleural masses (see "Lung and Pleura" criteria).

   Trauma 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. While other tests may provide information that is more detailed than EUS, have greater anatomic specificity, or identify alternative diagnoses, EUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, EUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous 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 thoracic and abdominal trauma.

Trauma EUS is well suited to mass casualty situations where it can be used to rapidly triage multiple victims. It can be performed on the patient with spinal immobilization and with portable equipment, allowing it to be used in remote or difficult clinical situations such as aeromedical transport, wilderness rescue, expeditions, battlefield settings, and space flight. Finally, serial trauma 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.

2. Indications/Limitations

a. Primary
   i. To rapidly evaluate the torso for evidence of traumatic free fluid or pathologic air suggestive of injury in the peritoneal, pericardial, and pleural cavities.

b. Extended
   i. Solid organ injury

   ii. Triage of multiple or mass casualties

c. Contraindications
   i. There are no absolute contraindications to trauma EUS. There may be relative contraindications based on specific features of the patient's clinical situation, eg, extensive abdominal or chest wall trauma.

   ii. The need for immediate laparotomy is often considered a contraindication to trauma EUS; however, even in this circumstance, EUS evaluation for pericardial tamponade or pneumothorax may be indicated prior to transfer to the operating room.

d. Limitations
   i. Trauma EUS is a single component of the overall and ongoing resuscitation. Since it is a focused examination, EUS does not identify all abnormalities resulting from truncal trauma. 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.

   ii. EUS in trauma is technically limited by:
      1. Bowel gas

      2. Obesity

      3. Subcutaneous emphysema

   iii. Trauma EUS is likely to be less accurate in the following settings:
      1. Pediatric patients

      2. Patients with other reasons for free fluid such as prior diagnostic peritoneal lavage, ascites, ruptured ovarian cyst, pelvic inflammatory processes

e. Pitfalls
   i. When bowel gas or other technical factors prevent a complete or adequate exam, these limitations should be identified and documented. As usual in emergency practice, such limitations may mandate further evaluation by alternative methods, as clinically indicated.

ii. 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.

iii. Some injuries may not give rise to free fluid and may therefore easily be missed by trauma EUS. These include contained solid organ injuries, mesenteric vascular injuries, hollow viscus injuries, and diaphragmatic injuries.

iv. Non-traumatic fluid collections such as ascites, or pleural and pericardial effusions, which are due to antecedent medical conditions, may be mistakenly ascribed to trauma. Credible history and associated clinical findings, as well as the sonographic features of the free fluid may suggest such conditions.

v. Trauma EUS does not specifically identify most solid organ injuries.

vi. EUS does not identify retroperitoneal hemorrhage.

vii. A negative trauma EUS is not accurate in excluding intra-abdominal injury after isolated penetrating trauma.

viii. Blood clots form rapidly in the peritoneum. Clotted blood has sonographic qualities similar to soft tissue and may be overlooked.

ix. Perinephric fat may be mistaken for hemoperitoneum.

x. Fluid in the stomach or bowel may be mistaken for hemoperitoneum.

xi. Small hemothoraces may be missed in the supine position.

xii. In the evaluation of the pericardium, epicardial fat pads, pericardial cysts, and the descending aorta have been mistaken for free fluid.

xiii. Patients with peritoneal or pleural adhesions with significant hemorrhage may not develop free fluid in the normal locations.

xiv. 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.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Trauma EUS provides information that is the basis of immediate decisions about further evaluation, management, and therapeutic interventions. Because of its direct bearing on patient care, the rendering of a diagnosis by trauma ultrasound represents the practice of medicine, and therefore is the responsibility of the treating physician.

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, trauma EUS should be performed as soon as possible (usually minutes) following the decision that the patient needs a sonographic evaluation.

Physicians of a variety of medical specialties may perform the FAST examination. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute traumatic injury, as outlined above.

4. Specifications for Individual Examinations

a. General Trauma EUS is performed simultaneously with other aspects of resuscitation. The transducer is placed systematically in each of 4 general regions with known windows to the peritoneum, pericardium and pleural spaces for detection of fluid and other sonographic abnormalities. The precise location of these regions varies from patient to patient, and is only used as a means to the real goal of identifying specific 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 and rotated to allow for real-time imaging of the underlying potential space(s). The ultrasound images obtained are interpreted in real-time as the exam is being performed. If possible, images may be retained for purposes of documentation, quality assurance, or teaching.

b. Technique

i. Overview. The trauma EUS exam evaluates 4 general regions or "views" for free fluid in defined potential spaces. 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 scientific investigations 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 sub-xiphoid, 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.

ii. Real-time scanning technique

1. The right flank. Also known as the perihepatic view, Morison's pouch view or right upper quadrant view. Four potential spaces for the accumulation of free fluid are examined in this region (listed in a cephalad to caudad direction): 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-clavicular 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. In order to minimize rib shadowing, the transducer should be placed in an intercostal space in a location between the mid-clavicular and posterior axillary lines, with the plane of the probe parallel with 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 angling the probe superiorly, the subhepatic space and the right pleural space may be visualized for fluid. Abnormal fluid collections in the pleural space are visualized as anechoic or hypoechoic collections above the diaphragm.

   Angling inferiorly allows visualization 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 visualize 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.

2. The pericardial view. Also known as the subcostal or subxiphoid view. To examine the pericardium, 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. Many find the transverse plane easier, especially in obese patients, since it requires slightly 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. Slight angulation in a caudal direction when the probe is held in a transverse orientation allows visualization of the IVC and hepatic veins including their normal respiratory variability. 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 or apical four-chamber views may be used. These are described in the "Cardiac" criteria.

3. Left flank. In this view, also known as the perisplenic or left upper quadrant view, four potential spaces are sonographically explored, analogous to the right upper quadrant view. These four spaces are: 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 utilized 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. 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. This requires that, on the left, the probe is rotated approximately 45 degrees clockwise from the long axis of the patient's body. Angulation superiorly allows visualization of the left pleural space. As on the right, the pleural spaces are investigated for evidence of hemothorax by looking for anechoic or hypoechoic collections above the diaphragm. In order to visualize 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 swept through all planes in a search for free fluid.

4. Pelvic. Also known as the suprapubic view, retrovesical, and rectovesical view (in the male), and the retrouterine, rectouterine, and pouch of Douglas view (in the female). This space is the most dependent peritoneal space in the supine position. A full bladder is ideal to visualize 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 immediately cephalad to the pubic bone. This maximizes the sonographic window afforded by the bladder. The probe is rocked from inferior to the dome of the bladder in a systematic manner through all tissue planes. The probe may be rotated 90 degrees counter-clockwise into the sagittal plane for additional visualization 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.

5. Anterior pleural (Bilateral). In non-collapsed lung, 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, ie, pneumothorax. In the supine position, the anterior pleura is examined by placing the probe in a sagittal plane in the rib interspaces between the clavicle and diaphragm. The approximate midclavicular line is used on both sides. It is necessary to adjust frequency, depth, focus and gain settings to optimally image these superficial structures. This exam is discussed in more detail in the "Lung and Pleura" criteria.

iii. Additional windows
1. Paracolic gutters. These potential spaces are anatomically continuous with the hepatorenal and splenorenal spaces. Windows inferior to the level of kidneys and next to the iliac crests may reveal bowel surrounded by fluid.

iv. Other considerations
Trendelenburg and sitting position may increase the sensitivity of the ultrasound exam for abnormal fluid in the right upper quadrant and pelvis, respectively. Serial trauma EUS 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.

5. Documentation
In performing trauma EUS exams, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Such interpretations should be documented in the medical record. Documentation should include the indication for the procedure, a description of the organs or structures identified and an interpretation of the findings. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Given the often-emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications
Generally, a curvilinear abdominal or phased array cardiac ultrasound probe at frequencies of 2.0-5.0 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 visualize deeper structures in the right upper quadrant in large patients. A linear probe or curvilinear probe with frequencies of 7.0 MHz and above would be optimal for visualizing the near field of pleural line. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. Quality Control and Improvements, Safety, Infection Control and Patient Education

Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Ultrasound-Guided Procedures

1. Introduction

The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners utilizing emergency ultrasound (EUS) to facilitate the performance of procedures in the emergency patient.

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. The Agency for Healthcare Research and Quality 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 toward a “one stick” standard. These ultrasound examinations are performed at the bedside to identify vascular anatomy and guide direct visualization and cannulation of vessels.

Additional procedural applications for ultrasound include assessing for potential abscess formation and to drain fluid collections that accumulate pathologically; confirming fracture reduction and endotracheal tube placement; assessing bladder volume and directing aspiration; guiding nerve blocks and arthrocentesis; and facilitating lumbar puncture or pacemaker placement.

The advantages of procedural ultrasound include, improved patient safety, decreased procedural attempts, and decreased time to perform many procedures in patients whom the technique would otherwise be difficult. It is important to recognize that procedural ultrasound is a method to identify relevant anatomy and pathology before proceeding with invasive procedures while aiding the accurate execution and minimizing procedural complications. Procedural ultrasound is an adjunct to emergency care.

2. Indications/Limitations

a. Primary
   i. Vascular access
      1. To identify central venous structures, their relative location and their patency in facilitating placement of central venous catheters.

      2. To identify peripheral venous structures, their relative location and patency in facilitating placement of peripheral venous access.

      3. To identify arterial structures, their relative location and flow characteristics in facilitating placement of arterial lines.

b. Extended
   i. To evaluate for and/or drain with ultrasound guidance or localization:
      1. soft tissue abscess

      2. peritonsillar abscess

      3. pericardial effusion (pericardiocentesis)

4. pleural effusion (thoracentesis)

5. peritoneal fluid (paracentesis)

6. joint effusion (arthrocentesis)

7. cerebrospinal fluid (lumbar puncture)

ii. To evaluate for and localize with ultrasound:
1. soft tissue foreign bodies
2. pacemaker placement and capture

3. fracture reduction

4. endotracheal tube placement

iii. Ultrasound-guided nerve blocks

c. Limitations
i. Procedural ultrasound is an adjunct to care. No modality is absolutely accurate. Procedural ultrasound should be interpreted and utilized in the context of the entire clinical picture.

ii. Procedural ultrasound may be technically limited by:
1. obese habitus

2. subcutaneous air

3. anomalous anatomy/prior surgical changes

d. Pitfalls
i. Needle localization and its associated artifact must be visualized before proceeding with any procedure. The short axis transverse approach allows only a cross section of the needle to be visualized by the ultrasound beam and may lead to errors in depth perception of the needle. The long axis orientation 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.

ii. 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 utilized.

iii. 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.

3. Qualifications and Responsibilities of the Clinician Performing the Examination
Physicians of a variety of medical specialties may perform procedural ultrasound. Training should be in accordance with specialty or organization specific guidelines.

4. Specifications for Individual Examinations

a. General – Ultrasound can be used systematically during the pre-scan to localize the relevant anatomy in orthogonal planes before executing the procedure in a sterile manner 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 sagittal and transverse planes. The probe should be initially placed at the primary window and then be fanned, rocked and rotated to allow for real-time imaging of the area(s) 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.

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

    i. Ultrasound Assisted: Anatomic structures are identified, and an insertion position is identified with ultrasound. The procedure is carried out without the use of real time ultrasound guidance.

    ii. Real-Time: The ultrasound transducer is placed in a sterile covering and the key components of the procedure are performed with simultaneous ultrasound visualization during the procedure (eg, using ultrasound to visualize a needle entering a vessel)

c. Procedural ultrasound examinations
    i. Internal jugular vein
    ii. Femoral vein
    iii. Subclavian vein
    iv. External jugular vein
    v. Brachial and cephalic veins
    vi. Arterial cannulation

d. Additional Procedures
    i. Soft tissue abscess drainage
    ii. Peritonsillar abscess drainage
    iii. Pericardiocentesis
    iv. Pleurocentesis
    v. Paracentesis
    vi. Arthrocentesis
    vii. Lumbar puncture
    viii. Fracture reduction

ix. Endotracheal tube confirmation

x. Bladder volume assessment-suprapubic aspiration

xi. Nerve blocks

5. **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. 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 examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. **Equipment Specifications**
Multiple probes can be used, yet high frequency (7.0-12.0 MHz) linear array transducers work best to image superficial and vascular structures. Microconvex endoluminal probes can be used to identify abscess formation in areas such as the oropharynx. Portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. **Quality Control and Improvements, Safety, Infection Control and Patient Education**
Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

Venous Thrombosis

1. **Introduction**
The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing emergency ultrasound studies (EUS) of the venous system in the evaluation of venous thrombosis.

   The primary application of venous EUS is in evaluation of deep venous thrombosis (DVT) of the proximal lower extremities. Lower extremity venous EUS differs in two fundamental aspects from the "Duplex" evaluation performed in a vascular laboratory. First, its anatomic focus is limited to two specific regions of the proximal deep venous system. Second, its sonographic technique consists primarily of dynamic evaluation of venous compressibility in real time. This approach to lower extremity proximal venous EUS is often referred to as limited compression ultrasonography (LCU). 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 extremity DVT using this technique. It is recognized that many emergency physicians have access to equipment with color flow and Doppler capabilities, and are experienced in its use. It is likely that they will augment their venous EUS with this technology.

   Lower extremity venous EUS is performed and interpreted in the context of the entire clinical picture. 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. EUS of the lower extremities does not identify all abnormalities or diseases of the deep venous system. If the findings of lower extremity venous EUS exam are equivocal, further imaging or testing may be needed.

2. **Indications/Limitations**

a. Primary
   i. Evaluation for acute proximal DVT in the lower extremities.

b. Extended
   i. Chronic DVT

   ii. Distal DVT

   iii. Superficial venous thrombosis

   iv. Diagnosis of other causes of lower extremity pain and swelling under consideration in the evaluation of DVT such as cellulitis, abscess, muscle hematoma, fasciitis, and Baker's cyst

   v. Upper extremity venous thrombosis

c. Contraindications
   i. Known, acute proximal DVT. If an ultrasound examination would not have any bearing on clinical decision-making, it should not be performed.

   ii. Other contraindications are relative, based on specific features of the patient's clinical condition.

d. Limitations
   i. EUS of the lower extremity 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 extremity 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.

   ii. A prior history of DVT may limit the utility of LCU. 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 extremity venous EUS examination.

   iii. Examination can be limited by:
      1. Obesity

      2. Local factors such as tenderness, sores, open wounds, or injuries

      3. The patient's ability to cooperate with the exam

e. Pitfalls
   i. A non-compressible vein may be mistaken for an artery, leading to a false negative result.

   ii. An artery may be mistaken for a non-compressible vein, leading to a false positive result.

   iii. 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.

iv. While thrombus may be directly visualized on examination, it is frequently isoechoic to unclotted blood and failure to see echogenic clot should not be used to exclude the diagnosis of DVT. This is especially problematic in obese patients due to the depth of some venous structures and resultant decrease in image clarity.

v. Inguinal lymphadenopathy may be mistaken for a non-compressible common femoral vein.

vi. Failure to arrange for repeat venous evaluation in patients with suspicion for isolated calf or distal DVT.

vii. Failure to consider the possibility of iliac or inferior vena cava obstruction as a cause for lower extremity pain or swelling. While color flow and Doppler techniques may identify the presence of these conditions, they are beyond the usual scope of the EUS exam.

viii. A negative scan for a lower extremity DVT does not rule out the presence of pulmonary embolism.

ix. Not recognizing 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.

x. Failing to recognize that a proximal greater saphenous vein thrombus, that is seen approaching the common femoral vein, will readily seed the common femoral vein and poses a significant risk and should be treated like a DVT.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

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 physician.

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, the EUS exam should occur as soon as the clinical decision is made that the patient needs a sonographic evaluation.

Physicians of a variety of medical specialties may perform a lower extremity LCU. Training should be in accordance with specialty or organization specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute DVT, as outlined above.

4. Specifications for Individual Examinations

a. General. Emergency ultrasound for the diagnosis of DVT evaluates for compressibility of the lower extremity deep venous system with specific attention directed towards key sections of the common femoral, femoral, deep femoral and popliteal veins. These sections constitute two short regions of the lower extremity, the inguinal region and popliteal fossa.

b. Technique

i. Identification of veins. For the purposes of lower extremity EUS, the proximal deep veins of the lower extremity are those in which thrombus poses a significant risk of pulmonary embolization. These include the common femoral, femoral (formerly superficial femoral vein), 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. The deep femoral vein is easily overlooked, but much like the proximal greater saphenous vein it readily seeds thrombus into the common femoral vein. Therefore, it should be assessed for compression as part of the proximal region.

   In the distal 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 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.

ii. Compression. 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.

iii. Patient positioning. To facilitate the identification of the veins and test for compression, they need to be distended. This is accomplished by placing the lower extremities in a position of dependency preferably by placing the patient on a flat stretcher in reverse Trendelenberg. If the patient is on a gurney where this is not possible, the patient should be placed semi-sitting with 30 degrees of hip flexion.

iv. Transducer. A linear array vascular probe with a frequency of 6 – 10 MHz and width of approximately 50 mm is often ideal. Narrower transducers may make it harder to localize the veins and to apply uniform compression. For larger patients, a lower frequency or even an abdominal probe will facilitate greater tissue penetration.

v. Real-time scanning technique.
   1. The common femoral vein, saphenous vein inflow, deep femoral and femoral vein region. Gel is applied to the groin and medial thigh for a distance about 10 centimeters 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. 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 color-flow or Doppler is utilized characteristic arterial or venous signals 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 commences at the level of the inflow of the greater saphenous vein into the common femoral vein, applying compression every centimeter. Compression should be continued through the bifurcation of the common femoral vein into its femoral and deep femoral veins and approximately 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 optimize the angle of interrogation should be used. In equivocal cases, comparison with the contralateral side may be helpful.

2. The 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 from about 12 centimeters superior, to 5 centimeters inferior 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 approximately 7 centimeters below the popliteal crease. In equivocal cases, comparison with the contralateral side may be helpful. The popliteal vein should be compressed just into the proximal distal branches to catch any calf thrombus about to seed the popliteal vein.

vi. Additional components of the exam.
   1. The femoral vein. As noted previously, this vein is not a primary focus of the standard lower extremity EUS evaluation, other than its proximal portion. In cases where there is a high suspicion of DVT and an otherwise normal exam of the common femoral and popliteal veins, the femoral vein may also be evaluated more extensively.

   2. Color flow and Doppler. Color flow and Doppler assessment may be used to localize the vessels, although the use of this technology is beyond the scope of the standard EUS exam. Additionally, data suggest color and power Doppler adds little in ruling out DVT.

vii. Gray scale identification of clot. While thrombus may be hyperechoic, and thus directly visualized on exam, it is also frequently isoechoic to unclotted blood. Consequently, failure to see echogenic clot should not be used to exclude the diagnosis of DVT.

5. Documentation

In performing venous EUS, images are interpreted by the treating physician 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 identified 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. Images should be stored as a part of the medical record and done so in accordance with facility policy requirements. Since the LCU exam 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.

6. **Equipment Specifications**
A linear array vascular probe with a frequency of 6.0 – 10.0 MHz and width of 6 – 8 cm is often ideal. Narrower transducers may make it harder to localize the veins and to apply uniform compression. For larger patients, a lower frequency or even an abdominal probe will facilitate greater tissue penetration. Color or power Doppler capabilities may be of assistance in localizing venous structures. Both portable and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. **Quality Control and Improvements, Safety, Infection Control and Patient Education**
Policies and procedures related to quality, safety, infection control and patient education should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.