American College of Emergency Physicians®
ADVANCING EMERGENCY CARE

POLICY STATEMENT

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Emergency Ultrasound Imaging Criteria Compendium

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Emergency Ultrasound Imaging Criteria Compendium

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Aorta

1. <u>Introduction</u>
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound studies (CUS) of the thoracic and abdominal aorta in patients suspected of having an acute abdominal aortic aneurysm (AAA) and/or acute aortic dissection (AAD).

   Ultrasound has been shown to rapidly and accurately identify both normal and pathologic states of the abdominal and thoracic aorta. Emergency medicine providers are capable of utilizing CUS for screening and identifying acute aortic pathologies.[1,2] Commonly, CUS is used to identify or exclude the presence of AAA. However, CUS of the thoracic and abdominal aorta can also identify the presence of dissection and other pathologies. Patients in whom a AAA is identified, assessment for free intraperitoneal fluid should occur despite recognizing that ruptures into the retroperitoneal space are difficult to identify on CUS. It is important to keep a strong clinical suspicion for rupture in the proper clinical setting. In the setting of type A aortic dissections, indirect signs (pericardial effusion, aortic regurgitation, and dilated aortic root) can also be identified with CUS to increase the sensitivity of making the diagnosis.[1]

   CUS evaluation of the aorta occurs in conjunction with other CUS applications, imaging studies and laboratory tests. CUS attempts to answer specific questions about a particular patient's condition. While other modalities may provide more detailed information, higher sensitivity, have greater anatomic specificity, or identify alternative diagnoses, CUS is non-invasive, rapidly deployed, repeatable and does not entail patient relocation from the resuscitation area. Further, CUS avoids delays to critical diagnoses, cost, specialized technical personnel, the administration of iodinated contrast agents and the biohazardous potential of radiation. These advantages make CUS a valuable addition to available diagnostic resources in the care of patients with time-sensitive or emergency conditions such as acute AAA or AAD. The use of contrast enhanced ultrasound (CEUS) can provide increased diagnostic certainty when diagnosing pathologic states of the aorta such as AAD or AAA with or without rupture.[3] Failure to identify or rule out these aortic pathologies on CUS exam should prompt additional emergent diagnostic modalities such as a computed tomography angiography (CTA) scan.[4] Additionally, emergency medicine (EM) physicians can utilize transesophageal echocardiography (TEE) safely and effectively during arrest or peri-arrest states to examine the aorta in those critical situations.

2. <u>Indications/Limitations</u>
   a. Primary Indication
      The rapid evaluation of the abdominal aorta from the diaphragmatic hiatus to the aortic bifurcation for evidence of aneurysm.
   b. Extended Indications:
      i. Abdominal aortic dissection
      ii. Thoracic aortic dissection
      iii. Intraperitoneal free fluid when AAA is identified
      iv. Iliac, splenic, and other abdominal artery aneurysms
      v. Identification of pericardial effusion, aortic regurgitation, and/or aortic root dilation (indirect signs) when suspicion for thoracic aortic dissection is present
   c. Contraindications
      There are no absolute contraindications to CUS of the abdominal or thoracic aorta. There may be relative contraindications based on the patient's specific clinical situation.
   d. Limitations

i. CUS of the aorta is a single component of the overall and ongoing resuscitation. Since it is a focused examination, CUS does not identify all abnormalities or diseases of the aorta. CUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. Transthoracic CUS, when conducted under optimal conditions, has been shown in several studies to have good sensitivity for the diagnosis of type A acute aortic dissection by direct or indirect signs.[1,2] If the findings of the CUS are equivocal, additional diagnostic testing may be warranted.

ii. Examination of the aorta may be technically limited by:
1. Obese habitus
2. Bowel gas
3. Abdominal tenderness
4. Physical obstructions (ie, Abdominal or thoracic dressings, bony structures, masses, ostomy/colostomy, etc)
5. Open abdominal or thoracic wounds

e. Pitfalls

a. 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 of the abdominal aorta.
b. 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.
c. 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.
d. The absence of free intraperitoneal fluid does not rule out acute AAA. This is due to understanding that most acutely ruptured AAAs have retroperitoneal bleeding and thus may not show free peritoneal fluid. The presence of retroperitoneal hemorrhage cannot be reliably identified by CUS.
e. If an AAA is identified, it still may not be the cause of a patient's symptoms.
f. The presence of free intraperitoneal fluid with an AAA, does not necessarily mean that the aneurysm is the source of the fluid. Acute blood cannot be differentiated from some other fluid substances (ie, ascites) on ultrasound.
g. 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.
h. Off-plane longitudinal images and transverse images not obtained at the level of maximal aortic diameter will underestimate the true diameter of the vessel and/or aneurysm.
i. 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.
j. 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.
k. 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.
l. Transthoracic and transabdominal CUS of the aorta alone lacks sufficient sensitivity to rule out the diagnosis of AAD. It should not be the sole method of evaluation to exclude

dissection when high clinical suspicion exists. Conversely, CUS has high specificity when direct signs, such as an intramural dissection flap, are present.[1] Indirect findings such as a dilated aortic root, and pericardial effusion should raise concern for dissection. Recent literature suggests CUS can be used in conjunction with risk stratification algorithms and lab testing (ie, D-Dimer) to improve accuracy in the diagnosis of AAD in certain low risk patients.[5]

3. Qualifications and Responsibilities of the Clinician Performing the Examination
   CUS 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 CUS represents the practice of medicine, and therefore is the responsibility of the treating physician.[6]

   Due to the time-critical and dynamic nature of acute ruptured AAA or aortic dissection, emergent interventions may be mandated by the diagnostic findings of CUS of the aorta. For this reason, CUS of the aorta should occur as soon as the clinical decision is made to evaluate the patient with ultrasound for these potential diagnoses.[6] Ideally the ultrasound information obtained can be readily available to consulting physicians, documented in accordance with professional standards and the images permanently stored in the patient records. These actions may further expedite patient care.

   Physicians of a variety of medical specialties may perform CUS of the aorta. Training should be in accordance with specialty or organization specific guidelines.

4. Specifications for Individual Examinations
   Abdominal Aorta
   a. General: Ultrasound images can be obtained demonstrating the abdominal aorta to evaluate for AAA and abdominal aortic dissection simultaneously with other aspects of the resuscitation. The abdominal aorta can be easily identified and accurately measured in the transverse plane. A typical landmark, the vertebral body, can be identified in the transverse plane. The vertebral body will show a hyperechoic line followed by an acoustic shadow. In this plane, the normal aorta is a circular, hypoechoic structure with a hyperechoic circumferential wall identified adjacent to the left anterior surface of the vertebral body.
   b. 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 perpendicular to the skin with the transducer marker towards the right side of the patient. The probe is swept 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 towards the patient's head and images are obtained in the longitudinal plane by sliding the probe inferiorly.
      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 artifact. Applying downward constant pressure with the probe, in conjunction with peristalsis, may dissipate bowel gas.

         After a systematic real-time scan in the 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.
4. Measurements. The aorta (and other abdominal arteries) is 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. Ideally a minimum of four locations are measured, which include the proximal, infrarenal, distal and iliac bifurcation or the aorta. A measurement of 3cm or less is used to describe a normal diameter.
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. When available, CEUS can provide additional information rapidly at the bedside to identify both ruptured and intact AAA.

Thoracic Aorta:

a. General: The thoracic aorta originates at the aortic valve ascending rightward and cephalad before curving leftward and back down caudad in a candy cane like pattern. Aortic root dilation/aneurysm can be identified and measured. Aortic dissections will appear as hyperechoic, mobile and/or fluttering linear flaps within the lumen of the aorta.
b. Real-time scanning:
   1. Overview: The proximal arch and descending thoracic aorta (DTA) can be identified through a transthoracic approach through a parasternal long axis (PLAX) approach. The root and ascending arch appear as longitudinal tubular structures identified as centrally anechoic with adjacent hyperechoic walls. The DTA is also seen in a transverse orientation as a centrally anechoic circular structure with hyperechoic circumferential walls and is visualized posterior to the left atrium in the same window. Additional views, such as the right parasternal and apical windows, can be utilized to optimize visualization and improve accuracy. When possible, placing the patient in the left lateral decubitus position with the left arm raised can help facilitate most of these cardiac views.
   2. Details of technique. Improved visualization of the aorta root can be achieved from the standard PLAX by translating the probe in a cephalad position, either sliding up a rib space or fanning the transducer beam more cephalad from the standard PLAX position. From this position, the ascending aorta can be measured at end-diastole in an anterior-posterior position from leading edge to leading edge (or "outside to inside"). A measurement of more than 4cm is considered dilated at the level of the aortic root. This finding, in the right clinical setting, should prompt further evaluation with CUS or additional imaging.
   3. Additional windows: An apical 5 chamber (A5C) view may allow visualization of the aortic root and proximal ascending aorta. The A5C view is obtained by finding the apical 4 chamber (A4C) view and fanning the ultrasound beam in a more cephalad orientation. (See Cardiac Section) Aortic dilation, a dissection flap and aortic regurgitation may be noted on this view. The ascending aorta, aortic arch and proximal descending thoracic aorta are evaluated utilizing the suprasternal notch view. Suprasternal notch view is obtained by placing the

probe in the suprasternal notch, directed inferiorly into the mediastinum. In certain patients with difficult windows, As stated in the cardiac section, a bolster under the patient's shoulders with the neck in full extension will facilitate this view allowing visualization of the aortic arch and great vessels which lay behind the sternum. Additional functions such as color flow or power doppler can be used to correctly identify the structures.

4. <u>Measurements:</u> The thoracic aorta is measured from L-L just distal to the aortic valve. This differs from the abdominal aorta which is measured from outer-to-outer edges. A measurement in adults of more than 4cm should be used as the threshold for dilatation.
5. <u>Additional technical considerations.</u> – Use of color and power doppler can help to identify flow on both or one side of the dissection flap. Use of CEUS can help to visualize dissection as well. CUS TEE in the appropriate clinical setting offers higher sensitivity and specificity for the diagnosis of thoracic aortic dissection than transthoracic methods.

5. <u>Documentation</u>
In performing CUS 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 in real time. 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 emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images. However, when CUS is utilized for critical decision making and coordination of care by specialists not performing the CUS, images should be made available to specialists in real time for review.

6. <u>Equipment Specifications</u>
Curvilinear or phased array ultrasound transducers can be utilized for evaluating the abdominal aorta. 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. A phased array transducer, 2.0 – 5.0 MHz multi-frequency, is ideal for transthoracic imaging. Harmonic imaging at the highest possible frequencies should be utilized when examining the thoracic aorta. Both portable and cart-based ultrasound machines may be used, understanding that image quality may be sacrificed with portable, hand-held devices.

7. <u>Quality Control and Improvements, Safety, Infection Control and Patient Education</u>
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.

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Cardiac

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

The primary applications of cardiac CUS are in the diagnosis or exclusion of pericardial effusion, cardiac tamponade as well as the evaluation of gross cardiac function and right heart strain. Increasingly, evaluation of the aortic root is considered an integral part 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
      iv. Evaluation of right heart strain
   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. Assessment for volume responsiveness, cardiac output, and stroke volume
      v. Procedural guidance of pericardiocentesis, pacemaker wire placement and capture.
   c. Contraindications
   There are no absolute contraindications to cardiac CUS. There may be relative contraindications based on specific features of the patient's clinical situation.
   d. Limitations

i. Cardiac CUS is a single component of the overall and ongoing evaluation. Since it is a focused examination CUS does not identify all abnormalities or diseases of the heart. cUS, like other tests, does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. Additional diagnostic testing may be indicated if the findings of the CUS are equivocal.
ii. Cardiac CUS is capable of identifying many conditions beyond the primary and extended CUS applications listed above. These include but are not limited to: assessment of diastolic dysfunction, valvular abnormalities, intracardiac thrombus or mass, ventricular aneurysm, septal defects, aortic dissection, and hypertrophic cardiomyopathy. While these conditions may be discovered when performing cardiac CUS, they are typically outside of the scope of focused cardiac CUS and should typically undergo appropriate consultant-performed imaging for confirmation or follow-up.
iii. Cardiac CUS 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. <u>Detection of pericardial effusion and/or tamponade</u>
      a. 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.[1]
      b. Small or loculated pericardial effusions may be overlooked. As with other CUS, the heart should be scanned through multiple tissue planes in two orthogonal directions.
      c. Pleural effusions may be mistaken for pericardial fluid. Evaluation of other areas of the chest usually reveals their characteristic shape and location. In addition, the relationship of an effusion with the descending aorta on the parasternal long axis view can help differentiate pericardial from pleural effusion.
      d. 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.
      e. The descending aorta may be mistaken for a posterior effusion. This can be resolved by rotating the probe to view the descending aorta in the transverse plane.
   ii. <u>Evaluation of gross cardiac activity in the setting of cardiopulmonary resuscitation</u>
      Sonographic evidence of cardiac standstill should be interpreted in the context of the entire clinical picture.[2] In a multicenter trial, 0.06% of ED patients who presented with cardiac standstill survived until discharge. For this reason, the presence of cardiac standstill during resuscitation cannot be used alone to terminate resuscitative measures.[3] CUS during CPR can extend the duration of pulse checks. To limit this a timekeeper should be designated to assure any CUS exam duration is less than the recommended 10 second interval, or a transesophageal probe can be placed by a qualified provider for continuous cardiac monitoring.
   iii. <u>Evaluation of global left ventricular systolic function</u>
      Clotted hemopericardium may appear hyperechoic or isoechoic relative to the myocardium and can be overlooked if the examining physician is expecting only anechoic appearing effusions.
   iv. <u>Evaluation of right heart strain</u>
      a. Cardiac CUS may reveal sonographic evidence of right ventricular strain in cases of massive pulmonary embolism sufficient enough to cause hemodynamic instability. However, a normal appearing RV does not exclude pulmonary embolism.

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

v. 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.

3. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>
   Cardiac CUS 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 CUS 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 CUS examination. For this reason, cardiac CUS 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. <u>Specifications for Individual Examinations</u>
   a. <u>General</u> - 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 CUS images. However, capturing moving images may be impractical in the course of caring for the acutely ill patient.
   b. Key components of the cardiac CUS 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 using the measured width of the effusion during diastole: trivial effusion (seen only in systole), small effusion (< 10 mm, often non-circumferential), moderate effusion (10-20 mm, circumferential), and large effusion (>20 mm).[4]
      ii. Echocardiographic evidence of tamponade.
         a. Qualitative visualization of RV diastolic collapse is most common however diastolic collapse of any chamber in the presence of moderate or large effusion is indicative of tamponade.
         b. Hemodynamic instability with a moderate or large pericardial effusion, even without identifiable right ventricle (RV) diastolic collapse, is suspicious for tamponade physiology, particularly in patients with known pulmonary hypertension.
         c. A dilated non-collapsible IVC (diameter > 2.1cm and <50% inspiratory collapse) in the presence of pericardial effusion is also suspicious for tamponade physiology.
         d. Other advanced findings of tamponade that may be used at the physician's discretion include:

i. Quantitative assessment of right ventricular diastolic collapse in the parasternal long axis view using M-mode at the mitral valve leaflet tip. The timing of right ventricular collapse can be correlated to diastole using the opening of the mitral valve leaflet.

ii. Ultrasonographic pulsus paradoxus identifies the exaggerated respiratory variation found in tamponade physiology using variation in mitral and tricuspid inflow velocities. Peak to peak inflow velocity differences of 25% or greater at the mitral valve and 40% or greater at the tricuspid valve suggests tamponade physiology.

iii. Evaluation of gross cardiac motion in the setting of cardiopulmonary resuscitation.

a. Cardiac standstill is demonstrated on CUS by the lack of myocardial contraction and has the gravest of prognoses. The decision to terminate resuscitative efforts should be made on clinical grounds in conjunction with the sonographic findings.[2,3,5]

b. Transesophageal echocardiography (TEE) is an advanced application of CUS and when used by properly trained individuals can be an invaluable diagnostic tool in cardiopulmonary resuscitation (see resuscitative TEE chapter). TEE is indicated when interpretable images cannot be obtained using standard TTE. Subcutaneous emphysema, hyperinflated lungs, and trauma are some patient level factors that may inhibit adequate TTE imaging. Ongoing CPR and crowding at the head of the bed are environmental factors that may contribute to poor TTE images.

iv. Evaluation of global left ventricular systolic function.

a. 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%).[6]

b. Advanced techniques used at the physician's discretion
E Point Septal Separation (EPSS) measures the longitudinal distance between the anterior mitral valve leaflet and the septum on the parasternal long axis view using M-mode. An EPSS value of > 7mm can be used to indicate a severely depressed ejection fraction.[7]

v. Evaluation of right ventricular strain

a. In the parasternal short axis view, the "D-sign" indicates right ventricular strain. The "D-sign" refers to a D-shaped left ventricle that is present throughout the cardiac cycle due to septal flattening from elevated pressures within the right ventricle.[8]

b. In the apical 4 chamber view, the right ventricle to left ventricle end-diastolic basal diameter ratio is normally 0.6:1. A ratio of RV:LV ≥ 1 indicates right ventricular dilatation.[9] Paradoxical septal movement may also be visualized in the apical 4 chamber view. This is when the septum paradoxically moves toward the LV in diastole instead of the typical movement toward the RV.

c. In the apical 4 chamber view, "McConnell's sign" indicates right ventricular strain. "McConnell's sign" is defined as a regional pattern of right ventricular dysfunction with akinesia of the mid free wall and hypercontractility of the apical wall.[10]

d. Advanced techniques used at the physician's discretion
Tricuspid Annular Plane Excursion (TAPSE) measures the longitudinal movement of the right ventricle. TAPSE is obtained by tracing the longitudinal movement of the lateral tricuspid valve using M-mode. A TAPSE of < 16 mm is indicative of right ventricular systolic dysfunction.[8]

5. <u>Documentation</u>
In performing cardiac CUS, 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 cardiac CUS indications but is not routinely used for the primary cardiac CUS indications. Both portable and cart-based ultrasound machines may be used for patient care.

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.

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Female Pelvic

1. Introduction

   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound studies (CUS) of the female pelvis in emergency patients to evaluate for evidence of acute pathology including ectopic pregnancy, ovarian cysts, fibroids, tubo-ovarian abscess, pelvic mass, and ovarian torsion.

   First trimester pregnancy complications such as abdominal pain and vaginal bleeding are common presenting complaints and assessment for intrauterine pregnancy (IUP) is well within the scope of emergency medicine (EM) practice. In an unassisted conception, obstetric ultrasound findings of an intrauterine pregnancy dramatically reduces the possibility of ectopic pregnancy.[1] Additionally there is strong evidence that CUS can reduce emergency department (ED) length of stay and reduce morbidity.[2,3] The scope of practice for pelvic ultrasound may vary depending on individual provider experience, comfort/skill level, and departmental policies**.** However, for those providers/institutions that choose to evaluate for gyn pathology, tubo-ovarian abscess, fibroids, ovarian cysts, ovarian torsion, and pelvic masses may be in scope.

   CUS 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 CUS, show greater anatomic detail, or identify alternative diagnoses. However, CUS is non-invasive, rapidly deployed, is repeatable, 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. Should a provider not identify a condition that is outside of their CUS scope of practice is not a failure of the CUS imaging strategy. Similarly, pursuing subsequent comprehensive imaging, that may identify conditions that are out of CUS scope, reflects an accepted conservatism within the practice.

   Transabdominal and transvaginal ultrasound are within the scope of EM practice and are a continuum of the same skill set. When indicated and available, transvaginal ultrasound may be performed by an emergency physician. There is good evidence that the transvaginal ultrasound exam is well received by patients and is no more painful or embarrassing than other aspects of standard obstetrical care.[4]

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 assisted reproductive therapy are not present.
      ii. When an IUP is identified, it is within the scope of EM practice to assess for gestational age fetal cardiac activity, multiple gestations, and fetal orientation in the uterus.
      iii. To assess for free fluid exceeding an expected physiologic amount.
   b. Extended
      i. Ovarian cysts
      ii. Fibroids
      iii. Tubo-ovarian abscess
      iv. Ovarian torsion assessment
      v. Directly identifying an ectopic pregnancy (versus recognizing there is no definitive IUP)

vi. 2nd/3rd trimester OB

c. Contraindications:

Pregnancy via assisted reproductive therapy should not be solely evaluated with a limited CUS exam. Assisted reproduction has an unacceptable rate of heterotopic pregnancy and therefore finding an IUP does not rule out ectopic pregnancy. Additionally, assisted reproduction carries the risk of ovarian hyperstimulation syndrome.

i. Transvaginal CUS
   a. Given the invasive nature of the exam, providers should always ask for consent prior to performing transvaginal ultrasound.
   b. Patients with an intact hymen, pediatric patients, and virgins should not undergo transvaginal CUS.
   c. Third trimester vaginal bleeding of unknown etiology or known placenta previa because transvaginal manipulation may worsen bleeding.
   d. Premature rupture of membranes due to increased the risk of infection and chorioamnionitis.
   e. Recent vaginal surgery, typically up to 6 weeks post-operative, as instrumentation may lead to hemorrhage, infection, or wound dehiscence.

d. Limitations

i. Large body habitus and increased adipose tissue may limit visualization on transabdominal ultrasound. Transvaginal imaging may improve diagnostic capabilities.

ii. Transvaginal exams can be uncomfortable particularly for patients with vaginismus. Vaginismus is a relative contraindication. Communication of the procedure, adequate lubrication, patient insertion of the probe, and downward pressure of the probe may aid tolerance to the exam.

iii. When evaluating for an IUP, delayed presentation or unknown gestational age poses a challenge as anatomy can be distorted or unexpected.

iv. The primary objective of a limited obstetric CUS is to rule out ectopic patients\ Detection of congenital or fetal abnormalities is outside the scope of CUS exams. Providers should advise patients CUS does not supersede routine obstetric care and follow-up.

v. Anatomy may be distorted in patients who have had gynecologic or rectal surgery.

vi. Multiple gestations are challenging due to variance in fetal positioning and location. Viability may be confounded, for example missed abortion of one fetus can affect the other viable fetus(es).

e. Pitfalls

i. CUS for ovarian torsion should be utilized to rule in ovarian torsion by identifying adnexal masses or ovarian enlargement, particularly when greater than 5cm. Para-ovarian, tubal, or para-tubal masses may be difficult to assess due to location in the adnexal and limitations with bowel gas. CUS sensitivity for torsion may be increased by assessing vascularity with doppler, however normal flow does not rule out torsion given intermittent torsion and the dual blood supply to the ovary.

ii. Utilize caution when assessing ectopic pregnancy of rare locations such as interstitial, cesarean section scar, or cervical ectopic pregnancy. Given proximity to endometrial tissue, interstitial and cesarean section scar pregnancies can progress later in the first trimester before becoming symptomatic. Increased sensitivity for detecting interstitial or cesarean scar ectopic pregnancy includes assessing for eccentrically located pregnancy and a myometrial mantle <5 to 7 mm. Cervical ectopic pregnancy can appear similar to an inevitable abortion. Gentle pressure may displace an inevitable abortion or serial exams aid in differentiating the two pathologies.

iii. After ruling out ectopic pregnancy, providers should avoid anchoring bias by assessing for other gynecologic and non-gynecologic pathology.

iv. Atypical uterine position such as a retroverted or retroflexed uterus can be limited on transabdominal exam. Providers enhance image quality by awaiting a full bladder, lying the patient flat, moving lateral to the midline, and applying gentle graded pressure. Transvaginal ultrasound often has superior visualization of the retroverted or retroflexed uterus.

v. Hemorrhage and free fluid may be difficult to recognize due to mixed echogenicity material in the pelvis from blood in various stages of coagulation.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Pelvic CUS 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 CUS 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 CUS of the pelvis. For this reason, CUS of the pelvis should occur as soon as possible when the clinical decision is made that the patient needs a sonographic evaluation.

Physicians of a variety of medical specialties may perform CUS 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. Similarly, Advanced Practice Providers (Nurse Practitioners and Physician Assistants) may be trained in this skill if adequately supervised.

4. Specifications for Individual Examinations

a. General – Organs and structures evaluated by pelvic CUS are scanned systematically in real time through all tissue planes in at least two orthogonal directions. The primary focus of the pelvic CUS is the identification of an intrauterine pregnancy which, in most patients, will rule out the possibility of an ectopic/heterotopic pregnancy. Additionally, identification of greater than physiologic free fluid, or clotted blood, particularly in the setting of a pregnant patient with no visible IUP is part of a primary focused exam. 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 an ectopic pregnancy. Further confirmation can be provided by connecting the hyperechoic vaginal stripe to the cervix and subsequently to the endometrial stripe of the uterus. An eccentrically located pregnancy less than 5 to 7 mm[5] from the edge of the myometrium is concerning for being an interstitial ectopic. Similarly, a sac that is in close approximation to the cervix or c-section scar and any of these findings should be referred for comprehensive imaging.

2. Fetus. An intrauterine pregnancy is confirmed by the presence of a yolk sac a hyperechoic ring, surrounded by an anechoic gestational sac, or fetal pole within the uterus. An intrauterine sac without a yolk sac or fetal pole visualized does not confirm pregnancy and should be termed a "nonspecific endometrial sac" to avoid any confusion about a gestation being present or not. Fetal viability is evaluated with fetal cardiac activity or fetal movement. Fetal heart rate can be assessed utilizing M-mode with fetal

heart rate calculation. Normal fetal cardiac activity in the first trimester is 110 to 180 beats per minute. Do not apply pulsewave Doppler to assess the fetal heart rate. Crown rump length estimates gestational age in the first trimester and is measured from the crown of the fetal head to the bottom of the torso and does not include the yolk sac.

3. Cul-de-sac. The cul-de-sac or Pouch of Douglas may contain a small amount of physiologic fluid in the normal female pelvis. In the absence of an IUP in a pregnant patient, fluid in the Pouch of Douglas raises the concern for ruptured ectopic pregnancy, and fluid in Morison's Pouch may be indicative of the need for operative intervention. Other causes of free fluid in the pelvis include blood (eg, ruptured ovarian cyst) and pus (eg. tubo-ovarian abscess).
4. Adnexa: The adnexa is the potential space between the uterus and the iliac vessels and contains the ovary, fallopian tube, and associated vessels and ligaments. Systematic evaluation of the adnexa in longitudinal and transverse plane is recommended, particularly in the setting when no IUP is identified.
5. Ovaries. When visualized, 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. Cyst or mass greater than 5 cm or an ovary with single greatest measurement greater than 5cm have increased risk of ovarian torsion. Additional features include presence of any mass, ovarian edema (stromal heterogeneity), follicles displaced to the periphery, abnormal adnexa placement (toward the midline), and free fluid in the pelvis. Due to the dual blood supply of the ovary, abnormal blood flow is specific however normal color or power Doppler and pulsed wave Doppler does not rule out adnexal torsion.
6. Fallopian tubes. The normal fallopian tube may 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 hydrosalpinx or tubo-ovarian abscess.

ii. Real-time scanning technique

1. Overview. When first evaluating a patient with laboratory confirmed pregnancy it is useful to bring the ultrasound device into the room with you on the initial encounter. If an IUP is confirmed, there may not be any need for additional testing and the patient could be directly discharged with close ob/gyn follow up. When the transabdominal exam is nondiagnostic, transvaginal ultrasound can be performed at the patient's bedside in conjunction with the pelvic examination portion of the physical examination to limit the time a patient spends in the lithotomy position. It is recommended that a chaperone be present for any 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. With the patient in the supine position the transducer is placed on the lower abdomen just above the symphysis pubis and the pelvic organs are examined through a window of the preferably distended bladder. Under distention of the urinary bladder may limit 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 adnexa are best examined in the transverse plane, angling the ultrasound beam to the right or left with the uterus in view.

3. Transvaginal. For the transvaginal examination, optimal imaging is achieved with an empty bladder and the patient in lithotomy position. 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 probe indicator is toward the ceiling and the examiner sweeps the transducer laterally to each side to visualize the uterus in its entirety. 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 and adnexa. 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.

   The intracavitary probe can be utilized to elicit sonographic tenderness of pelvic structures similar to Sonographic Murphy's Sign in the right upper quadrant. When the structure of interest, for example the cervix is directly in contact with the probe, applying pressure to the visualized structure can ascertain if there is sonographic cervical motion tenderness supporting the diagnosis of pelvic inflammatory disease.[6] Similarly, sonographic adnexal tenderness may support ovarian etiology such as ovarian torsion or pelvic inflammatory disease/tubo-ovarian abscess over other organ systems.[7]

5. Documentation
In performing CUS 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 and images stored in a PACS system when possible. 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. In scenarios where time for documentation is limited, providers should ensure that images are available to consultant teams and document when clinically appropriate.

6. Equipment specifications
A curved linear array abdominal transducer with a range of approximately 2.0 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 Doppler and pulsed wave Doppler are essential if an assessment of blood flow is to be made. Both hand-held 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. Transvaginal ultrasound transducers require high-level disinfection after use and one should adhere to institutional guidelines and practices when using this device.

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Gastrointestinal/Gut

1. Introduction

   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound (CUS) studies of the gastrointestinal system (GI CUS). Abdominal pain is a common presenting complaint in the emergency department. Among many possible etiologies, emergency ultrasound may be diagnostic for small or large bowel obstruction, diverticulitis and pneumoperitoneum. If bowel obstruction or diverticulitis is identified, CUS may help identify high risk features.

   CUS of the gut is 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 CUS, have greater anatomic specificity, or identify alternative diagnoses, CUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, CUS avoids the delays, costs, specialized technical personnel, and the biohazardous potential of radiation. These advantages make CUS a valuable addition to available diagnostic resources in the care of patients with time-sensitive or emergency conditions such as bowel obstruction, diverticulitis, and pneumoperitoneum as well as other causes of abdominal pain.

2. Indications/Limitations
   a. Primary
      i. Identification of small bowel obstruction (SBO)
      ii. Assessment for acute appendicitis in pediatric patients (see pediatrics chapter)
   b. Extended
      i. Identification of large bowel obstruction (LBO)
      ii. Assessment for acute appendicitis in adult patients

iii. Identification of acute colonic diverticulitis (ACD)
iv. Identification of pneumoperitoneum
v. Confirmation of orogastric/nasogastric or percutaneous gastrostomy tube location/placement

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

d. Limitations
i. CUS of the gut is a single component of the overall and ongoing evaluation. Since it is a focused examination, CUS does not identify all abnormalities or diseases of the gut. CUS, 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 CUS are equivocal, additional diagnostic testing may be indicated.
ii. The primary focus of gut CUS is to identify findings suggestive of small bowel obstruction. Extended uses of GI CUS include the identification of appendicitis in adult patients, LBO, pneumoperitoneum, diverticulitis, and confirmation of orogastric/nasogastric or percutaneous gastrostomy tube location. Other entities, including intestinal tumors or functional abnormalities of the gut are typically not within scope of a CUS exam.
iii. Examination of the gut may be technically limited by:
1. Obese habitus
2. Bowel gas
3. Abdominal tenderness
4. Surgical wounds/dressings
5. Pneumoperitoneum

e. Pitfalls
i. Fluid filled loops of bowel without dilation may be present in both gastrointestinal hemorrhage and diarrheal disease.
ii. Differentiating small versus large bowel relies on observance of the ultrasound characteristics specific to each type of bowel. If large bowel, with its larger normal diameter, is mistaken for small bowel, an erroneous diagnosis of small bowel obstruction may occur.
iii. Movement from the transmission of diaphragm breathing excursion may lead to error in misinterpreting akinetic bowel.
iv. Both ileus and bowel obstruction demonstrate dilated non-compressible loops of bowel. A sonographic transition point where non-dilated bowel is seen distal to dilated bowel can help diagnose SBO as a sonographic transition point will not be seen in ileus.
v. Obesity, overlying or adjacent bowel gas, and the bladder/pelvic structures may prevent an adequate examination for diverticulitis and could prevent the identification of a deep space abscess associated with complicated diverticulitis. Any exam limitations should be identified and documented and may warrant further evaluation by alternative methods.
vi. Colitis may cause some of the same changes seen in diverticulitis, such as bowel wall thickening and focal tenderness to probe pressure, leading to false positive diagnoses of diverticulitis.
vii. Epiploic appendagitis may be confused with diverticulitis as pericolonic fatty inflammation is seen in both conditions but epiploic appendagitis can be differentiated from diverticulitis as there is no bowel wall thickening.
viii. CUS is operator dependent and the quality and interpretation of images is heterogenous.
ix. The presence of findings consistent with bowel obstruction or diverticulitis does not rule out the presence of other life-threatening causes of abdominal pain such as aortic aneurysm/dissection, bowel infarction, bowel perforation, or acute appendicitis.
x. Intraluminal intestinal air may be mistaken for pneumoperitoneum if the anterior bowel wall cannot be differentiated from the parietal peritoneum.

xi. Reverberation/ring down artifact from the lung may be confused for reverberation artifact originating from within the parietal peritoneum. Careful attention to the location of the diaphragm will limit this pitfall.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

CUS of the gut 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 GI CUS 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 abdominal pain, emergency interventions may be undertaken based upon findings of the CUS exam. For this reason, CUS 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 gut 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 bowel pathology, as outlined above.

4. Specifications for Individual Examinations

a. General –Organs and structures evaluated in GI CUS are scanned systematically in real time through all tissue planes in at least two orthogonal directions. The primary focus of the GI CUS examination is the identification of dilated loops of bowel associated with small bowel obstruction. Evaluation of the stomach for the confirmation of orogastric/nasogastric or percutaneous gastrostomy tube location/placement as well as the identification of pneumoperitoneum, investigating diverticulitis, focal segments of loops of bowel with wall edema, diverticula, and inflamed peri-mesenteric fat stranding as described in "Extended Indications," are performed based on the clinical situation and the emergency physician's ultrasound experience.

b. Technique

i. Identification

1. Small bowel. The normal small bowel can be found throughout the entire abdomen and contains air, liquid, and chyme, partially digested food contents. Its varied appearance depends on the makeup and proportions of these luminal contents. Healthy small bowel is both non-dilated, diameter < 25 millimeters (mm), and demonstrates periodic peristalsis. The circular mucosal folds of the valvulae conniventes, otherwise referred to as plicae circulares, are not often visualized unless the segment of small bowel is fluid filled. They become readily apparent when the small bowel segment is fluid filled and dilated. Orientation of images of the small bowel are conventionally defined with respect to their axis in both transverse and longitudinal anatomic planes.
2. Large bowel. The large intestine can be identified by its expected location when scanning its approximate course, up the right flank (ascending colon), transversely across the upper abdomen (transverse colon) and down the left flank (descending colon) into the suprapubic region (sigmoid colon) and the presence of haustra. A normal large bowel has a diameter less than 50 mm and wall thickness under 5 mm. Non-obstructed large bowel typically contains large volumes of hyperechoic gas within the lumen that can obscure deeper structures.
3. Peritoneum. The peritoneum is identified on ultrasound as an echogenic line located posterior or deep to the abdominal musculature and its associated muscle sheath.
4. Stomach. The stomach is identified in the left upper quadrant as a well circumscribed fluid and air containing structure when not empty.

ii. Real-time scanning technique

1. Small and Large Bowel Obstruction: A general-purpose curved array abdominal probe

(5-2 MHz) or a small footprint or phased array probe is generally used. A linear transducer (10-5 MHz) may be selected in thin or pediatric patients. The abdomen should be systematically examined. A "lawn-mower" scanning technique using graded compression has been described so as not to miss areas of bowel. Begin in the inferior portion of the right lower quadrant with the transducer in transverse orientation. Using gentle graded compression, set the depth to visualize the structures of the retroperitoneum (iliopsoas muscle and iliac vessels) at the base of the ultrasound screen. While maintaining graded compression, slowly slide the transducer cephalad along the right paracolic gutter until the inferior border of the liver is reached. Slide the probe slightly midline and scan caudally until the inferior portion of the abdomen is reached. With each longitudinal pass up and down the abdomen, like mowing a lawn, slide the transducer a little more to the patient's left, until the entire abdomen is scanned. If dilated, fluid-filled loops of bowel are identified, these areas of interest are scanned in both transverse and longitudinal axis.

2. Diverticulitis: A general-purpose curved array abdominal probe (5-2 MHz) or a small footprint or phased array probe is generally used. When scanning the large intestine, the entire colon should be imaged methodically, following its expected course. For left-sided diverticulitis, one can start in the superior portion of the left paracolic gutter just below the inferior costal border. In transverse orientation, slide the transducer inferiorly along the descending colon while maintaining gentle graded compression. Approximately at the level of the anterior superior iliac spine, rotate the probe longitudinally and follow the sigmoid colon by sliding medially and inferiorly towards the bladder. It is important to focus on areas where the patient reports maximal pain or exhibits tenderness. If body habitus permits, use of a high frequency (10-5 MHz) linear probe will provide higher resolution images of the large intestine that may be helpful in identifying pathology such as thickened walls, diverticula and fat stranding. As with other CUS, areas of interest are scanned methodically through all tissue planes in at least two orthogonal directions.
3. Pneumoperitoneum: Use of a high frequency (10-5 MHz) linear probe is ideal except in situations where body habitus requires a lower frequency probe capable of imaging to greater depth. A general-purpose curved array abdominal probe (5-2 MHz) or a small footprint or phased array probe is also appropriate. The parietal peritoneum may be imaged throughout the entire abdomen. Patient position can be optimized for detection of pneumoperitoneum as free air will rise to the highest position in the abdominal cavity. If the patient is supine, the probe is positioned in the most anterior (ventral) position of the abdomen and the peritoneum is imaged with a focus on the epigastric and right upper quadrant areas, where free air tends to accumulate. The patient can also be positioned in a left lateral decubitus position and the probe placed in the right hypochondrium or over the liver. Left lateral decubitus positioning allows for imaging over the liver where bowel, containing confounding intraluminal air, is much less likely to be present. When assessing for air between the diaphragm and liver, it may be beneficial to place the patient in a semi-recumbent or upright position as air may rise to the top.
4. Gastric Ultrasound for NGT location: A general-purpose curved array abdominal probe (5-2 MHz) or a small footprint or phased array probe is generally used. Three standard probe positions can be utilized to obtain complete views of the stomach. For views of the fundus, the probe is placed in the midaxillary line, mid torso (commonly at the level of the xiphoid process) with the probe indicator directed toward the patient's head. The spleen and left hemidiaphragm are identified. The probe is then fanned or angled anteriorly to visualize the stomach. If the ribs and their accompanying shadows interfere with imaging, the probe can be rotated to an intercostal position, parallel to the ribs. Positioning the probe in the epigastric area, perpendicular to the anterior abdominal wall, with the indicator directed toward the patient's head provides a view of the antrum of the

stomach with the left lobe of the liver, inferior vena cava and superior mesenteric vein as landmarks. Fanning or angling the probe toward the left subcostal area allows views of the gastric body.

5. Appendicitis in an Adult - see pediatric appendicitis chapter

iii. Key components of the exam.

1. Bowel obstruction: While methodically scanning up and down the abdomen, the sonographer searches for dilated hyperechoic segments of fluid filled bowel. Once identified, the dilated segment is visualized in two planes and it's diameter measured. Small bowel that is larger than 25 mm in diameter is abnormal and may be indicative of obstruction or ileus. The presence of a transition point with collapsed distal bowel will differentiate between an obstruction and an ileus. The upper limit for normal large bowel is 50 mm in diameter which is differentiated from small bowel by the absence of valvulae conniventes or plicae circulares. The area is then investigated for the presence or absence of peristalsis which is best observed during long-axis view of the bowel and surrounding free fluid.
2. Diverticulitis: While methodically scanning the course of the large intestine, focus on the most common locations for diverticulitis (descending and sigmoid colon) and areas where the patient reports pain or tenderness when the probe is applied. Note diverticula and examine the colon for wall thickening (wall thickness measuring greater than 4-5 mm) and associated pericolic fat findings of increased echogenicity or decreased compressibility consistent with inflammation. Both longitudinal and transverse views of the colon should be obtained. A meta-analysis of the test accuracy of ultrasound found no significant difference in the diagnostic accuracy of ultrasound versus computed tomography and has been shown to have a sensitivity of 77 to 98% and a specificity of 80 to 99%.[1-3]
3. Pneumoperitoneum: While systematically scanning the parietal peritoneum, take note of areas of the peritoneum which appear more echogenic or are associated with shadowing or reverberation artifact. Avoid sustained pressure on the abdomen as this may displace free air, making it difficult to detect. The scissors maneuver may be utilized to confirm findings of pneumoperitoneum. This maneuver utilizes intermittent pressure in the right paramedian epigastrium to intermittently displace free air, causing associated reverberation artifact to disappear with pressure and reappear when pressure is released. With the patient supine, if no findings of pneumoperitoneum are seen while scanning the anterior (ventral) abdomen, place the patient in the left lateral decubitus position and scan over the liver as this may increase sensitivity for free air and avoid bowel loops and their potentially confounding intraluminal air.
4. Orogastric/nasogastric or percutaneous gastrostomy tube confirmation: Gastric views should be methodically interrogated for the presence of the tube in the stomach which will appear as an echogenic linear structure when the tube is visualized in its longitudinal plane. If the tube cannot be readily identified, gentle agitation of the tube and application of color flow doppler to help detect movement of the tube can be utilized. Real time guidance of percutaneous gastrostomy tube placement may aid in visualization of the tube during its entire course through the established tract. If the tube cannot be visualized within the stomach using the aforementioned methods, air or a mixture of air and normal saline have been injected through the tube to cause dynamic echogenic fog to exit the tip within the stomach, indirectly confirming the tube's gastric location. One may also scan the anterior neck, and confirm that the tube is in the esophagus before advancing it into the stomach. The esophagus is generally located to the left of the trachea and having a cooperative patient not in c-spine precautions turn their head to the right may improve visualization. If the tube is in the esophagus the air-filled tube may cause a "double track"

sign, similar to when assessing for esophageal intubation.
5. Appendicitis - See pediatric appendicitis chapter.

iv. Pathologic findings
1. Bowel obstruction - This diagnosis is based on the entire clinical picture in addition to the findings of the CUS.
    i. Dilated non-compressible fluid filled loops of small bowel (diameter > 25 mm) proximal to collapsed small bowel or ascending colon, or dilated fluid filled loops of large bowel (diameter > 50 mm). With a small bowel obstruction, the plicae circulares are prominently visualized (keyboard sign) and can be used to differentiate from the haustra seen in large bowel.
    ii. Peristalsis of the intestinal wall with "to-and-fro" movement of the fluid filled bowel demonstrates lack of forward flow of the luminal contents against a transition point and suggests a bowel obstruction.
    iii. Later findings of a high grade small bowel obstruction include complete akinesis of the dilated fluid filled loop of bowel with thickened edematous bowel wall (>3 mm). As intraluminal pressure increases, flattening or loss of the plicae circulares may occur. Finally, the presence of peritoneal free fluid or air may indicate perforation or ischemic bowel with translocation of intraluminal contents.
2. Diverticulitis - This diagnosis is based on the entire clinical picture in addition to the findings of the CUS.
    a. Presence of a diverticulum (outpouching from the bowel wall).
    b. Segmental, hypoechoic thickened bowel wall (> 4mm, measured from outer to inner wall).
    c. Pericolonic fat changes, specifically echogenic surrounding fat which has minimal compressibility.
    d. Focal tenderness on compression with a probe in conjunction with the above findings.
    e. Additional findings may include a fecalith, adjacent free fluid or a pericolonic fluid collection with internal debris or acoustic "dirty" shadowing consistent with abscess, and the pseudokidney sign - a thick hypoechoic wall with a central hyperechoic center resembling a kidney.
3. Pneumoperitoneum - the following CUS findings are consistent with a diagnosis of pneumoperitoneum:
    i. Enhancement of the peritoneal stripe: in the area where free intraperitoneal air abuts the parietal peritoneum, the peritoneum will have a more echogenic, thickened appearance.
    ii. "Dirty" shadowing (shadowing that is not pure black) that appears to be originating from the parietal peritoneum.
    iii. Ring down or reverberation artifact associated with the parietal peritoneum.
    iv. Inability to see typical anatomy directly inferior to the associated artifacts.
    v. Other signs may include intra-abdominal free fluid and air (echogenic foci) within the free fluid
4. Appendicitis - see pediatric appendicitis chapter
5. Other pathologic findings of the small and large intestine are generally beyond the scope of the CUS.

5. Documentation

In performing CUS of the gut, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Documentation of the gastrointestinal CUS 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.

6. Equipment Specifications
A curvilinear abdominal transducer or a small footprint or phased array probe with frequencies of 5-2 MHz can be utilized for all GI CUS indications. A linear transducer (10-5 MHz) may be selected in thin or pediatric patients for detection of bowel obstruction or to obtain higher resolution images of large bowel when examining for diverticulitis or the parietal peritoneum when examining for pneumoperitoneum. 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.

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Kidney and Bladder

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

Clinical ultrasound of the kidneys and urinary tract may identify both normal and pathological conditions. The primary indications for this application of CUS 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 CUS.

CUS 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 CUS, have greater anatomic specificity, or identify alternative diagnoses, CUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, CUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous potential of radiation. Specifically, research has shown that CUS is useful for diagnosing nephrolithiasis and has high specificity for detecting hydronephrosis linked to obstructing ureteral stones in renal colic.[1] Additionally, use of CUS has been shown to reduce length of stay in patients presenting with acute flank pain.[2] In an NIH funded multicenter trial assessing CUS, radiology ultrasound, vs computer tomography (CT) in patients with suspected nephrolithiasis, patients in the ultrasound arms had less cumulative radiation exposure, without significant difference in high-risk diagnoses with complications, serious adverse events, pain scores, return emergency department visits, or hospitalizations.[3] These advantages make US 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. <u>Indications, Limitations & Pitfalls</u>
   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
      viii. Foley catheter placement/confirmation/evaluation
   c. Contraindications: No absolute contraindications exist. Contraindications are relative, based on specific features of the patient's clinical condition including obesity, trauma, renal transplant.
   d. Limitations
      i. CUS of the kidney and urinary tract is a single component of the overall and ongoing evaluation of an emergency department patient. Since it is a focused examination, the scope of CUS is not intended to identify all abnormalities or diseases of the urinary tract. CUS, 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 CUS 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
         2. Paucity of subcutaneous fat
         3. Narrow intercostal spaces
         4. Bowel gas
         5. Abdominal or rib tenderness
         6. 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. Hydronephrosis is a common finding in third-trimester pregnancy. Appendicitis, diverticulitis, cholecystitis, and mesenteric adenitis have also been found concurrently with hydronephrosis.[4]
   iii. The presence of obstruction may be masked by dehydration.
   iv. Patients with an acutely symptomatic abdominal aortic aneurysm may present with symptoms suggestive of acute renal colic.
   v. Regardless of pain laterality, both kidneys should be imaged in order to identify the presence of either unilateral kidney or bilateral disease processes.
   vi. The bladder should be imaged as part of CUS of the kidney and urinary tract. Many indications of this CUS exam are caused by conditions identifiable in the bladder.
   vii. 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.
   viii. Absence of hydronephrosis does not rule out a ureteral stone. Many ureteral stones, especially small ones, do not cause hydronephrosis.
   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. Color doppler may be used to augment diagnosis of renal or ureteral stones as such stones will generate a tell-tale "twinkling" artifact.[5]

3. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>
   CUS of the kidneys and urinary tract provides information upon which immediate decisions for further evaluation, management, and interventions are based. Rendering a diagnosis by CUS impacts patient care directly and qualifies as the practice of medicine. Therefore, performing and interpreting CUS 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 CUS exam. For this reason, CUS 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, organization, or institutional specific guidelines. Physicians should render a diagnostic interpretation in a time frame consistent with the management of acute renal pathology, as outlined above.

4. <u>Specifications for Individual Examinations</u>
   a. <u>General.</u> An attempt should be made to image both kidneys and the bladder in patients with suspected renal tract pathology undergoing CUS. 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 CUS examinations.
   b. <u>Technique</u>
      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 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 90º counterclockwise 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 CUS 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 90º counterclockwise 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 in two planes: transverse (marker toward the patient's right) and sagittal (marker toward the patient's head), respectively. It is often identified cranial to pubic symphysis. Ideally, the bladder is scanned prior to voiding and again post-void if outlet obstruction is a concern. The kidneys should be scanned after voiding to avoid artifactual hydronephrosis. Such ideal conditions are rarely met with the exigencies of CUS and emergency care.
   To measure bladder volume, one must obtain the maximal length (longitudinal), width (transverse) and height (anteroposterior) measurements of the bladder. The length is only obtainable in the sagittal plane, and width only in the transverse plane. The height can be measured in either sagittal or transverse planes; however, it should only be measured once. Most machines will calculate a volume. All three measurements are multiplied in centimeters by a coefficient (shape-dependent, with a common default of 0.72) to receive a volume in milliliters.[6]

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 CUS examination.

   Troubleshooting a Foley catheter is centered around identifying the fluid-filled balloon. Normally a well-positioned, well-functioning Foley will have a fully decompressed bladder and only the balloon will be visualized.[7] In the setting of malfunction, one can assess the location of the balloon for malpositioning, including the balloon being in a diverticulum, prostate, urethra, or vagina.[8]

5. Documentation
   In performing CUS 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.

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Lung and Pleura

1. Introduction

   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound (CUS) studies of the chest to evaluate for causes of dyspnea.

   There are several primary and extended indications for lung ultrasound. It can be used for the rapid diagnosis of acute pneumothorax and is particularly sensitive for ruling out the presence of pneumothorax and pleural effusion.[1-3] Thoracic ultrasound may also be used in the diagnosis of abnormal interstitial fluid in the lungs as seen in congestive heart failure, ARDS, pulmonary contusion, and interstitial infections.[4] Advantages of thoracic ultrasound are rapid deployment in critically ill patients with immediate diagnostic information without the need to transport or transfer the patient. Additionally, thoracic ultrasound can be performed with portable or hand-held ultrasound machines in remote or resource limited clinical situations. During the COVID-19 pandemic, thoracic ultrasound was sometimes used to reduce the number of chest radiographs and CTs performed, thereby decreasing the number of healthcare workers exposed to these patients and sparing personal protective equipment.[5] Additionally, a provider may integrate the lung exam with sonographic evaluation of multiple organ systems within the context of the clinical scenario. It is important to understand that often 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 however, the literature demonstrates sensitivities and specificities greater than traditional imaging modalities such as chest radiography.[1,2,4,6,7,8] The judicious use of ultrasound can add to the rapid, non-invasive, and dynamic evaluation of the critical patient.[9]

2. Indications/Limitations
   a. Primary
      i. Acute pneumothorax
      ii. Abnormal collections of pleural fluid
      iii. Presence of interstitial lung fluid
         1. CHF
         2. ARDS
   b. Extended
      i. Presence of interstitial lung fluid beyond CHF/ARDS
         1. Pneumonia
            a. Viral

b. Bacterial
2. Pulmonary contusion
ii. Pulmonary fibrosis
iii. Rib Fractures

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. Morbid obesity
   ii. While bedside thoracic ultrasound is more sensitive than chest X-ray for diagnosis of many pulmonary pathologies, the performance of the exam is dependent on the skill level of the sonologist.[10,11]
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.[12]
   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, particularly when using M Mode, resulting in failure to identify pneumothorax.

3. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>
Thoracic CUS is a useful tool for prompt diagnosis of many thoracic pathologies. Thoracic Ultrasound is a modality that may be utilized by a variety of providers in various specialties. Training should be in accordance with specialty or organization specific guidelines. Because of its direct bearing on patient care, the rendering of a diagnosis by chest CUS 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 CUS exam. For this reason, CUS should occur as soon as the clinical decision is made that the patient needs a sonographic exam.

4. <u>Specifications for Individual Examinations</u>
   a. <u>General.</u> Thoracic CUS is often performed simultaneously with other aspects of resuscitation. The transducer is placed systematically in each of the appropriate windows based on the clinical scenario and suspected pathology. The ultrasound images are interpreted in real-time as the exam is being performed. Images should be saved to the medical record for purposes of documentation, quality assurance, and teaching.
   b. <u>Technique.</u> Overview. The chest ultrasound examination requires little patient preparation except for positioning in the bed at an ergonomic height for the examiner. In the absence of pleural adhesions, a pneumothorax typically occurs in the most anterior aspect of the chest in a supine patient and at anterior lung the apex of an upright patient. Conversely, pleural effusions or hemothoraces tend to follow gravity and accumulate posteriorly and inferiorly in the costophrenic

sulci. When evaluating a patient for pulmonary edema, the patient is often in a semi-recumbent or upright position. Traditionally, thoracic ultrasound is performed with the probe indicator positioned towards the patients head and the transducer perpendicular to the ribs; however, scanning parallel to the ribs may be useful when assessing lung parenchyma at a specific location. 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 supine trauma patient, the anterior chest is 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 parallel and lateral to the sternum at the anterior most chest and the orientation marker is directed cephalad in a sagittal plane. Two ribs with distal shadowing and the pleural line beneath the ribs should be identified. The physician should evaluate for pleural sliding. 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 or Z-lines (see below for description of these findings).[13] The absence of any of these findings is highly suggestive of the presence of a pneumothorax. Conversely, the presence of the "lung point" sign (created by the site of transition between expanded and collapsed lung) is pathognomonic of the *presence* of pneumothorax. 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 provider should ensure to interrogate each intercostal space from the apex to the diaphragm. The movement of the pericardium and the diaphragm 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. The posterior lung fields are less useful for detection of a pneumothorax in a supine patient
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 pneumothoraces but miss a smaller pneumothorax.[14]
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").[15]
6. Power Doppler Evaluation. Similar to above the probe should be placed parallel to the sternum at the anterior most portion of the chest wall. The air is a barrier to the detection of apposition of the pleural surfaces and demonstrates an absence of a color signal.[16]

ii. Pleural effusion

1. Evaluation of the bilateral lung bases in the supine patient. Similar to the evaluation of fluid in Morison's Pouch and the left upper quadrants, the physician can rapidly identify fluid above the diaphragm. Typically, a curvilinear or phased array probe is placed in the anterior or mid-axillary line at the level of the xiphoid process, with the orientation marker directed cephalad. Following the identification of the kidney, liver/spleen, and diaphragm, the examiner rocks or slides the probe cephalad to evaluate above the diaphragm. Free fluid in the hemithorax will be identified as an anechoic or black area above the diaphragm. The presence of a "spine sign", which is the ability to visualize the thoracic spine above the diaphragm, can also indicate the presence of a pleural effusion.[17] while the presence of a mirror artifact above the diaphragm typically rules out effusion. The examiner may also identify lung floating in pleural fluid. The lung may become sonolucent and the bronchial tree may be visible because of compressive atelectasis caused by the pleural effusion. The exam is then repeated on the contralateral side.
    i. This exam can be performed as part of the extended FAST (E-FAST) exam in trauma patients to identify hemothorax.
2. 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 sulci 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 or complex. This approach is typically utilized to facilitate thoracentesis.

iii. Interstitial lung fluid

1. 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 anterolateral thorax into eight zones.[18,19]
2. Evaluation. Using the phase array, curvilinear probes, or microconvex probe four zones in each hemithorax are defined approximately by the anterior axillary line (anterior and posterior) and the nipple line (superior and inferior) and should be interrogated for a complete exam. 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 other than their presence rules out pneumothorax at that scan location. Z-lines can be distinguished from B-lines by their lack of persistence past 3-5 centimeters where B-lines extend beyond 10 cm depth.
3. Interpretation. Scattered B-lines may be normal in the more posterior areas of lung in the supine patient but are abnormal if found anteriorly. When B Lines are found in multiple spaces, bilaterally, and anteriorly this is more specific for interstitial lung fluid/edema. These findings typically correlate with cardiogenic pulmonary edema, ARDS, but can also be seen in viral pneumonia.[20] If the B-lines are unilateral or more localized, a focal process such as pneumonitis, pneumonia or pulmonary contusion, in the setting of trauma, is more likely.[20, 21] Bilateral and extensive B-lines are more likely to be due to a more generalized process such as volume overload, heart failure, or ARDS.[20] In extreme

cases, the B-lines can become confluent, giving the appearance of a swinging curtain of artifact.

iv. Pneumonia

1. Viral and bacterial pneumonia. Lung ultrasound is a useful tool aiding in the diagnosis and monitoring of pneumonia.[22]
2. Evaluation. To perform this evaluation, the thorax is divided into regions as described above (see Interstitial Lung Fluid section above). A curvilinear or phased array probe is used to evaluate the lung parenchyma for sonographic signatures such as pleural line abnormalities, B-lines, dynamic air bronchograms, and pulmonary consolidation.
3. Interpretation. In the appropriate clinical setting, focal B-lines may be indicative of an early pneumonia. Diffuse B-lines can be identified in atypical and viral pneumonias. Dynamic air bronchograms represent bronchi filled with air and fluid. In the setting of lobar pneumonia, consolidated lung parenchyma may be visible; this is sometimes referred to as "hepatization" of the lung tissue due to the fact that the lung parenchyma develops a sonographic appearance similar to that of the liver. The shred sign can also be visualized at or below the level of the pleura, representing consolidation of the lung parenchyma.[4]

5. <u>Documentation</u>
   In performing CUS 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 structures and fields interrogated, 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. <u>Equipment Specifications</u>
   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 hand-held and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. <u>Quality Control and Improvements, Safety, Infection Control, and Patient Education</u>
   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.

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Ocular

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

The use of CUS 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.

CUS evaluation of the eye occurs in conjunction with other CUS 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 CUS, have greater anatomic specificity, or identify alternative diagnoses, CUS is non-invasive, is rapidly deployed and does not entail removal of the patient from the resuscitation area. Further, CUS avoids the delays, costs, specialized technical personnel, the administration of contrast agents and the biohazardous potential of radiation. These advantages make CUS 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. Assessment for retinal detachment (RD)
      ii. Assessment for vitreous detachment/hemorrhage
      iii. Assessment for intracranial hypertension (ICH) indirectly via optic nerve sheath diameter measurement and/or visualization of optic disc edema
   b. Extended
      i. Lens dislocation
      ii. Intraocular foreign body
      iii. Globe rupture
      iv. Retrobulbar hemorrhage
      v. Central retinal artery/vein occlusion
      vi. Subretinal hemorrhage
      vii. Posterior vitreous detachment (PVD)
      viii. Direct and consensual light reflex
   c. Limitations
      i. Patient's inability to tolerate exam secondary to eye pain
      ii. Known globe rupture
   d. Relative Contraindications
      i. Concern for globe rupture. This risk may be minimized with the use of a transparent film dressing (eg, Tegaderm) and copious gel over the closed eyelid to ensure no pressure is applied.
      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 CUS 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 CUS 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 ocular pathology, emergency interventions may be undertaken based upon findings of the CUS exam. For this reason, CUS 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. 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. 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.
      ii. 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 a light source is externally applied.
      iii. 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 horizontal lines of the iris, can be seen. Reverberation artifact may also be seen extending posteriorly from the lens.
      iv. 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.
   c. Real-time scanning technique
      i. 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 semi-recumbent), and a 5-14 MHz linear probe. For patient comfort, a Tegaderm may first be placed over the closed lid and then a generous amount of sterile ultrasound gel applied. The benefit of a Tegaderm is that only a small to no amount of gel needs to be applied to the orbit prior to scanning. A con is that it may adhere to eyelashes and skin. When not using Tegaderm, copious gel should be applied to fill the optic cup. The ophthalmic preset, if available, should be used with the power at 50%. Depth should be adjusted so the entire globe is visualized as well as several centimeters of the retrobulbar space and optic nerve.[1] The examiner should rest the examining hand on the patient's forehead, nose, or zygomatic arch to avoid unnecessary pressure on the globe. Typically the examination is begun on the affected side and scanning is performed in two planes while the patient is asked to move their eyes in all 4 directions (kinetic echography). This serves two purposes: 1) all quadrants may be assessed and 2) certain pathologies, such as retinal detachment and vitreous hemorrhage, are more easily identified since they move with eye movement. Gain should be adjusted to low/mid-range initially, and further examination should increase gain to higher ranges to detect PVD.
      ii. 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/detachment or foreign bodies. Attention should also be paid to the retrobulbar space for hemorrhage and the optic nerve for edema. Direct and consensual light reflex of the iris may be checked with an external light source 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.

iii. 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 cell disease, 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 the 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 but are not tethered to the optic nerve.
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 generally 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. This appears as a shifting fluid collection along the posterior globe that is slightly more echoic than the vitreous body and is 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 seen 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 pressure as well as any 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. At least two measurements should be performed; 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 cut-off shows high negative predictive value and excellent specificity compared to ophthalmologists' examination for papilledema.[2] Accepted pediatric cut-offs are 4.5mm for children ages 1-17 years old and 4mm for infants <1 year old.[3]
11. Optic disc edema. When traditional fundoscopy provides a less than ideal exam in the emergency setting, POCUS can be used to identify optic disc elevation suggestive of disc edema (sonographic papilledema). In the horizontal axis, with the patient instructed to maintain a fixed forward gaze, the posterior orbit is assessed along the retinal surface at the junction of the retrobulbar optic nerve and the globe. Presence of a smooth, echogenic prominence of the disc (cupping or crescent sign) is abnormal.[4,5] Optic disc height is measured between the anterior-most peak of the disc and its intersection with the arc of the posterior surface of the globe. A disc height of >.6mm is a sign of edema, with measurements >1mm highly specific for papilledema.[5]
12. Central retinal artery occlusion (CRAO). 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. This is an advanced application of ocular ultrasound and is best used with other clinical information to support the diagnosis, but not rule it out.
13. Light response. The pupil may be assessed 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 CUS 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 CUS 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 5 to 14 MHz is ideal, as this range will allow the sonographer to image the globe in detail.[6] 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.

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Pediatric Appendicitis

1. Introduction
   The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound studies (CUS) of the appendix in patients who present with right lower quadrant (RLQ). The evaluation of other RLQ structures, especially gynecologic entities, is considered in the criteria for Pelvic imaging compendium section.

   RLQ pain is a common emergency department (ED) complaint and can often be time consuming and carry a heavy burden to the ED. Assessment for acute appendicitis is a primary indication for CUS in pediatric patients, however is considered an extended indication for adults, particularly because of significant differences in habitus between these two patient populations, higher probability of an alternative diagnosis in adult patients, and a different threshold to expose a patient to ionizing radiation. However, the distinction between primarily indicated or extended may vary based on patient characteristics and the provider’s comfort in performing and interpreting imaging findings when caring for a patient of any age.

   Pediatric CUS assessment for acute appendicitis is a rapid and accurate diagnostic modality that is non-invasive and can occur in conjunction with other imaging and laboratory testing. It is a clinically focused examination, which in addition to the initial clinical pre-test probability for appendicitis, will enhance practitioner’s overall diagnostic accuracy. Alternative imaging such as computed tomography (CT) or magnetic resonance imaging (MRI) may offer additional data that may be more detailed than CUS, have greater specificity, or identify an alternative diagnosis. However, CT conveys the risk of exposure to ionizing radiation and MRI has a long study time that often requires sedation in the younger patient population. Therefore, CUS is considered an appropriate first-evaluation tool that can narrow a differential diagnosis for the practitioner and answer a specific clinical question in a timely and reliable manner.

2. Indications/Limitations
   a. Primary
      Detection of acute appendicitis
   b. Extended
      i. Gross examination of the RLQ, for evidence of inflammation and free fluid.
      ii. Intestinal inflammation
      iii. Evaluation for abscess
   c. Contraindications
      i. There are no absolute contraindications for performing CUS for the evaluation of appendicitis
      ii. Clinical instability is a relative contraindication for performing CUS.
   d. Limitations
      i. Given the focused nature of the limited evaluation, CUS cannot identify all abnormalities in the right lower quadrant. If the findings of the CUS are equivocal, and/or the clinical picture is concerning, then further imaging may be necessary.
      ii. CUS may be technically limited by:
         1. A patient's body habitus (obesity, severe scoliosis, or other chronic conditions)
         2. Bowel gas
         3. Significant stool burden
         4. Younger pediatric patients may not be as cooperative, therefore limiting results
         5. Patient tolerance of exam due to abdominal guarding and pain
         6. Lack of visualization of the full length of the appendix as it extends off the cecum
         7. Lack of visualization of the normal appendix
   e. Pitfalls
      i. During the CUS, if the practitioner encounters bowel gas, stool or the inability to obtain adequate images due to technical factors, these limitations should be documented and further imaging based on clinical suspicion may be warranted.
      ii. The small intestine may mimic the appendix, especially when there is an ileus. The lack of peristalsis makes it difficult to distinguish from a non-persistalsing appendix.
      iii. Absence of full evaluation of the length of the appendix does not eliminate the possibility of tip-appendicitis.
      iv. In some patients, a normal appendix may measure > 6mm in diameter. Lack of point tenderness, wall thickening or inflammatory changes can help differentiate these from acute appendicitis.
      v. Air within the appendix may be confused with an appendicolith which is hyperechoic and exhibits posterior shadowing.
      vi. The appendix is frequently found in the right lower quadrant. However, due to a wide range of anatomical variance, the appendix may be located in the right upper quadrant, mid-abdomen, or pelvis. The inability to find the appendix does not eliminate the possibility of appendicitis. The different stages of appendicitis can vary depending on the degree of inflammation. In more progressive disease, normal layers of an inflamed appendix may be lost, and local inflammation or fluid may be the only identifying abnormality visualized to suggest appendicitis.
      viii. In chronic appendicitis, peritoneal abscess formation may be appreciated on CUS and this may appear similar to RLQ free fluid collections. Abscess collections may appear in

various shapes and sizes, with notable septations and surrounding inflammatory changes. However free fluid tends to remain located in the inferior aspect of the RLQ as well as in the deep pelvic recesses. Clinical history, a high index of suspicion, as well further laboratory testing may aid in differentiating between the two entities.

3. Qualifications and Responsibilities of the Clinician Performing the Examination
   CUS of the appendix provides immediate information upon which a decision for further evaluation, management and interventions are based. Therefore, performing and interpreting CUS is the responsibility of clinicians trained in CUS of the appendix.

   Physicians of a variety of medical specialties may perform an appendix ultrasound 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 appendix pathology as outlined above. Because this is an important part of clinical care, the results of the CUS should be documented and reported in the medical record.

4. Specifications for Individual Examinations
   a. General - The practitioner should attempt CUS while the patient is in the supine position. Ultrasound images should focus on the RLQ and the practitioner should make every effort to identify anchoring anatomy such as the abdominal wall, bowel, psoas muscle, vascular structures, and bone to aid in identifying the appendix. The family/guardians and the patient should be made aware of the benefits and limitations of CUS, including that it is limited in scope, does not use ionizing radiation, and is repeatable if necessary.
   b. Technique
      i. Identification of RLQ structures.
         1. Abdominal wall - These structures provide the anterior borders to the RLQ. In the RLQ, with a transverse/axial plane orientation, probe indicator toward the patient's left, the near field structures include the abdominal wall soft tissue, followed by the rectus muscle medially, and internal and external oblique muscles fascia laterally. The peritoneal lining forms the posterior border to the abdominal wall. It is a hyperechoic line just below the muscle bundle separating the wall from the contents in the peritoneum.
         2. Ascending colon / cecum - The ascending colon is best seen in the longitudinal/sagittal plane on the patient's right lateral anterior abdomen just above the iliac crest. The colon is a non-peristaltic tubular structure that has thick mucosal lining, haustra delineating its segments, and may be filled with stool or fluid. Stool may appear "speckled" in appearance with scattered small hyperechoic non-shadowing air and fluid contents within the colonic lumen.
         3. Small intestine – The small intestine tends to be found more medially than its colonic counterparts. It is frequently peristalsing and may be liquid filled with some associated air-fluid artifacts. The small intestine tends to have thinner mucosal lining, except in the scenario of gastroenteritis. They may also appear flattened or irregularly shaped, and compressible when utilizing graded compression during the examination.
         4. Posterior/retroperitoneal structures in the RLQ – In the far field, the psoas muscle and the iliac vessels offer the deep border to the peritoneum. Just posterior to these structures include the pelvic bone appearing as a hyperechoic curved line with shadowing.
         5. The appendix – The appendix is a tubular structure, typically with an outside wall to outside wall diameter of less than 6 mm, in the anterior/posterior orientation. A non-inflamed appendix tends to be a compressible, non-peristaltic oval structure that is proximally attached to the cecum and terminating distally in a blind ended pouch.

Several mucosal layers may also be seen on the transverse image to give the appearance of a "target" sign. The characteristics described above are meant to differentiate between the appendix and the small intestine.

ii. Real-time scanning technique

Overview. The CUS of the appendix is best visualized using a high frequency linear (12-8MHz) with the patient in the supine position. A low frequency curvilinear probe (5-2MHz) may be required in patients who have a larger body habitus. The RLQ should be interrogated in the longitudinal and transverse planes, taking care to identify the ascending colon, cecum, psoas, iliac vessels, and the appendix.

iii. Key components of the examination.

1. Graded Compression Technique - Initially, when the probe is placed on the skin in the location of evaluation, gentle compression is performed. This technique allows for visualization of deeper structures by displacing intraluminal gas and stool, while also bringing possible pathology closer to the probe. Adequate compression is achieved when the psoas muscle and iliac vessels are in view and just underneath the rectus muscles. Analgesics or distractors may be required to improve cooperation with this part of the exam.
2. Point of maximal tenderness – If the pain is well localized, initially, the practitioner may focus the examination on the area of focal tenderness. Due to the variability of the anatomic position of the appendix, insonation in the transverse and longitudinal planes should be dictated by location of pain.
3. Finding the Cecum - The ascending colon is identified as the most lateral bowel structure in the right abdomen, with the scan starting at the level of the umbilicus. Once located, the practitioner traces the ascending colon distally caudally towards the cecum and into the pelvis. At any point along this anatomic scan the sonographer may find the appendix in long or short axis, though it most commonly arises off the medial cecal wall.

iv. Appendicitis - Sonographic Criteria for Acute Appendicitis

1. Size - > 6 mm diameter is a conservative measurement for diagnosing appendicitis.
2. Non-compressibility - The inflamed appendix is a non-compressible structure, whereas the normal appendix may exhibit some compressibility.
3. No Peristalsis – Absent peristalsis will help distinguish between the appendix and a peristaltic small intestine. However, in the setting of intestinal ileus, it may be difficult to distinguish between the appendix and small intestine, and other sonographic criteria will need to be documented to support a diagnosis of appendicitis.
4. Sonographic McBurney's Point - Pain with compression over McBurney's point may be an indicator for disease.
5. Appendicolith - This can be appreciated as a hyperechoic spherical structure within the appendix that is immobile with patient repositioning and usually causes posterior shadowing. Air in the appendix can also appear hyperechoic, but typically causes "dirty" shadowing and is less likely associated with other signs of acute appendicitis.
6. Peri-appendiceal inflammation – In some individuals, inflammation can be extensive and may be the initial sonographic finding alerting the sonographer to an inflamed appendix. Small anechoic fluid collections may be seen initially in the peri-appendiceal region, and later, large abscess collections may be appreciated. Additionally, the surrounding peritoneal fat may appear hyperechoic relative to non-inflamed areas - typical of "stranding" seen on CT.
7. Free Fluid – Fluid in the RLQ area will appear anechoic taking on an irregular shape as it layers between bowel loops and will not have a clearly defined mucosal border.

This may be from peri-appendiceal inflammation or secondary to ruptured acute appendicitis.

5. Documentation
In performing CUS of the appendix, images are contemporaneously obtained, interpreted, and used in clinical decision making. Documentation should be incorporated in the medical record, and 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.

6. Equipment Specifications
A linear transducer with frequencies of 12-8MHz is appropriate. In certain instances, a curvilinear transducer 5-2MHz may be necessary. 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.

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Pediatric MSK

1. Introduction
The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound (CUS) studies of musculoskeletal systems (MSK) in pediatric patients.

   Ultrasound allows the practitioner to rapidly assess patients for pathology that is difficult or impractical to assess by other means. Pediatric musculoskeletal ultrasound has many of the same indications, scopes, technique, and requirements as those done in adults. However, the presence of growth plates adds a level of complexity to these evaluations. Evidence of surrounding hematoma or inflammation as well as knowledge of MSK anatomy can be helpful to distinguish a fracture from a growth plate. If doubt remains, imaging of the contralateral side for comparison can be helpful.

   This section will discuss three musculoskeletal CUS applications that are unique to the pediatric patient: elbow fractures, skull fractures, and hip effusions.[1-3] Each is a clinically focused examination, which, in conjunction with history, physical examination and other imaging, can provide useful information for decision-making and patient care.

2. Indications/Limitations
   a. Primary
      i. Elbow fracture
      Joint effusion
      ii. Skull Fracture
      Evaluation of skull fractures in infants.

iii. Hip Effusion
Evaluation of hip effusion in the setting of limp, pain, or limited range of motion.

b. Extended
   i. Elbow fracture
      1. Lipohemarthrosis of the olecranon fossa
      2. Identification of fracture - supracondylar, lateral condylar, proximal ulna or radius
   ii. Skull Fracture
      None
   iii. Hip Effusion
      1. Guidance for joint aspiration.
      2. Identification of fractures and dislocations

c. Contraindications - all three conditions
   Need for immediate operative management

d. Relative contraindications - all three conditions
   Significant pain or open wounds over the area to be scanned

e. Limitations
   i. Elbow fractures
      1. The finding of an elevated fat pad can be non-specific and is not always associated with a cortical irregularity.
      2. Although it can be found in distal humerus fractures, more complex elbow fractures as well as radial head subluxation can also present with an elevated fat pad.
   ii. Skull Fracture
      Limiting scanning to only areas of the skull that are directly underlying obvious scalp hematomas can miss fractures that are not directly underlying or are adjacent to the hematomas.
   iii. Hip Effusion
      1. Identifying an effusion does not provide a definitive diagnosis, but rather informs the clinical decision making of the practitioner.
      2. Ultrasound does not replace clinical judgment, especially when emergent surgical procedures are indicated
   iv. Younger pediatric patients may not be as cooperative, therefore limiting results
   v. Patient habitus - less common in this age group

f. Pitfalls
   1. Elbow fractures
      a. Patient positioning can cause false positives as well as false negatives; superficial inflammatory change, or structures such as tendons and ligaments can be misidentified as lipohemarthrosis.
      b. Viewing in two orthogonal planes can help to minimize the risk of this false positive.
   2. Skull Fracture
      a. Suture lines can be easily confused for fractures. Associated overlying or nearby scalp hematomas can be helpful to differentiate fractures from suture lines.
      b. Similarly, sutures are regular and can be traced to a fontanelle, whereas a fracture is jagged and may be displaced. Lastly, sutures are symmetric, so imaging of the contralateral side can inform the interpretation by the sonologist.
      c. The absence of a fracture does not rule out an intracranial bleed.
   3. Hip Effusion
      a. Superficial inflammatory changes such as cellulitis can be mistaken for effusions.
      b. Complicated effusion can similarly be mistakenly attributed to skin changes.

3. Qualifications and Responsibilities of the Clinician Performing the Examination

Pediatric MSK CUS 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 MSK CUS 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 MSK pathology, interventions may be undertaken based upon findings of the CUS exam. For this reason, CUS 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 MSK ultrasound as long as they are familiar with both pediatric musculoskeletal anatomy/development, as well as the appearance of both normal and abnormal bony, skin, and soft tissue findings. 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 MSK disease, as outlined above.

4. Specifications for Individual Examinations
    a. General The MSK examination can be performed at the patient's bedside. Optimal patient positioning and pain control should be achieved prior to starting the exam. The family/guardians and the patient should be made aware of the benefits and limitations of CUS, including that it is limited in scope, does not use ionizing radiation, and is repeatable if necessary. The ultrasound probe is placed over the area of interest and imaging is performed in both sagittal and transverse planes. In pediatric patients, the provider should consider starting on the non-affected side to both gain the trust of the patient and awareness of growth plates and other symmetrical findings. 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. Interpretation should be done at the bedside immediately with performance of the real-time examination.
    b. Technique
        1. Elbow fractures - With the patient's elbow flexed to 90 degrees, a high frequency linear probe is placed sagittally at the distal humerus visualized as a hyperechoic bony cortex. The linear probe should then be moved distally towards the elbow until the olecranon fossa is visualized as a concave pocket at the distal humerus. Both longitudinal and transverse views of the olecranon fossa should be obtained.

        2. Skull fractures - Generously layer gel on the scalp of the infant to prevent pressure on a hematoma or potential fracture. Place the high frequency linear probe on the area of interest (either on the point of maximal tenderness or area of swelling). Evaluate the skull, which is visualized as the hyperechoic bony cortex, under the area of interest by fanning and sliding over the hematoma in two orthogonal planes. If no fracture is identified, extend the interrogated portion of the skull to include areas surrounding the hematoma as well.

        3. Hip Effusions - With the child lying supine, position the hip in a "frog leg" position (hip flexed, abducted, and externally rotated). The high frequency linear probe should be placed in a sagittal plane, parallel to the femoral neck, with the marker pointing towards the umbilicus. The femoral head, femoral neck, and ilopsoas muscle should be identified. Younger pediatric patients may have an open growth plate which is visualized as a smooth, regular, non-displaced space in the femoral head, otherwise known as the femoral capital epiphysis. Measure the distance between the anterior surface of the femoral neck and the posterior surface of the iliopsoas. Repeat on the contralateral side.
    c. Pathologic findings:
        1. Elbow fractures - Elevation of the posterior fat pad is defined as rise of the fat pad above the extension of the distal humeral line on longitudinal view or above a line connecting both lips

of the olecranon fossa on transverse view. Elevation of the fat pad above that line raises concern for a distal humerus fracture. Lipohemarthrosis is identified when heterogeneous echodensities are noted within the fat pad.

2. Skull Fracture - A skull fracture is identified as a cortical disruption or irregularity with or without surrounding hematoma.
3. Hip Effusion - An effusion is defined when the absolute size of the synovial fluid collection is >5 mm, or the affected side measures >2 mm larger than the unaffected side

5. Documentation

When performing CUS images are contemporaneously obtained, interpreted, and used in clinical decision making. 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, limitations of the exam, 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 emergent nature of such ultrasound examinations, the timely delivery of care should not be delayed by archiving ultrasound images.

6. Equipment Specifications

The Pediatric MSK applications described in this section involve superficial structures and therefore best visualization occurs with a high-frequency linear transducer (12-8MHz). Occasionally a low-frequency transducer curvilinear or phased array transducer of (5-2MHz) will be necessary to evaluate deep structures in larger sized patients. 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 concerns should be developed in accordance with specialty or organizational guidelines. Specific institutional guidelines may be developed to correspond with such guidelines.

References

1. Rabiner JE, Khine H, Avner JR, Friedman LM, Tsung JW. Accuracy of point-of-care ultrasound for diagnosis of elbow fractures in children. *Ann Emerg Med.* 2012;61(1):9-17.
2. Rabiner JE, Friedman LM, Khine H, Avner JR, Tsung JW. Accuracy of point-of-care ultrasound for diagnosis of skull fractures in children. *Pediatrics*. 2013;131(6):e1757-e1764.
3. Vieira RL, Levy JA. Bedside Ultrasonography to identify hip effusions in pediatric patients. *Ann Emerg Med*. 2009;55(3):284-9.

RUQ - Hepatobiliary Ultrasound

1. Introduction

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

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

CUS of the RUQ can be performed as a component of the overall clinical evaluation of a patient with abdominal pain, jaundice, or unexplained laboratory abnormalities (eg, elevated bilirubin). 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 CUS or identify alternative diagnoses, CUS is non-invasive, can be rapidly deployed, is repeatable and can be performed at the bedside. Further, CUS avoids the delays, costs, need for specialized technical personnel, administration of contrast agents, and risk of exposure to ionizing radiation of other imaging modalities. These advantages make CUS a valuable addition in the care of patients with time-sensitive or emergency conditions such as acute biliary colic choledocholithiasis cholecystitis, or choledocholithiasis, as well as other causes of abdominal pain.

2. <u>Indications/Limitations</u>
   a. Primary
      Identification of symptomatic cholelithiasis
      i. Identification of Cholecystitis
   b. Extended
      i. Common bile duct abnormalities, including dilatation and choledocholithiasis
      ii. Liver abnormalities, including tumors, abscesses, intrahepatic cholestasis, pneumobilia, hepatomegaly
      iii. Portal vein abnormalities
      iv. Abnormalities of the pancreas
      v. Other gallbladder abnormalities, including tumors
      vi. Unexplained jaundice
      vii. Ascites
      viii. Unexplained abnormal liver function tests
   c. Contraindications
      There are no absolute contraindications to RUQ CUS. There may be relative contraindications based on specific features of the patient's clinical situation.
   d. Limitations
      i. CUS of the RUQ is a single component of the overall and ongoing evaluation. Since it is a focused examination, CUS does not identify all abnormalities or diseases of the RUQ. CUS, 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 CUS are equivocal, additional diagnostic testing may be indicated.
      ii. The primary focus of RUQ CUS is to identify or exclude gallstones and their complications. Other entities, including but not limited to hepatic masses/lesions, abnormalities of the pancreas, or abnormalities of the portal system may not be considered out of scope of CUS and identification by a limited and focused exam is not expected.
      iii. Examination of the RUQ may be technically limited by:
         1. Obese habitus
         2. Bowel gas
         3. Abdominal tenderness
         4. Inability of the patient to participate in the exam or position themselves
         5. Previous abdominal surgeries
   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 such as radiologic ultrasound or computed tomography (CT).
iii. The gallbladder may be confused with other fluid filled structures including the portal vein, the inferior vena cava, hepatic or renal cysts, or loculated collections of fluid. These can be more accurately identified with careful scanning in multiple planes and the use of color flow Doppler.
iv. Measurement of gallbladder wall thickness should be made on the anterior wall, adjacent to the hepatic parenchyma in the transverse plane, to limit error secondary to oblique imaging and posterior acoustic enhancement artifact. Measurement of posterior gallbladder wall thickness may be inaccurate due to layered gallstones, acoustic enhancement from bile, and closely opposed loops of bowel.
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 should be visualized within the gallbladder in two orthogonal imaging planes.
vii. Small stones in the gallbladder neck may easily be overlooked or mistaken for lateral cystic shadowing artifact (ie, edge shadows). It may be necessary to image this area in several planes to avoid this pitfall.
viii. The sensitivity for identifying common bile duct stones is low and often are only identified by the shadowing they cause or an abrupt narrowing of the common bile duct.
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. In certain circumstances polyps in the neck of the gallbladder can cause obstruction.
xii. Gallbladder wall thickening may not represent biliary pathology, but may be physiological, as in the contracted, post-prandial state, hypoproteinemia, liver disease, anasarca, 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 abdominal pain such as aortic aneurysm or myocardial infarction.
xiv. Except for emergency physicians with extensive experience in CUS, evaluations of the liver, pancreas and Doppler examination of the portal venous system are not part of the normal scope of CUS of the RUQ.

3. Qualifications and Responsibilities of the Clinician Performing the Examination
CUS 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 CUS 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 CUS exam. For this reason, CUS 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. <u>Specifications for Individual Examinations</u>
   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 hepatobiliary CUS examination is the identification of gallstones and their complications (eg, impacted stone, cholecystitis). 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 the images of the gallbladder and common bile duct are conventionally defined with respect to their axes as longitudinal, transverse, and oblique.
            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 other 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 curvilinear 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 CUS, 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 or reverse Trendelenburg position. The transducer is placed high in the epigastrium with the indicator in a cephalad orientation. The probe is then 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 may be necessary. To perform this, the patient should be in the supine position. The probe is swept laterally from the sternal border to the midaxillary line until the gallbladder is located. If there is difficulty in locating the gallbladder in an intercostal view, the patient can be placed in Trendelenburg position and imaging can be performed during patient exhalation.
         4. Once the gallbladder has been located, its long and short axes should be examined. 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 (generally with the probe indicator to 12-1 o'clock).

The gallbladder is scanned systematically through all tissue planes in both the long and short axis views. In many patients, a combination of subcostal and intercostal windows can allow for views of the gallbladder from multiple directions and may help identify small stones, the gallbladder neck, the common bile duct, and with resolving artifacts.

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. 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 superficial to the portal vein. The common bile duct is usually more lateral than the hepatic artery or more to the left on the screen. In a longitudinal view of the portal triad, the common bile duct will be located superficial and parallel to the portal vein, while the hepatic artery will be perpendicular. The common bile duct can also be distinguished by its absence of a color flow Doppler signal.

iii. Key components of the exam. The gallbladder is systematically scanned with particular attention to the neck. For patients with a low-lying gallbladder, the fundus may be obscured by gas-filled colon. Left lateral 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 is made on the anterior wall between the lumen and the hepatic parenchyma. Measurements of gallbladder size are rarely helpful in CUS, 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. A Sonographic Murphy's sign can also be assessed by applying pressure to the gallbladder that elicits pain and a separate location in not over the gallbladder that elicits no pain.

The common bile duct, like other tubular structures, is most accurately measured when imaged in a transverse plane. The common bile duct should be measured by the intraluminal diameter (i.e., inside wall to inside wall). Anatomically, it is preferable to measure the common bile at its largest diameter, which typically occurs extra-hepatic. 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. When unclear, additional diagnostic testing should be performed.

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. The wall-echo-shadow (WES) sign may indicate the presence of densely packed gallstones without biliary fluid in the gallbladder. In the case of a WES sign, the normally fluid-filled gallbladder is replaced by an echogenic line and clean shadow posteriorly. This should be suspected in a patient who has not had a cholecystectomy but the gallbladders in not visualized.
2. Cholecystitis - This diagnosis is based on the entire clinical picture in addition to the findings of the CUS. The following sonographic findings support the diagnosis of cholecystitis.

a. A thickened, irregular, or heterogeneously echogenic gallbladder wall. Anterior wall thickness greater than 3 millimeters is considered abnormal. Inflammation is not a uniform process and the wall should be measured at its thickest location.
b. Pericholecystic fluid may appear as hypoechoic or anechoic regions seen along the anterior surface of the gallbladder adjacent to the hepatic parenchyma.
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 obstructive cholecystitis.

3. Common bile duct dilatation - The normal upper limit of common bile duct diameter has been described as 4-6 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.[1]
4. Pathologic findings of the liver and other structures are beyond the scope of the CUS.

5. <u>Documentation</u>
In performing CUS 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 CUS 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 any limitations experienced during the exam, 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. <u>Equipment Specifications</u>
A curvilinear transducer with frequencies of 2.0-5 .0 MHz is appropriate. A small footprint curved array probe or phased array probe can facilitate intercostal scanning. Both hand-held and cart-based ultrasound machines may be used, depending on the location and setting of the examination.

7. <u>Quality Control and Improvements, Safety, Infection Control and Patient Education</u>
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.

Reference

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Soft tissue/Musculoskeletal

1. <u>Introduction</u>
The American College of Emergency Physicians (ACEP) has developed these criteria to assist practitioners performing clinical ultrasound (CUS) 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. <u>Indications/Limitations</u>
   a. Primary
      i. Soft tissue: sonographic evaluation of
         1. Cellulitis versus abscess
         2. Evaluation of bursitis
         3. 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
         3. Identification of hematoma
      ii. Musculoskeletal
         1. Fracture detection and reduction
         2. Identification of tendon/ligament injury
         3. Joint dislocation assessment
         4. Diagnosis of tenosynovitis
   c. Contraindications
      Need for immediate operative management
   d. Relative contraindications
      Significant pain or open wounds over the area to be scanned
   e. Limitations
      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.
            e. Soft tissue seroma and hematoma may be difficult to distinguish from infectious fluid collections however detailed history and physical can inform this distinction.
         2. Bursitis

a. US alone cannot determine septic from non-septic bursitis, aspiration is required to make the diagnosis. In these scenarios, sonographic findings should be interpreted with clinical context.
b. Bursal distention is usually unilocular and compressible but can be confused for other structures such as ganglion cysts which are usually multilocular and non-compressible.
c. Most non-distended deep bursae are difficult to visualize.

3. 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.
4. 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
   d. Open growth plates in pediatric can be misinterpreted as acute injury
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. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>
ST-MSK CUS 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 CUS 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 CUS exam. For this reason, CUS 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.
         8. Lymph nodes. Are typically hypoechoic relative to surrounding soft tissue with a hyperechoic hilum. They have a cyst-like morphology meaning they are a sac-like pocket of tissue with defined borders. The recognition of abnormal lymph nodes is generally outside the scope of emergency medicine ultrasound practice.
      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 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 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 (squish sign).
         3. Bones. 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 anechoic/hypoechoic collection representing a joint effusion. The contralateral joint should be used for comparison.
5. Bursa: Ultrasound is useful for the evaluation of a symptomatic bursa. A high frequency linear array transducer is usually sufficient though may vary by location and patient size. A normal bursa will contain minimal to no anechoic or hypoechoic fluid and often measures less than 2 or 3 mm in thickness. While the distended bursa may show simple or complex fluid with or without synovial hyperemia. The bursa should be unilocular and compressible.
6. 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. Ultrasound has good diagnostic accuracy in the detection of upper and lower limb fractures, especially in the foot and ankle, in adult patients.[1] 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. Bursa. Knowledge of the anatomic locations of native bursae is important when evaluating joint swelling with concerns for bursitis. A high frequency linear array probe is used to slide and sweep over the area of interest to evaluate the fluid contents and walls of the bursa. Color Doppler can be used to evaluate for hyperemia of the walls, Lastly, evaluate for compressibility of the bursa. The contralateral bursa should also be evaluated for comparison.
5. 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. CUS is particularly useful in clinical scenarios where the presence of cellulitis versus abscess is unclear.[2]
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. Gas in the fluid collection may consist of scattered hyperechoic points with or without reverberation artifact. Larger amounts of air may coalesce and create hyperechoic lines with distal shadow. While soft tissue air is an abnormal finding, if the abscess is actively draining the clinical significance of air is less clear compared to a non-draining abscess.
3. Bursitis. A distended bursa reveals a fluid collection with either simple anechoic or complex hypoechoic or heterogenous fluid. Synovial hyperemia may also be present which is typically hypoechoic compared to the surrounding subcutaneous fat, but may vary in echogenicity. Color Doppler can be used to evaluate for hyperemia of the bursae walls.
4. Foreign bodies. Foreign bodies typically appear hyperechoic and may 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.
5. Foreign body localization and removal. See "Ultrasound Guided Procedures" criteria.
6. 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.[3]

7. 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 a simple 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. Extended applications of CUS for joint effusion include assessment for hemarthrosis and gout. Ultrasound of a hemarthrosis may reveal complex fluid with heterogeneous echos. In patients with gout an irregular band over the superficial margin of the articular cartilage described as the "double contour sign" may be visualized.[4] CUS should not replace arthrocentesis in a patient where septic arthritis is being considered.
8. 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 their needle into the most readily accessible fluid collection. This may be done in short or long axis depending on the site and sonographer preference.
9. 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 bone 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.
10. 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.
11. 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.

12. Tenosynovitis. 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/hypoechoic area around the tendon representing a collection of fluid suggesting infection. In addition, infected tendons may demonstrate enlargement when compared to the contralateral side.
13. Joint Dislocation: Ultrasound can be useful in a patient with suspected joint dislocation, particularly when the patient's habitus limits the physical exam or pain limits imaging quality. For shoulder dislocation the sensitivity and specificity for dislocation reaches 100%.[5] In this scenario, ultrasound can also be used to perform an intra-articular anesthetic block reducing the risk associated with procedural sedation and reduced ED length of stay. Like ultrasound for fracture reduction, ultrasound can be used for rapid assessment of successful relocation without having to move the patient or risk re-dislocation.

5. Documentation
In performing ST-MSK CUS, images are interpreted by the treating physician as they are acquired and are used to guide contemporaneous clinical decisions. Documentation of the ST-MSK CUS 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 2-5.0 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.

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Resuscitative TEE

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

   During cardiopulmonary resuscitation, the primary role of cardiac CUS is the identification of cardiac activity. Cardiac CUS may also aid in the diagnosis or exclusion of primary or secondary causes of cardiac arrest. However, the presence of several factors such as obesity, presence of equipment on the chest wall, and insufflation of air into the stomach make transthoracic echocardiography (TTE) images suboptimal in many cardiac arrest scenarios. In addition, there is evidence showing that the use of TTE during cardiac arrest may prolong pulse check duration.[1]

   Resuscitative transesophageal echocardiography (TEE) has emerged as an alternative modality to visualize the heart in patients presenting with cardiac arrest. A major advantage of TEE over TTE includes the ability to obtain images of higher quality without cessation of chest compressions which allows for real time monitoring during cardiopulmonary resuscitation. Resuscitative TEE is a focused cardiac CUS performed during cardiopulmonary resuscitation that aids in the diagnosis or exclusion of etiologies of arrest, including cardiac tamponade, left ventricular systolic dysfunction, and right ventricular dilatation/dysfunction. Resuscitative TEE has also been shown to decrease the duration of pulse checks as compared to TTE.[2] Years of safety data collected from ambulatory TEE patients suggest the modality is safe to use in patients with minimal adverse outcomes; however, in the Emergency Department, focused TEE is generally limited to use in patients in cardiac arrest or in critically ill states where patients are intubated and sedated.[3] As with other CUS, resuscitative TEE can be rapidly deployed and does not require the patient to be removed from the resuscitation area, which is a critically important advantage in the cardiac arrest or peri-arrest patient. These advantages make resuscitative TEE a valuable imaging tool during cardiopulmonary resuscitation.

2. Indications/Limitations
   a. Primary
      i. Evaluation of myocardial activity for evidence of cardiac standstill vs. organized contractions vs. disorganized myocardial activity.
      ii. Identification of etiology of cardiac arrest such as cardiac tamponade, left ventricular systolic dysfunction, and right ventricular dilatation/dysfunction.
      iii. Guidance of mechanical compressions in cardiopulmonary resuscitation.
      iv. Procedural guidance of pericardiocentesis, pacemaker wire and ECMO catheter placement.
   b. Extended
      i. Identification of left ventricular regional wall motion abnormalities.
      ii. Identification of proximal aortic dissection or thoracic aortic aneurysm.
   c. Contraindications
      i. Absolute contraindications to TEE include known esophageal obstruction, such as from a stricture or mass.
      ii. Resuscitative TEE requires intubation of the patient prior to TEE probe insertion.
   d. Limitations
      i. Resuscitative TEE is a single component of the overall and ongoing evaluation. Since it is a focused examination, resuscitative TEE does not identify all abnormalities or diseases of the heart and does not replace clinical judgment. Findings of resuscitative TEE should be interpreted in the context of the entire clinical picture. Additional diagnostic testing may be indicated if any findings of the TEE are equivocal.

ii. Comprehensive TEE is capable of identifying many conditions beyond the primary and extended applications listed above. These include but are not limited to the evaluation of the left atrial appendage for thrombi, evaluation of subtle valvular abnormalities, vegetations, or myxomas, or identification of septal defects. While the comprehensive TEE exam is outside the scope of many Emergency Physicians, it may be in scope for some EM providers, specifically those who are certified by the National Board of Echocardiography in Critical Care Echocardiography.

iii. TEE should not be performed for diagnostic purposes on the hemodynamically stable patient.

iv. Cardiac CUS is technically limited by:
1. Oropharyngeal or esophageal obstruction/distortion
2. Air within the esophagus
3. Air within left main bronchus limiting evaluation of aortic arch and proximal aorta
4. Necessity of intubation prior to probe insertion
5. Pneumomediastinum

e. Pitfalls[4]

i. Pitfalls for the detection of pericardial effusion and cardiac tamponade are similar to that of TTE (please refer to TTE cardiac CUS section).

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

iii. Foreshortening of cardiac chambers can occur if the omniplane is incorrectly placed. Retroflexion of the probe on the mid-esophageal 4 chamber view and anteflexion of the probe on the transgastric mid-papillary short axis view can mitigate foreshortening in order to fully evaluate the entire cardiac chamber.

iv. The TEE probe can be left in place throughout cardiopulmonary resuscitation and does not need to be removed for defibrillation.

v. 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.

3. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>

Resuscitative TEE 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 resuscitative TEE represents the practice of medicine and therefore is the responsibility of the treating physician.

Due to the time-critical and dynamic nature of cardiac arrest emergent interventions may be mandated by the diagnostic findings of a CUS examination. For this reason, resuscitative TEE should be performed by a qualified provider who has the available technology as soon as the clinical decision is made that the patient needs a sonographic evaluation and after determination that TTE views will be inadequate. If no TEE qualified provider is present during the resuscitation, or the ED facility has no access to a TEE transducer, care should default to traditional care with TTE CUS.

Physicians of a variety of medical specialties may perform resuscitative TEE. 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. <u>Specifications for Individual Examinations</u>

a. General - Images are obtained and interpreted in real time without requiring a pause in compressions during cardiopulmonary resuscitation. Patients will necessarily be intubated prior to insertion of the TEE probe. Images are ideally obtained in a supine position, though it is possible to perform TEE in the prone patient, if clinical scenario warrants. Images may be captured for documentation and/or quality review; however, given the emergent nature of resuscitative TEE, the exam should not be delayed for documentation purposes. As in TTE CUS, capturing moving images in video or cine loops with TEE is preferred to still cardiac images.

b. Primary resuscitative TEE views[4]
    i. Mid-esophageal 4 chamber
    ii. Mid-esophageal aortic long axis
    iii. Transgastric mid-papillary short axis
    iv. Mid-esophageal bicaval

c. Key components of the resuscitative TEE evaluation
    i. Evaluation of myocardial activity for evidence of cardiac standstill vs. organized contractions vs. disorganized myocardial activity.

       Cardiac standstill is demonstrated on CUS by the lack of myocardial contraction and has the gravest of prognoses with 0.06% of patients surviving to discharge.[5] The decision to terminate resuscitative efforts should be made on clinical grounds in conjunction with the sonographic findings. Visualization of organized myocardial contractions vs. fine ventricular fibrillation or tachycardia may be indiscernible on TTE but clearly evident on resuscitative TEE and may therefore inform subsequent patient management.[6]
    ii. Identification of etiology of cardiac arrest such as cardiac tamponade, left ventricular dysfunction, and right ventricular dilatation/dysfunction.[3,7]
        a. Hemodynamic instability with a moderate or large pericardial effusion, even without identifiable diastolic collapse, is suspicious for tamponade physiology.
        b. Assessment of the left ventricle may reveal hyperdynamic or an underfilled left ventricle which suggests hypovolemia. Evidence of depressed left ventricular systolic function suggests cardiogenic shock. At the treating physician's discretion, identification of regional wall motion abnormalities may suggest acute myocardial infarction.
        c. Evidence of right ventricular dilatation or right heart strain in conjunction with the patient's clinical context may increase suspicion for pulmonary embolism.
    iii. Guidance of mechanical compressions during cardiopulmonary resuscitation.
       The internipple line commonly used as an anatomical landmark for mechanical compressions is more likely to be located over the LVOT or proximal aorta than over the left ventricle. Resuscitative TEE may be used to guide optimal compression location directly over the left ventricle as well as to monitor the quality and depth of compressions.[3,8]
    iv. Procedural guidance of pericardiocentesis, pacemaker wire and ECMO catheter placement.
        a. Resuscitative TEE may be used to guide pericardiocentesis, pacemaker wire and ECMO catheter placement in cases where TTE is insufficient.[9,10]

5. <u>Documentation</u>
   In performing CUS 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. <u>Equipment Specifications</u>

A multiplane standard or disposable 2-10 MHz phased array TEE probe is sufficient for resuscitative TEE. It will be important to purchase a TEE probe that is compatible with the institution's ultrasound machine. The cardiac presets available on most equipment may be activated to optimize cardiac images. Doppler capability may be helpful in certain extended cardiac CUS indications but is not routinely used for the primary resuscitative TEE indications.[4]

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. The TEE probe requires high level disinfection as it is in contact with mucous membranes. Cleaning of the TEE probe should follow similar protocols for the disinfection of other TEE probes within the hospital.[4]

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Trauma

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

The FAST exam 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, and abdomen. It is performed as an integral component of trauma resuscitation. It is a clinically focused examination, which, in conjunction with historical and laboratory information, provides additional data for decision-making in trauma patients. While other tests may provide information that is more detailed than the FAST exam, have greater anatomic specificity, or identify alternative diagnoses, the FAST exam is non-invasive, is rapidly deployed, and does not entail removal of the patient from the resuscitation area. Further, FAST avoids the delays, costs, specialized technical personnel, the administration of contrast agents, and radiation associated with other imaging modalities. These advantages make the FAST a valuable addition to available diagnostic resources in the care of patients with acute thoracic and abdominal trauma.

The FAST examination is indicated for patients presenting with acute trauma to the chest or abdomen. It can be useful in both blunt and penetrating mechanisms and holds utility for patients that are hemodynamically stable or unstable. The incorporation of the FAST exam in the setting of hemodynamically unstable blunt trauma patients has been shown to reduce the time to operative disposition, decrease computed tomography (CT) utilization and overall costs associated with trauma care.[1] While the test characteristics improve when performed in hypotensive patients, a positive FAST exam has been shown to be a better predictor of need for critical intervention in stable patients than other non-CT parameters such as vital sign trends, injury severity score, clinical exam.[2,3] The FAST exam 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. Additionally, portable devices can be used in remote or difficult clinical situations such as aeromedical transport, wilderness rescue, expeditions, battlefield settings, and space flight.[4] Finally, serial FAST exams can be performed without the risk of radiation or poor diagnostics (such as the physical exam in this scenario). CUS (clinical ultrasound) can lead to earlier interventions, can expedite appropriate management and appropriate allocation of resources. These advantages make it a valuable resource in the care of trauma patients.

The utility of the FAST for pediatric patients is less well established than for adults. While its specificity has been reported to be as high as 96%, the sensitivity in pediatric patients is only 52%, making it less useful in the initial evaluation of pediatric trauma patients.[5] In a randomized clinical trial of hemodynamically stable children with blunt torso trauma, FAST was found to have no impact on clinical outcomes, resource utilization, emergency department (ED) length of stay, and missed intra-abdominal injuries.[6] As such, it is less commonly deployed in pediatric patients.[7]

2. <u>Indications/Limitations</u>
   a. Primary Indications
      To rapidly evaluate the torso for evidence of traumatic free fluid in the peritoneal, pericardial, and pleural cavities.
   b. Secondary Indications
      i. Evaluation of solid organ injury
      ii. Triage of multiple or mass casualties
   c. Contraindications
      i. There are no absolute contraindications to the FAST exam, although providers should not let performance of the FAST delay other necessary procedures.
      ii. There may be relative contraindications based on specific features of the patient's clinical situation (eg, extensive abdominal or chest wall trauma).
      iii. The need for immediate laparotomy is often considered a contraindication to FAST; however, even in this circumstance, evaluation for pericardial tamponade and pneumothorax may be indicated prior before transfer to the operating room.

d. Limitations
   i. The FAST is a single component of the overall and ongoing resuscitation. Since it is a focused examination, FAST does not identify all abnormalities resulting from truncal trauma. Like other tests, it does not replace clinical judgment and should be interpreted in the context of the entire clinical picture. If the findings of the FAST are equivocal, repeat evaluation and additional diagnostic testing may be indicated.
   ii. FAST in trauma may be technically limited by:
      1. Bowel gas
      2. Obesity
      3. Subcutaneous emphysema
   iii. FAST is likely to be less accurate in the following settings:
      1. Pediatric patients
      2. Patients with other reasons for free fluid such as physiologic pelvic free fluid, physiologic pericardial fluid, ascites, prior diagnostic peritoneal lavage, or ruptured ovarian cyst.

e. Pitfalls
   i. Studies show that peritoneal free fluid is not identified by FAST until 100-500 ml is present, and this varies depending on patient positioning and provider experience. Thus, a negative exam does not preclude the presence of small amounts of free fluid.
   ii. Some injuries may not give rise to free fluid and may therefore easily be missed by the FAST. These include contained solid organ injuries, mesenteric vascular injuries, hollow viscus injuries, and diaphragmatic injuries.
   iii. Non-traumatic peritoneal, pleural or pericardial fluid collections may be mistakenly ascribed to trauma.
   iv. FAST does not reliably identify solid organ injuries.
   v. FAST does not reliably identify retroperitoneal hemorrhage.
   vi. Blood clots form rapidly in the peritoneum. Clotted blood has sonographic qualities similar to soft tissue and may be overlooked.
   vii. Perinephric fat may be mistaken for hemoperitoneum. This is known as the double line sign where an operator visualizes hypoechoic fat between echogenic fascial planes.
   viii. Fluid in the stomach or bowel may be mistaken for hemoperitoneum.
   ix. Small hemothoraces may be missed in the supine position.
   x. In the evaluation of the pericardium, epicardial fat pads, pericardial cysts, and the descending aorta have been mistaken for free fluid.
   xi. Patients with peritoneal or pleural adhesions with significant hemorrhage may not develop free fluid in expected locations.
   xii. 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

The FAST exam 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 via the FAST exam represents the practice of medicine, and therefore is the responsibility of the treating physician.

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. Because this is an important part of clinical care, the results of the FAST should be documented and reported in the medical record.

4. Specifications for Individual Examinations
   a. General Principles
      The FAST exam is performed simultaneously with other aspects of resuscitation and should not delay the performance of other time critical interventions or procedures. The transducer is placed systematically in four general regions with known "windows" to the peritoneum, pericardium and pleural spaces for detection of fluid in potential spaces where pathological collections of free fluid are known to collect. The four windows are the right upper quadrant, left upper quadrant, pelvic, and subxiphoid. Within these windows there are views that should be systematically assessed for free fluid or clotted blood. To obtain these views the transducer is manipulated with rocking, fanning, rotating and sliding to allow for real-time imaging through all tissue planes. In the section below the FAST scanning technique is described. These are general guidelines however there are significant anatomical differences across patients and the sonologist may need to adjust their scanning based on what is seen on the viewing screen. Images should be retained for purposes of documentation, quality assurance, and teaching.
   b. Scanning Technique
      i. Image Order - 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. As the right upper quadrant window is most likely to be positive for intra-abdominal free fluid, many practitioners start with this view in patients with blunt trauma. From there, the remaining order of the views is variable with some providers preferring to complete all intra-abdominal views together to help minimize changes to the machine settings. Conversely, in patients suffering penetrating trauma, one of the most immediately fatal pathologies is pericardial tamponade. Therefore, it is generally recommended to start the FAST in the subxiphoid region to evaluate for a pericardial effusion in this scenario. For an extended or E-FAST the bilateral pleura are examined for the presence of pneumothorax.
      ii. Imaging Windows/Views
         1. The right upper quadrant window. This is also known as the perihepatic window, Morison's pouch window, or right upper quadrant window. Four potential spaces for the accumulation of free fluid are examined in this region: the pleural space, the subphrenic space, the hepatorenal space (Morison's pouch), the inferior aspect of the liver, and the inferior pole of the kidney, which is a continuation of the right paracolic gutter.

            The probe is placed on the right flank at the anterior-axillary line with the indicator to the patient's head. In order to minimize rib shadowing, the transducer should be placed in an intercostal space with the long-axis of the probe in a parallel plane with the ribs (about 45 degrees counterclockwise from the long axis of the patient's body). By sliding the probe superiorly, the right pleural and subphrenic spaces may be examined for free fluid. Sliding inferiorly allows visualization of Morison's pouch. The operator should fan through the space anteriorly and posteriorly to fully visualize any areas of free fluid. Small amounts of free fluid tend to collect around the caudal tip of the liver, so this is an important component of the right upper quadrant evaluation and may require sliding the probe inferiorly from Morison's pouch. Continuing to slide inferiorly 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. If rib shadowing prohibits visualization of these spaces, the probe can be placed in a subcostal location in the mid-clavicular line and rocked to visualize the more cranial spaces. Cooperative patients may facilitate this by being asked to "take a deep breath and hold" while the four potential spaces are examined.

Abnormal fluid collections are visualized as anechoic or hypoechoic collections. Free fluid typically assumes a spiculated appearance as it accumulates between rounded anatomic structures, making this a useful marker to distinguish free fluid from other anatomic fluid collections (eg, bowel, the gallbladder, renal or liver cysts). 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, and renal vein) appear black.

2. Left upper quadrant window. In this window, also known as the perisplenic or left upper quadrant window, four potential spaces are sonographically explored. These four spaces are: the pleural space, the subphrenic space, the splenorenal space, and the inferior pole of the left kidney, which is a continuation of the left paracolic gutter. The spleen can be a useful sonographic window, however being smaller, it provides a more limited window than the liver on the right. The optimal left upper quadrant window is routinely obtained more posteriorly and superiorly than the right upper quadrant window.

   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 patient's head and then rotated approximately 45 degrees to be parallel with ribs. Sliding or rocking 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. To visualize the inferior pole of the left kidney and the superior extent of the left paracolic gutter, it is usually necessary to slide the probe in a caudal direction.

   In each rib space, the probe is systematically swept through all planes in a search for free fluid. The operator should be aware that the stomach will be seen anteriorly to the splenorenal space and can be confused with free fluid, so attention to appropriate positioning of the probe is important. Isolated free fluid in the left upper quadrant is rare and will most likely be found in the subdiaphragmatic space.[8]

3. Pelvic. This view, also known as the suprapubic window, evaluates the rectovesicular space in a male and rectouterine (pouch of Douglas) space in a female. 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 fanned from the inferior aspect of the bladder to the dome of the bladder through all tissue planes. The probe is then rotated 90 degrees clockwise into the sagittal plane for visualization of the space in an orthogonal plane. Far-field gain settings usually need to be decreased in this view to account for the posterior acoustic enhancement caused by the fluid-filled bladder.

   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, such as in the presence of a Foley catheter, anechoic or hypoechoic free fluid may still be seen, however it is less reliable in ruling out the presence of smaller amounts of free fluid.

4. The pericardial window. To examine the heart and pericardial sac (commonly approached from the subcostal area), the liver is used as a sonographic window. The heart lies immediately behind the sternum, so it is often necessary to apply significant pressure and lower the angle of the probe until it is almost flat against the abdomen to

obtain an adequate image. In a cooperative and stable patient, having them take a deep breath and hold may bring the heart closer to the transducer, and flexing at the knees may release the abdominal musculature. The potential space of the pericardial sac is examined for fluid both inferiorly (between the diaphragmatic surface and the inferior myocardium) and posteriorly by fanning anteriorly and posteriorly through the space.

In some patients, the gastric bubble can inhibit this view. In that case, it may be beneficial to slide slightly to the patient's right and use a leftward rock to help maneuver around gas in the stomach. At times, 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.

5. Anterior pleural (Bilateral). In normal lung, the visceral and parietal pleura are intimately apposed, and slide against one another during respiration. Absence of identifiable pleural sliding is suggestive of separation of the parietal–visceral pleural interface by interposed gas indicating a pneumothorax. In the supine position, the anterior pleura are examined by placing the probe in a sagittal plane in the midclavicular line at the 3rd to 4th intercostal space. This is the most anterior location on the chest where air within a pneumothorax would typically accumulate in a supine patient. It is necessary to adjust frequency, depth, focus and gain settings to optimally image these superficial structures. The presence of lung sliding, b-lines/z-lines, or a lung pulse rules out pneumothorax at that location under the probe. Lack of plural sliding may be secondary to a pneumothorax, however apnea, mainstem intubation, and adhesion of the pleural layers will also result in lack of movement. M-mode can be used to aid in visualization of lung sliding bilaterally. This exam is discussed in more detail in the "Lung and Pleura" criteria.

iii. Other considerations
Trendelenburg position may increase the sensitivity of the ultrasound exam for abnormal fluid in the right upper quadrant and the sitting positing or reverse Trendelenburg can increase the sensitivity for pelvic free fluid. Serial FAST exams 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. Emerging research indicates some utility in select populations for the use of contrast-enhanced ultrasound to aid in the management of acutely injured patients.

5. Documentation
In performing FAST 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. When possible, images should be stored as a part of the medical record and done so in accordance with facility policy requirements.

6. Equipment Specifications
Generally, a curvilinear abdominal or phased-array 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 while a depth of field of up to 25 cm may be required in order to adequately visualize deeper structures in large patients. A high-frequency linear probe is optimal for visualizing the anterior pleural line in most patients, however a phased array or

curvilinear transducer can be used for patients with large habitus or if a linear transducer is not available.

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.

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Ultrasound-Guided Procedures

1. Introduction
   The American College of Emergency Physicians (ACEP) has developed criteria for clinicians utilizing emergency ultrasound (EUS) for procedural accuracy.

   The use of EUS has been shown to improve accuracy and proficiency of emergent procedures. Real-time sonographic visualization of anatomical structures allows for improved first pass success, reduction of adverse events, and improved provider confidence on technically difficult or high-risk patients. For example, EUS can determine patency of vascular structures thereby improving the success rate of both central and peripheral venous catheter placements while also reducing complication rates. The Agency for Healthcare Research and Quality highlighted ultrasound-guided central venous catheter placement as a key intervention to reduce adverse outcomes.

Additional procedural applications for ultrasound include guidance for incision and drainage of abscess, aspiration of body fluid collection, confirming fracture or joint reduction, confirmation of endotracheal tube placement, regional anesthesia, arthrocentesis, and lumbar puncture.

2. Indications
   a. Vascular access
      i. Identify central venous structures, their relative location to important anatomical structures and their patency in facilitating placement of central venous catheters.
      ii. Identify peripheral venous structures, their relative location to important anatomical structures and patency in facilitating placement of peripheral venous access.
      iii. Identify arterial structures, their relative location and flow characteristics in facilitating placement of arterial lines.
   b. Evaluation and drainage of abscess
      i. Soft tissue abscess
      ii. Peritonsillar abscess
   c. Evaluation and aspiration of body fluid
      i. Pericardial effusion (pericardiocentesis)
      ii. Pleural effusion (thoracentesis)
      iii. Peritoneal fluid (paracentesis)
      iv. Joint effusion (arthrocentesis)
      v. Cerebrospinal fluid (lumbar puncture)
      vi. Urinary retention (bladder aspiration)
      vii. Evaluation for soft tissue foreign bodies
      viii. Identify fracture and/or confirm reduction
      ix. Joint, bursa, and tendon injections
      x. Regional anesthesia for multimodal analgesia
      xi. Evaluation of pacemaker placement and capture
      xii. Confirm endotracheal tube placement
   d. Limitations
      i. Procedural ultrasound is an adjunct to care and has inherent limitations. 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
         4. Poor imaging from the operator
   e. Pitfalls
      i. The operator must be proficient with needle localization and its associated artifact before proceeding with any procedure. The out-of-plane approach allows only a cross section of the needle to be visualized and may lead to errors in needle tip placement. The in-plane approach allows the operator to trace the entire path and angle of the needle from the entry site at the skin, and is preferred when anatomically possible. Heel-toe technique, gel stand-off, beam steering and using echogenic needles can be utilized to improve needle visualization.
      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, shape, sonographic appearance (arteries tend to be circular in transverse view with muscular walls), and flow dynamics using Doppler ultrasound.
      iii. Abnormal structures should be compared to the unaffected contralateral side if possible. If uncertainty about the sonographic appearance of a structure persists, other imaging modalities should be investigated.

3. <u>Qualifications and responsibilities of the clinician performing the examination</u>
   Physicians of a variety of medical specialties may perform procedural ultrasound. Training should be in accordance with specialty or organization specific guidelines.

4. <u>Technical recommendations for each procedure</u>
   a. Prior to performing the procedure, a pre-scan of the relevant anatomy in two orthogonal planes should be performed.
   b. Acquire and use an appropriate sterility level probe cover.
   c. Prep and clean the skin prior to initiating the procedure
   d. When appropriate, employ standard sterile techniques to diminish the risk of infection.
   e. 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. Interpretation should be done at the bedside immediately with performance of the real-time examination.
   f. 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 (“mark&stick”).
      ii. Ultrasound-guided: The ultrasound transducer is placed in a 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)

5. <u>Procedural ultrasound examinations</u>
   a. Vascular access
      i. Central venous cannulation
      ii. Peripheral venous cannulation
      iii. Arterial cannulation
   b. Incision and drainage of abscess
      i. Soft tissue abscess drainage
      ii. Peritonsillar abscess drainage
   c. Body fluid aspiration
      i. Pericardiocentesis
      ii. Thoracentesis
      iii. Paracentesis
      iv. Arthrocentesis
      v. Lumbar puncture
      vi. Bladder aspiration/suprapubic catheter placement
   d. Soft tissue foreign body identification
   e. Confirmation of joint/fracture reduction
   f. Joint, bursa, and tendon injections
   g. Regional anesthesia
   h. Evaluate for pacemaker placement and capture
   i. Endotracheal tube confirmation

6. <u>Documentation</u>
   a. All ultrasound-guided or assisted procedures should be documented in a standard manner to include:[1]
      i. Indication for the procedure
      ii. Description of the organs or structures identified
      iii. Interpretation of the findings

iv. Complication(s) if any

b. 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 for image archival.

7. Equipment Specifications
   Multiple transducers can be used for procedural ultrasound. High frequency (7.0-12.0 MHz) linear array transducers have superior resolution for superficial and vascular structures. Curvilinear, low frequency transducers can be used to assess deeper structures such as when performing certain joint aspirations or nerve blocks. 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.

8. 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. In 2021 an intersocietal position statement on the disinfection of ultrasound transducers was published. If contamination of covered transcutaneous transducer with blood or other bodily fluids occurs, it can be eliminated with low-level disinfectants that are effective against mycobacteria and bloodborne pathogens (including hepatitis B virus, hepatitis C virus, and HIV.[2]

References

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Venous Thrombosis

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

   Lower extremity venous CUS differs in two fundamental aspects from the "Duplex" evaluation performed in a vascular laboratory. First, its anatomic focus is limited to specific regions of the proximal deep venous system whereas, in complete examinations, the entire course of the vein in question is scanned. Second, its sonographic technique consists primarily of real-time, dynamic evaluation of venous compressibility versus the duplex ultrasound which also involves Doppler evaluation (color flow and spectral Doppler waveform analysis). This approach to lower extremity proximal venous CUS is often referred to as focused or limited compression ultrasonography. Since B-mode (gray-scale) equipment is widely available, and because substantial scientific evidence supports the use of focused/limited compression ultrasonography, this guideline is focused on the evaluation of proximal lower extremity DVT utilizing this technique. However, emergency physicians today may have access to equipment with Doppler capabilities and are experienced in its use. These individuals may augment their examinations with this technology.

Lower extremity venous CUS is performed and interpreted in the context of the entire clinical picture. It is a clinically directed examination, which, in conjunction with historical, physical examination and laboratory information, provides additional data for clinical decision-making. It attempts to answer a specific question about an individual patient's condition. CUS of the lower extremities does not identify all abnormalities or diseases of the deep venous system. If the findings of lower extremity venous CUS exam are equivocal, further imaging or testing may be necessary.

2. <u>Indications/Limitations</u>
   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, lymphadenitis, aneurysm, 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. CUS of the lower extremity deep venous system is a single component of the overall and ongoing clinical evaluation. Since it is a focused examination CUS does not identify all abnormalities or diseases of the lower extremity veins. CUS, 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 CUS are equivocal, additional diagnostic testing may be indicated.
      ii. A prior history of DVT may limit the utility of venous CUS. The chronic effects of DVT are highly variable in extent, location, timing, and morphology. A completely normal venous CUS 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 focused lower extremity venous CUS examination.
      iii. Examination can be limited by:
         1. Obesity
         2. Local factors such as edema, tenderness, sores, open wounds, or injuries
         3. The patient's ability to cooperate with the exam
         4. Previous vascular surgery altering anatomy
         5. Anatomical variants (duplicated vessels, etc.)
   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. Challenging patient habitus (obesity, contraction, extremity edema) may limit exam quality.
      iv. Large superficial veins may be mistaken for deep veins, particularly in patients with DVT causing distension of collateral superficial veins. This can lead to both false positive and false negative results.
      v. Acute thrombus is frequently isoechoic to unclotted blood and failure to visualize echogenic clot should not be used to eliminate the possibility of DVT.
      vi. Failure to recognize a partially occlusive clot.
      vii. Inguinal lymphadenopathy may be mistaken for a non-compressible common femoral vein.

viii. A Baker's cyst can be mistaken as a non-compressible vein.
ix. When the limited CUS is negative for DVT failure to inform a patient that repeat venous evaluation in 5-7 days is recommended to assess for proximal propagation of a distal DVT.
x. Failure to consider the possibility of iliac or inferior vena cava obstruction as a cause for lower extremity pain or swelling. While Doppler techniques may identify the presence of these conditions, they may be beyond the usual scope of the focused CUS exam.
xi. A negative scan for a lower extremity DVT does not exclude the presence of proximal venous clot or pulmonary embolism.
xii. 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".
xiii. Failure to recognize that a proximal greater saphenous vein thrombus, that is seen approaching the common femoral vein, should be treated like a DVT.
xiv. Failure to identify an isolated thrombus (thrombus distal to the common femoral vein and proximal to the popliteal vein) is a potential pitfall however systematically scanning through the femoral and popliteal zones may reduce this risk.[1] Additionally, patients with normal femoral and popliteal venous compression and a negative d-dimer have equivalent outcomes to patients who undergo whole-leg ultrasonography.[2]
xv. Slow venous flow may be mistaken for thrombus if compression is not implemented.
xvi. Failure to compress the vein under investigation directly at a right angle can make it difficult to fully compress the vessel resulting in a false positive.

3. <u>Qualifications and Responsibilities of the Clinician Performing the Examination</u>
Limited compression ultrasound of the venous system provides information that is the basis of immediate clinical decision making. Because of its direct bearing on patient care, the rendering of a diagnosis by venous CUS 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 CUS exam. For this reason, the CUS exam should occur as soon as the clinical decision is made that the patient requires a sonographic evaluation.

Physicians of a variety of medical specialties may perform a lower extremity CUS. 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. Because this is an important part of clinical care, the results of the CUS should be documented and reported in the medical record.

4. <u>Specifications for Individual Examinations</u>
a. <u>General.</u> Emergency ultrasound for the diagnosis of DVT assesses 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. <u>Technique</u>
i. Identification of veins. For the purposes of lower extremity CUS, thrombus in the proximal deep veins of the lower extremity pose a significant risk of pulmonary embolization. These include the common femoral, femoral (formerly superficial femoral vein), deep femoral and popliteal veins. It is important to note that the superficial femoral vein is part of the deep system, not the superficial system as the name suggests. The deep femoral vein is easily overlooked, but like the proximal greater saphenous vein thrombus in this location readily

propagates into the common femoral vein. Therefore, it should be assessed for compression as part of the proximal region.

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 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 merging from the medial thigh. In relation to the companion arteries, the popliteal vein is superficial to the artery (more posterior). 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 (in transverse plane) 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. The patient should be fully undressed from the waist down (though briefs may be acceptable) and not performed in the standing position. To facilitate the identification of the veins and test for compression, venous distention is helpful. 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 may be placed in a semi-sitting position. To assess the femoral veins, the patient should externally rotate and abduct 10-30 degrees at the hip into a “frog leg” position and, in obese patients, they may assist the sonologist by lifting their pannus. There are 4 potential positioning options for assessment of the popliteal veins; prone with the ankle propped slightly to pool blood in the scanning zone and release posterior tendons (preferred), lateral decubitus, supine frog-leg position, and sitting with the leg off of the bed.

iv. Transducer. A linear array vascular probe with a frequency of 6 – 10 MHz is ideal. Narrow transducers may make it harder to localize the veins and to apply uniform compression. For larger patients, a lower frequency setting on the linear transducer or even a curvilinear 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. Coupling 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. The vein and artery may have almost any relationship with one another, although the vein is frequently seen posterior to the artery the farther from the inguinal canal. Distinction of the two vessels may therefore depend on size (the vein is usually larger), shape (the vein is more ovoid) and compressibility (unless thrombosed). Doppler can be utilized to differentiate characteristic arterial or venous signals. Identification of the junction of the greater saphenous and common femoral vein is a useful anatomic landmark. Compressive evaluation of the vessel commences at the highest view obtainable at the inguinal ligament, cephalad to the junction with the greater saphenous vein. Angling superiorly, a short section of the distal common iliac vein might be scanned. Systematic scanning commences cephalad to the junction with the greater saphenous 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 and additional imaging may be indicated.

2. The popliteal vein. 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 and additional imaging may be indicated. The popliteal vein should be compressed just into the proximal distal branches to catch any calf thrombus threatening to seed the popliteal vein.

vi. Additional components of the exam.

1. The deep femoral/femoral veins. As noted previously, these veins are not a primary focus of the standard lower extremity CUS evaluation, other than their proximal portions. In cases where there is a high suspicion of DVT and an otherwise normal exam of the common femoral and popliteal veins, these vessels may also be evaluated more extensively. A d-dimer may also be used to risk stratify this population.
2. Doppler. Color flow and spectral Doppler assessment may be used to localize and interrogate the vessels, although the use of this technology is beyond the scope of the standard CUS exam.

5. Documentation

In performing venous CUS, imaging is 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 CUS should document the presence of complete, partial or absent compressibility 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 venous CUS exam is a dynamic test with compression repeated multiple times over the lengths of examined vessels, 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 sufficient.

6. Equipment Specifications

A linear array transducer with a frequency of 6.0 – 10.0 MHz is ideal. Narrower transducers may make it harder to localize the veins and to apply uniform compression. For larger patients, a lower frequency setting on the linear transducer or a curvilinear probe may facilitate greater tissue penetration. Doppler capabilities may be of assistance in localizing and interrogating venous structures. Both hand-held 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.

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ACEP Emergency Ultrasound Section Writing Committee and contributors:

Editors: Nova L Panebianco, MD, FACEP; Javier E. Rosario, MD, FACEP; Penelope Chun Lema, MD, FACEP; Arun Nagdev, MD; Marina Shpilko, DO

Aorta: Javier E. Rosario, MD, FACEP; Mark A. Newberry, DO, FACEP

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Female Pelvis: Nova L Panebianco, MD, FACEP; Courtney R. Cassella, MD

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Trauma: Lori Ann Stolz, MD, FACEP

Ultrasound-Guided Procedures: Arun Nagdev, MD; Brian D. Johnson, MD, FACEP; Tobias Kummer, MD, FACEP

Venous Thrombosis: Christopher C. Raio, MD, FACEP