POCUS

THE ESSENTIALS OF BEDSIDE ULTRASOUND GUIDED PROCEDURES

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Critical Care Service Line
Resident and Fellow Section
Society of Interventional Radiology
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THE ESSENTIALS OF BEDSIDE US GUIDED PROCEDURES

Contributors
❖ Jacob Wochna
❖ Dinh-Huy D. Nguyen
❖ Pouya Aghajafari
❖ Navjit Dullet
❖ Jonathan Friedman
❖ Rick Artrip
❖ Sipan Mathevosian
❖ Jonathan Barclay
❖ Henry Szeto
❖ Ian Sullivan
❖ Jay Gajera
❖ Sydney Rubin
❖ Suhag Patel
❖ Rakesh S. Ahuja
❖ Rajath Rao
❖ Matthew Chiarello
❖ Vikrant Bhatnagar
❖ David Kopylov

Editors
❖ Dinh-Huy D. Nguyen
❖ Sipan Mathevosian
❖ Navjit Dullet
❖ Kartik Kansagra
❖ Rakesh Ahuja
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THE ESSENTIALS OF BEDSIDE US GUIDED PROCEDURES

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Procedure: Rapid Ultrasound for Shock and Hypotension (RUSH)

**AUTHORS:**
Henry Szeto

**EDITORS:**
Navjit Dulett
Sipan Mathevosian
**Rapid Ultrasound for Shock and Hypotension (RUSH)**

**Indications**
1. Undifferentiated shock and/or hypotension

**Absolute Contraindications**
1. None

**Goals**
1. Evaluate for cause of hypotension in a patient by examining three systems:
   a. **Pump** (heart, pericardium)
   b. **Tank** (IVC, lungs, thoracic and peritoneal cavities)
   c. **Pipes** (abdominal aorta and lower extremity veins)

This exam may aid in diagnosing the type of shock (hypovolemic, cardiogenic, obstructive, or distributive).

**Preoperative Preparation**
1. None

**Procedure**
1. Obtain a 3.5–5 MHz phased array transducer and a 7.5–10 MHz linear array transducer. The linear array transducer will be used to evaluate lungs and lower extremity veins. Use the phased array transducer for all other examinations.

**Pump (heart):**
2. Place the phased array transducer in parasternal long position.
3. Identify the heart and evaluate contractility, right heart strain, and for pericardial effusion.
4. The transducer may also be placed in the apical or subxiphoid position for a more complete evaluation.

**Tank (IVC, thoracic and peritoneal cavities, lungs):**

**IVC:**
5. Place the phased array transducer in a sagittal orientation in the subxiphoid position. Identify the liver, right atrium, and IVC.
6. Observe the IVC for respiratory variation.
7. In M-mode, place the scan line approximately 2cm inferior to cavo-atrial junction. Ensure probe is midline of the IVC for accurate assessment.
8. Record a clip through inhalation and exhalation. Maximum IVC diameter occurs during exhalation and vice versa. Note this relationship is reversed in ventilated patients.
9. Measure minimum and maximum diameter of IVC. The IVC compressibility index (CI) is the minimum divided by the maximum diameter. In general, an IVC diameter >2cm or compressibility index <50% indicates a hypovolemic state or low cardiac output. IVC compressibility has an inverse relationship with CVP measurement.
   - IVC < 2.1cm, CI > 50% has an estimated CVP of 0-5 mmHg
   - IVC > 2.1cm, CI < 50% has an estimated CVP of 10-20mmHg

**E-FAST (thoracic and peritoneal cavities, lungs)**

**RUQ:**
10. Place the phased array transducer in the intercostal space between ribs 8-11, posterior to mid-axillary line.
11. Identify the liver and kidney interface (Morrison’s pouch) and evaluate the entirety of the space for fluid. Next, slide the probe cephalad and evaluate for fluid above the diaphragm. The probe may be obliqued parallel to ribs to eliminate rib shadowing.

**LUQ:**
12. Place the phased array transducer in the intercostal space between ribs 6-9, along the posterior axillary line. Identify the spleen-kidney interface and evaluate peri splenic and splenorenal spaces for fluid. Next, slide the probe cephalad and evaluate for fluid above the diaphragm.

**Suprapubic:**
13. Place the phased array transducer immediately superior to the pubic symphysis in a transverse orientation. Fan cephalad and caudad to evaluate for free fluid posterior to the bladder. In men, free fluid collects in the rectovesical space. In women, free fluid may collect in the rectouterine or vesico-uterine spaces.

14. Rotate the probe to a sagittal orientation and fan right and left to re-evaluate these spaces.

Anterior Thorax:

15. Place the linear array transducer in a sagittal orientation on the third or fourth intercostal space, along the mid-clavicular line. Evaluate for lung sliding. Repeat on other side. Absence of lung sliding is strongly suggestive of pneumothorax. In a semi-supine patient, air is most likely to accumulate anteriorly.

16. Switch to the phased array transducer and place on anterolateral position in the intercostal spaces between ribs 2-5. Evaluate for B-lines, which would appear as "spotlights" emerging from the pleural line and extending into the far field. This is suggestive of pulmonary edema.

Pipes (abdominal aorta, femoral and popliteal veins):

Aorta:

17. Place the phased array transducer in transverse orientation on the midline near the epigastrium. Identify the aorta, which is the thicker walled, pulsatile vessel to the anatomical left of the IVC. If bowel gas obscures vision, apply steady pressure to transducer to displace bowel gas.

18. Evaluate for aneurysm or dissection. An outer wall-to-wall diameter of >3cm is abnormal. Risk of rupture is greatly increased when aneurysm diameter is >5cm.

19. Re-evaluate in sagittal position to characterize shape of aneurysm.

20. Slide transducer caudal until the iliac bifurcation to evaluate the infrarenal aorta in both transverse and sagittal orientation.

21. If a dissection is identified, evaluate the flow within the true and false lumens with color flow and note the extent of dissection.

Femoral and popliteal veins:

22. Place the linear array transducer in a transverse orientation on the common femoral vein, just below the inguinal ligament. The vein is medial to the artery and is compressible.

23. Scan inferiorly towards the confluence of the saphenous, superficial, and deep femoral veins. Compress periodically while scanning. A thrombus will appear as a non-compressible, hyperechoic mass within the lumen of the vein. Repeat on the other leg.

24. Next, place the transducer in a transverse orientation posterior to the knee. Identify the popliteal vein.

25. Begin scanning in the superior part of the popliteal fossa and proceed inferiorly until the trifurcation of the calf veins. Compress periodically to evaluate for thrombus.

Rush protocol summary:

Table 1: RUSH protocol summary

<table>
<thead>
<tr>
<th>RUSH Exam</th>
<th>Hypovolemic shock</th>
<th>Cardiogenic shock</th>
<th>Obstructive shock</th>
<th>Distributive shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>Hypercontractile heart</td>
<td>Hypercontractile heart</td>
<td>Pericardial effusion, RV strain</td>
<td>Hypercontractile heart</td>
</tr>
<tr>
<td></td>
<td>Small heart size</td>
<td>Dilated heart size</td>
<td>Hypercontractile heart</td>
<td>Hypercontractile heart (early sepsis)</td>
</tr>
<tr>
<td>Tank</td>
<td>Flat IVC</td>
<td>Distended IVC</td>
<td>Distended IVC</td>
<td>Normal/small IVC</td>
</tr>
<tr>
<td></td>
<td>Flat IJV</td>
<td>Distended IJV</td>
<td>Distended IJV</td>
<td>Normal/small IJV</td>
</tr>
<tr>
<td></td>
<td>Pleural fluid</td>
<td>Lung rockets</td>
<td>Absent lung sliding (PTX)</td>
<td>Pleural fluid (crescent)</td>
</tr>
<tr>
<td></td>
<td>Pleural effusions, ascites</td>
<td></td>
<td></td>
<td>Pleural fluid (peritonitis)</td>
</tr>
<tr>
<td>Pipes</td>
<td>AAA</td>
<td>Aortic dissection</td>
<td>Normal</td>
<td>DVT</td>
</tr>
</tbody>
</table>

Table 2: Using the RUSH protocol to diagnose the type of shock

<table>
<thead>
<tr>
<th>Step no. 1</th>
<th>Step no. 2</th>
<th>Step no. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>Pericardial effusion:</td>
<td>Left ventricular contractility:</td>
</tr>
<tr>
<td></td>
<td>(a) Effusion present?</td>
<td>(a) Hyperdynamic?</td>
</tr>
<tr>
<td></td>
<td>(b) Signs of tamponade?</td>
<td>(b) Normal?</td>
</tr>
<tr>
<td></td>
<td>Diastolic collapse of R Vent +/– R Atrium?</td>
<td>(c) Decreased?</td>
</tr>
<tr>
<td>Tank</td>
<td>Tank volume:</td>
<td>Tank leaks:</td>
</tr>
<tr>
<td></td>
<td>(1) Inferior vena cava:</td>
<td>(1) E-FAST exam:</td>
</tr>
<tr>
<td></td>
<td>(a) Large size/small lobe collapse?</td>
<td>(a) Free fluid Abd/Pelvis?</td>
</tr>
<tr>
<td></td>
<td>(b) Small size/large lobe collapse?</td>
<td>(b) Free fluid thoracic cavity?</td>
</tr>
<tr>
<td></td>
<td>— CVP high —</td>
<td>(2) Pulm edema:</td>
</tr>
<tr>
<td></td>
<td>— CVP low —</td>
<td>Lung rockets!</td>
</tr>
<tr>
<td></td>
<td>(2) Internal jugular veins:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) Small or large?</td>
<td></td>
</tr>
<tr>
<td>Pipes</td>
<td>Abdominal aorta aneurysm:</td>
<td>Thoracic aorta aneurysm/dissection:</td>
</tr>
<tr>
<td></td>
<td>Abd aorta &gt; 3 cm?</td>
<td>(a) Aortic root &gt; 3.8 cm?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Intimal flap?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) Thor aorta &gt; 3 cm ?</td>
</tr>
</tbody>
</table>

Actionability

1. This screening exam rapidly evaluates for potential causes of shock and hypotension to guide treatment of a critically ill patient.

References


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Procedure: eFAST Exam

**AUTHORS:**
HENRY SZETO

**EDITORS:**
DINH-HUY D. NGUYEN
NAVJIT DULET
**eFAST Exam**

Goals

1. Evaluate for free fluid in thoracic and peritoneal cavities, hemopericardium, pneumothorax, and fluid status of patient.

Indications

1. Traumatic injury to chest or abdomen
2. Undifferentiated shock and/or hypotension

Absolute Contraindications

1. None

Preoperative Preparation

2. None

Technique

1. Obtain a 2–5 MHz phased array or curvilinear probe.

   ❖ Pericardium:

   2. Place the transducer in subxiphoid position. Identify the heart and evaluate for injury/hemopericardium. If body habitus prevents good visualization, the transducer may be placed in parasternal long position.

   ❖ RUQ:

   3. Place the transducer in the intercostal space between ribs 8–11, posterior to mid-axillary line. Identify the liver and kidney interface (Morrison’s pouch) and evaluate the entirety of the space. Next, slide the probe cephalad and evaluate for fluid above the diaphragm. The probe may be obliqued parallel to ribs to eliminate shadowing.

   ❖ LUQ:

   4. Place the transducer in the intercostal space between ribs 6–9, along the posterior axillary line. Identify the spleen-kidney interface and evaluate perisplenic and splenorenal spaces. Next, slide the probe cephalad and evaluate for fluid above the diaphragm.

   ❖ Suprapubic:

   5. Place the transducer immediately superior to the pubic symphysis in a transverse orientation. Fan cephalad and caudad to evaluate for free fluid posterior to the bladder. In men, free fluid collects in the rectovesical space. In women, free fluid may collect in the rectouterine or vesico-uterine spaces. Rotate the probe to a sagittal orientation and fan right and left to re-evaluate these spaces.

   ❖ Anterior Thorax

   6. Place the transducer in a sagittal orientation on the third or fourth intercostal space, along the mid-clavicular line. Evaluate for lung sliding. Repeat on other side.

   ❖ IVC

   7. Place the transducer in a sagittal orientation in the subxiphoid position. Identify the liver, right atrium, and IVC.

   8. In M-mode, place the scan line approximately 2cm inferior to cavo-atrial junction. Ensure probe is midline of the IVC for accurate assessment.

   9. Record a clip through inhalation and exhalation. Maximum IVC diameter occurs during exhalation and vice versa.

10. Measure minimum and maximum diameter of IVC. Divide the minimum by the maximum diameter. This is the IVC compressibility index. In general, an IVC diameter >2cm or compressibility index <50% indicates a hypovolemic state. IVC compressibility has an inverse relationship with CVP measurements.
Actionability

1. This screening exam can help triage unstable patients for emergent operation or advanced imaging (CT) and stable patients for advanced imaging (CT), serial eFAST exams, or observation.
2. FAST exam may need to be repeated if there is persistent or new onset hypotension.

Images


Image: pneumothorax visualized, a-lines are far more prominent and numerous than in normal lung, absence of lung sliding will also be seen. B lines and comet tails are less likely to occur in the presence of pneumothorax. Image from Richards J, McGahan J. Focused Assessment with Sonography in Trauma (FAST) in 2017: What Radiologists Can Learn.

References

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Procedure: IVC Volume Status

Authors: Navjit Dullet

Editors: Navjit Dullet
**IVC Volume Status**

**Indications**
1. Assessing and monitoring intravascular volume status in patients, such as treatment of CHF exacerbation or hypovolemic shock. This study can be used to determine whether a patient should be for their diaries, or whether they are in need of additional fluids. This can be used as a supplementation, or temporary substitute to more invasive measures, such as CBP monitorization or pulmonary artery catheterization.

**Absolute Contraindications:**
1. None

**Preoperative Preparation:**
1. None

**Procedure**
1. Position the patient supine, as level as allowable.
2. Select the 5 – 1 MHz transducer cardiac type transducer.
3. Place the transducer and the sub-xiphoid position. Identify the IVC, right atrium, and liver.
4. Use M – mode to measure the diameter of the IVC. Place the single scanline at a point along the IVC, approximately 2 cm inferior to the right atrium – IVC junction. Also ensure that the probe is at the midline of the IVC to ensure accurate measurement of IVC diameter.
5. Save the clip through inhalation – exhalation. Maximum diameter occurs in exhalation, minimum diameter occurs in inhalation.
6. Measure the maximum diameter of the IVC. The IVC compressibility index (IVC – CI) can be calculated using this number. It can give an indication of intravascular volume status. This is calculated by dividing the minimum diameter by the maximum diameter.
7. The compressibility index gives an indication of the variability in IVC size throughout the respiratory cycle, which can correlate with intravascular volume status and cardiac function. In general, IVC diameter > 2cm or a compressibility of <50% indicates a hypervolemic state. IVC compressibility has an inverse relationship with CVP measurements.
8. Kircher et al. found a correlation between IVC size, percent compressibility, and mmHg CVP, shown in the chart below.

<table>
<thead>
<tr>
<th>IVC Size (cm)</th>
<th>Percent of Collapsibility (%)</th>
<th>CVP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>&gt;50</td>
<td>0-5</td>
</tr>
<tr>
<td>1.5-2.5</td>
<td>&gt;50</td>
<td>6-10</td>
</tr>
<tr>
<td>1.5-2.5</td>
<td>&lt;50</td>
<td>11-15</td>
</tr>
<tr>
<td>&gt;2.5</td>
<td>&lt;50</td>
<td>16-20</td>
</tr>
</tbody>
</table>

**Actionability**
1. These measurements can provide indication of whether diuresis or fluid replacement is necessary. Values between 15 – 50% have been found to be diagnostic for heart failure, and variation of 15% or less in IVC diameter has been found to be diagnostic for CHF.

**Images**

![Image: US view showing the inferior vena cava. Photo credit radiopaedia.org](https://www.radiopaedia.org)
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Procedure: Cardiac Exam

AUTHORS: NAVJIT DULEET

EDITORS:
Cardiac Exam

Indications
1. Focused cardiac ultrasound examination is performed to evaluate cardiac function, pericardial effusion/tamponade, and volume status. Point-of-care ultrasonography of the heart does not provide as detailed images as proper echocardiographic, so it’s uses are more limited. Thus, focused point-of-care ultrasound is not the best test for evaluation of the valve function.

Goals
1. to identify LV dimensions and systolic function, right ventricular systolic function, volume status, and pericardial effusion/tamponade physiology.

Contraindications
1. There are no absolute contraindications for this study

Procedure
1. Obtain a 5 – 1 MHz cardiac transducer point-of-care ultrasound device.
2. Parasternal long axis is performed with the transducer in the 3rd or 4th intercostal space. The notch of the probe must be directed towards the sternum. The probe should be placed at the left lateral border of the sternum, just at the sternal – costal angle. If you can’t obtain a good image, then move to the next lower intercostal space. There should be visualization of the right ventricle, left ventricle, mitral valve, aortic valve, interventricular septum.
3. Apical 4 chamber view is performed with the probe at the apex of the left ventricle, located at the apical impulse. The probe is oriented towards the right shoulder, with the notch at the 2 or 3 o’clock position. The left ventricle, left atrium, right ventricle, and right atrium should be visualized.
4. Subcostal views may be the only views available to ventilated patients. Subcostal views can be both short axis and 4 chamber. With this view, the transducer will be placed under the xyphoid, with the notch at the 3 o’clock position. The probe is oriented towards the patient’s sternum. In order to get this view, the probe can be placed vertically 3 cm below the xyphoid, then angled upward until the 4 chambers are visualized.
5. Using these views, the area surrounding the ventricles and pericardium can be visualized for fluid, signifying pericardial effusion or cardiac tamponade.
6. Parasternal long axis view can be used to evaluate left ventricular function and left atrial enlargement. Left atrial enlargement has been found to be characterized by a maximum end systolic diameter of greater than 4 cm
7. LV dysfunction can be considered when mitral E point separation (see figure below, also known as EPSS) is greater than 7mm. This is the distance between the mitral valve and the septum in early diastole. EPSS > 7mm correlates with a low EF (~30%).
8. and left ventricular systolic dysfunction can be considered present when mitral valve anterior leaflet “E-point” (point of greatest amplitude of the anterior leaflet of the mitral valve on M – mode) to septum separation greater than 1 cm in early diastole, which corresponds to an ejection fraction of less than 55%.

Actionability
1. This exam can indicate whether a patient may have pericardial effusion progressing to tamponade, whether the patient is in heart failure, or even an indication of volume status for the patient, however and IVC exam would be better suited for this purpose.

Images

Figure: parasternal long axis view. LA (left atrium), MV (mitral valve), ALMV (anterior leaflet, mitral valve), PLMV (posterior leaflet, mitral valve), LV (left ventricle), IVS (interventricular septum), PWLV (posterior wall, left ventricle), DA (descending aorta), AO (ascending aorta), AoV (aortic valve), RVOT (right ventricular outflow tract). Photo credit radiopaedia.org
Figure: Apical 4 chamber view. LA (left atrium), RA (right atrium), IAS (interatrial septum), MV (mitral valve), TV (tricuspid valve), MVAL (mitral valve anterior leaflet), MVPL (mitral valve, posterior leaflet), LV (left ventricle), IVS (interventricular septum), TVAL (tricuspid valve anterior leaflet) TVSL (tricuspid valve anterior leaflet) RSPV (right superior pulmonic vein) LIPV (left inferior pulmonic vein). Photo credit radiopaedia.org


Video References
2. https://www.sonosite.com/media-library/3d-how-apical-4-chamber-view

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Procedure: Ultrasound Guided Pericardiocentesis

**AUTHORS:**
Vikrant Bhatnagar

**EDITORS:**
Navjit Dullet
Sipan Mathevosian
Ultrasound Guided Pericardiocentesis

Goal

1. To use a portable ultrasound to guide pericardiocentesis to aspirate fluid from the pericardial sac

Indications

1. Cardiac tamponade
2. Symptomatic pericardial effusion with hemodynamic compromise. Without hemodynamic compromise, US pericardiocentesis can be considered in cases refractory to medical management
3. Large pericardial effusion, with size < 2cm
4. Suspicion of infectious pericardial effusion (TB, bacterial, fungal)

Contraindications

1. Aortic dissection
2. Myocardial rupture
3. Traumatic effusion with hemodynamic instability
4. 1-3 warrant immediate surgical intervention rather than US pericardiocentesis. Pericardiocentesis can be considered in a case-by-case basis if the patient decompensates on the way to surgical intervention.
5. Relative contraindications are uncorrected coagulopathy, thrombocytopenia, and anticoagulant use

Equipment

1. 18 gauge spinal needle OR large bore needle from a central line kit
2. 20 or 30cc syringe
3. Local anesthetic
4. 25 gauge (1.5 inch) needle for anesthetic
5. Sterile supplies: betadine and drape
6. Catheter or trocar needle kit if continued drainage required
7. Type and cross for patient as blood products may be needed in case of complications

Consent

Discuss possible complications/risks including:

1. Bleeding
2. Infection
3. Damage to adjacent structures
4. Local anesthesia
5. Entry site hematoma
6. Arrhythmia
7. Myocardial damage
8. Cardiac perforation
9. Pneumothorax
10. Mortality

Procedure

1. Identify an approach that opens to the largest effusion pocket. Several different methods exist, including apical, parasternal, and subxiphoid
2. Parasternal carries a risk of pneumothorax and damage to intercostal vessels
3. Apical carries a risk of ventricular puncture and pneumothorax
4. Subxiphoid may not be optimal due to distribution of pericardial effusion, path to reach effusion pocket may be longer, and structures (i.e. liver) may be inadvertently traversed.
5. Patient should be positioned at 30 degrees, with slight rotation to left side to enhance effusion fluid collection in anterior/inferior part of chest
6. Sub-Xiphoid Approach
   a. Place probe in Sub-Xiphoid area, angled up into chest using liver as window
   b. You should first see Right Ventricle (RV)
   c. Pericardial effusion will be a black anechoic area above the RV
   d. Evaluate the IVC, will be enlarged
   e. Use measurement markers on Ultrasound monitor to measure the distance between RV and where needle will be inserted
   f. Add local anesthetic with a standard 25g (1.5 inch) needle over the site of planned entry
g. Utilize a 18 gauge 15cm needle for entry to effusion
h. Typical entry point is 1cm inferior to the left xiphocostal angle. Once needle beneath cartilage cage, lower needle angle to 30 degrees to the chest wall. Advance needle towards left mid-clavicle.
i. Needle will appear on screen and should guide advancement
j. Aspirate and advance needle every 1-2 mm until fluid drawn back
k. Once blood aspirated, inject agitated saline (~5mL) to confirm appropriate location under ultrasound
l. If trochar technique used, advance catheter over needle, remove needle. Otherwise, insert guidewire through needle to pericardial space, and exchange needle for drainage catheter over guidewire using Seldinger technique
m. Utilize sheath needle, j-wire, and drainage catheter for aspiration of pericardial fluid

7. Parasternal Approach
   a. Place probe in Left Parasternal position in the 4th or 5th intercostal space
   b. You should first visualize anterior part of the right ventricle (RV) first
   c. Pericardial effusion will be seen as a black anechoic area above the RV
   d. Use measurement markers on Ultrasound monitor to measure the distance between RV and chest wall where needle will be inserted
   e. Add local anesthetic with a standard 25g (1.5 inch) needle over the site of planned entry
   f. Utilize a 18 gauge 9cm needle for entry to effusion
g. Needle inserted parallel to probe and directed at 45 degree angle towards effusion
h. Needle will appear on screen and should guide advancement
i. Aspirate and advance needle every 1-2 mm until fluid drawn back
j. Once blood aspirated, inject agitated saline (~5mL) to confirm appropriate location under ultrasound
k. If trochar technique used, advance catheter over needle, remove needle. Otherwise, insert guidewire through needle to pericardial space, and exchange needle for drainage catheter over guidewire using Seldinger technique

8. Pericardial drain can be left in place for 24-72 hours, which should be a sufficient time to prevent recurrence
9. Limit acute pericardial fluid drainage to less than 500mL to avoid pericardial decompression syndrome.

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Image courtesy of FOAMcast
Complications

1. Mortality
2. Arrhythmia
3. Cardiac Perforation
4. Pericardial/Epicardial Thrombus
5. Injury to neighboring structures, including arteries/veins, diaphragm, liver
6. Pneumothorax
7. Infection
8. Bleeding
9. Transient hypotension from vagal stimulation
10. Pericardiocentesis catheter occlusion

References

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Procedure: Ultrasound Guided Swan-Ganz Catheter Insertion

**AUTHORS:**

*VIKRANT BHATNAGAR*

**EDITORS:**

*DI NH-HUY D. NGUYEN*
Ultrasound Guided Swan-Ganz Catheter Insertion

Goal
1. To use a portable ultrasound to guide swan-ganz catheter insertion in the pulmonary artery

Indications
1. Cardiovascular illnesses such as pulmonary hypertension, cardiogenic shock, mixed shock states, cardiac tamponade, mechanical complications of STEMI (e.g., RV infarction, ventricular septal rupture, and papillary muscle rupture), evaluation for heart or lung transplantation.

Contraindications
1. Patients with septic shock, ARDS, acute decompensated heart failure, undergoing high risk surgery, right-sided endocarditis, tumors, or masses, severe coagulopathy and thrombocytopenia. Relative contraindication is the presence of left bundle branch block.

Equipment
1. 2-D Ultrasound
2. Pulmonary-artery catheter is 110 cm long and 5 to 8 French in diameter
3. This catheter has 4 lumens:
   i. Blue lumen/CVP port represent the Right Atrial Lumen - 30 cm from the tip of the catheter and rests within the RA.
   ii. White/Clear lumen terminates close to the prior lumen - 31 cm from the tip of the catheter and lies in the RA. This port is used for infusion.
   iii. Yellow lumen is the pulmonary artery (PA) lumen is the distal port at the tip of the catheter. Used for PA pressure measurement.
   iv. Red port is the balloon port. Helps place the tip of the catheter in the PA. Use air to inflate balloon.
   v. Thermistor is a red/white connector that contains a temperature-sensitive wire that terminates 4 cm proximal to the tip of the catheter. Connection of the thermistor port to cardiac output (CO) monitor allows determination of a CO using thermodilution.
4. Electronic pressure monitor, preferably one capable of displaying multiple tracings simultaneously
5. Local anesthetic, 25 gauge (1.5 inch) needle for anesthetic, 10 cc syringe
6. 18-gauge introducer needle
7. Guidewire
8. #11 blade scalpel
9. Introducer sheath with an internal obturator
10. Sutures, a needle driver, scissors, and an antibiotic-impregnated adhesive dressing.
11. Sterile supplies: saline flushes, chlorhexidine, drape, surgical cap, mask with eye shield, gown, gloves
12. CAUTION: catheter tip may induce ventricular arrhythmias, a defibrillator and transvenous pacemaker should be available at all times.

Procedure:
1. Use high-frequency vascular probe on the ultrasound to identify correct vessel and that no thrombus exists in the vessel.
   i. Right Internal Jugular Vein and Left Subclavian Veins are preferred.
2. Prep and drape in usual sterile fashion.
3. Use a sterile ultrasound probe to identify the R-IJV and use the 25-gauge needle to infiltrate the skin and subcutaneous tissue with lidocaine.
4. Insert the introducer sheath using modified Seldinger technique
5. Advance the 18-gauge needle into the vein while applying negative pressure to the syringe. Use Ultrasound to visualize needle entry.
6. Once dark-red, non-pulsatile blood is aspirated, remove the syringe and insert the guidewire through the needle.
7. Use the scalpel to make a 3-4 mm incision adjacent to the needle, and then remove the needle. While holding the guidewire to ensure that it remains accessible and does not embolize, insert the sheath over the guidewire until the hub fills the wound.
8. Remove guidewire from the sheath, and then attach a sterile flush to the port to ensure brisk flow.
9. Attach the distal port of the pulmonary-artery catheter to the main pressure monitor.
10. Place the catheter tip level with the patient's heart, and set the pressure to zero.
11. Orient the catheter so that its curvature follows its expected path, and then insert it into the sheath.
12. Advance the catheter to 15 cm (i.e., halfway between the first two thin marks), at which point its tip will lie outside the sheath, and then inflate the balloon.
13. Continue to advance the catheter until a RA pressure waveform is transduced.
14. The distance to the RA is typically 15 to 20 cm from an IJ or subclavian vein.
15. Advance the catheter another 5 to 10 cm until a RV pressure waveform is transduced.

16. Advance the catheter another 5 to 10 cm until a PA pressure waveform is transduced.

17. Advance the catheter until the waveform indicating pulmonary-capillary wedge pressure is transduced.

18. Once measurements have been completed, deflate the balloon and confirm the reappearance of a PA pressure waveform. If this waveform does not reappear, slowly withdraw the catheter until it does.
19. Aspirate blood from the distal port to measure the mixed venous oxygen or pulmonary-artery saturation.
20. Note the final position of the catheter. Confirm that the balloon has deflated.
21. Fasten the plastic sleeve to the sheath, which will secure the catheter and reduce the risk of infection.
22. Suture the sheath to the skin and apply adhesive dressing.
Potential Complications:

1. Infection of the insertion site
2. Ventricular arrhythmias and right bundle-branch block
3. Air embolism
4. Pulmonary-artery perforation
5. Pulmonary infarction
6. Thrombosis

Resources:

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Procedure: Contrast Ultrasound for Shunting/PFO

AUTHORS:
RICK ATRIP

EDITORS:
DINH-HUY D. NGUYEN
NAJIT DULLETT
Contrast Ultrasound for Shunting/PFO

Goal
1. To use contrast ultrasound for cardiac shunt detection

Indication
1. Contrast ultrasound can be used for shunt detection, to diagnose a persistent left superior vena cava, and to estimate right ventricular systolic pressure. Contrast echocardiography can improve echocardiographic border delineation of Doppler signal, permit detection of R to L shunts and assess myocardial perfusion.

Equipment
1. 2-D Echocardiography system
2. Cardiac ultrasound probe
3. Sterile ultrasound gel
4. Alcohol wipes
5. IV catheter
6. Agitated saline
7. Masks, gowns, gloves for medical personnel

Procedure
1. Obtain consent from the patient
2. Secure IV access in the antecubital fossa if available. If not available, the dorsal surface of the hand. Begin injection of the agitated saline, which allows for enhanced visualization of the atria and ventricles and allows for identification of a shunt.
3. Parasternal long axis is performed with the transducer in the left 3rd or 4th intercostal space. The notch of the probe must be directed towards the sternum.
   a. The probe should be placed at the left lateral border of the sternum, just at the sternal – costal angle. If you can’t obtain a good image, then move to the next lower intercostal space. There should be visualization of the right ventricle, left ventricle, mitral valve, aortic valve, interventricular septum.
4. Apical 4 chamber view is performed with the probe at the apex of the left ventricle, located at the apical impulse.
   a. The probe is oriented towards the right shoulder, with the notch at the 2 or 3 o’clock position. The left ventricle, left atrium, right ventricle, and right atrium should be visualized. Apical four chamber view is the most helpful in identifying shunts.
5. Subcostal views maybe the only views available to ventilated patients. Subcostal views can be both short axis and 4 chamber. With this view, the transducer will be placed under the xiphoid, with the notch at the 3 o’clock position.
   a. The probe is oriented towards the patient’s sternum. In order to get this view, the probe can be placed vertically 3 cm below the xiphoid, then angled upward until the 4 chambers are visualized.
6. Using these views, the area surrounding the ventricles and pericardium can be visualized for fluid, signifying pericardial effusion or cardiac tamponade.
7. Parasternal long axis view can be used to evaluate left ventricular function and left atrial enlargement. Left atrial enlargement has been found to be characterized by a maximum and systolic diameter of greater than 4 cm, and left ventricular systolic dysfunction can be considered present when mitral valve anterior leaflet “E-point” (point of greatest amplitude of the anterior leaflet of the mitral valve on M –mode) to septum separation greater than 1 cm in early diastole, corresponding to an ejection fraction of less than 55%.
8. Imaging will show contrast crossing the atrial or ventricular septum during imaging, this helps with the diagnosis of shunt or PFO.
Findings

References

5. Image: Michael Main, MD (St. Luke’s Mid America Heart Institute, Kansas City, Missouri).
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Procedure: Ultrasound to Evaluate Pneumothorax

**AUTHORS:**

**EDITORS:**

**NAVIJIT DULLET**

**SIPAN MATHEVOSIAN**
Ultrasound Evaluation of Pneumothorax

Indications
1. Rapid evaluation for when pneumothorax may be suspected. Ultrasound has a high sensitivity and specificity for the diagnosis of pneumothorax. Delay in diagnosis and treatment may lead to progression of pneumothorax and possibly hemodynamic instability.

Absolute Contraindications
1. None

Preoperative Preparation
1. None if only evaluating for the presence of pneumothorax. Sterile procedure and chest tube tray if bedside decompression is anticipated.

Procedure
1. Obtain a cardiac or linear array high frequency ultrasound probe
2. Air will arise to the least dependent area of the chest. Focus initial ultrasound examination at these locations. In a supine patient, this is between the 2nd and 4th intercostal spaces, mid-clavicular line. In an upright patient, initial examination should focus on the apical-lateral position.
3. Place the ultrasound with the indicator pointing cephalad. Identify the ribs with posterior shadowing behind them. Exam will focus on the area between the two ribs. You should be able to see the layers of pleura and lungs sliding.
4. Presence of pleural sliding is an indication of normal aerated lung. This is identified as horizontal movement along the pleural line.
5. If available, M-Mode can be used. In M-Mode, a ‘waves on sandy beach’ appearance should appear, indicating movement of the pleura. M-Mode is especially useful in patients with poor respiratory reserve. The ‘waves’, visualized closest to the probe, represent the static portion of the chest above the pleural line. The ‘sand’ represents the movement/sliding below the pleural line.
6. Negative predictive value of lung sliding is reported as high as 99-100%.
7. Lung sliding may be absent in additional conditions, including ARDS, pulmonary fibrosis, consolidations, atelectasis, phrenic nerve paralysis.
8. An additional notable feature of pneumothorax is an absence of Comet-tail artifact (which is generated by visceral pleura). These are not visualized when pneumothorax occurs. Additionally, A-Lines (lines that are parallel to the pleura) will be present in pneumothorax. The presence of A-lines and absence of comet-tail artifact is a clue that a patient may have a pneumothorax.

References
4. Images courtesy of: em.emory.edu (LEFT); rebelem.com (RIGHT)
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Procedure: Evaluation of Pulmonary Edema

**Authors:**

**Editors:**

**Navjit Dullet**
**Evaluation of Pulmonary Edema**

**Indications**
1. Pulmonary congestion and pulmonary edema are a major cause of morbidity and mortality. Pulmonary edema may be both due to cardiac and noncardiac processes. Physical examination is essential in titrating management for patients with pulmonary edema. Bedside ultrasound examination is a method to quickly evaluate critically ill patients for the presence and progression of pulmonary edema.

**Goals**
1. To use portable bedside ultrasound to assist in the evaluation and management of pulmonary edema in acutely ill patients.

**Contraindications**
1. There are no absolute contraindications to ultrasound evaluation for pulmonary edema

**Procedure**
1. Obtain a cardiac ultrasound (such as a 5 – 1 MHz) transducer. Alternatively, a higher frequency linear transducer can also be used.
2. Place the patient in a supine position
3. Start by examining the intercostal space in a longitudinal view. This minimizes the impact of rib shadowing on examination. Scan medially to laterally, towards the posterior axillary line. Common imaging locations may include the parasternal, mid-clavicular, anterior axillary, and middle axillary planes. Move inferiorly and superiorly to adjacent intercostal spaces and repeat the examination.
4. Change to a transverse view and repeat the examination.
5. Look for B-lines, which are artifacts that are present in approximately 20% of patients, and typically represent pulmonary congestion or pulmonary edema in most patients. Finding of 3 or more B-lines in the anterior or lateral fields is always abnormal. B-lines are a result of reverberation artifact from thickened inter-alveolar septa. B-lines that are 7 mm apart are indicative of interstitial edema (intralobular edema), while those that are 3 mm apart are more indicative of alveolar edema (interlobular edema). B-lines appear as lines extending from the transducer to the deepest visualized point on the ultrasound screen.
6. A-lines are usually nonpathologic, and they appear as equidistant transverse bands.
7. The severity of pulmonary edema can be evaluated by the number of B-lines. Less than 5 B-lines indicates no edema, 5 – 15 indicates mild edema, 15 – 30 indicates moderate edema, and > 30 indicates severe edema.
8. Correlation with transthoracic echo may be recommended to differentiate cardiogenic versus non-cardiogenic pulmonary edema. Noncardiogenic pulmonary edema will typically have more patchy pattern of B-lines while cardiogenic pulmonary edema may have a more diffuse pattern. BNP is recommended. Additionally, patients may have a combination of cardiogenic and non-cardiogenic pulmonary edema.
9. Treatment can be monitored by assessing the number and pattern of B-lines.

**Actionability**
1. Noncardiogenic pulmonary edema benefits from oxygen and positive pressure ventilation, while cardiogenic pulmonary edema benefits from aggressive preload in afterload management.

![Example of B lines (B7 lines), which correlate with thickened interlobular septa. Photo credit Litchenstein et al.](image)

**References**
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Procedure: Thoracentesis

Authors: Navjit Dullet
Editors:
Ultrasound Guided Thoracentesis

Indications
1. Ultrasound-guided thoracentesis can be performed when there is evidence of fluid collection within the pleural space identified on other imaging modalities. Ultrasound evaluation can also be performed on patients with worsening respiratory status. This procedure is both diagnostic and/or therapeutic, since fluid can be sent for analysis.

Goals
1. To identify a fluid collection within the pleural space that is amenable to drainage via thoracentesis.

Contraindications
1. Skin infection or subcutaneous tissue infection at the desired side of entry
2. Insufficient volume of fluid (maximum pleural depth > 1 cm)
3. Some studies/recommendations call for an INR > 2.0, or platelets < 50,000, however, a study posted in the American Journal of Roentgenology found no hemorrhagic complication reported, despite some patients having an INR > 3.0 and plt < 30,000.
4. As with paracentesis, procedure should be used with caution or avoided in patients with severe bleeding diathesis, such as DIC.

Pre-Procedure Preparation
1. If possible, hold NOACs for 24 hours. Plavix for 5 days, and Warfarin for 5 days. Aspirin can be continued
2. NOACs can be resumed 24 hours after procedure
3. Therapeutic Lovenox can be resumed 12 hours after procedure
4. Warfarin can be resumed 12 hours after procedure

Consent
Discuss possible complications/risks including:
1. Bleeding
2. Infection
3. Damage to adjacent structures
4. Local anesthesia
5. Entry site hematoma
6. Pneumothorax
7. Possible need for IR intervention if persistent hemorrhage

Procedure
1. Obtain a convex array 2 – 5 MHz ultrasound probe. Alternatively, a 5 – 1 MHz cardiac probe can also be used.
2. Place the patient in a seated position, with their back facing the operator
3. Start by placing the ultrasound probe on the lateral back of the site of interest. Scan the interspace, and try to identify anatomical structures, such as the diaphragm and liver or spleen depending on the side selected.
4. Work superiorly, continuing to scan the interspaces. Identify the largest fluid pocket (the deepest fluid area). As a reminder, fluid appears anechoic, however effusion fluid may be more heterogeneous if an empyema is present.
5. Mark the desired site of entry using a pen cap or a marking pen. Make sure to visualize the area through several respiratory cycles to ensure that lung tissue does not move into the desired path. Additionally, try to make the target site greater than 10 cm away from midline, since intercostal arteries may be more tortuous near the spine.
6. Measure the distance from the skin surface to the edge of the pleura. A longer needle may be needed if this distance is larger than the needle present in the thoracentesis kit that is used
7. Proceed with sterile preparation
8. Anesthetize the marked area using lidocaine or an equivalent solution. Advance the needle towards the superior border of the inferior rib at the intercostal space that is selected. Additionally, aspirate once you believe you are near the fluid collection. Advance the needle up to the pleural surface, and aspirate as you advance the needle. Once/if you are able to aspirate pleural fluid, pullback the needle slightly. Inject additional lidocaine, since the pleural surface is the area that is very sensitive to pain.
9. Create a skin nick using a scalpel at the desired side of entry
10. Depending on the method used (direct needle versus catheter placement), the next steps will vary
11. For direct needle thoracentesis, advance the thoracentesis needle while aspirating with the syringe. Continue until pleural fluid is aspirated. Remove the syringe and attach a three-way stopcock with tubing. Attach a syringe to the open end of the three-way stopcock. Aspirate pleural fluid, and sent for analysis if needed. Attach the tubing to a collecting container, and start draining pleural fluid if needed
12. If a catheter is used, advance the catheter with a trocar. The needle should not be advanced further than the distance to pleural fluid as identified on ultrasound. Once pleural fluid is aspirated, advance the catheter/trochar an additional ~2mm. Then, remove the trocar while advancing the catheter. Ensure that all drainage holes are within the fluid collection. Attach a three-way stopcock to the catheter and attach a syringe and a drainage bag to the other 2 ports on the three-way. Aspirate pleural fluid and sent for analysis if needed.
13. Monitor the fluid collection with ultrasound if desired. Once a sufficient quantity of fluid has been removed (no more than 1.5L), prepare for removal of the needle were catheter. Have a Tegaderm and gauze ready
14. Remove the needle, and quickly place a piece of gauze and pressure over the entry site. Place a Tegaderm over this piece of gauze. This is important to reduce the likelihood of pneumothorax. Pneumothorax can occur in approximately 12 – 30% of thoracentesis
PROCESSIONS

15. If the pneumothorax occurs, it is usually small and resolves spontaneously. Order a chest x-ray to monitor progression if necessary.

Common tests to order on pleural fluid include cell count, protein, LDH, pH, glucose, amylase. If infection is suspected, order Gram stain and culture. If malignancy is suspected, order cytology.

Complications
1. Pain
2. Cough (stop removing pleural fluid if patient coughs several times)
3. Pneumothorax
4. Hemathorax
5. Arterial laceration
6. Laceration of adjacent structures, including diaphragm, liver, and spleen
7. Empyema
8. Tumor seeding (if malignant effusion)

Actionability
1. Drainage of a pleural effusion can provide symptomatic relief for a patient who may have been having difficulty breathing. In addition, fluid analysis can guide treatment and therapeutic options.

References
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Procedure: Ultrasound Evaluation of Pleural Drains (Chest Tubes)

**Authors:**
Jonathan Friedman

**Editors:**
Denh-Huy D. Nguyen
Ultrasound Evaluation of Pleural Drains

Goals
1. Emergent placement of a pleural drain may be necessary to re-expand or decompress the lung and mediastinum in cases of pneumothorax or a rapidly expanding effusion. Point of care ultrasound examination and guidance can be used to quickly evaluate the need for and assist in the placement of a pleural drain while avoiding malpositioning, such as in the subcutaneous, intraabdominal, or transdiaphragmatic planes. Furthermore, troubleshooting already placed drains may be also possible.

Indications
1. Pneumothorax
2. Hemothorax
3. Chylothorax
4. Empyema
5. Recurrent effusion

Absolute Contraindications
1. Skin infection overlying entry point

Relative Contraindications
1. Coagulopathy
2. Pulmonary adhesions
3. Trauma

Procedure
1. The patient is placed in a position that is appropriate for chest tube insertion, typically with the head partially elevated and the ipsilateral arm raised over their shoulder. Patient can be placed in a supine position (reclined to 40-45 degree angle) or fully seated position.
2. A linear probe can be used to evaluate for pneumothorax or pleural fluid collections as described in the pneumothorax POCUS guide.
3. The diaphragm should be identified and the lowest possible site for tube insertion should be chosen while avoiding the diaphragm.
4. Once a suitable site is found, color doppler is used to identify the intercostal artery, typically along the upper third of the intercostal space.
5. Local anesthesia should be given subcutaneously, superficial to the rib and then work the needle to above the inferior margin of the rib and apply further anesthetic to deep tissues. Ultrasound can be used to ensure correct depth of anesthetic.
6. The pleural drain is then placed using a surgical or Seldinger technique, depending on the type of tube and requirements for drainage.
7. Ultrasound is then used to confirm correct placement of the drain. A surgical tube or pigtail catheter may not be fully visualized within the scope of the transducer, but adequate depth can be obtained to see whether the tube correctly inserts into the pleural space and is oriented away from the subcutaneous tissues, diaphragm or adjacent organs.

Complications
1. Bleeding
2. Infection (i.e. at entry site or empyema)
3. Clogged tube
4. Malposition
5. Re-expansion pulmonary edema
6. Pneumothorax
7. Iatrogenic injury to adjacent organs and structures including diaphragm, liver, lung, heart, aorta, intercostal artery
Figure: Ultrasound schematic showing pleural effusion, lung, and shadow caused by ribs. Caudal position shown to the right. Intercostal artery location shown below the rib. Image credit: Vetrugno et al. An easier and safe affair, pleural drainage with ultrasound in critical patient: a technical note.

References

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Procedure: Evaluation for Pulmonary Emboli

**AUTHORS:**
SIPAN MATHEVOSIAN

**EDITORS:**
DINH-HUY D. NGUYEN
**Evaluation for Pulmonary Emboli**

**Goal**
1. To learn techniques in bedside assessment of pulmonary emboli by ultrasonography.

**Indications**
1. In patients for which there is a clinical suspicion for pulmonary embolism but for whom CT pulmonary angiography is unavailable or contraindicated (e.g. PE A arrest, shock/hypotension with signs of right heart failure, unstable patient, contrast allergy, renal contraindication, pregnancy)
2. Best with triple POC (lung, echo, DVT) ultrasounds
3. Cannot definitively rule out PE, but with high clinical suspicion and positive ultrasonographic findings, may be beneficial for early diagnosis and early treatment especially in an emergent setting. Sensitivity and specificity approach that of older single or two row detector CT, but not that of multi detector CT.

**Contraindications**
1. No contraindications exist for this procedure.

**Technique**
1. Obtain a 5 MHz micro-convex ultrasound probe with a small footprint.
2. Position the patient sitting upright, arms raised and behind the head to widen the intercostal spaces and outwardly rotate the scapula.
3. Vertical examination of 6 areas should be performed: paravertebral, midscapular, posterior axillary, midaxillary, anterior axillary, and midclavicular. Both longitudinal and transverse images should be taken, starting with the area of pain if present.
4. Conversely, in the unstable or dyspneic patient, the BLUE protocol positions can be scanned. Two hands are placed side by side on the chest, parallel and just inferior to the clavicle with the fingertips at the sternum. The 3 BLUE points are the midpoint of each hand, and the middle edge of the inferior hand.
5. Findings characteristic of PE are wedge-shaped, triangular, or rounded, pleural-based hypoechoic lesions with or without pleural effusion.
6. In the dyspneic patient, according to BLUE protocol, an A profile (lung sliding with A-lines at anterior wall = normal anterior profile) plus a positive DVT study is consistent with pulmonary embolism.
7. More likely to detect lower lobe PE given accessibility with ultrasound
8. If infarct is hemorrhagic rather than pale infarct, atelectasis may be visible for only a few hours to a day
9. Evaluation of the right ventricle should also be performed to look for signs of right heart strain (specific, not sensitive. Please see cardiac echo material for more information. In short, parasternal long axis, parasternal short axis, parasternal RV inflow, apical 4 chamber, and right ventricle focused apical 4 chamber.
10. Right heart dimensions measures at end diastole: base > 42 mm, mid RV > 35 mm, long > 86 mm indicative of right ventricular dilation.
11. Switch to left parasternal short axis to view the right ventricle outflow tract (RVOT) and obtain distal RVOT diameter at end diastole. RVOT diameter > 27 mm indicative of dilation.
12. Subcostal views of the IVC proximal to hepatic veins should be viewed and measured for inspiratory collapse. IVC > 2.1 cm and <50% collapse with inspiration is indicative of elevated right atrial pressures.
13. Switch to subcostal 4 chamber view to evaluate for bowing of the inter-ventricular septum into the left ventricle.
14. Next, ultrasonographic evaluation of the lower extremities should be performed to look for DVT. Please see the appropriate section for details.

**Actionability**

1. This exam can indicate whether a patient may have a pulmonary embolism in the setting of acute decompensation, or CTPE unavailability or contraindication.

**References**

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Procedure: Diagnosing Alveolar Interstitial Syndrome

**Authors:**
Jacob Wochna

**Editors:**
Dinh-Huy D. Nguyen
## Diagnosing Alveolar Interstitial Syndrome

**Goal**
1. To utilize ultrasound to diagnose alveolar interstitial syndrome.

**Indications**
1. Rapid detection of alveolar interstitial syndrome (AIS) with ultrasound may be utilized in the setting of dyspnea. AIS encompasses both acute and chronic conditions. Acute Respiratory Distress Syndrome (ARDS), interstitial pneumonia, pneumonitis, and pulmonary edema are among the acute causes of AIS via diffuse involvement of the interstitium. Pulmonary fibrosis is a chronic condition of the interstitium which causes diffuse impairment of the alveolocapillary exchange capacity.

**Absolute Contraindications**
1. None.

**Procedure**
1. Obtain a 1-5 MHz curvilinear transducer and set the initial depth setting to 14 cm.
2. Place the patient in the supine position.
3. Divide the chest into right and left anterior and lateral sections. The anterior sections are bounded by the clavicle superiorly, diaphragm inferiorly, sternum medially, and anterior axillary line laterally. The lateral sections are bounded by the axilla superiorly, diaphragm inferiorly, anterior axillary line anteriorly, and posterior axillary line posteriorly. Each of these sections are divided into a superior and inferior area, for a total of eight sections on the chest (Figure 1).
4. Each of the eight sections must be examined to diagnose AIS.
5. Examine an intercostal space in the longitudinal view in each section and assess for artifact. Vertical hyperechoic lines that extend from the lung-wall interface and spread to the edge of the screen are termed B line (or comet tail) artifacts (Figure 2). These B lines will move synchronously with lung sliding. This artifact is due to extravascular fluid presence in the interstitium, surrounded by air, resulting in a high impedance gradient. This is not a normal finding in a healthy lung, outside of the most inferior intercostal space.
6. To diagnose AIS, a minimum of three B line artifacts must be present in each scan, there must be diffuse positivity in more than one scan per side, and these findings must be identified bilaterally.
7. This constellation of findings guides the differential towards AIS. To determine which disease state is causing the appearance of AIS on ultrasound, there are qualities that can be detected on the scan. Diffuse parenchymal lung disease, which occurs in pulmonary fibrosis, will demonstrate an irregular, fragmented pleural line, small hypoechoic subpleural areas, and B lines in a nonhomogeneous distribution. ARDS can present with sonographic findings of anterior subpleural consolidations, absence or reduction in lung sliding, spared areas with normal parenchyma, irregular, fragmented, or thickened pleural line, and nonhomogeneous distribution of B lines.

![Figure 1: Depiction of the chest wall areas which need to be scanned for the diagnosis of alveolar interstitial syndrome (AIS). Areas 1 and 2: upper and lower anterior sections, respectively. Areas 3 and 4: upper and lower lateral sections, respectively. These sections will need to be scanned on the contralateral side of the chest wall for a complete evaluation of AIS. AAL = Anterior axillary line. PAL = Posterior axillary line. (Figure adapted from Volpicelli et al.).](image-url)
Findings

Figure 2: Appearance of hyperechoic B line artifact (white arrow) extending from the pleural line to the inferior portion of the screen on lung ultrasound. This image was taken in the setting of acute pulmonary edema. (Figure adapted from Volpicelli et al.).

References:
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Procedure: Dialysis Fistula Planning and Assessment

**AUTHORS:**
SIPAN MATHEVOSIAN

**EDITORS:**
DINH-HUY D. NGUYEN
Dialysis Fistula Planning and Assessment

Goals
1. To evaluate the vasculature and understand principles of surgical dialysis fistula creation.
2. To evaluate a fistula and assess for inflow, outflow, and conduit problems

Indications
1. Preoperative evaluation and assessment of vasculature prior to surgical fistula creation
2. Assessment of preexisting dialysis fistula for maturation and troubleshooting.

Contraindication
1. None

Procedure:
I: Preoperative assessment
1. Obtain a linear (vascular) transducer probe.
2. Position the patient sitting with outstretched arms; tie a tourniquet around the biceps of the desired arm to dilate the venous system.
3. NOTE: surgical considerations for placement include vascular anatomy, but also include handedness, work/vanity, prior dialysis fistulas, prior or current indwelling lines/pacers/hardware, prior radiation or surgery to the field, hand/arm pain or swelling, and history of severe CHF.
4. NOTE: Assessment of the palmar arc for collateral flow with Allen’s test should be performed prior to planning.
5. Short axis scans of the radial artery should be performed and the vasculature should be assessed for pulsatility, calcifications, and size. The radial artery should ideally be > 3mm, pulsatile, and with minimal calcifications to facilitate a surgical anastomosis.
6. Short axis scans of the venous anatomy should be performed, starting from known to unknown. Assess the cephalic and basilic veins for size and for proximal patency. The vein should ideally be greater than 2.5mm (preferably 3) and have upstream patency.
7. NOTE: in general, the ideal order of anastomoses is distal to proximal as to not occlude or jeopardize potential upstream veins; radial-cephalic -> brachial-cephalic -> brachial-basilic.
8. 5. Assess the central vein to look for stenosis or occlusion.

II: Maturation assessment and troubleshooting.
1. Obtain a linear (vascular) transducer probe.
2. Position the patient sitting with outstretched arm.
3. Palpate the vein for a thrill. Observe the skin for aneurysmal dilation.
4. NOTE: a pulse with no thrill can indicate an occlusion.
5. NOTE: aneurysmal dilatation can be from central venous occlusion (can also be from repeated access).
6. Scan in short access along and find the anastomosis; scan along the venous side and assess for patency, stenosis, occlusions, and size criteria.
7. NOTE: The mature native dialysis fistula must have a 6 mm vein (dilated from venous hypertension), be < 6mm from the skin (for access), be 6-10 cm in length (for cannulation), and have >600ml/s flow (used preferably 2-3 months after creation).
8. NOTE: the mature fistula graft does not have these criteria; maturation occurs after scarring down of the surgical site to prevent hematoma and bleeding during cannulation (usually around 2 weeks post creation)

Actionability
1. This exam assesses for preoperative planning for surgical fistula creation and assesses for maturation postoperatively. The exam is also used for trouble shooting and evaluation of occlusion and stenosis.

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Procedure: Renal Stone Evaluation

**AUTHORS:**
*RICK ARTRIP*

**EDITORS:**
*DINH-HUY D. NGUYEN*
Renal Stone Evaluation

Goal
1. To use ultrasound to evaluate for renal stones in the urinary tract

Indication
1. Ultrasound evaluation is useful in patients who have renal insufficiency or cannot tolerate contrast. It is also good at characterizing radiolucent filling defects that CT detects.

Equipment needed
1) 2-D Echocardiography system
2) Curvilinear probe
3) Sterile ultrasound gel
4) Masks, gowns, gloves for medical personnel

Procedure
1) Place the patient on the exam table in the supine position
2) Expose the left and right lateral back, at the abdominal level, in order adequately to scan both poles of the kidney
3) Place the ultrasound gel and probe in the mid axillary space, with the probe in a longitudinal orientation with indicator toward the patient’s head
4) Right Kidney:
   a) Slide the probe until you find the hepatorenal interface
     i) If rib shadow is present, rotate the probe in a counterclockwise fashion for full visualization
5) Left Kidney:
   a) The left kidney sits higher than the right kidney because the spleen is not as large, it is recommended to place the probe a couple rib spaces higher to best visualize the left kidney
6) Scan through the kidney looking for hydronephrosis and calculi - scan anterior to posterior, and superior to inferior
7) Bladder
   a) Place the probe in the suprapubic region
   b) Scan the bladder superior to inferior
   c) Identify the junction of the ureters to the bladder

Findings
1. Hydronephrosis. Image from Em.Rap
2. Kidney stone

![Image: example of nephrolithiasis. Echogenic stone visualized within the renal calyx. Image from radiopaedia.org.](image)

References

1. How to Scan the Kidneys Using Ultrasound. (2017, October 4). Retrieved from https://www.youtube.com/watch?v=XaAmKXUAcn0
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Procedure: Ultrasound Guided Lumbar Puncture

**AUTHORS:**
- Navjit Dullet

**EDITORS:**
- Dinh-Huy D. Nguyen
- Sipan Mathevosian
Ultrasound Guided Lumbar Puncture

Goal

1. To use ultrasound visualization to understand anatomy and improve the accuracy of traditional lumbar puncture technique

Indications

1. Obtain CSF for diagnostic and/or therapeutic purposes

Contraindications

1. Ultrasonography for lumbar puncture does not have any absolute contraindications
2. Other contraindications include those for lumbar puncture, including but not limited to signs of infection at the planned access site, elevated intracranial pressure due to cerebral mass, spinal cord trauma, uncorrected coagulopathy

CONSENT

Discuss possible complications/risks including:

1. Bleeding
2. Infection
3. Damage to adjacent structures
4. Local anesthesia
5. Headache
6. Persistent CSF leak

Coagulopathy/Anticoagulation

1. INR > 1.5, Plt > 50
2. Hold NOACs for 48 hours, Warfarin for 5 days, Plavix for 5 days, therapeutic Lovenox x 24 hours, UFH for at least 6 hours
3. Warfarin can be resumed 12 hours after procedure, NOACS can be resumed 48 hours after procedure

Technique

1. After obtaining consent for procedure, place the patient in a lateral decubitus position, or have them sit upright. Patient will need to be in lateral decubitus position if opening pressure desired.
2. Obtain a higher frequency (5 – 10 MHz) probe for normal BMI patients, and a lower frequency probe (2 – 4 MHz) for higher than normal BMI patients.
3. Start by identifying anatomic landmarks on the patient if possible. Position the probe in the transverse position at the level of the iliac crests. You may be able to visualize the spinous process of L4 as a hypoechoic structure (a ‘bump’) with acoustic shadowing. Move the probe inferiorly along the spine, and try to identify additional spinous processes and the sacrum. The sacrum can be identified as a solid fused bone while the spinous processes will have spaces between them (interspinous spaces).
4. Mark the midline position of the vertebral body with a marking pen. This will serve as a reference point.
5. Move the probe along the spine. Mark the next highest and next lowest spinous processes (optional).
6. Switch the probe to a long axis position along the spine. Move the probe along an imaginary line connecting the points that you had drawn. You should be able to visualize the interspinous spaces as the space between the hypoechoic spinous processes.
7. Identify a target interspinous space.
8. Steps 8 and 9 are optional. Mark the level of the interspinous space on both sides of the probe. 2 marks will be made, one mark just to the left of the probe, another just to the right. Remove the probe, and draw a line connecting the 2 marks that were just made. Draw another line connecting the spinous process above and below the airspace that was marked.
9. The intersection of the 2 lines that were just drawn marks the ideal target location for entry of the spinal needle and the midline approach. If paramedian approaches taken, the entry point of the spinal needle would be just to the right or left of the intersection.
10. At this point, you can also measure the skin – ligamentum flavum distance, which can help guide how large of a spinal needle will be needed.
11. Prep the patient for lumbar puncture using sterile technique. Place a sterile ultrasound cover over the ultrasound probe if real time needle guidance is planned.
12. If real-time ultrasound guidance is used, place the ultrasound probe over the widest interspinous space. Rotate the transducer 45° into an oblique paramedian view, ensuring that the probe is aligned in a plane from the spinous process of the superior vertebra to the lamina of the inferior vertebra.
13. Slide the transducer slightly superior and medial, and insert the spinal needle where the probe previously was. Track the needle with ultrasound visualization as you approach the ligamentum flavum.
14. Once the ligamentum flavum is pierced, check for CSF as you advance the needle 1 – 2 mm at a time.
Paramedian sagittal oblique of the lumbar spine: Ligamentum Flavum (LF); Epidural Space (ES); Posterior Dura (PD); Anterior Complex (AC); Cauda Equina (CE); Intrathecal Space (ITS); Erector Spinae Muscle (ESM); Intervertebral Disc (IVD).

Actionability

1. Ultrasound guidance can improve the accuracy of lumbar puncture technique. Fluid collected from lumbar puncture can be sent for analysis, or fluid can be trained for therapeutic purposes.

Post Procedure Care

1. Place a bandage over the site of entry. There are no restrictions on activities after LP. Warn patients that they may experience a headache, which will subside within a day.

Reference Video
https://www.youtube.com/watch?v=ndnZxAcNjdg

References

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Procedure: Ophthalmic Artery Doppler

**AUTHORS:**
**RICK ARTRIP**

**EDITORS:**
**DHINH-HUY D. NGUYEN**
**SIPAN MATHEVOSIAN**
**Ophthalmic Artery Doppler**

**Goal**
1. To evaluate blood flow in the ophthalmic artery using color doppler.

**Indication**
1. Ophthalmic artery doppler can be used to assess flow characteristics of the ophthalmic artery and establish a relationship with the internal and common carotid arteries. Ophthalmic artery doppler can also be used to assess the cerebral effects and the impact of pharmacotherapy in the management of pre-eclampsia.

**Equipment needed**
1) 2-D Echocardiography system  
2) Linear array high frequency probe  
3) Sterile ultrasound gel  
4) Masks, gowns, gloves for medical personnel

**Procedure**
1) Place the patient at a 45˚ angle on the examination table.  
2) Have the patient close the eye that is going to be examined.  
3) Place ultrasound gel on the probe, using copious amounts of gel will prevent pressure being applied to the eyeball.  
4) Apply the probe to the patient’s eye, with the indicator facing laterally or superiorly depending if you are taking a horizontal or vertical approach to examine the retinal artery.  
5) Transducer is placed horizontally on the patient’s eye and Doppler is turned on. Ophthalmic artery is identified by its direction of flow toward the probe and pulsatility.  
6) Pulsed-wave Doppler is applied, sample volume is placed 15 mm behind optic disc, medial to optic nerve. The sample volume should be 2 mm in length.  
7) Three to five consistent cardiac cycles are obtained.

**References**

- **EDV** = end-diastolic volume, **FDP** = first diastolic peak velocity, **PSV** = peak systolic velocity
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Procedure: Peritoneal Shunt Assessment

**AUTHORS:**
Suhag Patel
Sipan Mathevosian

**EDITORS:**
Sipan Mathevosian
Navjit Dullet
**Peritoneal Shunt Assessment**

Goals
1. To become familiar with ventriculoperitoneal shunt components: proximal (ventricular) catheter, reservoir, one-way valve, distal catheter.
2. To evaluate peritoneal components for patency and for potential shunt complications including obstruction, migration, and disconnection.
3. To evaluate shunt reservoir for potential neurosurgical ventricular tap in critically ill patients with shunt obstruction.
   NOTE: This is generally done by palpation similar to port access but ultrasound guidance may be needed in setting of complex cranial surgeries or uncertain location.
4. To understand that, in general, all malfunctions lead back to neurosurgery for revision.
   NOTE: Patients with suspected shunt malfunction should be evaluated with shunt series and non-contrast CT scan of the head. A CT abdomen may be needed if intraabdominal component is suspected as source of malfunction, and abdominal POCUS can be used for early problem identification.

Indications
1. Evaluation of patient with suspected shunt malfunction with suspected peritoneal component malfunction. Patients typically present with nausea, vomiting, altered mental status, or signs of elevated ICP.
2. Ventricular shunt tap in the critically ill patient with suspected shunt malfunction.
   NOTE: ventriculotriatal and ventriculopleural shunts are not specifically discussed.

Contraindications
1. None for peritoneal ultrasound evaluation.
2. Infection over ventricular site is absolute contraindication to tap. Coagulopathy and lack of shunt imaging are relative contraindications. Note that increased ICP is not a contraindication.

Procedure
I: Peritoneal component evaluation:
1. Obtain a curvilinear (2-5MHz) transducer.
2. Broadly scan the abdomen until a portion of the catheter is identified (linear echogenicity). Follow the catheter until the tip is identified.
3. The catheter tip should be evaluated for presence of a peritoneal CSF pseudocyst which will appear as a hypoechoic/anechoic collection at the shunt tip. Evaluate the collection for internal debris or septations that may suggest an infected pseudocyst which will guide need for removal.
4. Follow the catheter back in its entirety and evaluate for disconnection, fracture, or migration (will be better evaluated by plain radiograph).
5. Scan the remainder of the abdomen for fluid collections and include the groins to evaluate for inguinal hernia secondary to decreased peritoneal resorption; note that the catheter tip may be in an inguinal hernia sac causing obstruction.

II: Ventricular CSF Tap
6. Obtain a linear (vascular) transducer probe.
7. Position the patient supine and scan through the scalp in the region of the reservoir in both shot and long axes.
8. Patient should be prepped in the usual sterile fashion.
9. Attach/place a 23-25 G butterfly needle into the reservoir under ultrasound guidance (note caveats made in Goals section). Butterfly needle should be pre-attached to 3-way stopcock with manometer to evaluate pressure.
10. If there is CSF flow, the obstruction is DISTAL. Repeated slow drainage of CSF fluid filling the manometer can be performed, with repeat measurements until pressure is less than 20 cmH20. Do not drain quickly as this can cause subdural hematoma.
11. If there is no CSF flow, the obstruction is proximal and needs operative revision emergently.

Actionability
1. This exam assesses ventriculoperitoneal shunt catheters for post-operative complications including obstruction, migration, and fracture. This exam is limited in the evaluation of VPS but can be helpful in early problem identification, particularly of distal obstruction. Neurosurgical ventricular reservoir tap may occasionally require ultrasound guidance.
References


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Procedure: Central Venous Access

**AUTHORS:**

Dinh-Huy D. Nguyen

**EDITORS:**
Central Venous Access

Goal
1. Used in emergency situations to administer resuscitation fluids and medications (i.e. pressors). Can be used for hemodynamic monitoring, transvenous pacing, and venous procedures/interventions.

Indications
1. Access for central catheters and ports
2. Access for fluid and medication administration
3. Parenteral nutrition

Absolute Contraindications
1. Severe coagulopathy (plt < 20k, and INR > 3), however, procedure can be performed after administration of platelets and FFP
2. Presence of another device at site
3. Bacteremia

Preoperative Preparation
1. Identify appropriate location for access
   1. Jugular vein (internal and external) - reliably accessible with low complication rates
   2. Subclavian vein (avoid in coagulopathy)
   3. Femoral vein – used for uncooperative patients, emergent access when ultrasound is not available

Consent
1. Discuss possible complications including:
   a. Blood loss
   b. Hematoma
   c. Infection
   d. Damage to adjacent structures

Preparation
1. Ideally, patient is in Trendelenburg position, however, in critically ill and obese patients, this is often not an option.
2. Using sterile technique, drape and prepare site and use sterile gown, mask, gloves and cap.
3. Local anesthesia and possibly sedation should be used to ensure comfort and little movement as possible from patient.

Procedure
1. Identify the vein with ultrasound when available (preferred)
2. Infiltrate the skin with local anesthetic
3. Cannulate the vein (needle or angiocatheter) and confirm the intravenous location of the needle
4. Insert the guidewire into the vein through the access needle or angiocatheter
5. Remove the needle or angiocatheter while controlling the guidewire
6. Make a small stab incision in the skin at the puncture site adjacent to the guidewire
7. Advance the dilator over the guidewire into the vein, maintain control of the guidewire and ensure it does not advance with the catheter, then remove the dilator
8. Thread the catheter over the guidewire, maintain control of the guidewire and ensure it does not advance with the catheter.
9. Remove the guidewire, taking care to control the catheter
10. Sequentially aspirate blood from each access hub and flush with saline to ensure functioning of the catheter
11. Suture the catheter into place and dress the site using sterile technique
12. Confirm the position of the tip of the catheter

Possible Early Complications
1. Bleeding
2. Pain
3. Blood loss
Possible Late Complications

1. Infection
2. Hematoma
3. Pain
4. Thrombosis
5. Embolism

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Procedure: Femoral Venous Access

Authors: Jay Gajera

Editors: Dinh-Huy D. Nguyen
**Femoral Vascular Access**

**Goal**
1. Most common method of gaining central venous access in emergency situations is via femoral vein cannulation. The predictable location of the femoral vein as well as the relative large vessel calibre makes them an easy target for ultrasound guided cannulation as well as blind technique.

**Indications**
1. Emergency Venous access during CPR
2. Hypotensive trauma patients
3. Urgent haemodialysis access
4. Provision of irritant medications not suitable for long term peripheral venous administration
5. CVP monitoring

**Absolute Contraindications**
1. Venous injury at the level of the femoral veins or proximally in the iliac veins or IVC
2. Anatomic abnormality in SVC/lower limb venous drainage
3. Known or suspected venous thrombosis on the proposed side of cannulation
4. Ambulatory patient (risk of catheter displacement)

**Relative Contraindications**
1. Coagulopathy – innate or acquired (anticoagulation)
2. Previous long term venous catherization
3. Known vasculitic disorder
4. Previous radiation therapy

**Anatomy**
1. Femoral vein is medial to the Femoral artery in the Femoral triangle
2. Mnemonic = Lateral -> NAVEL (Nerve, Artery, Vein, Empty space, Lymphatics) -> Medial
3. Reminder to remain below inguinal ligament to minimize risk of peritoneal puncture

**Technique**
1. Patient preparation: obtain informed consent, place patient in a supine position, consider bed height, use protective sheets to prevent a mess
2. Surveillance: identify surface landmarks of inguinal region, palpate femoral artery and use ultrasound to grossly evaluate region to identify the femoral vein and its course – ensure collapsibility of femoral vein upon application of pressure – mark the site of cannulation
3. Sterile technique: don personal protective equipment, commence decontamination of femoral region with chlorhexidine prep and drape
4. Preparation of equipment: identify all equipment to be used including venepuncture needle, guidewire and dilator, as well as central line. Prime all lumens of central line using normal saline. Good practice to organize equipment in the order that they will be used for the procedure.
5. Local Anaesthetic: using a fine gauge needle, infiltrate superficial skin and subcutaneous tissue with 2-5ml of lidocaine
6. Venepuncture: using ultrasound identify the vein, and advance trochar/needle (attached to a syringe) for initial venepuncture until flashback is visualized, maintain negative pressure by elevating plunger of the syringe during needle advancement

7. Seldinger technique: insert guidewire through the lumen of the needle and gently advance, if resistance is encountered rotate and reattempt. Do not force the guidewire against resistance. Ensure the guidewire is grasped at all times throughout the procedure to avoid risk of guidewire embolization, remove the needle while guidewire is firmly held in position

8. Scalpel: create small nick at entry site to permit entry of the dilator + central line

9. Dilator: Railroad the dilator device over the guidewire and use it to create a tract for easy passage of the central line – some force may be required. Again being mindful of maintaining control of the guidewire at all times. Remove the dilator and apply pressure at the entry site with gauze as bleeding will occur

10. Central Line insertion: railroad the central line over the guidewire and advance all the way to the hilt. Remove the guidewire. Check patency of all lumens by aspirating and flushing with normal saline.

11. Suture line in place and apply sterile dressings – site should be examined daily

Complications

1. Infection – superficial or systemic
2. Guidewire embolism
3. Arterial puncture
4. Haematoma
5. Pseudoaneurysm formation
6. Venous thrombosis
7. Peritoneal puncture +/- bowel laceration
8. Bladder puncture
9. Femoral nerve injury

References

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Procedure: Radial Artery Access

**Authors:**

**Editors:**

**Dinh-Huy D. Nguyen**

**Navjit Dullet**
Radial Artery Access

Indications
1. When frequent blood gases are necessary
2. For real-time monitoring of blood pressure during shock, major surgery, hypertensive emergency, or vasopressor therapy.

Absolute Contraindications
1. None

Preoperative Preparation
1. Locate palpable arterial pulse
2. Perform Allen Test (alternatively use ultrasound) to ensure ulnar collateral patency

Consent
1. Discuss possible complications including:
   a. Blood loss
   b. Hematoma
   c. Infection
   d. Damage to adjacent structures

Procedure
1. Once radial artery is identified, ensure site is properly prepped with sterile technique.
2. Integral-guidewire technique:
   a. Non-dominant hand finds the artery using ultrasound while the dominant hand inserts needle-guidewire-catheter unit at a 30-45 degree angle until pulsatile blood flow returns.
   b. The unit is then stabilized and the guidewire is advanced through the needle and catheter into the artery.
   c. The needle-guidewire unit is then stabilized and the catheter is then advanced into the artery over the wire.
   d. The needle-guidewire unit is then removed.
   e. The catheter is then hooked up to a “zeroed” arterial bag for pressure monitoring.
3. Separate guidewire technique (guidewire and needle-catheter unit are separate)
   a. *Preferred for arteries with deeper access
   b. Non-dominant hand palpates artery and then locates artery via ultrasound.
   c. Dominant hand holds needle-syringe unit at a 30-45 degrees to arm and is advanced over identified artery until pulsatile blood return is seen
   d. Stabilize needle with non-dominant hand while dominant hand removes syringe from needle
      i. Once syringe is removed, if blood return continues, continue to advancement of guidewire
      ii. Once syringe is removed, if blood return STOPS, adjust needle until blood returns before inserting guidewire.
   e. Stabilize needle with non-dominant hand and with dominant hand insert guidewire into back end of needle.
      i. Advance slowly and note any resistance in guidewire. Advance until guidewire is in the vessel well beyond the tip/length of the needle.
      ii. If resistance is felt, DO NOT pull back on guidewire independently. The tip of the needle could cut the guidewire and it could be lost in the needle.
      iii. If adjustments to needle and guidewire are necessary, move both needle and guidewire together as a unit.
   f. To remove the needle, stabilize the guidewire with a pinch and pull the needle towards the end of the guidewire. DO NOT let go of guidewire from back end of needle until guidewire obtained from site of insertion.
   g. Once needle is removed from overtop guidewire, place catheter into artery using over-the-wire technique.
4. Attached arterial line bag to catheter making sure line was zeroed and observe for good waveform.

Possible Early Complications
1. Bleeding
2. Pain
3. Blood loss

Possible Late Complications
1. Infection
2. Hematoma
3. Pain
4. Thrombosis
5. Embolism

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Procedure: Diagnostic Whole Leg Ultrasound for Suspected DVT

Authors:
Jonathan Barclay

Editors:
Dinh-Huy D. Nguyen
Sipan Mathevosian
Diagnostic Whole Leg Ultrasound for Suspected DVT

Goal
1. To evaluate for acute deep vein thrombosis in the lower extremities.

Indications
1. Patients with clinical manifestations of lower extremity DVT with or without risk factors for thrombus.
2. Patients with suspected DVT and moderate or high probability of DVT based on the gestalt and/or Wells criteria
3. Patients with suspected DVT and low probability of DVT based on gestalt and/or Wells criteria, but elevated D-dimer (eg, >500 ng/mL)

Absolute Contraindications
1. None

Procedure Preparation
1. Position the patient;
   a. Expose the leg of interest up to the groin
   b. The patient’s leg should be slightly bent, with the hip rotated so the knee points laterally.
2. Make sure to have enough ultrasound gel prior to starting

Consent
1. A complete leg ultrasound is an extremely low risk procedure. The most common side effect is pain or discomfort with compression.

Procedure
1. With the probe in axial orientation, begin at the mid-inguinal point and find the femoral vessels.
2. Beginning with the common femoral vein (above the entry point of the long saphenous vein), apply gentle pressure to compress the vein. Acquire dual images, one with the patent vein and one with compression.
3. Move the probe distally, regularly compressing the vein and watching for any echogenic material within the lumen. Acquire dual images of the proximal superficial femoral vein, and its first branch, the deep femoral vein. Continue pressure along the SFV until the mid thigh.
4. Turn the probe 90 degrees into longitudinal orientation and enable color doppler and pulse wave doppler to visualize flow within the SFV.
   a. Normal venous flow should exhibit a response to Valsalva. To demonstrate this, ask the patient to inhale, hold, and exhale. Flow should decrease during inhalation and holding, then increase with exhalation. Acquire images of the pulse wave response.
5. Return the probe to axial/transverse orientation and continue down the distal SFV, acquiring dual images, until its insertion into the adductor canal.
6. Place the probe, in axial position, behind the knee joint in order to visualize the popliteal vein as it exits the adductor canal. Acquire dual images.
7. Rotate the probe into longitudinal orientation and enable color doppler to better visualize the distal SFV as it becomes the popliteal vein. Acquire spectral doppler images as described previously.
8. Moving distally, place the probe lateral to the tibial tuberosity to visualize the popliteal vein as it exits the adductor canal. Acquire dual images.
9. Move medial to the tibial tuberosity to find the posterior tibial and peroneal vessels, acquire dual images.
   a. Here, you may probe longitudinally and enable color doppler to show patency. Squeezing the patients leg distal to the probe while imaging should provide augmented flow visible on the color doppler.
10. Continue to image distally moving down the posterior tibial and peroneal vessels, before returning to the anterior tibial vein and imaging distally.
   a. Moving distally in transverse, the veins may be difficult to visualize. You may demonstrate flow by using color doppler and augmenting flow by squeezing the leg distal to the probe as described previously.
11. Be sure to image any additional symptomatic areas of the leg.
12. You may also image the contralateral CFV with spectral doppler to evaluate symmetry.

Interpretation
1. Positive: A positive DVT study is determined by non-compressibility of any imaged vein.
   a. Lack of compressibility is >95% sensitive and specific for DVT
2. Negative: A negative study is one that demonstrates compressibility of all imaged veins
3. Nondiagnostic: When there is uncertainty about whether a DVT is present or absent, typically due to three main reasons:
   a. Difficulty visualizing veins (possibly due to morbid obesity or severe edema)
   b. Small veins or atypical appearing abnormalities of uncertain significance.
   c. Patients with previous DVT who may have a recurrent DVT vs. chronic scarring of the vein.
      i. Thrombus is normally soft and deformable with probe pressure, and demonstrates a smooth surface and enlarged vein.
ii. Post-thrombotic change/scarring is typically rigid and nondeformable with probe pressure. The surface may be irregular with calcifications and the vein may be normal or decreased in size.

iii. Best indication for recurrent DVT is an abnormality in a previously normal segment of vein.

Limitations
1. Suspected iliac or IVC thrombosis cannot typically be assessed by vein compression. If there is concern for lesions proximal to the CFV such as an iliocaval DVT, pelvic venous CT or MR venography are suggested.

Figures

References
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Procedure: Ultrasound Evaluation for Aortic Dissection

**AUTHORS:**
Vikrant Bhatnagar

**EDITORS:**
Navjit Dullet
Sipan Mathevosian
Transthoracic Ultrasound for Aortic Dissection

Goal
1. To use transthoracic echocardiogram/ultrasound to assess for aortic dissection

Indication
1. TTE can provide evaluation of portions of the ascending aorta, aortic arch, and proximal descending aorta in the event of suspected aortic dissection (back pain, syncope, significant hypertension etc.)

Procedure
TTE
1. Proximal ascending aorta is visualized in the parasternal long axis view. More superior portion of ascending aorta can be visualized by scanning superior intercostal spaces or tilting the ultrasound probe more cranially.
2. Imaged portions of the aorta should be examined for dilation, dissection, or intramural thrombus
3. Place a cardiac probe in the left parasternal view, and obtain a long axis view of the heart (see POCUS guide on cardiac exam)
4. Observed the LVOT and proximal aorta for dissection flaps. The absence of a dissection flap on TTE does not exclude the presence of proximal dissection.
5. The aortic arch and descending aorta can be visualized posterior to the long and short axis cardiac views on TTE.
6. In the parasternal long axis view, descending aorta can be visualized in cross section at the location of the posterior AV groove
7. In the parasternal short axis view, a longitudinal view of the aorta can be seen.
8. The aortic arch can be visualized from the suprasternal notch.
9. Aorta can be imaged in the abdomen using trans-abdominal approach with an abdominal probe.
10. TTE is most accurate at detecting proximal dissections (notable for visible intimal flap)

TEE
1. Sedate the patient or Anesthetize the oropharynx with a topical local anesthetic
2. Insert a bite block
3. Place patient in a left lateral decubitus position
4. Slowly insert the transducer past the oropharynx
5. Ask the patient to swallow if not sedated
6. Insert two fingers into the mouth guiding the probe and depressing the tongue
7. Advance the probe in a neutral position transducer into the esophagus or stomach
8. Proximal Ascending Aorta in long axis view: mid-esophageal angle with transducer angle between 120-140°; ante-flex probe to maneuver for better imaging
9. Mid-ascending Aorta in long axis view: upper-esophageal angle with transducer angle between 90-110°; withdraw probe from the prior angle
10. Mid-ascending Aorta in short axis view: upper-esophageal angle with transducer angle between 0-30°; rotate probe clockwise from the prior angle
11. Descending Aorta in short axis view: transgastric to mid-esophageal angle with transducer angle between 0-10°; slightly flex the probe
12. Descending Aorta in long axis view: transgastric to mid-esophageal angle with transducer angle between 90-100°; slightly flex the probe
13. Aortic Aorta in long axis view: upper-esophageal angle with transducer angle between 0-10°; withdraw probe from the previous angle
14. Aortic Aorta in short axis view: upper-esophageal angle with transducer angle between 70-90°
Complications

1. No complications for TTE examination
2. TEE complications include:
   a. Respiratory depression
   b. Arrhythmias
   c. Bronchospasm
   d. Death
   e. Damage to adjacent structures (i.e. esophageal perforation)

Actionability

1. Allows for evaluation of aortic dissection. If a type B dissection identified, medical management can be started. If a type A dissection identified, patient can be prepared for surgery

References

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Procedure: Carotid Evaluation

**AUTHORS:**

**RAJATH RAO**

**EDITORS:**

**NAVJIT DULLET**

**SIPAN MATHEVOSIAN**
Carotid Evaluation

Goals
1. To detect a narrowing/blockage due to plaques, or clots within the carotid vasculature in order to explain any present neurologic symptoms, as well as to prevent any future manifestations of arterial disease, trauma, or malformations in the carotid arteries.

Indications
1. Focal neurological signs (i.e TIA, stroke, amaurosis fugax)
2. Carotid bruit
3. Pulsatile neck mass
4. Follow-up exam on patients with known carotid disease
5. Unexplained non-hemispheric neurologic symptoms
6. Suspected subclavian steal syndrome
7. Suspected carotid artery dissection, AV fistula, or pseudoaneurysm
8. Syncope, seizures, dizziness
9. Screening for high risk patients with a history of atherosclerosis, head and neck radiation, vasculitis, fibromuscular dysplasia
10. Neck trauma
11. Hollenhorst plaque on retinal exam

Absolute Contraindications
1. There are no absolute contraindications to carotid ultrasound

Procedure
1. Patient should be supine, with mandible lifted, and extended inferior neck muscles
2. High frequency linear array probe set at 7 Mhz or higher
3. Blood flow to US signal should be between 45 and 60 degrees
4. For normal carotid arteries, color velocity scale should be set between 30-40 cm/sec.
5. Caution with displaying the color velocity scale. If the color velocity scale is set below the mean velocity of blood flow, it may be difficult to identify a high velocity turbulent jet in stenosis. If the color velocity scale is set higher than mean velocity of blood flow, stenosis may be missed.
6. Caution with near occlusion, blood flow may be lower than color velocity thresholds, giving a false positive appearance of total occlusion. In this situation, evaluate the region using low color velocity settings (<15cm/sec).
7. Short-axis view of blood vessels (transverse image): the patient is observed from the caudal side (the foot side), and the patient’s right side is presented on the left side of the image obtained
   a. SA view to be made in at least two directions, i.e., anterior and lateral (posterior) directions, so that inadequate depiction in one direction may be made up for by depiction in another direction
8. Long-axis view of blood vessels (longitudinal image): the direction is presented on the image obtained.
9. When checking for atherosclerotic lesions, maximum intima-media thickness (max IMT) of the common carotid artery, bulbous and internal carotid artery on the right and left side is an indispensable parameter, and mean intima media thickness (mean IMT) of the common carotid artery may be measured as an optional parameter
10. Use short-axis view to measure Percent stenosis, the primary parameter in Carotid artery disease
   a. If PSV (peak systolic velocity) of the stenotic area is > 1.5 m/s, NASCET % stenosis is estimated to be 50% or higher. If PSV is > 2.0 m/s, NASCET % stenosis is estimated to be 70% or higher
11. Society of Radiologists in Ultrasound (SRU) Consensus for grading stenosis is below (Table 3):

Actionability
1. Presence of a plaques/clots in the carotid vasculature leading to stenosis or aneurysm may be in indication for open endarterectomy, endovascular intervention, and/or adjustment of medical therapy.
TABLE 3
Consensus Panel Gray-Scale and Doppler US Criteria for Diagnosis of ICA Stenosis

<table>
<thead>
<tr>
<th>Degree of Stenosis (%)</th>
<th>Primary Parameters</th>
<th>Additional Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICA PSV (cm/sec)</td>
<td>Plaque Estimate (%)*</td>
</tr>
<tr>
<td>Normal</td>
<td>&lt;125</td>
<td>None</td>
</tr>
<tr>
<td>&lt;50</td>
<td>&lt;125</td>
<td>&lt;50</td>
</tr>
<tr>
<td>50–69</td>
<td>125–230</td>
<td>≥50</td>
</tr>
<tr>
<td>≥70 but less than near occlusion</td>
<td>&gt;230</td>
<td>≥50</td>
</tr>
<tr>
<td>Near occlusion</td>
<td>High, low, or undetectable</td>
<td>Visible</td>
</tr>
<tr>
<td>Total occlusion</td>
<td>Undetectable</td>
<td>Visible, no detectable lumen</td>
</tr>
</tbody>
</table>

* Plaque estimate (diameter reduction) with gray-scale and color Doppler US.

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Procedure: Paracentesis

**AUTHORS:**

Rakesh S. Ahuja

**EDITORS:**

Navjit Dullet

Sipan Mathevosian
Paracentesis

Indications
1. Performed in all patients with new-onset or worsening ascites of unknown etiology for diagnostic or therapeutic purposes, or in patients with recurrent symptomatic ascites of known etiology for therapeutic purposes.

Absolute Contraindications
1. Disseminated intravascular coagulation

Preoperative Preparation
1. Clinical evaluation: Detailed medical and surgical history, physical examination (in particular, if performing large volume paracentesis, determine if etiology of ascites is cirrhotic versus non-cirrhotic).
2. Review imaging: If not apparent on clinical examination and no prior imaging is available, consider performing ultrasonography to determine volume of ascites, location of adjacent bowel/organs. Color flow imaging may be beneficial in detecting subcutaneous varices as well as mapping the course of the inferior epigastric arteries.
3. Hold clopidogrel 5 days before procedure. Hold one dose of LMWH before procedure. No need to hold ASA.

Consent
1. Discuss possible complications/risks including:
   A. Bleeding
   B. Infection
   C. Damage to adjacent structures
   D. Local anesthesia
   E. Entry site hematoma
   F. Persistent leakage of ascitic fluid
   G. Paracentesis-induced circulatory dysfunction (PICD)

Procedure
1. Obtain pre-procedural laboratory testing including INR (if receiving warfarin anticoagulation or known suspected liver disease. Per SIR guidelines, correct INR <2.0 with FFP, Vitamin K); aPTT (if receiving intravenous unfractionated heparin: no consensus on management); Platelets: check if warranted by clinical history, replete if < 50,000/μl.
2. Position patient supine, head slightly elevated.
3. Using ultrasound guidance, mark access site (preferentially right or left paracolic gutters).
4. Perform sterile prep of abdominal entry site.
5. Administer local anesthetic (typically 1% or 2% lidocaine) - start with skin wheal then anesthetize entry tract through the peritoneum.
6. Perform skin incision at entry site. (5 Fr paracentesis needle is typically used from commercial pre-packaged paracentesis kits. Traditionally, these kits include a 6 Fr or 8 Fr drainage catheter introduced into the peritoneum by an obturator which becomes blunt upon entering the abdominal cavity, preventing damage to the viscera). Consider "Z-track technique" to minimize post-procedure ascitic leak. With this technique, the skin and subcutaneous tissues are held taut while the catheter is advanced, and then released upon entry into the peritoneum.
7. Ascitic fluid should enter syringe upon entering peritoneum. Remove syringe and inner stylet - form pigtail, confirming positioning with ultrasound guidance. If diagnostic paracentesis, obtain 60 mL of ascites and obtain appropriate laboratory testing.
8. Attach tubing to pigtail catheter; opposite end can be attached to three-way stopcock and drainage bag, or vacuum bottle.
9. Once fluid stops freely flowing, attempt to slightly reposition catheter and apply slight manual pressure on abdomen to get more fluid.
10. Remove catheter and apply manual compression for hemostasis. Apply sterile occlusive dressing and/or suture incision, particularly if persistent ascitic leak.

Post-Procedure Care
1. Although controversial, the use of albumin has been suggested in large volume paracentesis (defined as > 5 liters). General consensus is 6-8 g of IV albumin for every liter removed, administered at the end of the procedure.
2. Other studies have suggested that 3 mg of terlipressin may be equally beneficial in preventing PICD and less expensive than IV albumin.
Possible Early Complications
1. Abdominal wall hematoma
2. Persistent Ascitic Leak
3. Hypotension

Possible Late Complications
Paracentesis-Induced Circulatory Dysfunction (PICD):
1. After large volume paracentesis, hypovolemia triggers activation of the renin–angiotensin-aldosterone (RAA) system; if albumin is not replaced, can develop impaired renal function and rapid recurrence of ascites. Severe cases can lead to hepatorenal syndrome and/or death.
2. Associated with hypotension, hyponatremia, elevated plasma catecholamine and renin levels
3. PICD is estimated to occur in 80% of cases of large volume paracentesis without albumin substitution; this drops to 15-35% when volume expanders are used.

References
5. Images courtesy of: https://proceduralist.org/paracentesis/paracentesis-kit-supplies/
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Procedure: Evaluation for Cholecystitis

**AUTHORS:**

IAN SULLIVAN

**EDITORS:**

DINH-HUY D. NGUYEN

NAVJIT DULLET
**Evaluation for Cholecystitis**

**Goals**

1. Visualize the gallbladder
2. Measure the gallbladder wall width
3. Characterize the gallbladder as distended vs non-distended
4. Assess for the presence of pericholecystic fluid
5. Identify gallstones and assess for obstructing stones in the gallbladder neck or cystic duct
6. Attempt to illicit a sonographic Murphy's sign
7. Assess for signs of gallbladder wall rupture or impending rupture, such as wall disruption and ulceration/focal bulging respectively
8. Evaluate the common bile duct, intrahepatic and pancreatic ducts for more proximal or distal obstruction

**Indications**

1. Right upper quadrant ultrasound is indicated as the initial imaging step in all cases of pain where a biliary etiology is suspected.

**Contraindications**

1. None.

**Procedure/Interpretation**

1. Equipment: A 3 to 5-MHz sector transducer is used to evaluate the right upper quadrant.
   a. Use subcostal and intercostal approaches
      i. Deep inspiration is helpful in subcostal approach
      ii. During the intercostal approach, the liver can be used as a window
2. Positioning: Obtain scans in a variety of positions including left posterior oblique, left lateral decubitus, prone and upright
   a. This allows assessment of mobility of intraluminal structures and their differentiation from non-mobile mural structures
3. Gallbladder: Assessment
   a. Wall thickening
      i. Over 3mm is abnormal
   b. Distension
      i. Subjective in assessment
   c. Pericholecystic fluid
   d. Impacted stones
      i. Gallbladder neck
      ii. Cystic duct
   e. Murphy's sign
      i. Cessation of inspiration during deep palpation of the right upper quadrant
   f. Pitfall: A gallstone filled gallbladder may be mistaken for gas-filled bowel
      i. Stones produce a 'clean' shadow vs the 'dirty' shadow of bowel gas
      ii. The "wall-echo-shadow" complex identifies the gallbladder
         1. Three lines corresponding to the wall, echoic stones and shadow
   a. Smaller stones may not show shadowing initially
      i. A higher frequency transducer can elicit shadowing in small stones
         1. The patient can be repositioned to clump stones together
         a. These will shadow in aggregate
   b. Gallstones located in the gallbladder neck may be impacted
   c. Gallstones in the cystic or common bile ducts may cause obstruction
      i. Biliary ductal dilatation may be seen in conjunction with obstructing stones or as a secondary sign for non-visualized obstructing stones or other obstructive causes such as mass lesions

**Emphysematous Cholecystitis**

1. Emphysematous cholecystitis manifests on ultrasound as intramural nondependent hyperechogenicity that demonstrates dirty shadow and ring down artifact
Incidentals

1. Consider evaluation for intrahepatic or pancreatic duct dilatation. Consider evaluation for right hydronephrosis.

Labs

1. Consider correlation with labs including WBC, bilirubin, alkaline phosphatase, AST and ALT. Amylase and lipase may be useful when concurrent pancreatitis is suspected.

Actionability

1. Positive: Urgent surgery is treatment of choice in patients presenting acutely. Antibiotics and supportive care may be successful in downgrading to elective. Percutaneous cholecystectomy is useful in patients who are not well enough for surgery or as a bridge to surgery.
2. Negative: Consider HIDA scan

Images

![Image: Acute cholecystitis with gallbladder wall thickening to 3.5mm. Image from Radiopaedia.org.](image1)

![Image: Emphysematous cholecystitis. Ill defined wall and dirty shadowing noted. Image from Radiopaedia.org](image2)

Resources

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Procedure: Ultrasound Guided Cholecystostomy

AUTHORS: NAVJIT DULEET

EDITORS: SIPAN MATHEVOSIAN
Ultrasound Guided Cholecystostomy

Goals
1. Use ultrasound guidance to perform percutaneous cholecystostomy.

Indications
1. Percutaneous cholecystostomy is indicated in poor surgical candidates in treatment/management of acute cholecystitis (calculous, acalculous). Risk factors for acalculous cholecystitis include trauma, recent surgery, shock, burn injury, sepsis, intensive care unit admission, total parenteral nutrition (TPN), and prolonged fasting.
2. Alternative/secondary decompression of the biliary system (e.g. due to biliary strictures).
3. Alternative treatment for acute cholangitis when endoscopic intervention is not an option.

Contraindications
1. Interposition of bowels over the path to the gallbladder.
2. Coagulopathy is a relative contraindication to cholecystostomy.
3. Traditionally, an INR < 1.5 and platelets < 50,000 are preferred, however, a study by Dewhurst et al. found no difference in complications between patients with normal coagulation and patients who were coagulopathic.
4. Ascites – though patients can be treated with paracentesis before percutaneous cholecystostomy.

Pre-procedure Preparation
1. Patient should be fasting for 6 hours
2. Appropriate pre-procedure imaging – ultrasound, HIDA, or CT scan
3. Appropriate blood tests (LFT’s, basic electrolytes ect.)
4. Prophylactic antibiotics should be given 12-24 hours before intervention

Consent
1. Discuss possible complications/risks including:
   a. Bleeding
   b. Infection
   c. Damage to adjacent structures
   d. Local anesthesia
   e. Entry site hematoma
   f. Peritonitis
   g. Sepsis
   h. Pneumothorax
   i. Bowel perforation

Procedure/Interpretation
1. Equipment: A 3 to 5-MHz convex transducer is used to evaluate the right upper quadrant.
2. There are two approaches that can be used – transhepatic and transperitoneal.
3. The transhepatic approach provides more catheter stability, reduces bile leakage, and results in faster tract formation (see image). It may result in more bleeding than the trans-peritoneal approach.
4. The transperitoneal approach is preferred in diffuse liver disease (i.e. metastasis).
5. Evaluate anatomy surrounding the gallbladder using the convex transducer.
6. Perform sterile preparation of the desired entry site.
7. Anesthetize the skin in the area of the desired entry point (lidocaine, etc.)
8. Two techniques may be used: modified Seldinger technique and the Trochar technique.
9. Seldinger Technique
   a. Insert a fine 18-gauge needle into the gallbladder.
   b. Use a 0.35” guidewire to secure access.
   c. Dilators are then used to dilate the tract to 1Fr size higher than the desired drainage catheter.
   d. Place the drainage catheter into the formed tract.
   e. Once the catheter is within the gallbladder, advance the catheter over the inner stiffener.
   f. Remove the guidewire and lock the drainage catheter in place.
10. Trochar Technique
    a. Advance the trochar (needle + catheter) into the gallbladder. Once the needle/catheter are within the gallbladder lumen, advance the catheter over the trochar needle.
11. Attach the catheter to a drainage (usually a bulb drain).
12. Drain should be maintained in place for at least 4 weeks, or until tract formation (ascites, steroid use, uncontrolled diabetes may delay tract formation).
13. Catheter should be flushed with saline 1-2x/day.

Complications
1. Hemorrhage
2. Catheter dislodgement
3. Sepsis
4. Bile peritonitis
5. Pneumothorax
6. Recurrent cholecystitis

Resources
4. Images courtesy of Dr. Thomas Snow, Radiopaedia ID 37090

Transhepatic needle approach into an inflamed gallbladder
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Procedure: Percutaneous Gastrostomy Tube Placement/Replacement/Visualization

Authors: Sydney Rubin
Editors: DinHuy D. Nguyen
Navjit Dullet
**Percutaneous Gastrostomy Tube Placement/Replacement/Visualization**

**Goal**
1. To use ultrasound to guide and evaluate gastrostomy tube placement.
2. To confirm the location of gastrostomy tube

**Indications**
1. Provide nutritional support for patients with functional gastrointestinal systems and disorders that interfere with oral intake.
2. Access for nutritional supplement, fluid and medication administration.

**Contraindications**
1. Uncorrectable coagulopathy
2. Unsatisfactory percutaneous access to the stomach
3. Active peritonitis
4. Abdominal wall infection at site of tube insertion
5. History of gastrectomy
6. Lack of informed consent

**CONSENT**
1. Discuss possible complications/risks including:
2. Bleeding
3. Infection
4. Damage to adjacent structures
5. Local anesthesia
6. Entry site hematoma
7. Peritonitis
8. Bowel perforation

**Equipment**
1. Ultrasound system with curved ultrasound probe
2. Sterile ultrasound gel
3. Nasogastric or orogastric tube
4. Cope gastrointestinal suture anchor set
5. Hydrophilic guide wire
6. Puncture needle preloaded with an anchor
7. Gastrostomy tube (size dependent on patient body habitus)

**Preparation**
1. Ideally, patient is placed in supine position.
2. Using sterile technique, drape and prepare site. Use sterile gown, mask, gloves and cap.
3. Local anesthesia and possibly sedation should be used to ensure comfort and little movement as possible from patient.

**Procedure for Placement**
1. Use a curved ultrasound probe to identify abdominal structures including, the stomach, colon, small bowel, and medial edge of the liver.
2. Pass orogastric or nasogastric tube.
3. Observe gastric distension with ultrasound while instilling warm saline to fill the stomach.
4. Identify puncture site, junction of the upper two thirds and lower third of the stomach and halfway between the greater and lesser curvatures.
5. Fasten stomach to the anterior abdominal wall using two or more gastric T-fasteners.
6. Under ultrasound guidance and with stomach still in apposition to abdominal wall, insert introducer needle into the gastric lumen between the T-fasteners.
7. Advance a guide wire into the gastric lumen through the needle and confirm placement.
8. Withdraw the introducer needle, keeping the wire in place.
9. Create a small skin incision next to the guide wire.
10. Advance the dilator over the wire and into the stomach using ultrasound guidance.
11. Measure the tract length and select appropriate gastrostomy tube.
12. Place a tube through the dilator and advance into the stomach.
13. Inflate the balloon and use ultrasound to confirm tube has been placed in gastric lumen and not intramurally.
14. Remove wire and dilator.
15. Secure the T-fasteners and gastrostomy tube.
Procedure for Replacement/Verification of Location

1. Caution with this procedure as there is limited data. The study where this technique was described was limited to 10 patients and used verification with pH of aspirate and contrast radiographs.
2. Use ultrasound to visualize anatomy, including the stomach, rectus abdominus musculature, and if possible, the fistula tract.
3. Obtain a longitudinal view of the stomach, which will enable visualization of the G-Tube as it passes through the stomach wall, into the stomach. A smaller G tube than the originally sized G tube may need to be used.
4. Slide the ultrasound probe distal to the G tube, and turn the probe to an oblique angle, which should produce a cross sectional view of the G tube within the stomach lumen if replacement is successful.
5. Apply color doppler over the tip of the G-Tube and oscillate the G tube. This should produce colorflow within the lumen of the stomach if placement is successful.

Possible Complications

1. Peritonitis
2. Bleeding/hemorrhage
3. Deep stomal infection
4. Aspiration pneumonia
5. Tube displacement requiring repeat procedure
6. Sepsis
7. Internal organ injury
8. Superficial stomal infection
9. Minor periostomal leakage
10. Tube dislodgement/Burried Bumper Syndrome

Images

Image: G Tube passing through original tract and into the stomach. Image from Wu et al. Ultrasound can accurately guide gastrostomy tube replacement and confirm proper tube placement at the bedside. J Emerg Med.

References
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Procedure: Small Bowel Obstruction

**AUTHORS:**

**EDITORS:**

**Navjit Dullet**
**Small Bowel Obstruction**

**Indications**
1. To evaluate for small bowel obstruction in the setting of abdominal pain, decreased voiding, decreased bowel sounds, or decreased caloric intake. Ultrasound examination may be performed more rapidly, with less radiation, compared with x-ray.

**Goals**
2. To use multiple sonographic views of the abdomen to measure small bowel diameter, and evaluate for the presence of small bowel obstruction

**Contraindications**
1. There are no absolute contraindications to ultrasound examination for SBO

**Procedure**
1. Obtain an abdominal ultrasound transducer (curvilinear 2.5-5MHz or 3.5-5MHz).
2. Place the patient in a supine position.
3. Examine the following regions using sonography: the bilateral colic gutters, epigastric, and suprapubic regions.
4. Scan the bowel as a sweep from the epigastrum, across the mid abdomen, down to the pelvis.
5. The presence of fluid-filled dilated bowel, measuring greater than 2.5 cm with a collapsed distal bowel segment indicates a possible obstruction. However, a distal bowel segment may not be visualized. Additional findings of small bowel obstruction may be decreased or absent bowel peristalsis. Other criteria are multiple fluid filled non compressible bowel loops (adjacent to collapsed bowel segment), localized edema of bowel wall with increased thickness, or free fluid between dilated bowel loops.
6. The jejunum can be distinguished from the ilium by the presence of valvulae conniventes.
7. Bowel wall thickening greater than 3 mm on ultrasonography may indicate bowel ischemia or infarction as a result of SBO, warranting more aggressive management.

**Actionability**
1. Diagnosis of SBO in a timely fashion can assist in appropriate management. If SBO is diagnosed, and nasogastric tube can be placed for decompression. The presence of bowel wall thickening indicates the need for additional imaging, and possible surgical intervention. Once SBO is diagnosed, referrals can be made to appropriate clinical services.

**Images**

Image showing dilated loop of small bowel with a diameter consistent with SBO. Photo from Pourmand et al. The Accuracy of Point-of-Care Ultrasound in Detecting Small Bowel Obstruction in Emergency Department. Emerg Med Int.

**References**
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Procedure: Testicular/Ovarian Torsion

Authors: Matthew Chiarello

Editors: Navjot Dullet
        Sipan Mathevosian
Ultrasound of Testicular and Ovarian Torsion

Indications
1. Testicular Ultrasound- All male patients with acute scrotal pain with/without swelling should undergo a scrotal/testicular ultrasound. Scrotal swelling, asymmetry or enlargement.
2. Female Pelvic Ultrasound of Ovarian Torsion- Assessing a female with acute pelvic/lower abdominal pain

Goals
1. Visualize the testicles/ovaries, evaluate blood flow/vascularity (compared to the contralateral site is very important in evaluation), location/orientation, hydrocele, testicular edema/infarction. Visualize spermatic cord and evaluate for twisting of the cord.
2. Size of ovary, peripheralization of follicles, edema, presence of an ovarian mass/cyst (lead point for torsion)

Contraindications
1. No absolute contraindications to scrotal ultrasound/transabdominal probe in females.
2. Transvaginal ultrasound may be contraindicated depending on the virginial status of the patient, in pediatric patients and may be refused depending on patient preference.

Procedure/Interpretation
Testicular Ultrasound
1. Position the patient prone, with the scrotum supported by a towel (placed between the thighs. Use warm gel to minimize pressure/contraction of scrotal skin. Use a high frequency, linear transducer (at least 8-5 MHz).
2. Start with a midline trans grayscale image to visualize both testicles at the same time.
   ○ Compare echogenicity of the testicles, should be very smooth and symmetric. Heterogeneity, hypoechoic testicle- are signs of edema/torsion.
   ○ Compare orientation. Is the long axis of one oriented vertically and the other horizontally? That would be suspicious for torsion.
   ○ Compare scrotal skin to evaluate for asymmetric thickness/scrotal edema.
3. Midline trans color Doppler
   ○ Compare relative vascularity. Be mindful of scale (as always with color). Is one testicle increased or is the opposite side decreased in vascularity?
4. Evaluate each individual side.
   ○ Measure each testicle in 3 dimensions. Unilateral enlarged testicle may be edematous/torsed, or undergoing torsion/de-torsion.
   ○ Scan through entire testicle to evaluate echogenicity and echotexture with grayscale. Turn on color doppler, select vessel for spectral analysis- get both arterial and venous flow. Evaluate for presence of a hydrocele.
   ○ Scan through the spermatic cord, evaluate for a twisting.
   ○ Evaluate epididymis (epididymitis/orchitis may present similarly to torsion).

Female Pelvic Ultrasound
1. Trans abdominal probe is used to assessing ovary location, ovaries are usually better evaluated on the transvaginal probe
   ○ A cine clip starting midline sagittal (long) at the bladder, and scanning laterally may be useful in identifying abnormal position/orientation of the ovary; for instance ovary located superior to the bladder would be suspicious
2. Transvaginal probe (or this may be done with a transabdominal probe in applicable)
   ○ Measure each ovary in 3 dimensions, evaluate echogenicity and echotexture with grayscale. Turn on color doppler, select vessel for spectral analysis- get both arterial and venous flow. Attempt to identify vascular pedicle and evaluate for a twist.
   ○ Evaluate for the presence of a cyst/mass (lead point for torsion), peripheralization of normal ovarian follicles, presence of pelvic free fluid is nonspecific but can be very helpful- especially complex fluid
   ○ IMPORTANT: B-mode is the most important modality and used to evaluate asymmetric SIZE/EDEMA and PERIPHERAL FOLLICLES (due to edema). A torsed ovary can have arterial flow as venous supply is first compromised.

Summary/Take-away:
1. Presence of arterial flow does not rule out testicular/ovarian torsion, high arterial pressure may allow detectable arterial flow during torsion.
2. Use location, orientation, unilateral increased size, decreased echogenicity, heterogeneous echotexture, spermatic cord/vascular pedicle twist
3. In females, evaluate for asymmetric ovary size/edema, peripheralization of follicles, and free fluid. Flow does not exclude diagnosis.
Images

RIGHT - US of bilateral scrotum showing normal color flow on right testes with absent color flow on left testes. L hydrocele also noted.
LEFT - Edematous ovary with peripheralization of the follicles. Images from Radiopaedia.org

References
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Procedure: US-Guided Percutaneous Liver Biopsy

**AUTHORS:**

**EDITORS:**

**DAVID KOPYLOV**

**DINH-HUY D. NGUYEN**
US-Guided Percutaneous Liver Biopsy

Goal
1. Obtain a tissue sample from a specific hepatic lesion or a random sample of liver tissue.

Indications
1. Random Liver Biopsy
   a. Acute liver injury
   b. Chronic liver disease
   c. Graft versus host disease
   d. Liver transplant rejection
2. Target liver biopsy
   a. Differentiate between a benign or malignant liver lesion in which imaging is equivocal
   b. Differentiate between primary or secondary malignant liver lesion.

Absolute Contraindications
1. Uncorrectable coagulopathy*

Relative Contraindications
1. Massive ascites
   • A transjugular approach is often preferred in patients with severe coagulopathy or massive ascites.
2. Uncooperative patient
3. Portosystemic gradient measurement required
4. Avoid biopsy of known vascular lesions

Procedure Preparation
1. Hold NOACs for 48 hrs prior to procedure
2. Hold Plavix for 5 days prior to procedure
3. Hold warfarin for 5 days prior to procedure
4. Anti-platelet agents can be resumed 48-72 hours
5. Warfarin can be resumed the day after the procedure

Procedure
1. Perform a planning ultrasound evaluation of the target area to determine the safest percutaneous route to the target area.
   a. A 3 to 5 MHz multiarray transducer is preferred. For subcapsular lesions, a high frequency linear probe can be used.
   b. Approaches:
      i. Intercostal
      ii. Subcostal
      iii. Xyphoid
2. Give local anesthetic with a standard 25G needle at the site of planned entry.
3. Make a small nick at the site so that the biopsy needle can pass more easily through the skin.
4. The percutaneous biopsy can be performed using a single needle or coaxial technique.
   a. Single needle (often used for a random liver biopsy):
      i. Set the appropriate throw distance on the core biopsy gun.
      ii. Spring load the core biopsy gun.
      iii. Place the core biopsy gun through the skin nick and direct it into the liver using ultrasound guidance.
      iv. Press the button to fire the core biopsy gun.
      v. Remove the core biopsy gun. The specimen will be exposed in needle notch, which can be subsequently collected on a glass slide or in a specimen container.
         1. Pros – samples multiple areas of the liver to decrease the risk of a false negative
         2. Cons – repeated punctures of the liver capsule
   b. Coaxial (often used for a targeted liver biopsy):
      i. Insert a 17-19G outer guide needle into the nick and direct it into the area of interest in the liver using ultrasound guidance.
      ii. Place a spring-loaded core biopsy gun into the guide needle.
      iii. Press the button to fire the core biopsy gun.
      iv. Remove the core biopsy gun from the guide needle. The specimen will be exposed in needle notch, which can be subsequently collected on a glass slide or specimen container.
         1. Pros – obtaining multiple samples without having to re-access the lesion each time, reduced risk of tumor seeding
         2. Cons – decreased ability to sample different areas of a lesion
5. Consider q15 minute vital checks for the hour following procedure
Complications:
1. Major:
   a. Hemorrhage requiring intervention
   b. Pneumothorax
   c. Malignant track seeding
   d. Gallbladder/bowel perforation
2. Minor/More common:
   a. Hemorrhage not requiring intervention
   b. Abdominal pain

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Procedure: Bladder Volume Assessment

**AUTHORS:**

**EDITORS:**

**NAVJIT DULET**

**DINH-HUY D. NGUYEN**

**SIPAN MATHEVOSIAN**
Bladder Volume Assessment

Indications
1. Volume analysis by portable ultrasound can be used to help determine the etiology of decreased urinary output as a result of outlet obstruction, postoperative urinary retention, neurogenic bladder, stroke, neurogenic injury among other pathologies. Ultrasound can also help classify a urinary problem as a storage disorder, voiding disorder, or both.

Goals
1. To use a portable ultrasound to determine whether there is urinary retention or incontinence. The scan results should be correlated with other clinical measures, such as urinary analysis and CBC.

Contraindications
1. There are no absolute contraindications to bladder ultrasound

Procedure
1. Obtain a low-frequency (5 – 1 MHz) ultrasound transducer
2. If a measurement of PVR is desired, have the patient void completely prior to examination
3. Place the ultrasound transducer approximately 1 inch above the pubic synthesis, and angle the probe inferiorly. The bladder should be visualized as a medium to large sized anechoic region.
4. Turn on color flow, and see whether the ureteral jets can be visualized posteriorly
5. Assess for bladder stones, masses, or irregular wall thickening.
6. 3 dimensions need to be measured for bladder volume assessment: length, width, height. From these measurements, the prolate ellipsoid equation can be used to calculate volume. The equation is as follows: volume = length x width x depth x 0.52.
7. Other studies have looked at using a single dimension for volume assessment. Daurat et al. found that a largest transverse diameter of < 9.7cm was found to exclude a bladder volume of > 600 mL

Image courtesy of RadiologyAssitant.nl

Actionability
1. Measurement of water volume can help determine the etiology for urinary retention or urinary incontinence. Excessive postvoid residual volumes may require single catheterization, or placement of a Foley catheter or suprapubic catheter if there is continued urinary retention.

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Procedure: Ruptured Ectopic Pregnancy

**AUTHORS:**
MATTHEW CHIARELLO

**EDITORS:**
NAVJIT DULLET
Ruptured Ectopic Pregnancy

Background/Indications
1. Acute pelvic pain and/or vaginal bleeding in a female with a positive bHCG.

Goals
1. To visualize either an intra-uterine or an extra-uterine pregnancy. Determine location (tubal [95%], interstitial, cornual, cervical, intra-abdominal, scar, heterotopic), and if ruptured, unruptured, or live

Contraindications
1. No absolute contraindications

Procedure/Interpretation
1. It is very helpful to have bHCG levels at the time of interpretation of the pelvic ultrasound.
2. For bHCG <2000- it may be too early to visualize an intra-uterine pregnancy sonographically. bHCG level should normally double every 2 days .
3. (+) bHCG and no gestational sac identified- pregnancy of unknown location; differential includes ectopic vs early intrauterine pregnancy vs completed miscarriage.
   a. bHCG should be trended, and pelvis US should be repeated.
4. Trans-abdominal probe is useful for a wide overview of anatomy and look for free fluid. Trans-vaginal probe will provide much more detail and diagnostic sensitivity.
5. Scan through the uterus to identify an intra-uterine gestational sac, fluid in the endometrial cavity may be misinterpreted as a gestational sac (pseudo gestational sac).
   a. Double-decidual sign- confirms fluid is actually the gestational sac.
   b. Presence of a yolk sac- also confirms this is the gestational sac.
   c. If an endometrial gestational sac is present, ectopic is extremely unlikely (heterotopic- both an intrauterine and an extrauterine pregnancy).
6. Scan towards each adnexa, identify adnexal mass- usually complex cystic but may be simple cyst or less likely solid.
   a. Attempt to separate mass from ovary (ovarian ectopic can occur, but quite rare). Apply pressure with US probe, while recording a cine clip to separated out the mass from the normal ovarian tissue.
   b. Color flow may demonstrate a “ring of fire” around the ectopic, but this may also be seen with a corpus luteum (which will be located intraovarian).
   c. Tubal ring sign- echogenic ring around ectopic- confirms tubal location.
7. Once the ectopic pregnancy is identified, attempt to identify a fetal/cardiac motion (live).
8. Signs of rupture look for pelvic free fluid, complex free fluid/hemoperitoneum and hematosalpinx. Use the trans-abdominal probe to look up in upper abdomen/Morrison’s pouch for free fluid.
   a. Pelvic hemorrhage and positive bHCG: PPV 86-93%.
9. Special Circumstance: Interstitial Ectopic
   a. Ectopic located within the intramyometrial tube, gestational sac will be eccentrically located, and surrounded by thin (<5mm) myometrium.
   b. Uterine line sign- thin echogenic line in myometrium, is the interstitial tube, borders gestational sac.
      i. Ruptured interstitial ectopic high mortality-uterine artery proximity.

Actionability
1. Briefly, treatment separated into medical vs surgical management.
   a. Medical Management usually with orally administered methotrexate, methotrexate or KCl may be directly injected into gestational sac. Recommend also discussing case with Ob/Gyn service.
      i. Relative contraindications: Rupture, mass >3.5cm, live (fetal cardiac activity), bHCG >6000.
   b. Consult Ob/Gyn for surgical management.

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**AUTHORS:**

**EDITORS:**

NAVJIT DULEET
Necrotizing Soft-Tissue Infections (NSTI)

Indications
1. Assessing a wound, skin color or texture change, and ruling out necrotizing fasciitis, since necrotizing fasciitis may have a similar appearance to cellulitis in some instances.

Absolute Contraindications
1. None

Procedure
1. Obtain a linear array transducer for both longitudinal and transverse imaging.
2. Prepare examination area, and place ultrasound probe on suspected area of necrotizing fasciitis.
3. Diagnostic features of necrotizing fasciitis include changes in subcutaneous fat, changes in underlying fascia, changes in underlying muscle. Other findings include fascial and subcutaneous tissue thickening, abnormal fluid accumulation in deep fascial layer, and occasionally, subcutaneous air. A key distinguishing factor between cellulitis and necrotizing fasciitis is the appearance of turbid fluid between fascial planes.
4. Subcutaneous emphysema may be seen, however, it may be a finding late in the course of a NSTI. Gas will be very echogenic.
5. Some studies have suggested NSTI can be suggested by deep fascial thickening, thickening of overlying fatty tissue, or a fluid layer > 4mm thick overlying deep fascia. Fluid spaces tracking along deep fascia are not seen in cellulitis.
6. Within the muscle, ill-defined hypoechogenicity may be found secondary to inflammatory process, however, hypoechogenicity may also be found, representing muscle swelling.

Cautions
1. Sensitivity of ultrasound for detecting necrotizing fasciitis varies depending on the location and extent of tissue involvement. Consequently, ultrasound should not be used to rule out the diagnosis of necrotizing fasciitis. Correlate imaging with clinical picture and labs, utilizing scores such as the LRINC score. US cannot be definitively be used to exclude a diagnosis of NSTI.

Actionability
1. Ultrasound can aid in the diagnosis of suspected necrotizing fasciitis; however, it should not be used to exclude the diagnosis.

Images

Image: Example of subcutaneous gas represented by echogenic foci with acoustic shadowing. Photo from Russell F, Duncan T. Case Report: Diabetic Pain. ACEP.

References
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Procedure: Arthrocentesis

AUTHORS:
POUYA AGHAJAFARI

EDITORS:
DINIHUY D. NGUYEN
NAVJIT DULLET
SIPAN MATHEVOSIAN
Arthrocentesis

Goal
1. Ultrasound guided arthrocentesis allows the interventional radiologist to identify target structure for aspiration with improved accuracy compared to non-guided procedures.

Indications
1. Lack of surface anatomical landmarks due to body habitus
2. Proximity to neurovascular structures
3. A bleeding diathesis
4. Aberrant anatomy
5. Deeper structures
6. Need to avoid radiation

Contraindications
1. Overlying infection
2. Inaccessible joint space
3. Bacteremia
4. Adjacent osteomyelitis
5. Uncontrolled coagulopathy
6. Joint prosthesis

Consent
1. Bleeding - Warfarin or DOACs do not need to be held prior to procedure, however a smaller needle size (22 gauge) is preferred
2. Infection
3. Damage to adjacent structures
4. Local anesthesia
5. Entry site hematoma

Procedure
1. Perform a preliminary scan which will identify relevant structures that are to be avoided during procedure. For thin patients a higher-frequency (6-13 MHz) linear probe can be used. For patients with a muscular build or higher BMI, a lower frequency probe can be used. Bony landmarks should be used, which appear very hypoechoic with echogenic rim. Use color to find hyperemic areas/synovitis.
2. Appropriately position the patient for the aspiration. For knees, flex the knee to 15-20 degrees.
3. Mark the overlying skin and prepare in usual sterile fashion.
4. Anesthetize the skin with small gauge needle.
5. Under ultrasound guidance, advance the needle into skin 1cm medial or lateral to the upper 1/3 of the patella, with the needle directed towards the intercondylar notch. The needle should be directed 45 degrees inferiorly, and 45 degrees posteriorly.
6. Use an 18-20 gauge with a 5mL syringe. If the effusion is large, can use a 20mL syringe.
7. Aspirate as you advance the needle under ultrasound guidance.
8. Once aspiration is complete, send fluid for appropriate analysis (i.e. cell counts, crystal analysis), and place a band-aid over the entry point.
9. Other joints include carpal, wrist, elbow, shoulder, hip joints; also include subacromial or trochanteric bursa. Please see UptoDate article in references for approaches.
Actionability
1. This exam will allow more accurate aspiration for diagnostic and therapeutic purposes.

Possible Early Complications
1. Hemarthrosis
2. Superficial bleeding
3. Tendon rupture
4. Neurovascular damage/damage to adjacent structure

Possible Late Complications
1. Septic Joint
2. Hemarthrosis
3. Septic Bursitis

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Procedure: Incision and Drainage of Abscess

AUTHORS:  
Navjit Dullet

EDITORS:  
Dinh-Huy D. Nguyen
**Incision and Drainage of Abscesses**

**Goal**

1. To identify a superficial abscess that can be treated with incision and drainage or needle guided aspiration.

**Indications**

1. Ultrasound guidance can be used to determine whether superficial or deep infection/infectious process is an abscess amenable to incision and drainage, or whether it is a process more amenable to antibiotic treatment, such as cellulitis.

**Contraindications**

1. No abscess identified on ultrasound examination
2. No clear target for incision and drainage, such as a deep abscess
3. Overlying vascular or nervous structures

**Consent**

Discuss possible complications/risks including:

A. Bleeding
B. Infection
C. Damage to adjacent structures
D. Local anesthesia
E. Need to enlarge area of I&D due to larger than expected abscess

**Additional Preparation**

1. Patients at risk of bacterial endocarditis (rheumatic heart, central lines in place etc.) should be given antibiotic prophylaxis with strep coverage antibiotics prior to I&D.
2. Sterile prep
3. Gauze
4. 25-30 gauge needle
5. Culture swab
6. Scalpel or blade
7. Saline syringe
8. Forceps

**Technique**

1. Obtain a high-frequency linear probe if one is available. A lower frequency probe may also be used, however, resolution may not be optimal. If a linear transducer is not available, a curvilinear transducer may also be used.
2. Scan over the area of interest, adjusting depth as necessary. This area may be identified by swelling, color changes, warmth, or pain.
3. The characteristic appearance of an abscess is a hypoechoic or anechoic region, with variable amounts of hyperechoic debris within abscess cavity. The depth may need to be changed depending on the location of the abscess.
4. Once an area of interest is identified, manipulate the transducer to visualize the entire abscess cavity in one plane. Then rotate the probe by 90°, and try to visualize the entire cavity. Large abscesses (>5cm by palpation or ultrasound) may be more amenable to surgical intervention.
5. Slide the transducer to the midpoint of the abscess cavity (the area of maximal fluctuance)
6. Using a marking pen, make a circle around the abscess cavity.
7. Prep the area of interest with sterilization procedure and anesthetize the region.
8. Proceed with the incision and drainage, either making an elliptical area around the cavity, or a linear incision. Probe the cavity with forceps to break loculations, and irrigate with saline.
9. If the abscess cavity is deeper, it may be more amenable to needle aspiration. Once the area of interest is breached, ultrasound needle localization can be used to gain access to the abscess cavity. As you are advancing the needle, hold suction on a syringe. Once the abscess cavity is entered, paralytic material should be visualized within the syringe.
10. Send fluid or specimen for culture, initiate empirical antibiotics per practice preferences.
11. Place bandage or dressing over needle insertion site after cleaning the region. It is recommended to let I&D abscesses close by secondary intention
12. Patient may need to have a more thorough I&D performed depending on size of abscess and complexity of the collection

**Complications**

1. Inadequate drainage may lead to recurrence of abscess, or increased size of abscess, or other infection (osteomyelitis, tenosynovitis, etc).
2. Aggressive I&D may lead to bacteremia
Actionability

1. Once a superficial abscess is identified, the region can be marked, and then incision and drainage or needle guided aspiration and be performed to drain the abscess cavity, and potentially alleviate patient pain.

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Procedure: Ultrasound Guided Single Injection Peripheral Nerve Blocks

**Authors:**
Jonathan Barclay

**Editors:**
Navjit Dullet
Ultrasound Guided Single Injection Peripheral Nerve Blocks

Goal
1. To provide localized anesthesia to patients in patients via administration of anesthetics directly to the nerve.

Indications
1. In general, used to avoid side effects and complications of general anesthesia (particularly respiratory) and provide analgesia while minimizing opioid use.
   a. Patients at risk for respiratory depression from general anesthesia
   b. Difficult airway
   c. High risk postoperative nausea and vomiting
   d. Patients who wish to remain conscious or avoid systemic meds
   e. Outpatient interventions
   f. Patients with severe acute localized pain poorly managed with systemic meds

Relative Contraindications
1. Active infection at the site of injection
2. Antithrombotic agents or coagulopathy
3. Pre-existing neural deficit at the site of the block

Absolute Contraindications:
1. Patient inability to cooperate or refusal
2. Allergy to local anesthetics
3. Lack of knowledge of adjacent anatomy

Consent
1. Patient should be made familiar with the precautions and care needed during the recovery of the block.
   a. Time to resolution of the block is extremely variable between block location, patient, and anesthetic.
      i. Lidocaine may last anywhere from 3 to 8 hours, while bupivacaine may last 6 to 30 hours.
   b. Care should be made to avoid injury to the anesthetized limb and avoid falls
      i. Equipment such as protective padding, slings, crutches, or wheelchairs may be necessary.
2. Patients should be warned of potential complications:
   a. Nerve injury
   b. Hematoma
   c. Local anesthetic systemic toxicity
   d. Allergic reaction
   e. Infection
   f. Myotoxicity
   g. Secondary injury

Procedure Preparation
1. Directed medical history should be obtained with a focus on any conditions that may impact the decision to perform a block (such as coagulopathy, respiratory compromise, allergies, etc.).
2. Patients should follow normal fasting guidelines for surgery in the case that deep sedation or general anesthesia is needed.
3. Obtain intravenous access and have resuscitation equipment available prior to the procedure.
4. Some patients may benefit from light sedation to improve comfort during the placement of a block.
   a. Doses are titrated to optimize patient comfort while maintaining consciousness for communication and cooperation.
   b. Typical doses for healthy adults include IV midazolam 1-2mg and fentanyl 25-100mcg.
5. Throughout the procedure, pulse oximetry, ECG, and blood pressure should be monitored.
6. Make sure to gather materials, such as a sterile ultrasound kit, appropriate length and size needles and syringes, as well as anesthetic of choice.

Procedure
1. Begin by taking surveillance images with the ultrasound to localize the nerve of interest, marking the location of optimal visualization on the patient’s body. Be sure to identify associated anatomic structures such as nearby nerves, vessels, and bony/soft tissue structures.
2. Prep the procedure site in the usual sterile fashion and place the ultrasound probe in a sterile plastic sheath.
3. Using sterile ultrasound gel, again locate the target nerve and associated structures.
a. The target nerve can be imaged in either the short axis or long axis view, and the optimal view may change based on operator preference or the anatomical site. Color doppler is helpful to recognize blood vessels.

b. Remember to acquire surveillance images for documentation.

4. When the optimal view is obtained, hold the probe immobile and gather the needle used for the block. Common needles used are 1.5 inch 25 or 27 gauge needles, and common anesthetic is 1% lidocaine. 2-5mL may need to be used.

5. Plan your needle path to the target nerve.
   a. Ideally, you should approach the nerve tangentially, projecting the needle so that its tip will land adjacent to the nerve, not aiming for its center.

6. Using the “in-plane” approach, position the needle parallel to the long side of the transducer and within the field of view of the ultrasound. Beginning at the skin surface, slowly inject lidocaine to anesthetize the needle track as you advance.
   a. The “in-plane” approach should always allow you to visualize the needle tip and body, allowing for safer insertion.
   b. The bevel of the needle tip should face up towards the transducer in order to better see the tip.
   c. Do NOT advance the needle without seeing the tip.
   d. If you lose the tip from view, small injections of lidocaine or saline may help you localize it again.

7. Once the needle tip is positioned accurately near the target nerve, gently aspirate to ensure negative intravascular placement.

8. Inject the local anesthetic of choice in small aliquots, observing for pain or high-pressure during injection.
   a. You should visualize a spread of fluid at the needle tip during injection.
   b. Anesthetic should spread circumferentially and longitudinally around the nerve for a proper block.
   c. For nerves enclosed in fascia, aim to fill the fascial confines with anesthetic.
   d. For single nerves in extremities, aim to create a donut of anesthetic around the nerve.

9. Remove the needle then clean and bandage the procedure site appropriately.

Complications
1. Nerve injury
2. Hematoma
3. Local anesthetic systemic toxicity
4. Allergic reaction
5. Infection
6. Myotoxicity
7. Secondary injury

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Procedure: Peripheral Nerve Evaluation

**AUTHORS:**

**EDITORS:**

*Navjit Dullet*
Peripheral Nerve Evaluation

Indications
1. Ultrasound examination of peripheral nerves allows for dynamic imaging of neurological structures, which may be useful in the evaluation of peripheral nerve disease, entrapment, trauma, tumor, or infection. Ultrasound examination can typically be performed faster than MRI evaluation. Additionally, ultrasound examination of peripheral nerves can provide visualization for targets of nerve blocks.

Goals
1. To visualize peripheral nerves and evaluate for trauma, tumors, mass effect, entrapment, or procedures.

Contraindications
1. There are no absolute contraindications to this procedure.

Procedure
1. Obtain a high-frequency linear transducer. Superficial nerves can be scanned with a 17 – 5 MHz transducer or a 18 – 8 MHz transducer.
2. Using anatomical landmarks, proceed with scanning areas that nerves may be located. Start with the short axis at an easy to identify anatomical landmarks (such as the ulnar nerve passing just posterior to the brachial artery), and follow the nerve up or down the extremity.
3. In short axis, the nerve may appear as hypoechoic bundles with hyperechoic material in between (honeycomb pattern). The hyperechoic connective tissue in college and surrounding the hypoechoic nerve fascicles is usually more hyperechoic than surrounding muscle and tendons. Peripheral nerves can be seen in the fat or fascial planes superficial to muscles.
4. Long axis view can also be utilized. In the long axis, the hypoechogenic nerve can be distinguished from the more echogenic tendons/muscles.
5. Some of the imaging findings you may encounter include nerve transection, visualization of a tumor adjacent to the nerve (appears as a soft tissue mass), understanding anatomy (such as if an intervention is planned in proximity to a peripheral nerve), visualization of entrapment syndromes.
6. Nerve entrapment or compression may be seen as proximal dilation/enlargement of a nerve structure, decreased echogenicity, or increased vascularity.
7. Proceed with nerve block procedure if it is planned, advancing the anesthetic needle under ultrasound guidance towards the nerve, however, do not hit the nerve with the needle. Injecting anesthetic posterior to the desired nerve may be enough.

Actionability
1. The visualization of peripheral nerve structures can be used to evaluate for nerve injury, entrapment, mass effect, and help guide procedures. Information can then be used to guide referral to appropriate clinicians.

Possible Complications of Nerve Block
1. Hematoma formation
2. Damage to adjacent structures
3. Local infection
4. Pneumothorax (depending on nerve location)

Images

Image: example of visualization of the median nerve in carpal tunnel syndrome. Note proximal enlargement. Image from radiopaedia.org.
Image: example of short axis view of the median nerve. Nerve appears as a hypoechogenic structure, while tendons are echogenic. Image from radiopaedia.org.

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Procedure: Foreign Body Removal

**AUTHORS:**
Jonathan Barclay

**EDITORS:**
Dinh-Huy D. Nguyen
**Foreign Body Removal**

**Goal**
1. To remove soft-tissue foreign bodies under local anesthesia and ultrasound guidance.

**Indications**
1. Patients with suspected or diagnosed soft tissue foreign bodies.
   a. Foreign bodies are typically the results of accidents in the home or workplace and consist of wood, metal, or glass.
   b. Beware standard x-rays may not detect organic or plastic foreign bodies.
2. Removal of foreign bodies with small entry holes, where the risks of surgical removal outweigh the benefits.

**Relative Contraindications**
1. Longstanding foreign body – surgery is indicated in order to deal with potential supervening complications.
2. Open wounds
3. Associated lesions to neurovascular structures or tendons requiring surgical repair

**Absolute Contraindications**
1. Patient refusal or inability to consent or cooperate.

**Consent**
1. US guided FB removal is minimally invasive and carries a low risk of complications, steps are taken to minimize these risks. Patients should be informed of potential complications including:
   a. Infection
   b. Injury to surrounding tissues
   c. Bleeding
   d. Scarring
2. Failure to remove a foreign body with ultrasound guidance does not preclude traditional surgical removal.

**Procedure Preparation**
1. Begin with diagnostic ultrasound to establish the exact location of the foreign body.
   a. Identify any nearby structures (vessels, nerves, tendons).
   b. Plan out a potential safe and feasible approach to the foreign body, avoiding nearby structures.
   c. Acquire diagnostic images.
2. Gather materials for procedure:
   a. Sterile ultrasound kit
   b. 22- or 25-G needle syringe
   c. Lidocaine or other preferred local anesthetic
   d. Scalpel
   e. Surgical forceps
   f. Steri-Strips and/or sutures, sterile dressing
3. Position the patient to allow easy access to the suspected foreign body based on the diagnostic scan.

**Procedure**
1. Prep the patients skin under sterile conditions.
2. Visualize the foreign body once again using ultrasound.
3. Inject a small amount of local anesthetic subcutaneously to numb the planned needle insertion site.
4. Using an “in-plane” approach, insert the needle to the foreign body, following your planned path to avoid any vulnerable surrounding structures.
5. Inject a small amount of local anesthetic (e.g., 2-3mL lidocaine) close to the foreign body.
   a. In many cases, injecting the anesthetic next to the foreign body will help separate it from surrounding tissues, and make removal easier.
6. Slowly retract the needle while continuing to inject local anesthetic in order to numb the path prior to removal.
7. Under constant ultrasound guidance, make a small incision at the needle insertion site using the scalpel.
   a. The incision should be just large enough for the surgical forceps to be inserted into, or in the case of a larger foreign body, wide enough for the foreign body to pass through.
   b. The scalpel should be inserted until its tip reaches the foreign body in order to create a path between the foreign body and the skin surface.
8. While maintaining ultrasound guidance, use your dominant hand to insert the surgical forceps through the incision.
9. Use arms of the forceps to displace the tissues surrounding the foreign body and grip it.
10. Slowly remove the forceps and foreign body
11. Use ultrasound to ensure there are no remaining foreign body fragments.
12. Disinfect the skin area once again and close the incision with either steri-strips or sutures depending on its size.
13. Prescribe antibiotic prophylaxis to prevent any iatrogenic septic complications caused by manipulation of the foreign body (e.g., Augmentin 1g bid for 7 days).

Image: Forceps being used to grasp and remove foreign body under ultrasound guidance. Image from Callegari et al. Ultrasound-guided removal of foreign bodies: personal experience.

References
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THE ESSENTIALS OF BEDSIDE US GUIDED PROCEDURES

Brought to you by:
Education Committee of the ICU Service Line- Resident and Fellow Section, Society of Interventional Radiology

Procedure: Ultrasound Diagnosis of Subperiosteal Abscess

AUTHORS: NAVJIT DULLET

EDITORS:
Ultrasound Diagnosis of Subperiosteal Abscess

Indications
1. Subperiosteal abscess can be a complication of osteomyelitis. Common sites of involvement include the metaphysis and the orbit, secondary to proximity to sinuses. Subperiosteal abscess may require surgical draining, as delay may result in bone necrosis. Subperiosteal abscesses are more frequently found in pediatric patients compared with adult patients.

Goals
1. To identify a subperiosteal fluid collection in the setting of infection to aid management and/or referral for drainage.

Contraindications
1. There are no absolute contraindications to ultrasound examination of suspected subperiosteal abscess.

Procedure
1. Identify an area of interest based on patient symptoms (pain, redness) or alternative imaging (such as a prior x-ray).
2. Obtain a linear transducer (13 – 6 or 15 – 6 MHz).
3. Scan over the region of interest in both the transverse and longitudinal planes. The cortex of normal bone appears as a dense echogenic band. Muscle layers appear hypoechoic with linear bands running across.
4. If a subperiosteal abscess or fluid collection is present, there will be subtle cortical changes. There will be a raised peristemeum, which may appear as a thin echogenic band that appears more proximal to the dense echogenic band representing the cortex. The raised peristemeum may not be clearly visible. In between these 2 echogenic regions, there will be a hypoechoic/anechoic region, representing the fluid collection. If the raised peristemeum is not clearly visible, a subperiosteal abscess may appear as a hypoechoic/anechoic collection lying adjacent to the echogenic band of the cortex.
5. This fluid collection can either be drained with needle aspiration, through surgical intervention, or treated with antibiotics.

Actionability
1. This exam may show the presence of a hypoechoic region adjacent to the cortex, representing a subperiosteal abscess. Correlation with other clinical markers, such as CRP, WBC can guide management decisions. The treatment options for subperiosteal abscess include needle drainage, surgical removal, or medical management with antibiotics.

Image

![Image: Subperiosteal Abscess. Image from Weenders et al. Subperiosteal abscess in a child. Trueta’s osteomyelitis hypothesis undermined.]

References
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Procedure: Ultrasound Guided Joint Steroid Injections

AUTHORS:

Editors:

Navjit Dullet
Ultrasound Guided Joint Steroid Injections

Indications
1. Pain secondary to inflammatory joint conditions, such as osteoarthritis, bursitis, rheumatoid arthritis, tendinitis, muscle strain among others
2. Pain secondary to joint condition that requires excessive amounts of oral or IV pain medications, or pain that is not adequately controlled by oral or IV pain medication

Goals
1. Utilize ultrasound imaging to guide steroid injections of joints, tendons, or other soft tissue structures

Contraindications
1. Caution should be used if a patient is on anticoagulation. For deeper injections, goal INR should be below 1.5. For superficial injections, INR can be between 2 and 3.
2. Infection in proximity to the targeted area of interest (osteomyelitis, cellulitis, etc).

Preoperative Preparation
1. Anesthetic and steroid solutions
2. 25-30 gauge needle for anesthetic injection
3. 22-25 gauge needle and 1-10mL needle for injection

Procedure
1. Obtain an ultrasound probe with a frequency suitable for the desired injection location. For shoulders in thinner individuals, a higher-frequency (6 – 13 MHz or similar) linear probe can be used. For patients with a higher BMI or those with a muscular build, a lower frequency probe can be used.
2. Place the patient in a supine or prone position depending on the target structure. The patient should not be sitting up for steroid injection.
3. Identify the area of interest (joint space, tendon, etc.), and scan to understand anatomy. Tendons appear as echogenic fibrillar structures with parallel lines in the longitudinal plane, and multiple dots in the transverse plane. A joint space may appear as a hypoechoic region due to fluid.
4. Approaches for different anatomical structures
   a. Knee: the medial or lateral aspect of the knee, inferior to the patella, is safe for injection. Identify the medial or lateral margin of the patella, and advance the needle under the patella
   b. Hip: use a lower frequency probe to identify the femoral head as well as the femoral vessels. Advance the needle lateral to the femoral vessels towards the visualized joint space. Use color flow to identify additional vasculature, such as the circumflex femoral vessels. Direct the needle towards the lower aspect of the joint capsule, while keeping the femoral neck and joint space and long axis
   c. Wrist: utilize a high-frequency probe (around 15 MHz, hockey-stick probe).
   d. Shoulder: Place a high-frequency probe in the bicipital groove, halfway between the clavicle and the anterior axillary fold. Long head of the biceps tendon can be visualized. Move the probe more easily in order to visualize the subacromial bursa and supraspinatus muscle.
   e. AC Joint: Place US probe in a coronal plane over the AC joint. The anechoic joint space can be visualized in contrast to the echogenic clavicle and acromion. Needle injection can be made from lateral to medial, directed towards the lateral margin of the clavicle. Subacromial joint space is approximately 4mm below the capsule.
   f. Other joint spaces that can be treated are the GH joint space, Subacromial/Subdeltoid bursa, common flexor tendon, ulnar collateral ligament, lateral epicondyle, wrist/radial/ulnar joint, and more. Applications for joint injection can be seen in The Atlas of Ultrasound Guided Musculoskeletal Injections
5. Sterilize the region of interest. Place ultrasound probe cover on ultrasound probe. Advance a needle (25gauge) while aspirating. Once the area of interest is reached, inject an anesthetic solution. This is then followed by a steroid solution. Caution with mixing steroid injection and anesthetic as this may result in clumping.
6. Medication dosing:
   a. Hydrocortisone: 10-25mg for small joints, 50mg for large joints
   b. Methylprednisolone: 2-10mg for soft tissue, 10-80mg for large joints
   c. Decadron: 0.5mg-3mg for soft tissue and small joints, 2-4mg for large joints

Actionability
1. This exam allows for more accurate steroid injection for inflammatory pain relief
Complications
1. Infection
2. Bleeding
3. Hemarthrosis
4. Tendinopathy
5. Local tissue atrophy
6. Local tissue necrosis
7. Skin atrophy/depigmentation

References