**POCUS: Point-of-Care Ultrasound**

*This handout contains a written transcript of the narration in the online presentation. Please review the online presentation for additional material including interactive multimedia content, illustrations, practice questions, references, and audio.*

You can access the online presentation at: [www.apexanesthesia.com](http://www.apexanesthesia.com)

**Case Study**

Gretchen is providing anesthesia for a patient undergoing a robotic-assisted hysterectomy. The patient became hypoxemic several minutes after being placed in the steep Trendelenburg position. The end-tidal CO₂ waveform did not change from baseline, and Gretchen appreciated breath sounds bilaterally. Given the clinical context (i.e., the recent position change), Gretchen considered endobronchial intubation in her differential. She placed a linear array ultrasound transducer on the patient’s chest to assess for lung sliding. While she identified lung sliding on the right, she noted its absence on the left. Gretchen withdrew the endotracheal tube approximately 1.5 cm and the patient’s oxygen saturation improved. She documented the presence of right-sided endobronchial intubation in the electronic medical record, and the surgical procedure began without incident.

As an extension of bedside clinical assessment, point-of-care ultrasound (POCUS) is changing the way we make decisions at the bedside. Several U.S. medical schools, recognizing the inherent value of ultrasound, offer training in its application as early as the orientation period. To keep up with the trends, CRNAs must also become proficient with these techniques. In this objective, we’re going to discuss POCUS in context of evaluating the heart, lungs, stomach, and airway. We intend to orient you to the clinical applications of point-of-care ultrasound, so understand that this is only a starting point on a longer journey to clinical competence. Indeed, there’s simply no substitute for hands-on instruction and a lot of practice.

**Cardiac: Overview**

Point-of-care cardiac ultrasound serves as an extension of the clinical exam that helps us evaluate a wide variety of cardiac complications. With this in mind, it is not intended to replace a comprehensive echocardiographic examination. Instead, its value is that it helps us answer binary (yes/no) questions about the patient’s clinical status. To that end, it provides data that helps us answer a variety of question including:

- Is there left or right ventricular failure?
- Are regional wall motion abnormalities present?
- Is there valvular dysfunction?
- Is there a pericardial effusion?
- Is the patient's volume status adequate?
- Will the patient be responsive to fluids?
- Are there gross signs of chronic heart disease?
- Is there an intracardiac mass?

Repeat assessment during perioperative care can provide valuable insight into changes in patient status. To obtain the most reliable information, it’s recommended that the cardiac structures should be viewed in at least two planes.
Cardiac Anatomy: Part 1

One of the more challenging aspects of cardiac ultrasound is that we must use our mind’s eye to compile a series of two-dimensional images into a three-dimensional model of the patient’s heart. So, before we discuss cardiac imaging, we’re going to briefly review the cardiac anatomy required to help us better understand and interpret our ultrasound images.

The heart resides in the mediastinum, deep to the sternum and superior to the diaphragm. Note that the long axis of the heart is not the same as the long axis of the body. The apex of the heart is on the patient’s left at the fifth intercostal space in the midclavicular line. This is where you’ll find the point of maximum impulse. The base of the heart is opposite the apex. It forms the upper border of the heart, and it lies just inferior to the second rib. The base contains the atria, and it’s also where the great vessels connect to the heart. Know that the right ventricle is anterior relative to the left ventricle, and that the left ventricle is posterior and lateral to the right ventricle.

The pericardium is a fluid-filled sac that envelops the heart and the proximal regions of the great vessels. The outside is called the fibrous pericardium. The inside is called the serous pericardium, which can be divided into two parts – the parietal layer and the visceral layer. The pericardial cavity is a potential space between the parietal and visceral layers, and it contains about 10 – 25 mL of serous fluid that provides lubrication as the heart beats inside the mediastinum. Excess fluid or blood inside the pericardial cavity is called pericardial effusion, and this can constrict the heart’s movement contributing to tamponade physiology.

How does the heart receive its blood supply? The left and right coronary arteries (LCA and RCA) arise from the aortic root. The LCA divides into the left anterior descending and circumflex arteries. Knowing the two margins of the heart helps us better understand the nomenclature of the coronary vessels. The right side has a more acute margin, while the left side has a more obtuse (or less acute) margin. So, the right RCA gives rise to acute marginal branches and the circumflex gives rise to obtuse marginal branches. The LAD courses along the septal groove, where it gives rise to several septal branches as well as diagonal branches that supply the anterior wall of the left ventricle. As we move to the posterior view of the heart, you can see the posterior descending artery. In about 80% of patients, the RCA supplies the PDA, and we call this right dominance. In the remainder of patients, the circumflex or the RCA and the circumflex supply the PDA, and we call this left dominance and co-dominance, respectively. The coronary sinus resides in the posterior AV groove, and it’s the primary drainage point for the cardiac venous blood.

How does blood flow through the heart? There are two atria and two ventricles. The atria are separated by the atrial septum, and the ventricles are separated by the ventricular septum. The right and left atria receive blood from the systemic and pulmonary circulation, respectively. The atria serve a reservoir function, and they act as priming mechanisms for the ventricles. Blood passes from the RA to the RV through the tricuspid valve, and blood traveling from the RV to the pulmonary arteries passes through the pulmonic valve on its way to the lungs. Blood returning from the lungs (via the pulmonary veins) enters the LA, and then it flows across the mitral valve to enter the left ventricle. The left ventricle pumps blood across the aortic valve, where the blood then flows into the aorta on its way to the systemic circulation.

Cardiac Anatomy: Part 2

Now that we’ve reviewed the essential cardiac anatomy, take a few minutes to review the anatomy of the great vessels and their relationship to each other as well as the relative positions of the four cardiac chambers. We’re going to view the heart from four angles to develop your three-dimensional understanding. This exercise will help you better understand the sonoanatomy in the next section. Click each view to learn more.
Cardiac: Technique

The basic cardiac exam relies on three standard imaging windows: parasternal, apical, and subcostal. Although we can obtain many imaging views through these three standard imaging windows, the basic cardiac ultrasound examination is typically comprised of five core views that include parasternal long-axis, parasternal short-axis, apical 4-chamber, subcostal 4-chamber, and subcostal inferior vena cava. Over the next several pages, we'll discuss each of the core views and address the following questions about each one:

- How do I obtain the view?
- What structures should I see?
- What can this view tell me?

As we discussed in the ultrasound objective, we'd like to remind you that the cardiology convention is different than the conventional radiology (or abdominal) settings. When using cardiac settings, the transducer's orientation marker should point to the patient's anatomic left, and the orientation marker on the screen appear will appear on the top right.

Parasternal Long-Axis

It's best to place the patient in the left lateral decubitus position, as this brings the heart closer to the anterior chest and reduces the influence of lung artifact. Alternatively, the patient can be positioned supine. Place a phased-array transducer just left of the sternum at the third or fourth intercostal space (although a window may be obtained anywhere between the second and fifth intercostal space). Point the orientation marker towards the patient's right shoulder. The ultrasound beam should cut along an imaginary line running from the patient's right shoulder to his left hip, as this should approximate the long axis of the heart.

The optimal image includes the mitral and aortic valves as well as the left atrium, left ventricle, left ventricular outflow tract, aorta, a small portion of the right ventricle, and pericardium. The anteroseptal and inferolateral walls of the LV are visible. For this view and the others that follow, you can click to show and hide the illustration that’s superimposed over the ultrasound video.

The parasternal long-axis view is primarily used to assess left ventricular function, where we look for wall motion abnormalities, the extent of myocardial thickening during systole, and E-point septal separation. If the tip of the anterior leaflet of the mitral valve comes within 1 cm of the septum during systole, then we can reasonably assume that the ejection fraction exceeds ~ 40%.

The parasternal long-axis view can also help you assess chamber size as well as valvular integrity. Do the aortic and mitral valves open well? Are they calcified and possibly stenotic? Is there prolapse or a problem with coaptation? Color Doppler provides additional insight into valvular function, and it’s important to pay attention to the direction of blood flow in the context of the cardiac cycle. For instance, you would expect to see the jet of mitral regurgitation during ventricular systole.

The parasternal long-axis view will also aid in the identification of dynamic obstruction of the left ventricular outflow tract as well as pericardial effusion. Know that a pericardial effusion will reveal fluid anterior to the descending thoracic aorta, while a left plural effusion will be posterior to the descending thoracic aorta.

Parasternal Short-Axis

Starting with the previous position, rotate the transducer 90 degrees clockwise so the orientation marker points to the patient’s left shoulder. Take care not to slide the transducer during the rotation.

Although you can obtain several different views in the parasternal short-axis, the mid-ventricular level is the most important
during the basic cardiac exam. You should see both papillary muscles of the left ventricle. To prevent errors in interpretation, it’s essential that the left ventricular cavity appears circular and not like an oval (which suggests that you’re off-axis). Of the five core views, the parasternal short-axis is the only one where you can see the six segments of the left ventricle. As a general rule, the LAD perfuses the anterior segment of the LV, the circumflex perfuses the lateral LV, and the right coronary artery perfuses the posterior LV.

The parasternal short-axis view at the mid-ventricular level allows you to assess left ventricular function as well as segmental wall motion. Also, you can assess septal movement in the context of right ventricular motion, where bowing of the septum towards the left ventricle suggests right ventricular dysfunction.

**Apical 4-Chamber**

Next, we’re going to obtain the apical window to obtain a 4-chamber view. With the patient in the left lateral decubitus position, place the probe at the point of maximum impulse. This is usually just inferolateral to the left nipple in men and under the inferolateral quadrant of the left breast in women. Point the transducer’s orientation marker to the patient’s left side with the ultrasound beam pointing towards the patient’s right shoulder. When compared to the parasternal views discussed earlier, it’s typically more difficult to obtain a high-quality apical 4-chamber view.

When the transducer is placed correctly, the septum should run vertical and reside in the middle of the screen. In this view, we can see the four cardiac chambers as well as the mitral and tricuspid valves. Note that the left side of the heart appears on the right side of the screen. The anterolateral and inferoseptal walls of the LV are visible.

The apical 4-chamber view helps us assess and compare right and left ventricular size and function. Additionally, we can evaluate the integrity of the mitral and tricuspid valves.

**Subcostal 4-Chamber**

With the patient supine, place the transducer in the midline just inferior to the xiphoid process. The transducer’s orientation marker should point to the patient’s left side. You may need to apply a good amount of pressure, which can be uncomfortable for some patients. Asking the patient to bend his knees may help relax the abdominal musculature. If excess bowel gas impedes your view, you can use the liver as your acoustic window by sliding the transducer to the patient’s right.

You should be able to visualize the four cardiac chambers, where the right ventricle resides closest to the top of the screen. The septal and lateral walls of the LV are visible.

You can access right ventricular function, where the free wall of the right ventricle is uniquely visualized in this view. Also, you can compare the relative sizes of the right and left ventricular cavities. Finally, the subcostal 4-chamber view is the most sensitive view for assessing pericardial fluid and thus the presence of pericardial effusion. To this end, it’s the best view to assess the degree of right-sided chamber collapse in the setting of pericardial tamponade.

**Subcostal Inferior Vena Cava**

From the subcostal 4-chamber view, rotate the transducer 90 degrees. From here, you can tilt the beam in the posterior direction.

The ideal image reveals the inferior vena cava in long-axis and places the IVC-right atrial junction in the middle of the screen. In some patients, it’s easy to confuse the aorta with the IVC. The aorta pulsates during systole, has a thicker wall, and can’t be tracked to the right atrium. Color Doppler won’t help here, because the aorta and IVC may exhibit pulsatile flow. In the patient who is spontaneously ventilating, the diameter of the IVC will decrease during inspiration and increase during
expiration. Conversely, during mechanical ventilation the diameter of the IVC increases during inspiration and decreases during expiration.

Assessing the diameter of the IVC throughout the respiratory cycle provides insight into the patient’s volume status. IVC collapse suggests hypovolemia. Assessing volume responsiveness tends to be most accurate in patients who are mechanically ventilated, where IVC distension of at least 12 – 18% during inspiration predicts fluid responsiveness. M-mode is useful in this calculation. IVC dilation is highly specific for pericardial tamponade. If the IVC is not dilated (less than 2.5 cm) and you observe respiration variation, then you can reasonably rule out tamponade physiology.

**Gastric: Overview**

Pulmonary aspiration of gastric contents is a major anesthetic-related complication that contributes to perioperative morbidity and mortality. The severity of aspiration is based on three things: the pH, volume, and makeup of the gastric contents. While we've traditionally relied on fasting guidelines to assist with risk stratification, these guidelines have several shortcomings. For instance, they're dependent on obtaining an accurate patient history, and they fail to account for a variety of conditions that may impact gastric emptying.

Point-of-care gastric ultrasound helps us determine the character and volume of material in the patient’s stomach, and the literature shows a high degree of sensitivity and specificity for the detection of a full stomach. Therefore, point-of-care gastric ultrasound helps us answer the question of, “is the patient at risk for aspiration or not?” In this way, gastric ultrasound informs clinical decision making in three types of situations:

1. The patient’s NPO status is unknown (such as a language barrier, depressed level of consciousness, or cognitive dysfunction).
2. There’s a lack of adherence to fasting instructions (such as an emergent or urgent procedure).
3. There’s a likely delay in gastric emptying (such as diabetic gastroparesis, critical illness, trauma, pregnancy, chronic opioid use, or neuromuscular disease).

**Gastric: Anatomy**

The anatomy of the stomach is relatively simple. There are two sphincters that control the entrance and exit of food, where the lower esophageal sphincter resides at the gastroesophageal junction, and the pyloric sphincter resides at the junction of the pylorus and duodenum. The body of the stomach comprises most of its mass, the fundus is located near the top, and the antrum resides in the lower region of the stomach. The purpose of the antrum is to hold food until it is released to the small intestine, and it’s the primary anatomy of interest for assessment of gastric contents. Why is this? On gastric ultrasound, the pylorus often appears empty even when food remains in the stomach (this could yield a false-negative result), and the body of the stomach can be difficult to visualize due to air that’s often inside. For these reasons, our interest lies in the volume of the gastric antrum. Understand that the inferior vena cava runs behind the pylorus, and the abdominal aorta runs behind the antrum. Therefore, during gastric imaging these vessels serve as key reference points that confirm that you’re viewing the correct gastric anatomy. The aorta will be oriented towards the patient’s left, and it’ll be pulsatile during systole. By contrast, the IVC will be oriented towards the patient’s right, and it may be pulsatile throughout the cardiac cycle.

**Gastric: Technique Part 1**

The patient should be placed in the right lateral decubitus position. This allows air to rise to the top of the stomach while gravity moves gastric contents in the direction of the pylorus to fill the antrum. Performing gastric ultrasound in the supine position will likely underestimate the volume of gastric contents. A history of gastric surgery or a substantial hiatal hernia may hinder your ability to view the required anatomy. A curvilinear probe is placed midline just below the xiphoid process,
with the transducer’s orientation indicator pointing cephalad. A history of gastric surgery or a substantial hiatal hernia may hinder your ability to view the required anatomy.

You should see the tip of the left lobe of the liver, and just inferior to that you’ll see the antrum of the stomach. Note the anechoic border around the stomach. This isn't fluid, but rather is the muscularis propriae. You can see the pancreas deep to the stomach and the aorta is deep to the pancreas. Sometimes, you’ll see the superior mesenteric artery.

Your job is to determine if the stomach is full or empty. If the stomach is empty, the antrum will either appear flat or like a small oval, which is sometimes referred to as a “bull’s eye.” Contents inside the stomach will make the antrum look round and distended. Clear liquids will be anechoic. If the patient drank milk or some other non-clear liquid, then these fluids will likely appear hyperechoic. Solid food will appear as bright particulate matter in the antrum.

**Gastric: Technique Part 2**

How do our findings affect clinical decision making? If the antrum is empty (grade 0), then there’s a low risk of aspiration. If there’s only clear fluid, but the gastric volume is less than 1.5 mL/kg, then there’s also a low risk of aspiration (Grade 1). For context, greater than 95% of fasted patients present with a grade 0 or 1. If the clear fluid volume exceeds 1.5 mL/kg, then there’s a high risk of aspiration (Grade 2). Additionally, the presence of non-clear fluids (such as milk) or particulate matter suggests a high risk of aspiration. How do we calculate the volume of clear gastric fluid? We need to measure the cross-sectional area (CSA) of the antrum at the level of the aorta with the patient in the right lateral decubitus position. To minimize the influence of measurement error, the CSA value should be the average of three separate measurements. Next, we can input the CSA value into this equation: Gastric volume (mL) = 27 + 14.6 x CSA – 1.28 – age (years).

**Lung: Overview**

In the domain of anesthesia, lung ultrasound has a wide variety of clinical applications including evaluation of pneumothorax, pleural effusion, esophageal intubation, endobronchial intubation, cardiogenic pulmonary edema, and pulmonary embolism. In many situations, lung ultrasound has demonstrated superiority over conventional diagnostic methods such as chest radiography, fluoroscopy, and CT scanning. Additionally, lung ultrasound is an essential part of modern trauma assessment in the form of extended-focused assessment with sonography in trauma examination (or e-FAST) (6). Although we won’t cover e-FAST in this objective, you can learn more with the resources we’ve provided on the learn more tab.

**Lung: Anatomy**

Here’s a brief review of the anatomy you’ll need to perform lung ultrasound.

The thoracic cage is formed the sternum anteriorly, thoracic vertebral column posteriorly, and 12 symmetrically paired ribs on each side. The lungs reside inside, and they extend inferiorly to about the fifth intercostal space. The intercostal muscles reside between the ribs, and they can be divided into the external intercostals, internal intercostals, and innermost intercostal muscles. These muscles are innervated by the intercostal nerves with a blood supply from the intercostal arteries and veins. The parietal pleura can be found deep to the ribs, and the visceral pleura cover the outer surface of the lungs. The potential space between the parietal and visceral pleura is called the pleural cavity, and this region contains a small amount of air and pleural fluid that lubricates the pleural surfaces allowing them slide over one another during inspiration and expiration. The lung parenchyma resides below the visceral pleura.
Lung: Technique

Let’s take a look at the sonoanatomy. Observe the two hyperechoic ribs, and you’ll see the pleura as a hyperechoic line in the intercostal space just below the rib line. The pattern of the two ribs and the pleural line is called the bat sign, where the ribs form the wings, and the pleural line forms the body. Although it looks like the pleura disappears as it passes under the ribs, understand that this is due to a shadow artifact caused by the high tissue impedance of the ribs. An important point to keep in mind is that you can’t really see the lung itself. Recall that aerated lung is well... full of air, and air doesn’t transmit ultrasound very well. So, everything you see deep to the pleura is the result of air artifact. Having said this, this region can contribute vital diagnostic information, so we can’t ignore it. For instance, normal artifacts include A lines and B lines. A lines are horizontal lines that result from reverberation artifact due to the pleura acting as a strong reflector. B lines (sometimes called comet tails) are vertical lines. They can be a normal finding, but they can also suggest pathology such as pulmonary edema.

During normal physiology, you’ll see lung sliding throughout the respiratory cycle. This sign confirms that the parietal and visceral pleura are in apposition and that there isn’t any air or excess fluid between the pleurae. Lung sliding is often described as having a shimmering quality to it. The absence of lung sliding is a key finding of pneumothorax. Although the lack of lung sliding is sensitive for pneumothorax, it is not specific. Indeed, other etiologies such as endobronchial intubation can also abolish lung sliding. Let’s think back to Gretchen in the case study at the beginning of this objective, where she diagnosed endobronchial intubation with ultrasound.

To confirm proper depth of the endotracheal tube, clinicians traditionally auscultate the lungs to confirm bilateral breath sounds. You may remember that Gretchen heard bilateral breath sounds, but you may be surprised to learn that auscultation has low sensitivity and specificity in the diagnosis of endobronchial intubation (1,2). Indeed, there’s good evidence that even in non-stressful environments, experienced clinicians are (at best) able to detect no more than 2/3 of endobronchial intubations by ear alone. This number may deteriorate further when auscultation is performed by less experienced clinicians and in stressful situations. The current evidence suggests that point-of-care lung ultrasound is vastly superior to auscultation in the detection of endobronchial intubation, where ultrasound has a 93% sensitivity and 96% specificity for differentiating tracheal versus bronchial intubation. Knowing these things helped Gretchen quickly and safely manage her patient’s complication.

Airway Assessment

It’s well appreciated that bedside airway assessment suffers from low sensitivity and specificity, so can point-of-care ultrasound helps us more effectively identify patients with a difficult airway? There’s a growing literature in this domain, where investigations look at sonographic evaluation of the airway such as tongue size, neck soft tissue, mandibular mobility, and cervical mobility. Furthermore, airway ultrasound may also be beneficial in predicating difficult mask ventilation. While these findings show promise, more work is required to establish best practices in this domain of airway management. We’ve provided a series of recent articles for additional learning.

Key Points

Point-of-care ultrasound serves as an extension of clinical examination, where its primary purpose is to help us answer binary (yes/no) questions that inform clinical decision making. Examples include: Does the patient have left ventricular failure? What about a full stomach? Does the patient have a pneumothorax?

As ultrasound becomes more ubiquitous in clinical practice, it’s incumbent upon all CRNAs to become proficient with this technology.

Before importing POCUS into practice, one must first master image acquisition and image interpretation. While there are online resources to assist with your learning, there is simply no substitute for hands-on instruction under the guidance of an experienced provider.
### References

**Textbooks:** These books are included on the CPC Exam Bibliography published by the NBCRNA


**Textbooks:** These books are not included on the CPC Exam Bibliography published by the NBCRNA


**Articles:**


