Focused ultrasound for cholelithiasis and acute cholecystitis

Philips tutorial

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Contents

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1 Introduction

Healthcare providers worldwide commonly evaluate patients with undifferentiated abdominal pain. Right upper quadrant (RUQ) abdominal pain due to gallbladder disease is common, however, patients often have insidious presentations that can easily be confused with other abdominal, cardiac, and even pulmonary pathologies.

Assessment of abdominal pain can be challenging for even the most experienced clinician. Point-of-care (POC) ultrasound can be a powerful tool when used in conjunction with the clinical exam to determine the presence of gallbladder disease. Understanding the relevant ultrasonographic findings present in cases ranging from acute cholecystitis (AC) to biliary colic and having a simplified ultrasound technique to locate and image the gallbladder may improve the clinician's ability to identify acute cholecystitis.

Deciding between safely discharging a patient or proceeding to further radiologic imaging can be difficult even for the experienced clinician. The use of point-of-care ultrasound to aid the physician in identifying AC may reduce unnecessary studies and subsequent delays in a busy emergency department.

2 Clinical case

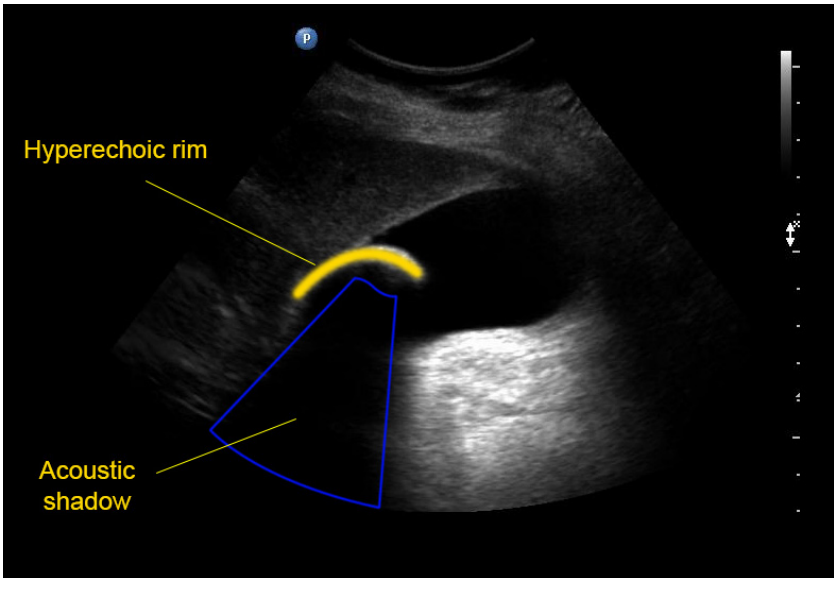
A 45-year-old female presents to the Emergency Department (ED) with complaints of epigastric pain and vomiting. Her past medical history includes diabetes and hypertension. The patient describes her pain as intermittent for the past three days and worsening today after eating a meal. Her vital signs are stable and abdominal examination reveals moderate-to-severe epigastric tenderness. The rest of her physical examination is unremarkable. Appropriate intravenous analgesia and antiemetic therapy are provided. Based on the differential diagnosis, a point-of-care ultrasound exam to identify gallbladder pathology is performed.

3 Identification of acute cholecystitis

The primary goal of the POC ultrasound examination is to determine the presence of gallstones (cholelithiasis) since almost all cases of acute cholecystitis (AC) involve obstructing stones. Ultrasound has been proven to be an extremely sensitive test for the detection of gallstones.[1,2]

With moderate training, non-radiologists performing point-of-care ultrasound for the detection of gallstones have been shown to be highly accurate when compared to radiologist-read "comprehensive" ultrasound studies.[3-5]

Interrogation of the entire gallbladder is necessary to determine the presence or absence of gallstones, paying special attention to the neck of the gallbladder — the location of obstructing stones. Sonographically, gallstones will typically have hyperechoic rims with a resultant acoustic shadowing **[Figures 1a** and **1b]**.



[Figures 1a and **1b]**
Ultrasound image demonstrating the presence of a gallstone. Note the hyper-echoic rim and the resultant acoustic shadow.

Clinicians should be aware of patient risk factors for acalculous cholecystitis. Fortunately, acalculous cholecystitis is uncommon (less than 5% of cases of acute cholecystitis) and most commonly occurs in post-operative patients in the setting of multi-organ failure and during chronic parenteral nutrition.[6] The point-of-care ultrasound exam should not be used to rule out AC in this population.

Secondary findings

Secondary findings of acute gallbladder pathology on ultrasound include:

- Gallbladder wall-thickening
- Pericholecystic fluid
- Sonographic Murphy's sign

Gallbladder wall (GBW) thickness can be measured using ultrasound. The upper limit of normal for GBW thickness is 3-4 mm. Similarly, it is important to remember that inflammation of the gallbladder, causing a thickened appearance of the wall, can be seen in other common pathologies (e.g., hepatitis, ascites, protein-losing nephropathies, etc.). Similarly, it is important to note that after eating, the gallbladder will contract and will appear to have a thickened gallbladder wall.

Pericholecystic fluid due to gallbladder inflammation is a specific sign of AC.[2] Pericholecystic fluid will appear as anechoic space around the gallbladder on ultrasound. Patients with other causes for "third-spacing" of fluid due to increased hydrostatic pressure (e.g., congestive heart failure, etc.) or decreased oncotic (osmotic) pressure (e.g., cirrhosis, protein-losing nephropathy, etc.) may also have pericholecystic fluid.

If a POC ultrasound exam demonstrates the presence of a thickened gallbladder wall or pericholecystic fluid and gallstones are NOT clearly visualized, the clinician should consider the possibility of either a small gallstone in the neck of the gallbladder or other non-gallbladder causes.

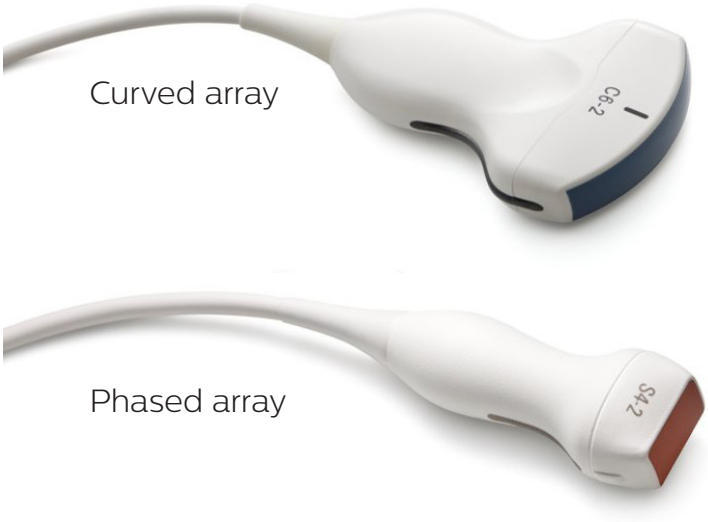
Sonographic Murphy's sign (SMS) is defined as maximal abdominal tenderness due to applied pressure of the ultrasound transducer over the visualized gallbladder. In combination with other sonographic and clinical markers, SMS can be useful in the diagnosis of AC.[7]

Biliary and common bile duct (CBD) obstruction

The localization and determination of biliary obstruction is the most challenging aspect of right upper quadrant ultrasound examination and requires more advanced skills. Studies comparing radiologist-to-emergency physician ultrasound evaluations demonstrate poor intraobserver reliability, with a high level of specificity, but a low sensitivity.[4] Even between radiologists, a high degree of intraobserver disagreement occurs.
The identification of biliary obstruction requires additional training and experience.

4 Ultrasound techniques

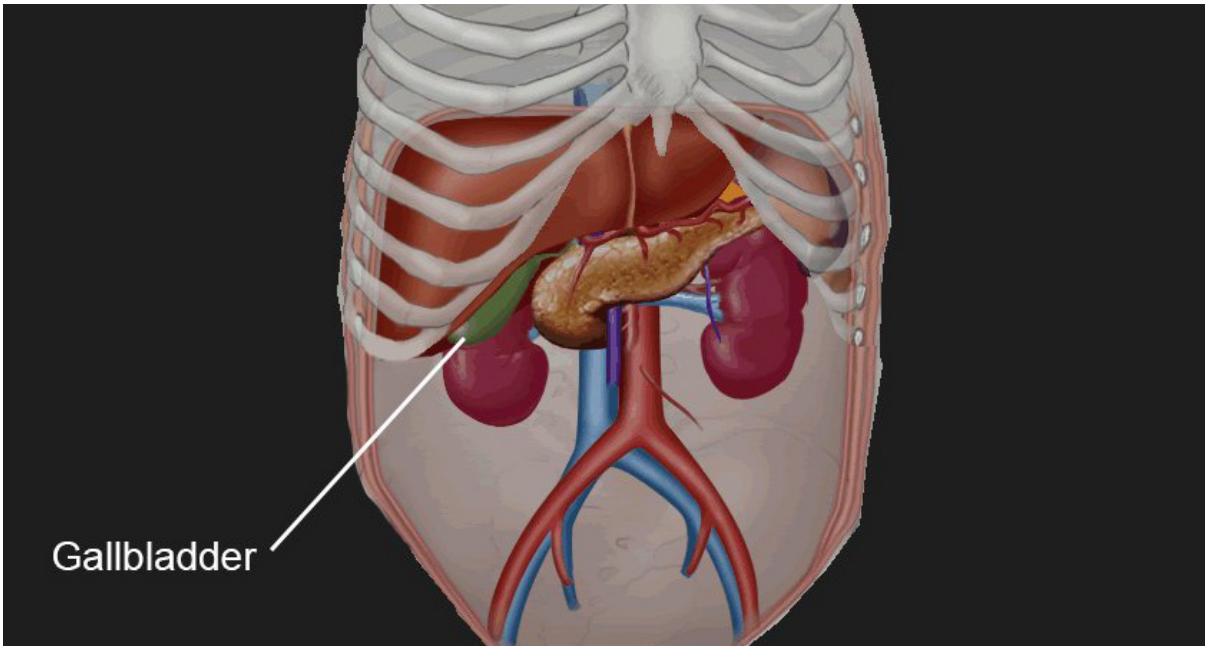
Usually, a low-frequency curved array transducer is used to image the gallbladder; however, a low-frequency phased array transducer can also be used **[Figure 2]**. Low-frequency transducers used to image the gallbladder are usually in the 2-6 MHz range.



[Figure 2]
Low-frequency curved array transducer and a low-frequency phased array transducer.

An “abdomen” exam-type or -preset should be used. The transducer orientation marker will be directed cephalad or to the patient’s right for the gallbladder exam.

The gallbladder is highly variable in shape, size, location and orientation. This can make the gallbladder challenging to image **[Figure 3]**.



[Figure 3] Anatomical illustration demonstrating the position of the gallbladder in the abdomen. The orientation, size, and shape of the gallbladder can be highly variable.

The entire gallbladder should always be scanned in two perpendicular planes to determine the presence or absence of gallstones. The neck of the gallbladder is a common location for gallstones to lodge, which can be the cause of severe pain and unremitting biliary colic. Identification of the portal circulation will help delineate the neck of the gallbladder.

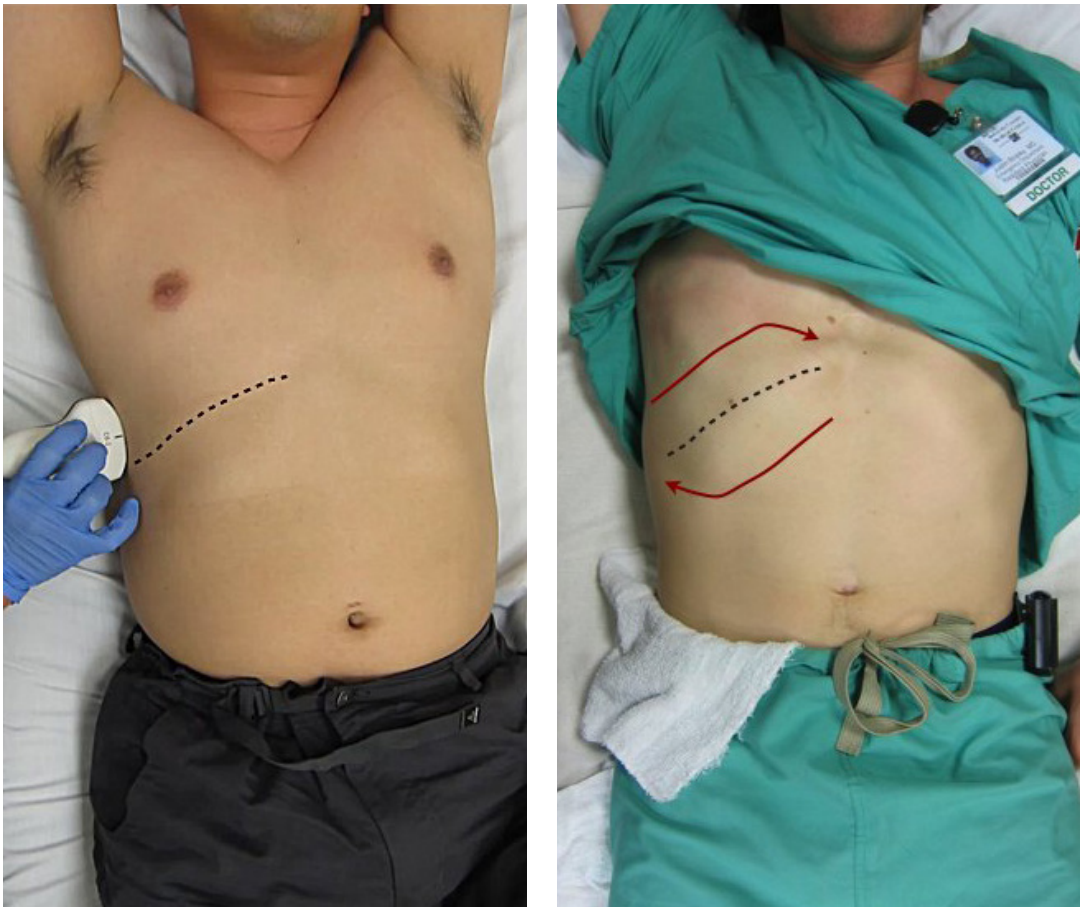
Due to the common presence of bowel gas in the non-fasted ED patient, the classically taught technique of positioning the transducer under the right costal margin often will not provide an adequate view of the gallbladder. The following simplified step-by-step approach can help the novice sonographer reproducibly locate the gallbladder.

Locating the gallbladder

- Place the transducer in the same location as when identifying Morrison's Pouch during a FAST examination (coronal plane in the anterior axillary line with the transducer orientation marker pointing cephalad).

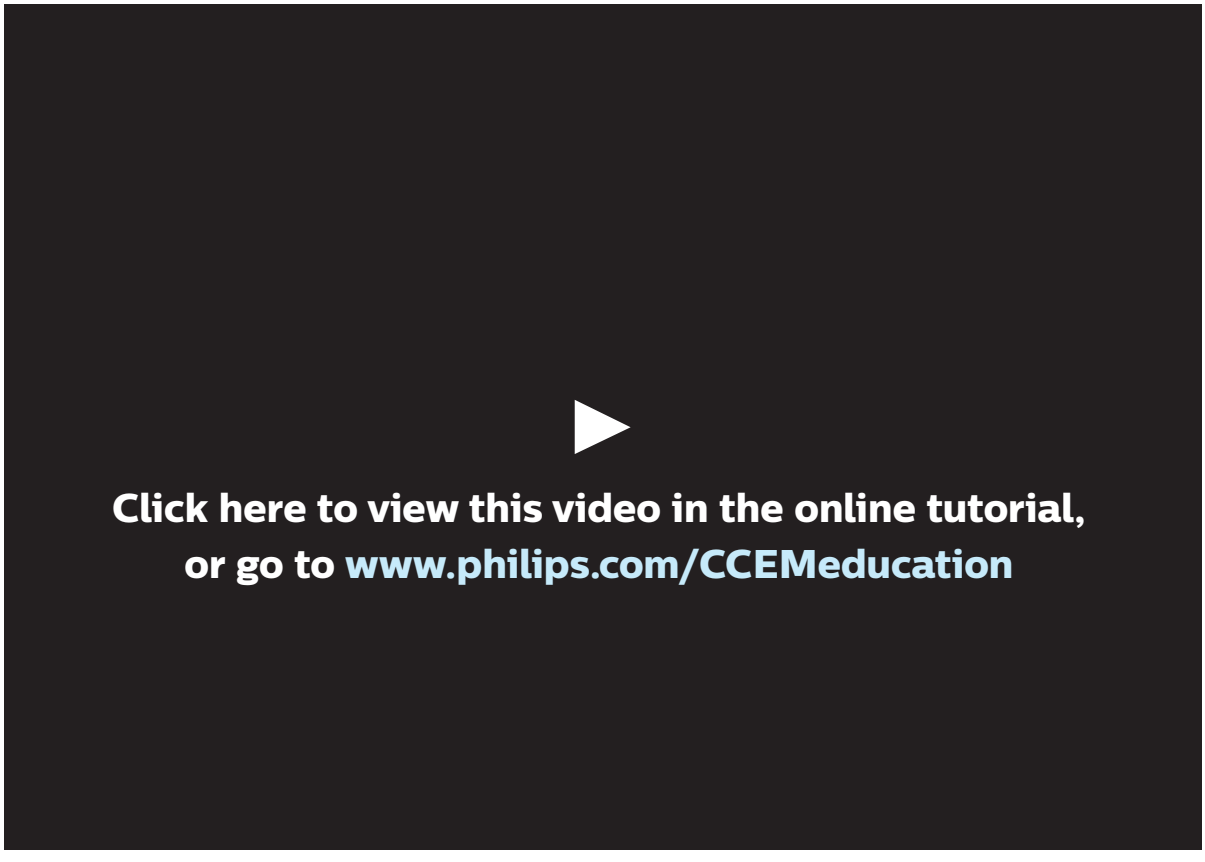
- Slowly slide the transducer above the costal margin medially, aiming the transducer into the abdomen while keeping the transducer orientation marker cephalad **[Figure 4]**. Identify the liver and its vasculature.

- Traverse the entire liver with the transducer, and then slide the transducer below the costal margin. Then move the transducer laterally until an anechoic/fluid-filled structure is located **[Video 1]**.



[Figure 4] Start at Morrison's Pouch and fan the transducer more intraperitoneal *(left photo)*. Sweep above the coastal margin and then come back under the liver *(right photo)*.

[Video 1]

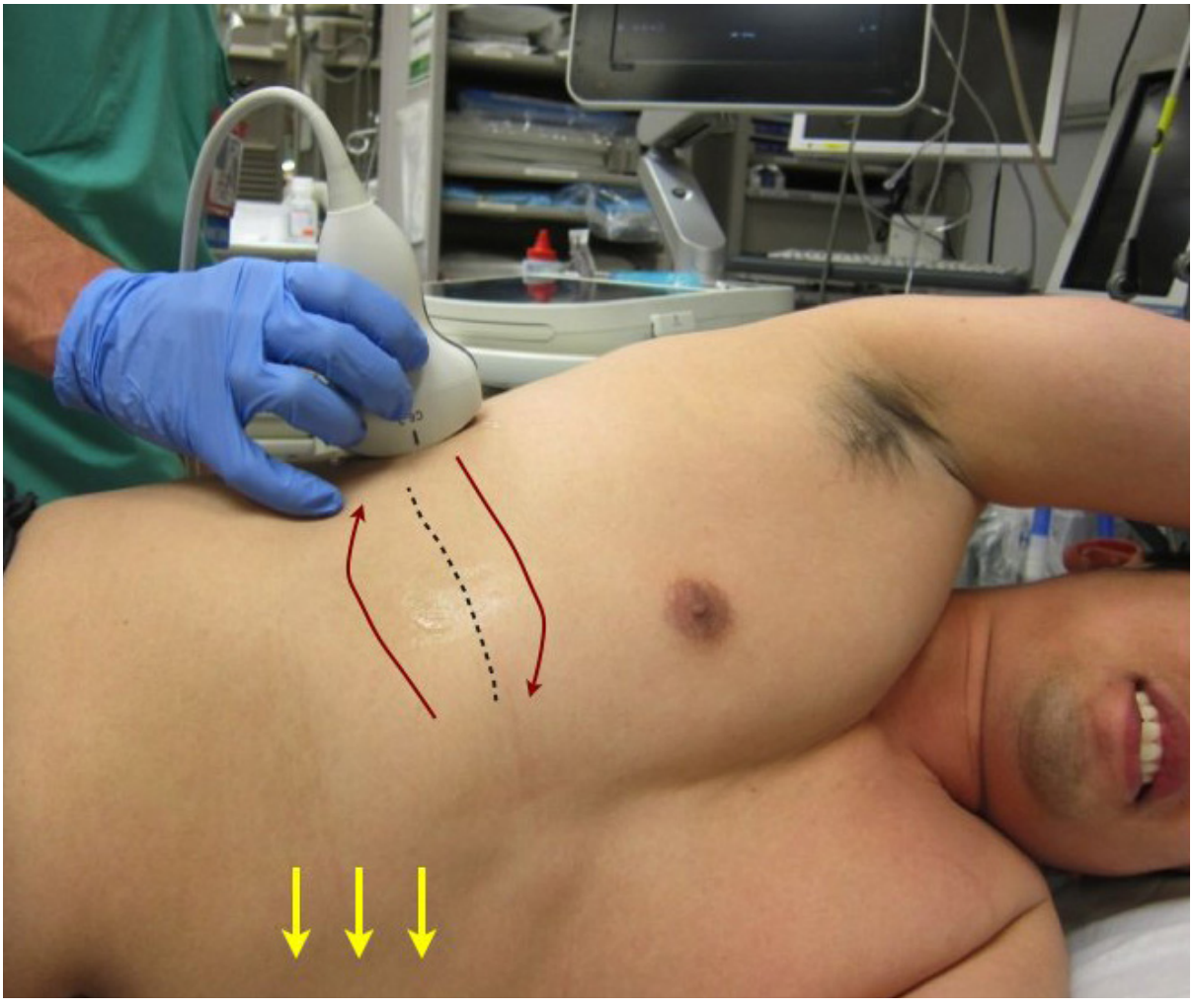


Video demonstrating the position, orientation, and movement of the transducer when locating the gallbladder. Note that the transducer is slid medially above the costal margin, traversing the entire liver, and then slid laterally below the costal margin until the gallbladder is located.

- The gallbladder will appear as a large anechoic/fluid-filled sac in the liver parenchyma surrounded by a hyperechoic wall.

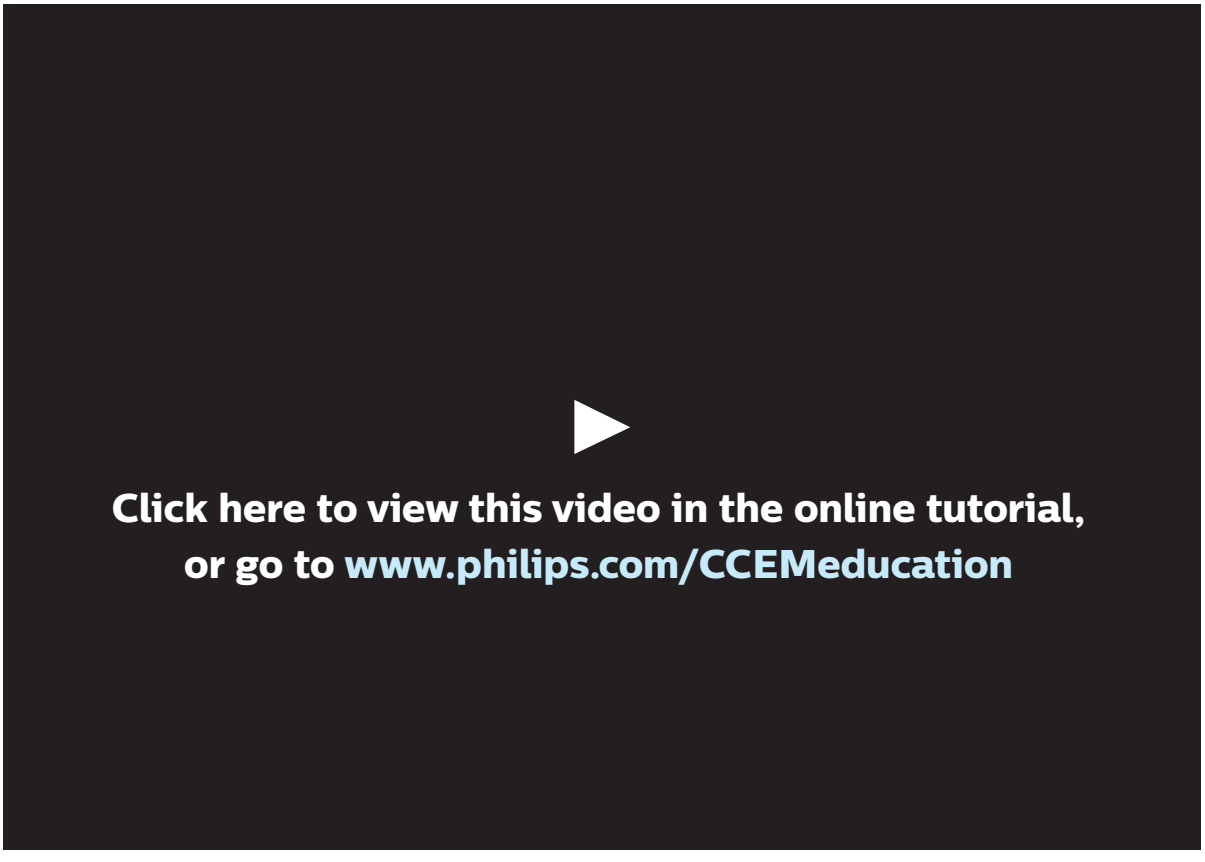
  Tip: Be careful not to falsely identify either the inferior vena cava or other vascular structures as the gallbladder. If needed, color Doppler can be used to differentiate the gallbladder from vascular structures.

- If the gallbladder is not located, move the patient into a left lateral decubitus (LLD) position **[Figure 5]** and repeat the scan (from the lateral aspect of the liver to the midline, and back down under the costal margin) **[Video 2]**. The LLD position will displace bowel gas and often improve the ability to locate the gallbladder.



[Figure 5] Place the patient in LLD position (allowing bowel gas to move to a dependent position) and then sweep above and below the liver again.

[Video 2]



Video demonstrating the position, orientation, and movement of the transducer when locating the gallbladder with the patient in the LLD position.

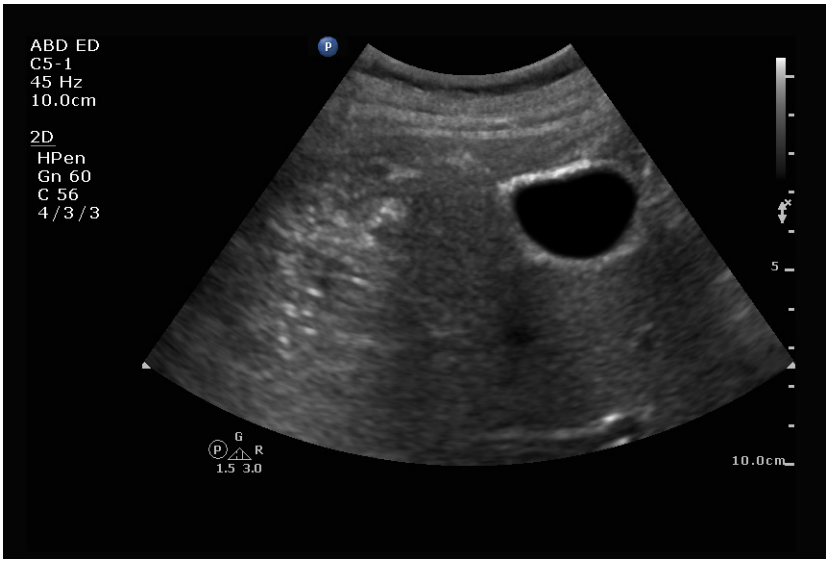
Imaging the gallbladder

- Once the gallbladder is identified, obtain a sagittal (long-axis) view by rotating the transducer in a clockwise manner until a clear view of the entire length of the gallbladder is seen **[Figure 6a]**. Then fan the ultrasound beam through the entire gallbladder to identify the presence of gallstones **[Video 3]**.

- Using this view, the neck of the gallbladder can be identified (it will lie next to the portal circulation). See "Imaging the neck of the gallbladder".

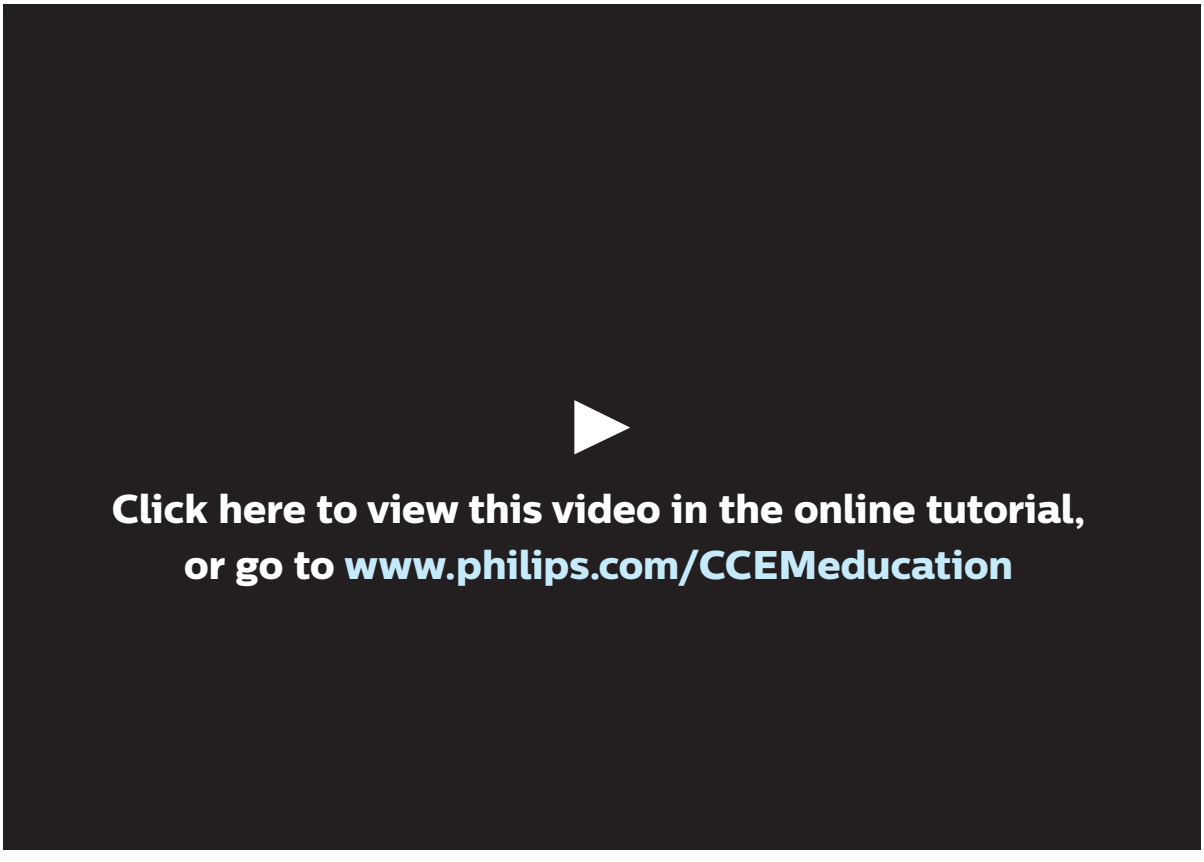
- Rotate the transducer 90° until a transverse view of the gallbladder is obtained (transducer orientation marker will be toward the patient's right side) **[Figure 6b]**. Again, fan the ultrasound beam through the entire gallbladder looking for the presence of gallstones **[Video 4]**.

[Figure 6a]
Image of a sagittal view of the entire length of the gallbladder.



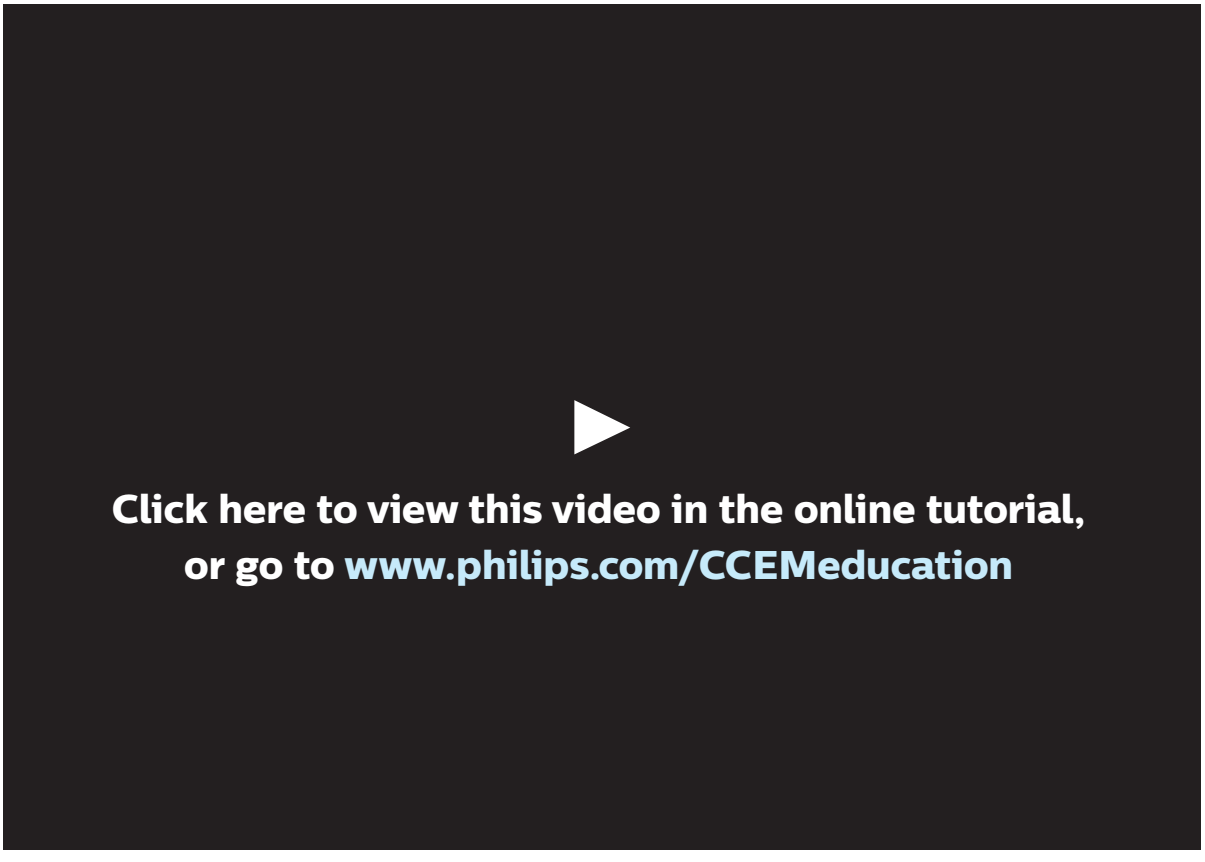
[Figure 6b]
Image of a transverse view of the gallbladder.

[Video 3]



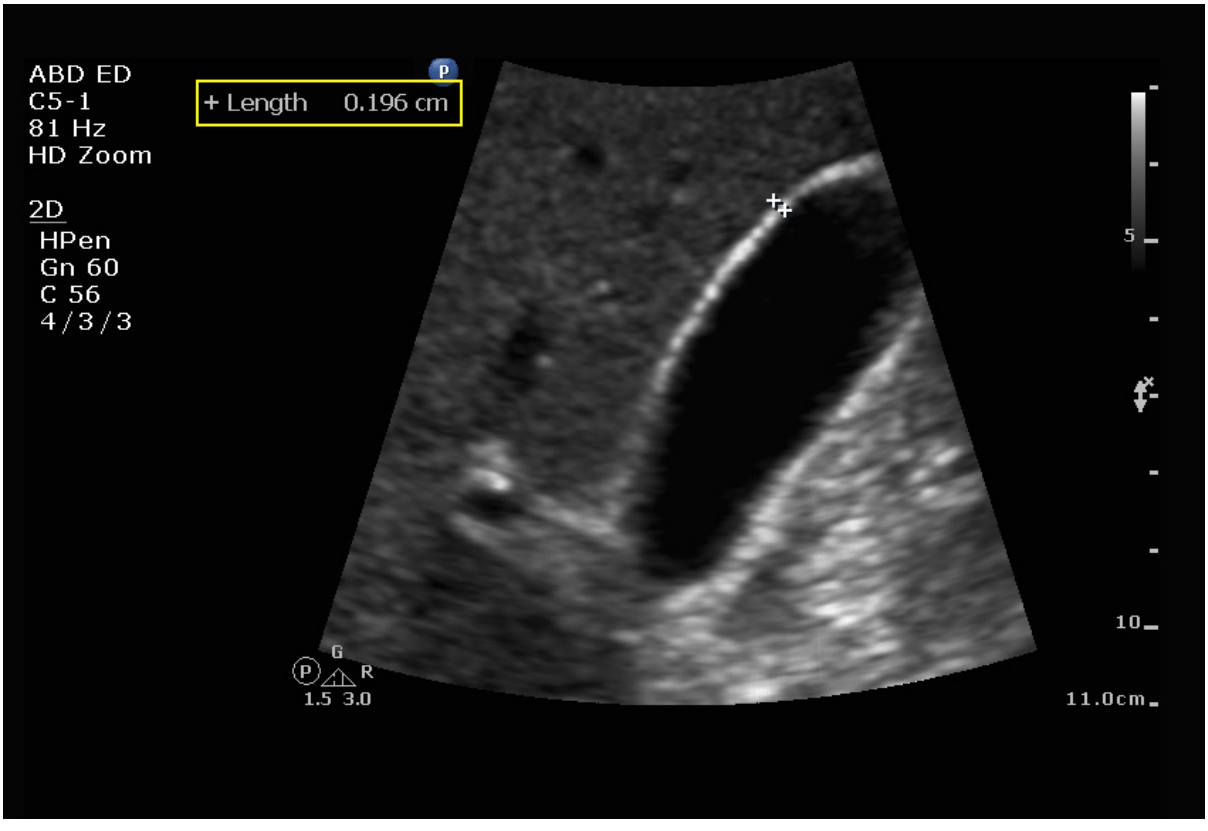
Scan of a sagittal sweep through a normal gallbladder.

[Video 4]

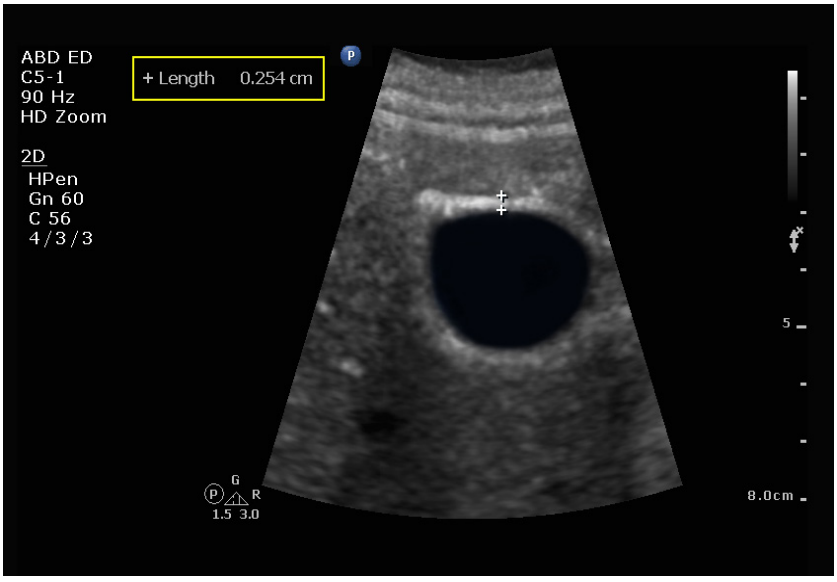


Scan of a transverse sweep through a normal gallbladder.

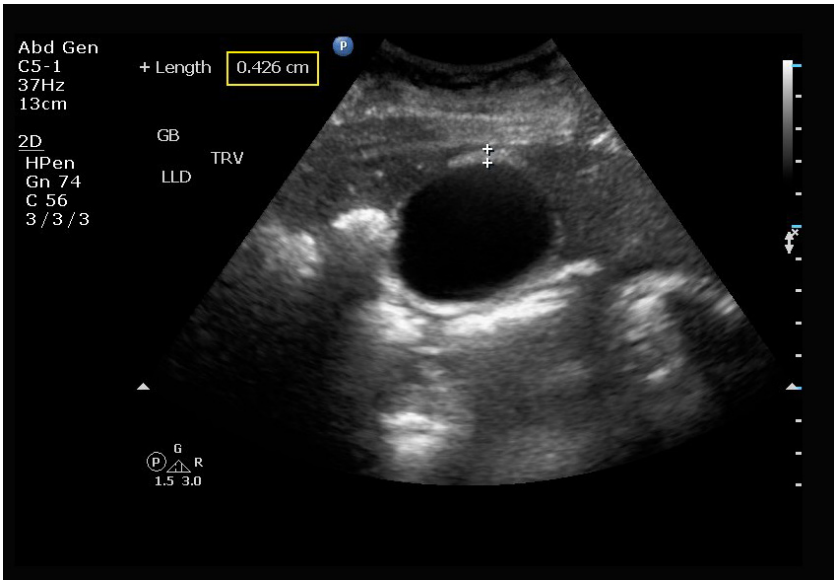
- Measure the anterior wall of the gallbladder. We recommend measuring the most proximal wall of the gallbladder (closest to the transducer) **[Figures 7a, 7b** and **7c]**. The normal gallbladder wall is usually less than 3-4 mm.



[Figure 7a] Measurement of anterior wall of the gallbladder in the sagittal view. This image demonstrates a normal GBW thickness measuring 1.96 mm (0.196 cm). Note that this is a zoomed image.



[Figure 7b]
Measurement of the anterior wall of the gallbladder in the transverse view. This image demonstrates a normal GBW thickness measuring 2.54 mm (0.254 cm). Note that this is a zoomed image.



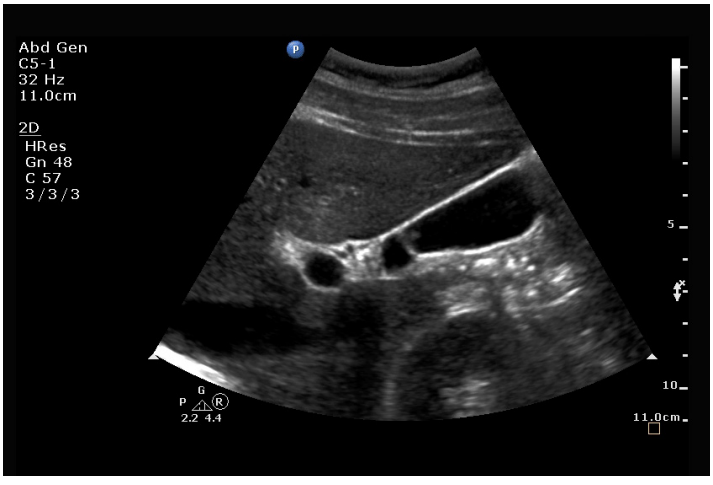
[Figure 7c]
This image demonstrates a thickened gallbladder wall measuring 4.26 mm (0.426 cm). Note that this image is *NOT* zoomed.

Tip: Use the depth and zoom controls to obtain an ideal image for measurements.

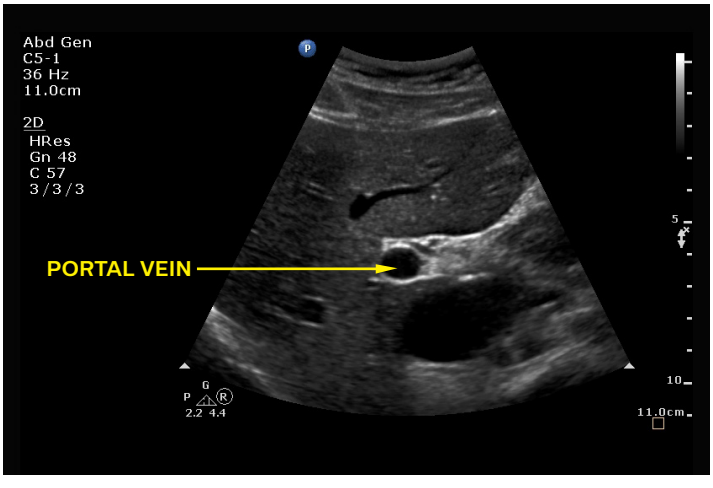
Imaging the neck of the gallbladder

- If possible, we recommend performing this exam with the patient in left lateral decubitus (LLD) position.
- Identify the gallbladder in a long-axis view, then identify the porta hepatis (portal vein, hepatic artery, and CBD). With the gallbladder in the long axis, the porta hepatis will be in the transverse/short axis, resulting in the classic "exclamation point" **[Figure 8a]**.
- The portal vein normally lies below the CBD and hepatic artery at the bottom of the gallbladder neck. In the normal state the portal vein is the largest vessel in the porta hepatis and is easily identified **[Figure 8b** and **Video 5]**.

  Tip: Color flow Doppler can aid in differentiating between portal vein, hepatic artery, and CBD. (The CBD will not have a color flow Doppler signal.)
- Use subtle transducer movements (slight fanning in both a left-to-right manner and cephalad-to-caudad manner) to interrogate the entire neck of the gallbladder.
- After the porta hepatis and, specifically, the portal vein are identified in short axis, rotate the transducer 90° to identify the porta hepatis in the long axis **[Figure 8c** and **Video 6]**.



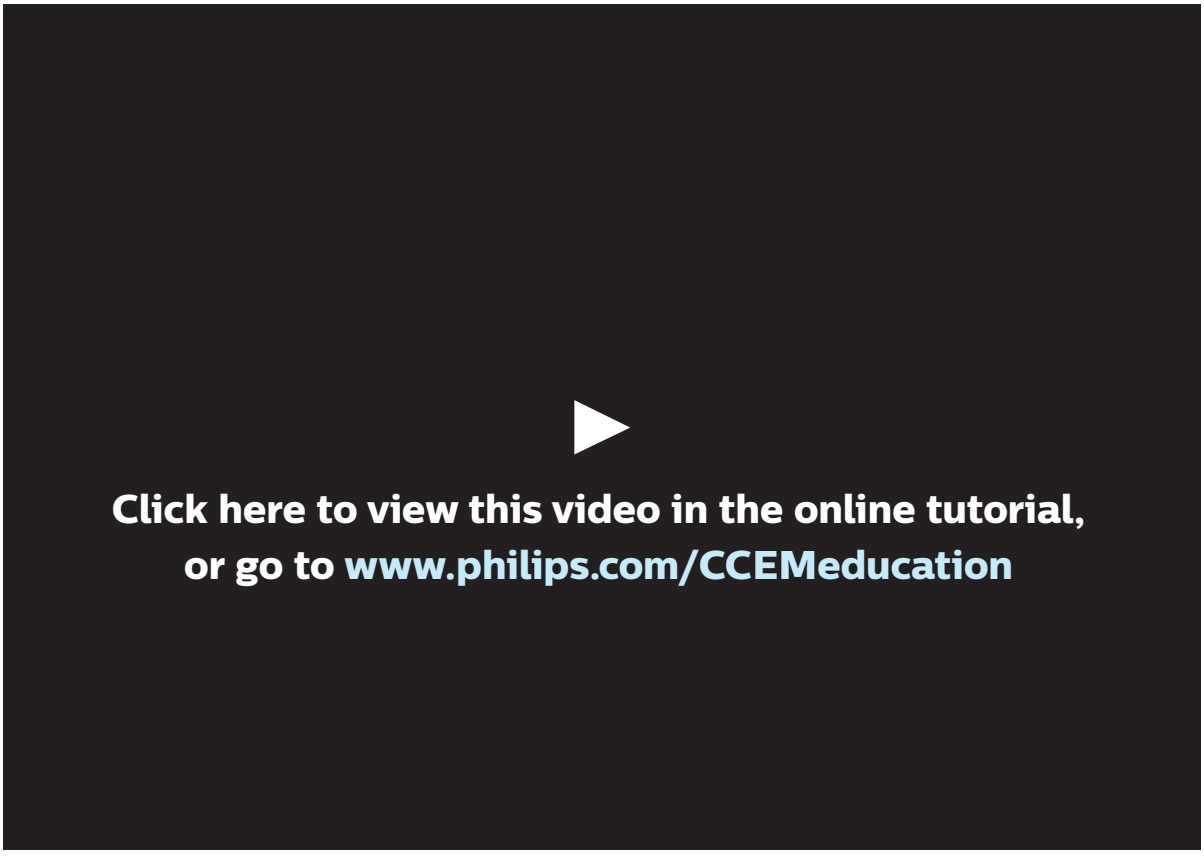
[Figure 8a]
Image demonstrating the classic "exclamation point" – the gallbladder in long axis and the porta hepatis in short axis.



[Figure 8b]
Image demonstrating the transverse view of the porta hepatis (portal vein, hepatic artery, and CBD).

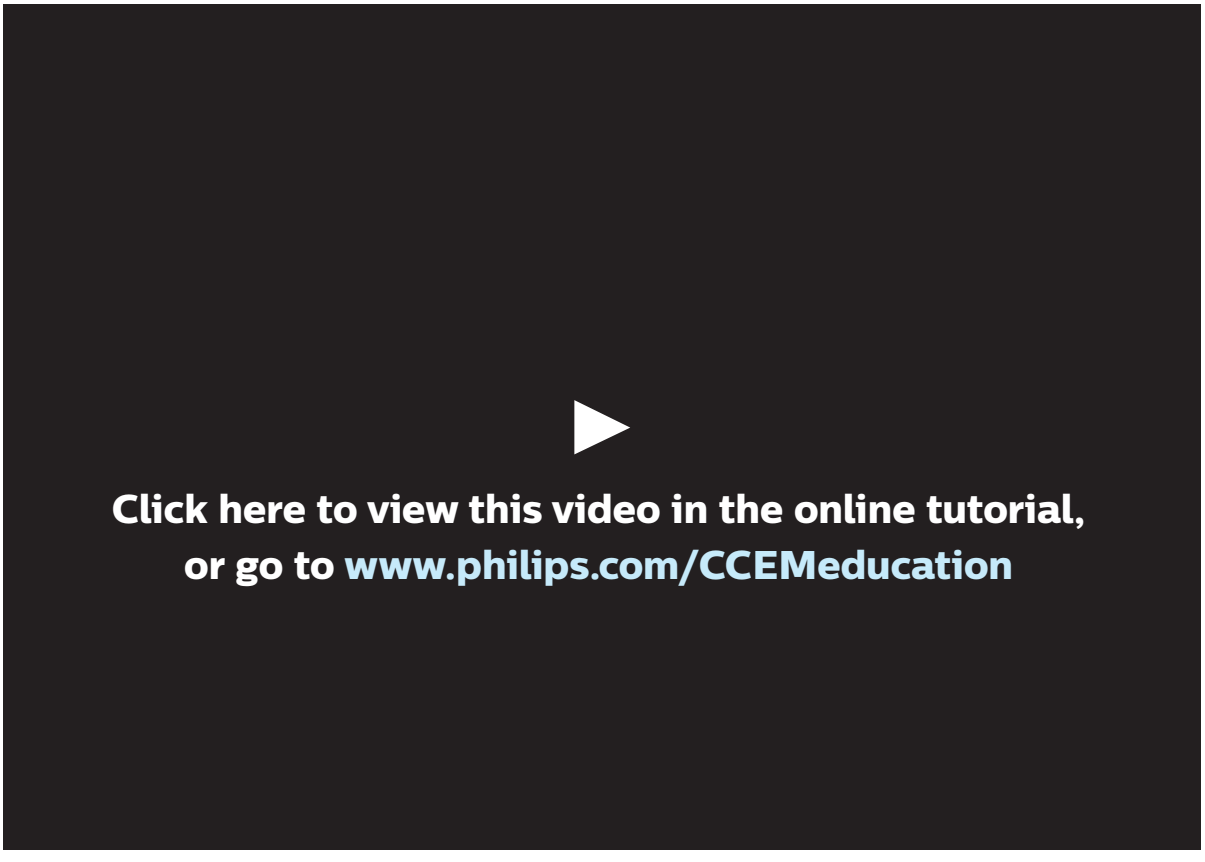
[Figure 8c]
Image demonstrating the long-axis view of the portal vein.

[Video 5]



Video demonstrating the transverse view of the porta hepatis in a normal gallbladder.

[Video 6]



Video of the long axis of the portal vein with color flow Doppler. Color flow Doppler can aid in differentiating between portal vein, hepatic artery, and CBD. The CBD will not have a color flow Doppler signal.

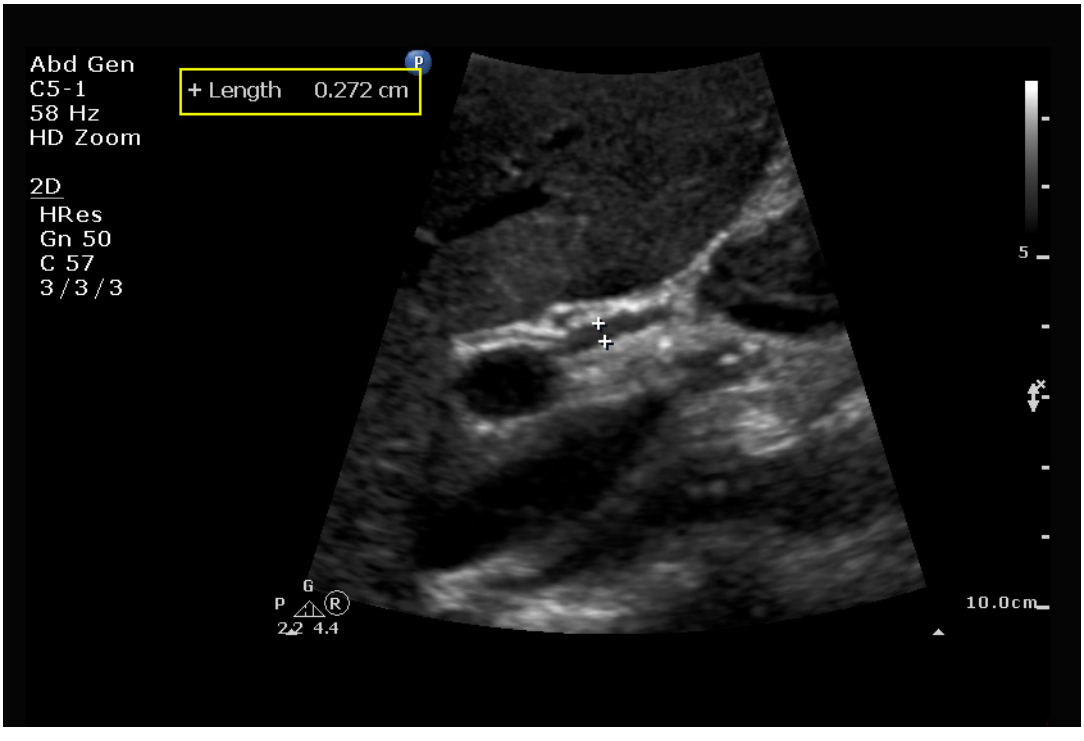
- Because the CBD is often difficult to locate and measure, we recommend evaluating the porta hepatis by specifically looking to see if there are two large tubular vessels present (portal vein and CBD). If two are noted, then we recommend further interrogation and measurement as well as correlation with the clinical picture and laboratory results (bilirubin levels, lipase levels, liver function tests).

Measuring the CBD

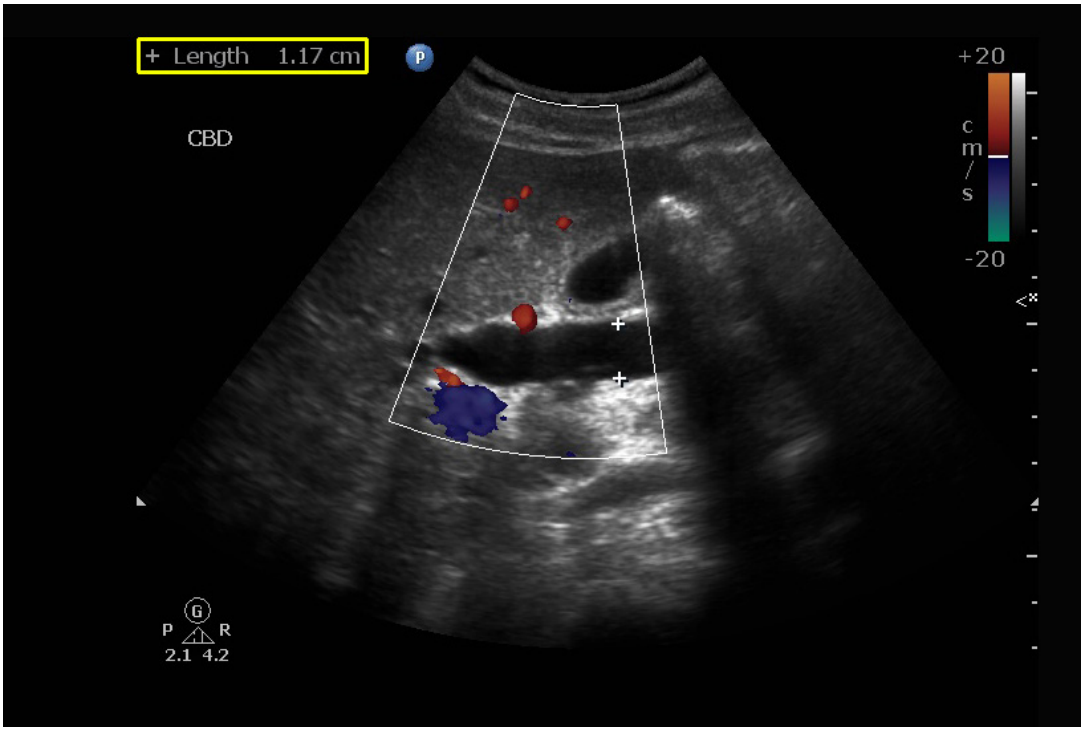
With practice, obstructive pathologies of the biliary circulation can be detected with bedside ultrasound. Novice sonographers should be aware that performing ultrasonographic CBD measurements can be very challenging.

The upper limit of the CBD diameter is still debated in the literature. We recommend using 8 mm as the upper limit in conjunction with laboratory values (bilirubin and lipase) to aid in detecting cases of choledocholithiasis.

Measure the CBD from the interior margin of the anterior wall to the interior margin of the posterior wall **[Figure 8d** and **Figure 8e]**.



[Figure 8d] Image demonstrating a normal CBD measuring 2.72 mm (0.272 cm). Note the image is zoomed and the measurement is from the interior margin of the anterior wall to the interior margin of the posterior wall.



[Figure 8e] Image of a dilated CBD measuring 11.7 mm (1.17 cm).

Tip: Determining the exact location of the CBD wall edge can be difficult. We recommend using the zoom feature to achieve the most accurate measurements.

Clinicians who cannot clearly visualize the neck of the gallbladder should not make clinical decisions based on their findings.

Why the gallbladder may not be identified

The gallbladder may be difficult to identify in two instances:

- The gallbladder is completely contracted after a meal.
- The gallbladder is completely filled with gallstones.

For comprehensive outpatient studies, patients are routinely asked to arrive fasting. This allows the gallbladder to distend, which facilitates ultrasound visualization. In the emergency department setting, patients with AC are almost always unable to eat large meals because of their pain. Therefore, in most cases the emergency medicine clinician should be able to visualize the gallbladder fairly easy.

The contracted gallbladder, in contrast, is often small, appears to have a thickened gallbladder wall due to the contracted state, and is only visualized by scanning through the liver (above the costal margin).

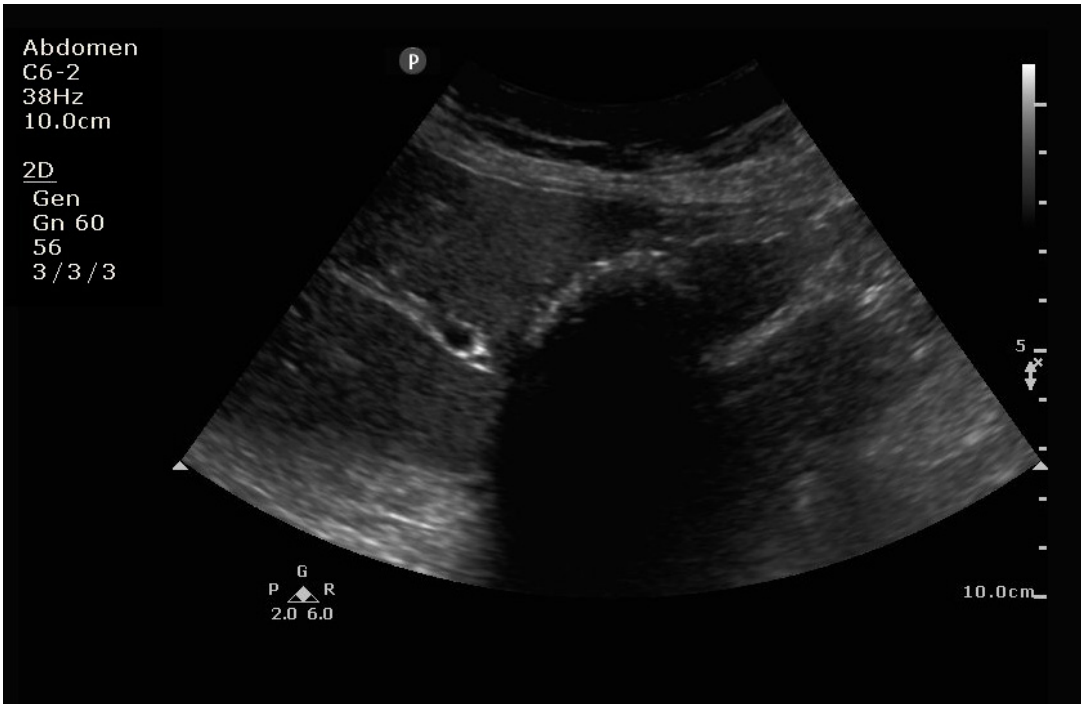
If the gallbladder is completely filled with gallstones, the classical anechoic/fluid-filled sac will be replaced with a shadow that originates from the liver. This is called the Wall Echo Shadow sign (WES) **[Figure 9]**. Novice sonographers often confuse the WES sign with rib or bowel shadows.

The following points can help differentiate the WES sign from rib or bowel shadows:

- Rib shadows originate from the skin surface and not from the liver parenchyma.

- Bowel gas will have a mixed (not purely anechoic) shadow and will demonstrate movement/peristalsis if the transducer is kept over the area in question.

- Scanning the patient in both the supine and LLD positions helps to confirm that similar images/findings are obtained.



[Figure 9] Image demonstrating the WES sign in a gallbladder. The gallbladder is completely filled with gallstones and the shadows of the gallstones originate from the liver.

5 Clinical pearls

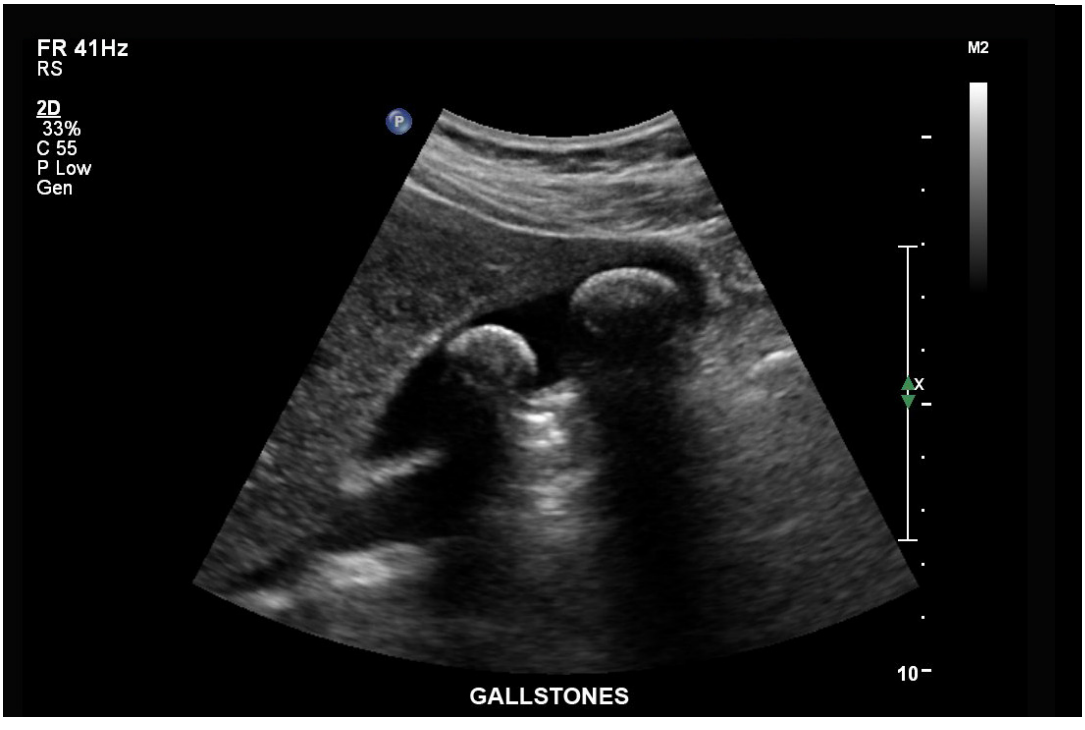
- The LLD position is optimal for gallbladder imaging, but it may not be feasible in all patients with severe abdominal pain.
- Having the patient take a deep breath can sometimes aid in getting a good view of the gallbladder.
- Gallstones will have a hyperechoic rim with acoustic shadowing and will be mobile.
- Because gallstones are gravitationally mobile, they will “move” when the patient is repositioned (unless a stone is “lodged”).
- Gallbladder polyps do not move and do not produce a shadow.
- Determining gallstone location within the gallbladder is an important aspect of the clinical care of the patient with suspected gallbladder pathology.

- When small gallstones are located in the neck of the gallbladder, it may be difficult to see the hyperechoic rims. Sonographic shadows may be the only visible sign of their presence.
- Impacted stones may be an indicator of patients who have a higher probability of progressing to acute cholecystitis.
- Small stones and ultrasonographic signs of AC can be missed if a clear view of the entire gallbladder and its contents is not obtained.
- Not evaluating the neck of the gallbladder is a common mistake of ultrasound novices.
- Ultrasound findings should be correlated with the clinical picture and laboratory results (bilirubin levels, lipase levels, liver function tests).

6 Common ultrasound findings

Gallstones in the fundus of the gallbladder [Figure 10a]

- Commonly seen when scanning the RUQ.
- Gallstones demonstrate an acoustic shadow and are mobile when the patient's position is changed.



[Figure 10a] Image demonstrating two large gallstones in the fundus of the gallbladder.

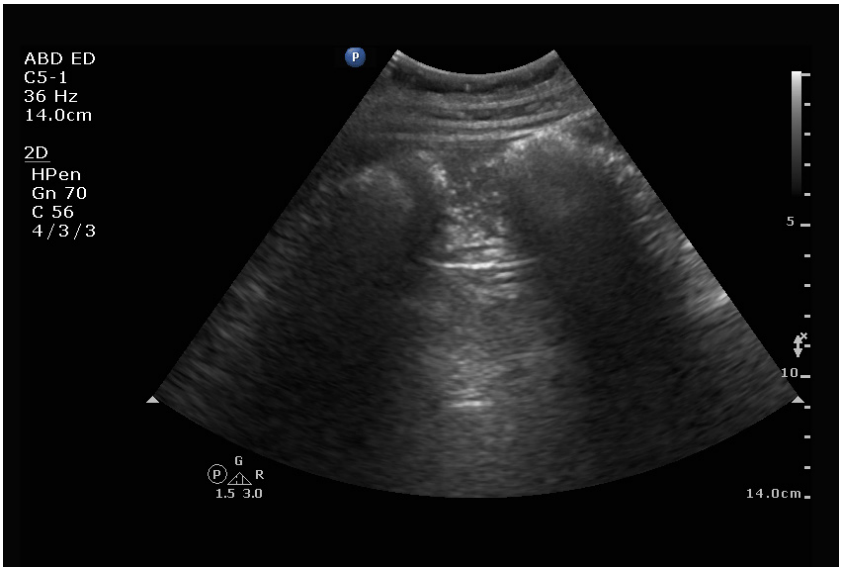
Gallstones in the neck of the gallbladder [Figure 10b]

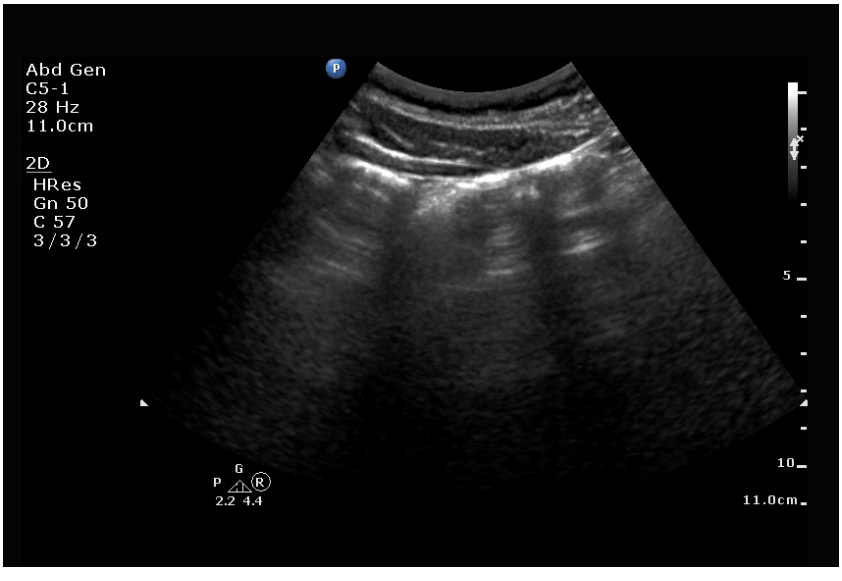
- A more subtle finding that can indicate a more severe process.
- Detection of an acoustic shadow in the region of the gallbladder that is adjacent to the porta hepatis.

[Figure 10b] Image demonstrating a gallstone in the neck of the gallbladder.

False-positive bowel wall shadow [**Figures 11a** and **11b**]

- A very common false-positive finding produced by bowel wall lying next to the gallbladder.
- More commonly seen when the gallbladder is scanned with the patient in supine position.
  - Differentiation can be made by looking for movement (peristalsis) of the shadow, or the loss of shadow when placing the patient in left lateral decubitus (LLD) position.
  - Also, unlike an acoustic shadow from a gallstone, shadows produced by bowel gas are mixed (isoechoic and anechoic) and have increased scatter artifact.





[Figures 11a and **11b]**
Two images demonstrating false-positive bowel wall shadow.

Wall Echo Shadow (WES) sign [Figure 12]

- Another common finding that can be difficult for the novice sonographer.
- A gallbladder filled with stones is seen as a shadow and can be mistaken as either bowel gas or a rib shadow.
- The differentiation can be difficult, but unlike bowel gas, there is no peristalsis of the underlying shadow and no scatter artifact that is common when ultrasound waves hit air.

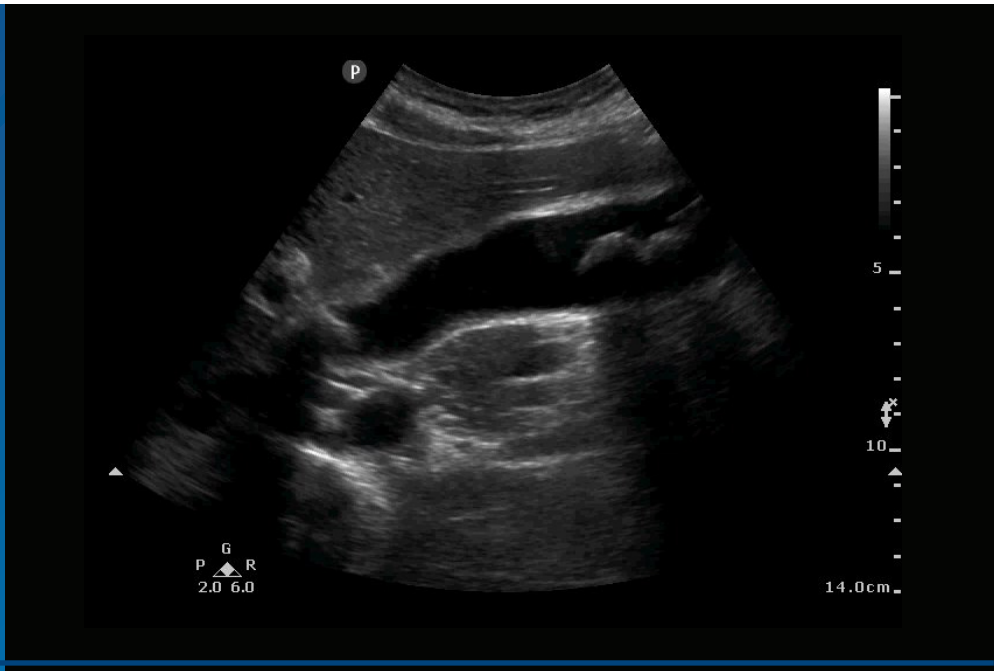
[Figure 12] Image demonstrating the WES sign in a gallbladder.

False-positive polyps

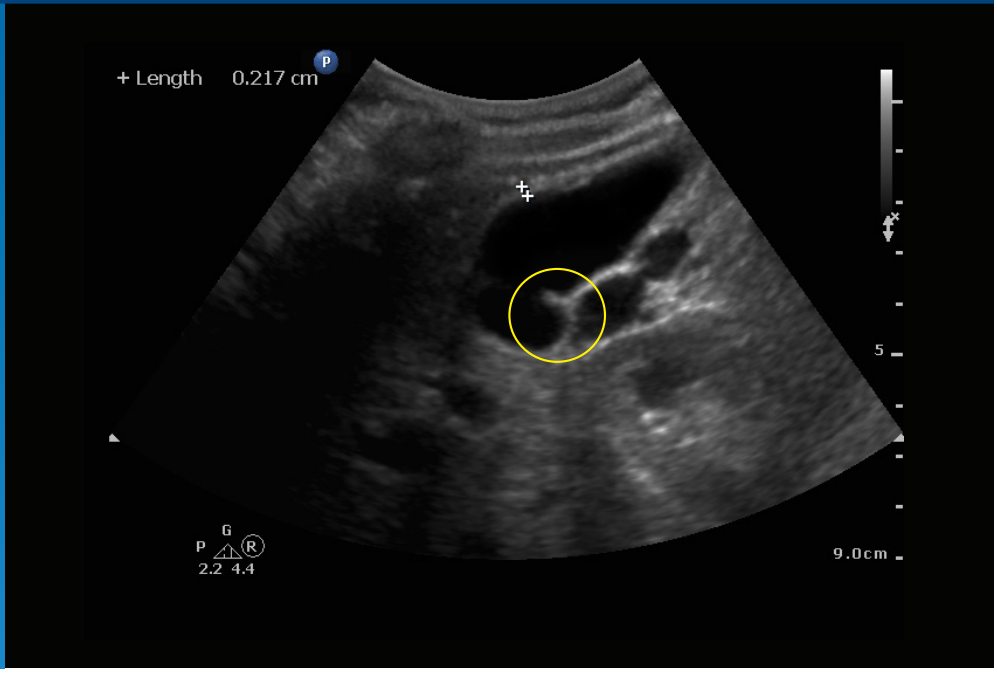
- A false-positive finding that can be confusing for the beginning sonographer.
- A false-positive polyp is characteristically hyperechoic/isoechoic lesions/masses that do not produce an acoustic shadow and do not move when the patient is repositioned.

7 Image and video gallery

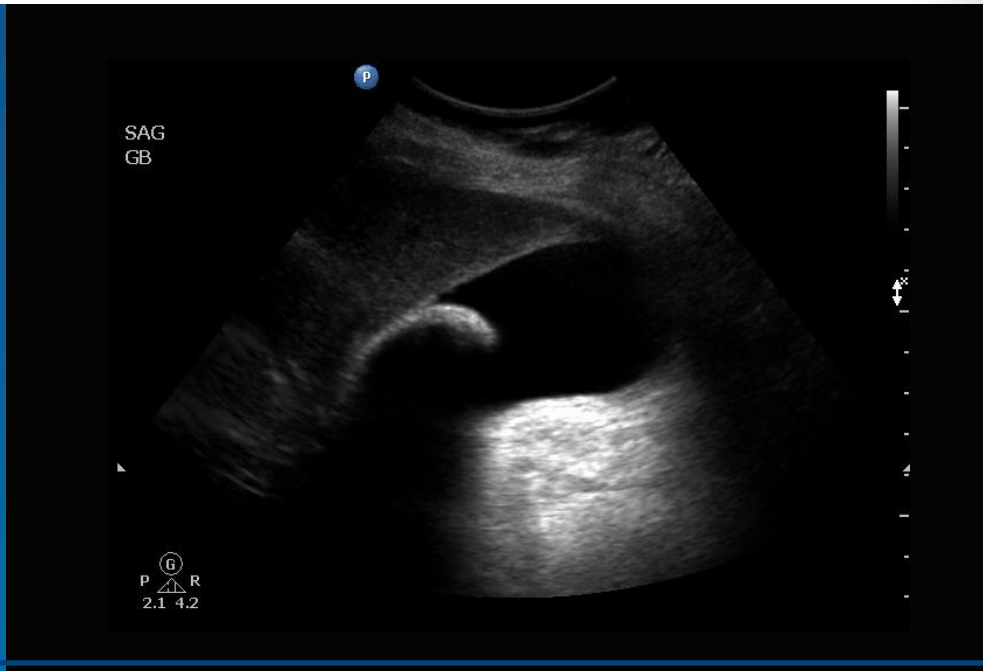
1 Gallstones with shadowing. There are two gallstones in the fundus of the gallbladder (screen right) and one gallstone in the neck of the gallbladder (screen left).



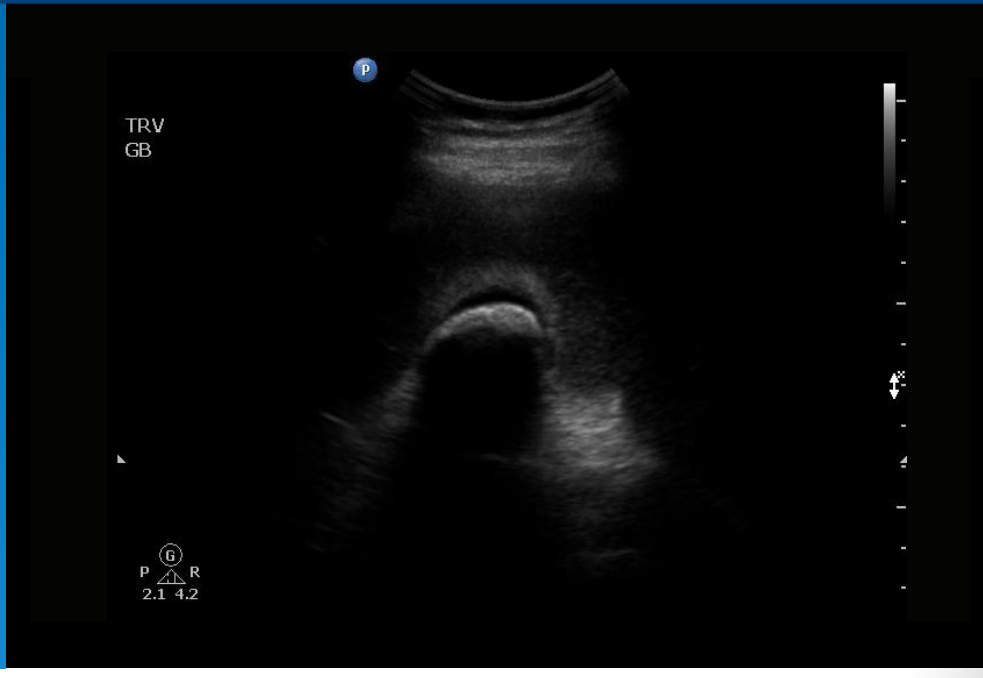
2 Gallbladder with a fold.



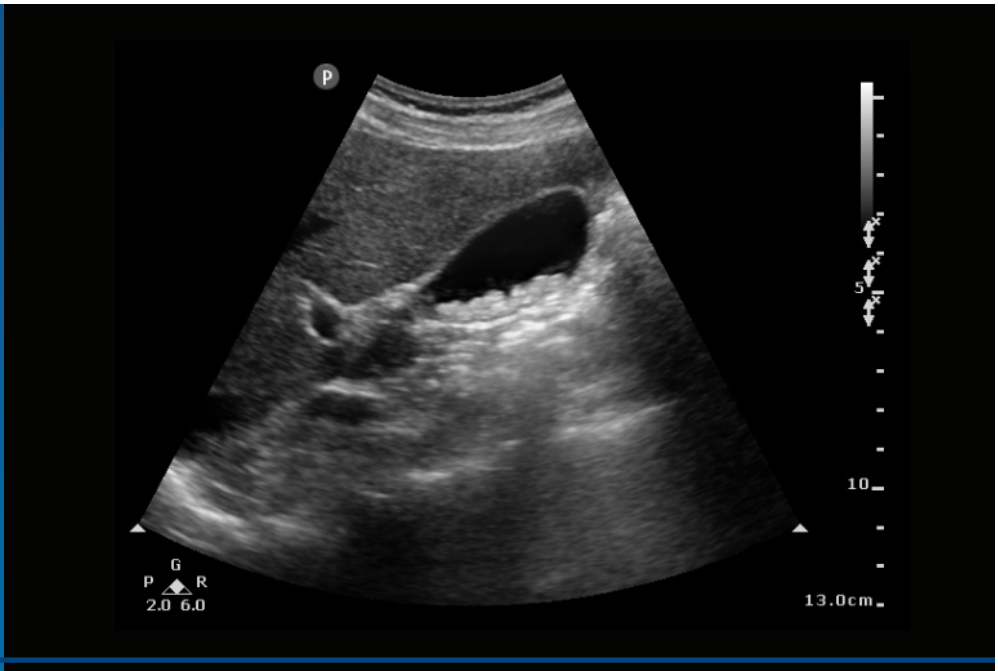
3 **Sagittal view of gallbladder with a large gallstone.**



4 **Transverse view of gallbladder with a large gallstone.**

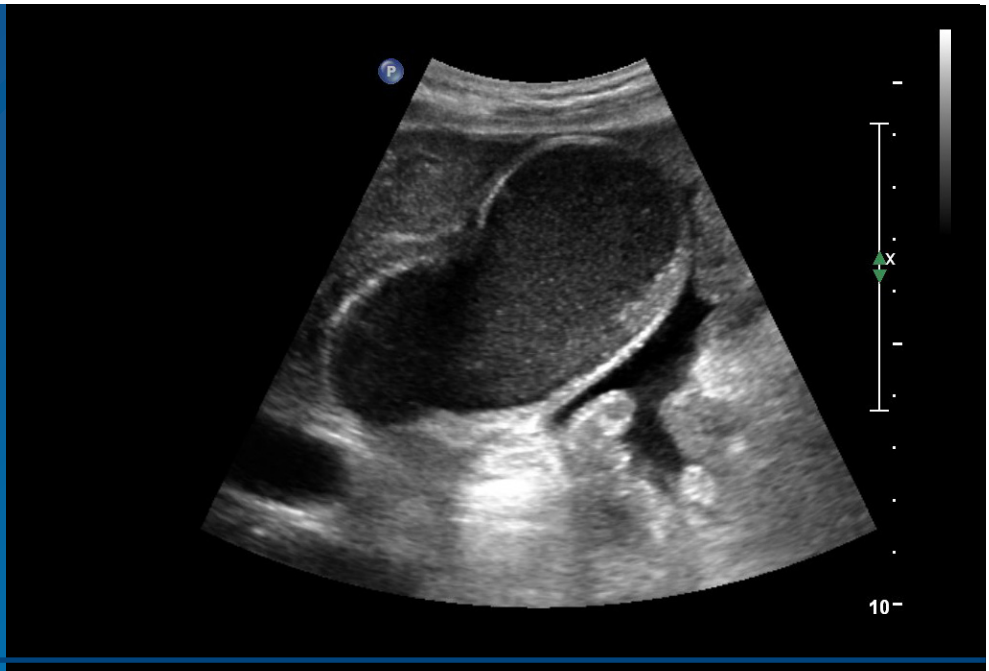


5 **Sagittal view of gallbladder with multiple small gallstones.**

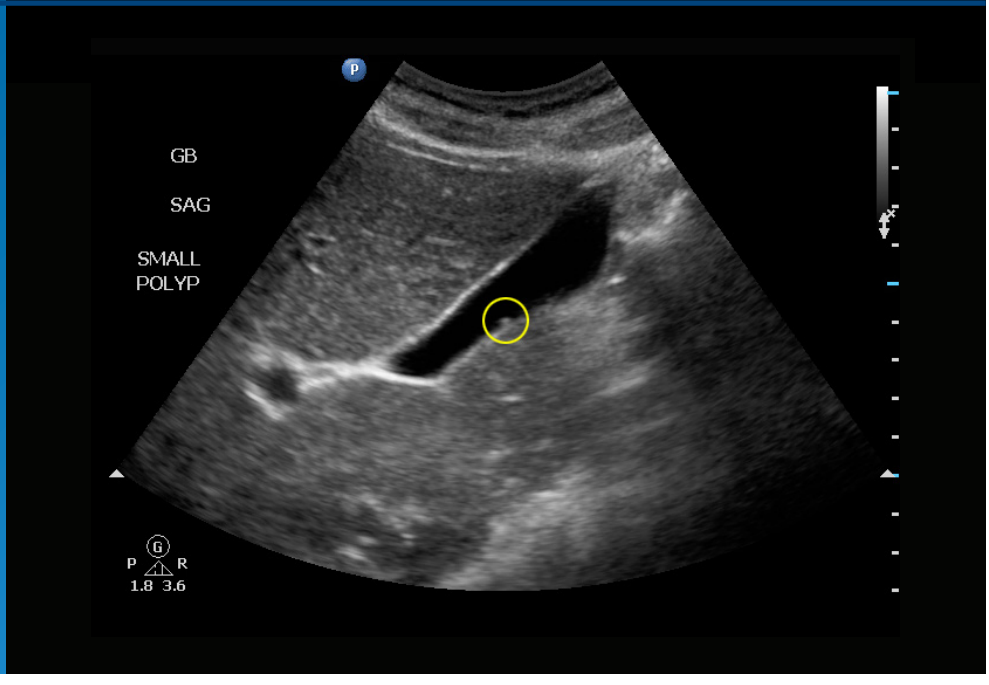


6 **Transverse view of gallbladder with multiple small gallstones.**

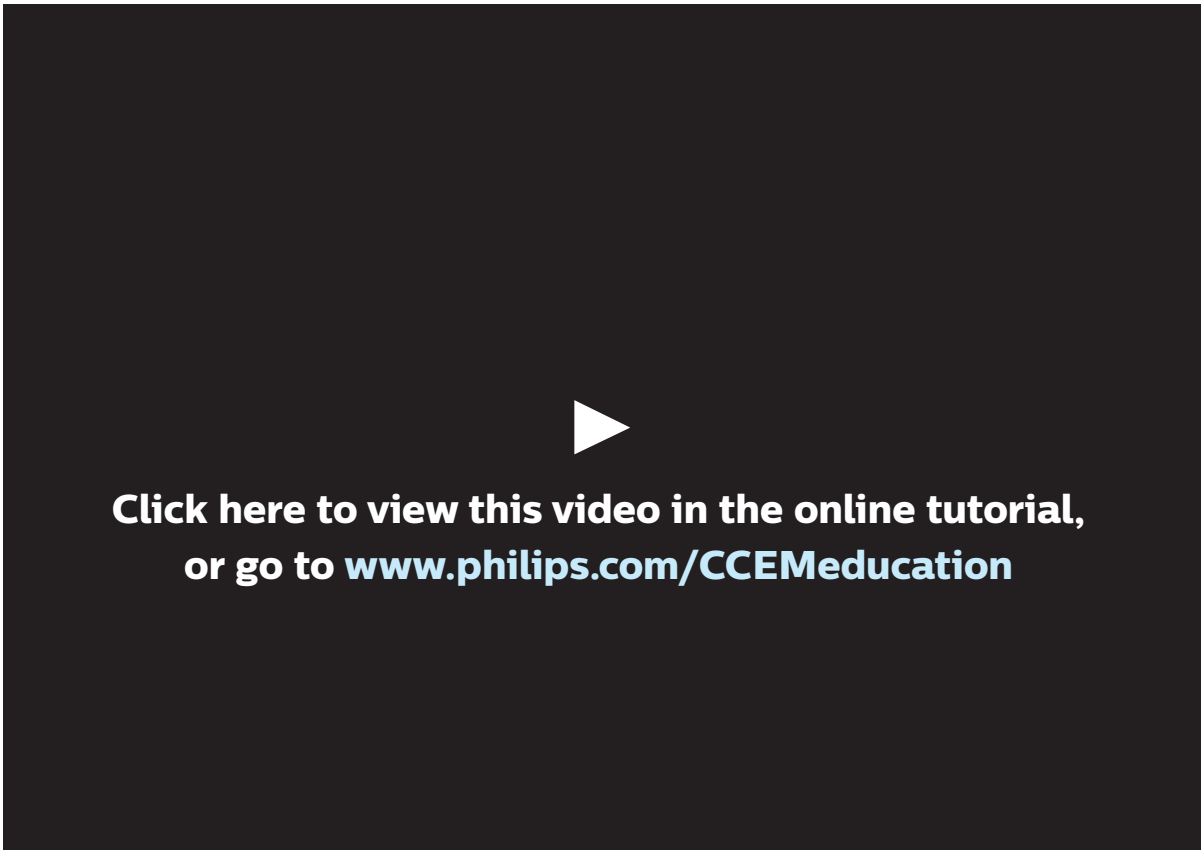
7 **This image demonstrates a distended gallbladder with internal echoes. Note the free fluid posteriorly.**



8 **Image of a gallbladder with a small polyp.**

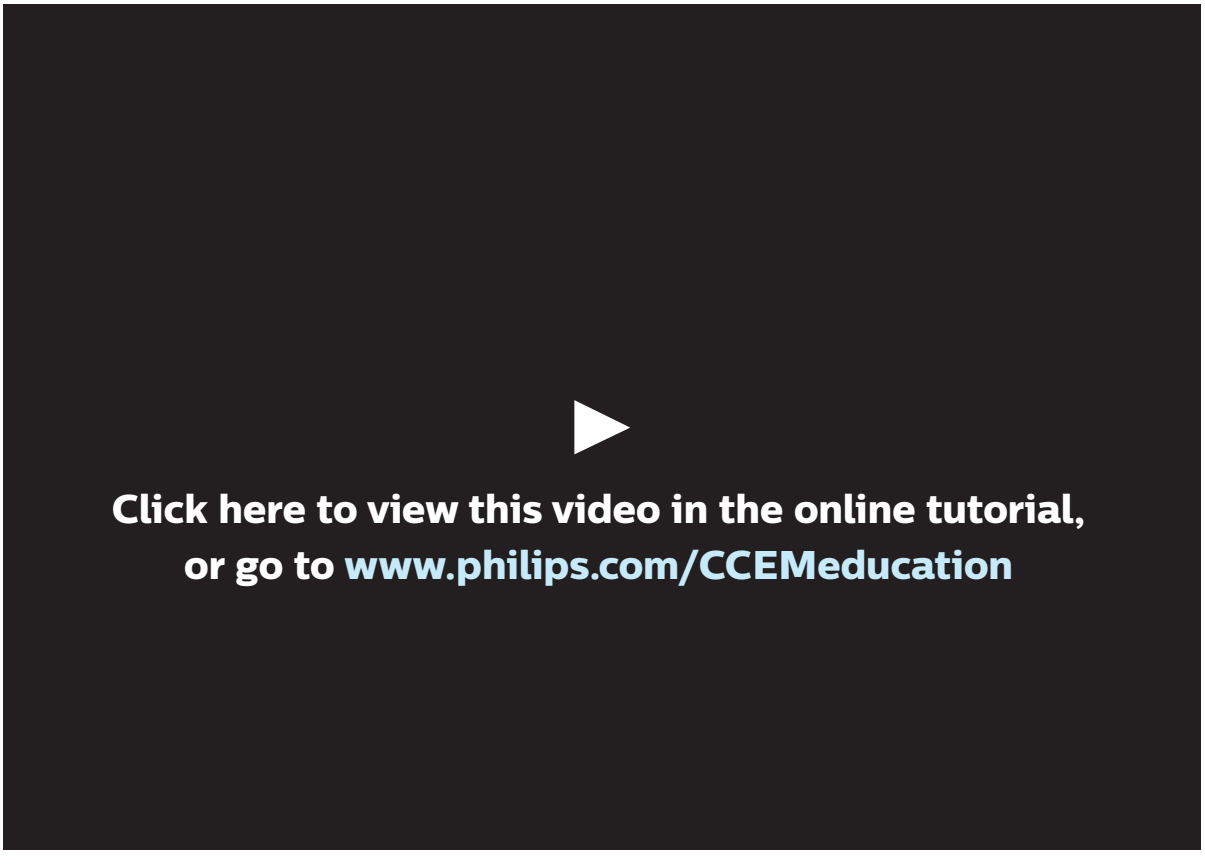


[Video 7]



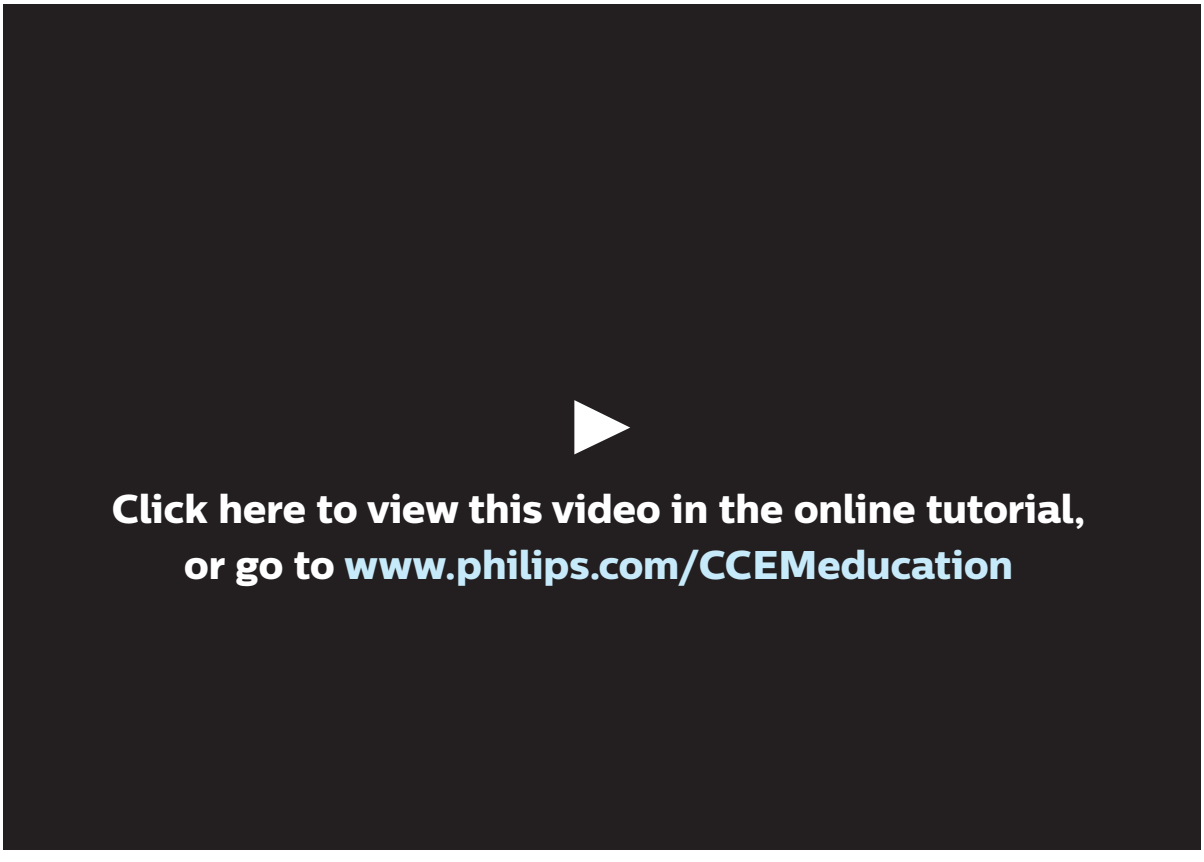
Sagittal image of gallbladder demonstrating presence of stones and sludge.

[Video 8]



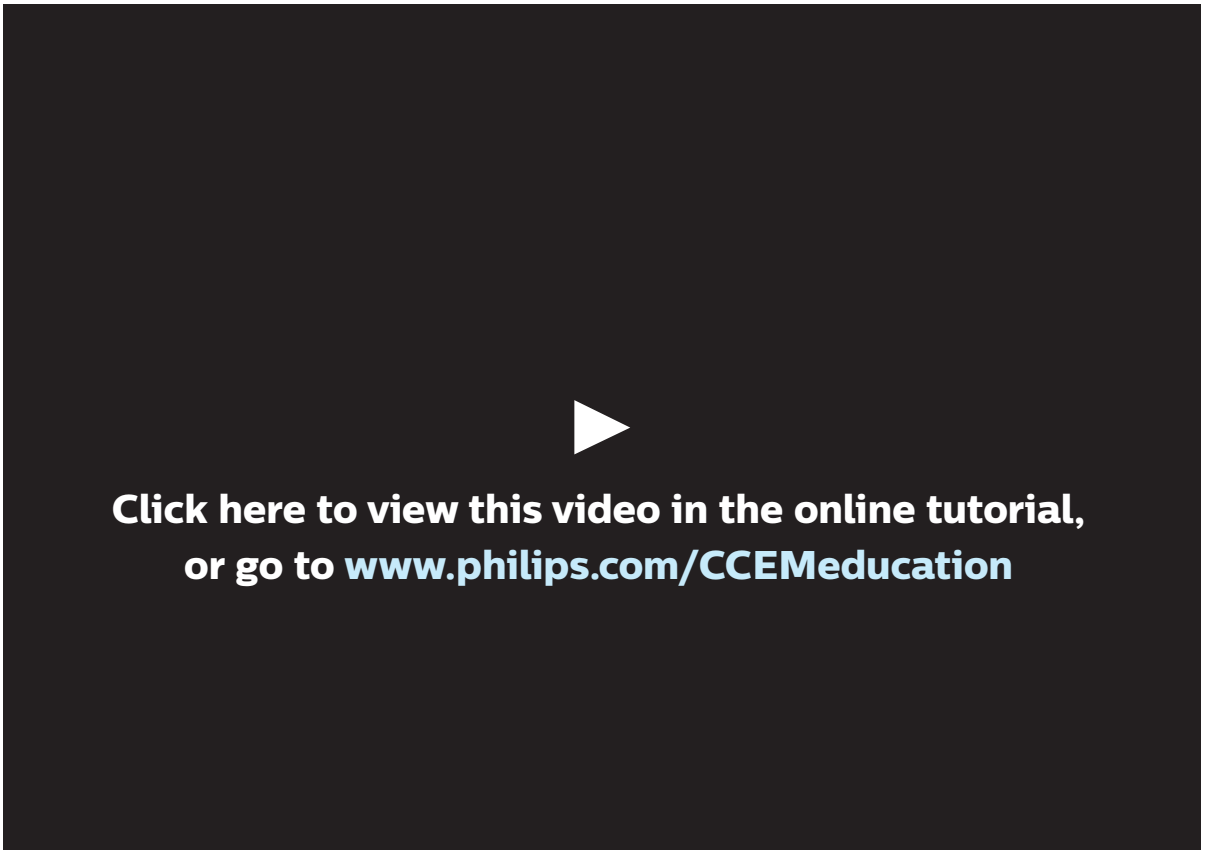
Sagittal sweep demonstrates multiple gallstones in a cluster toward the fundus.

[Video 9]



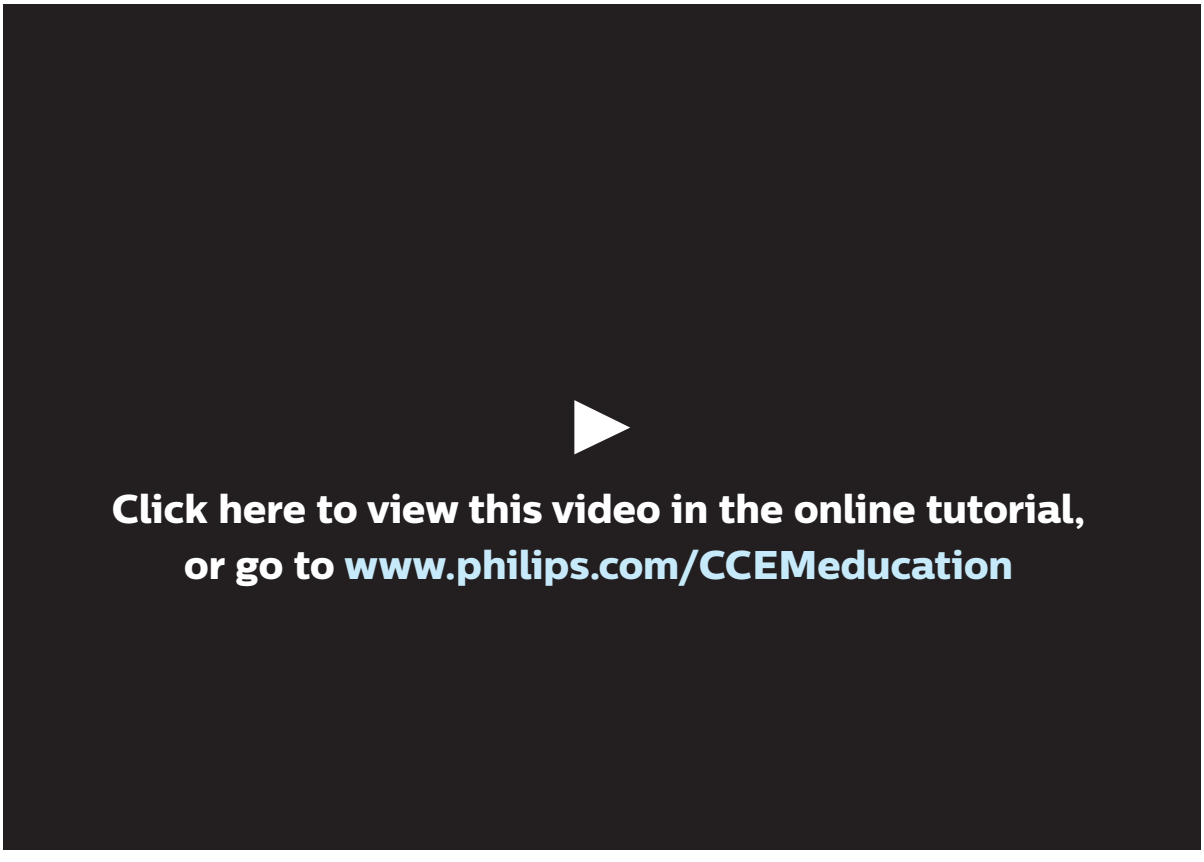
Transverse sweep of gallbladder with gallstones.

[Video 10]



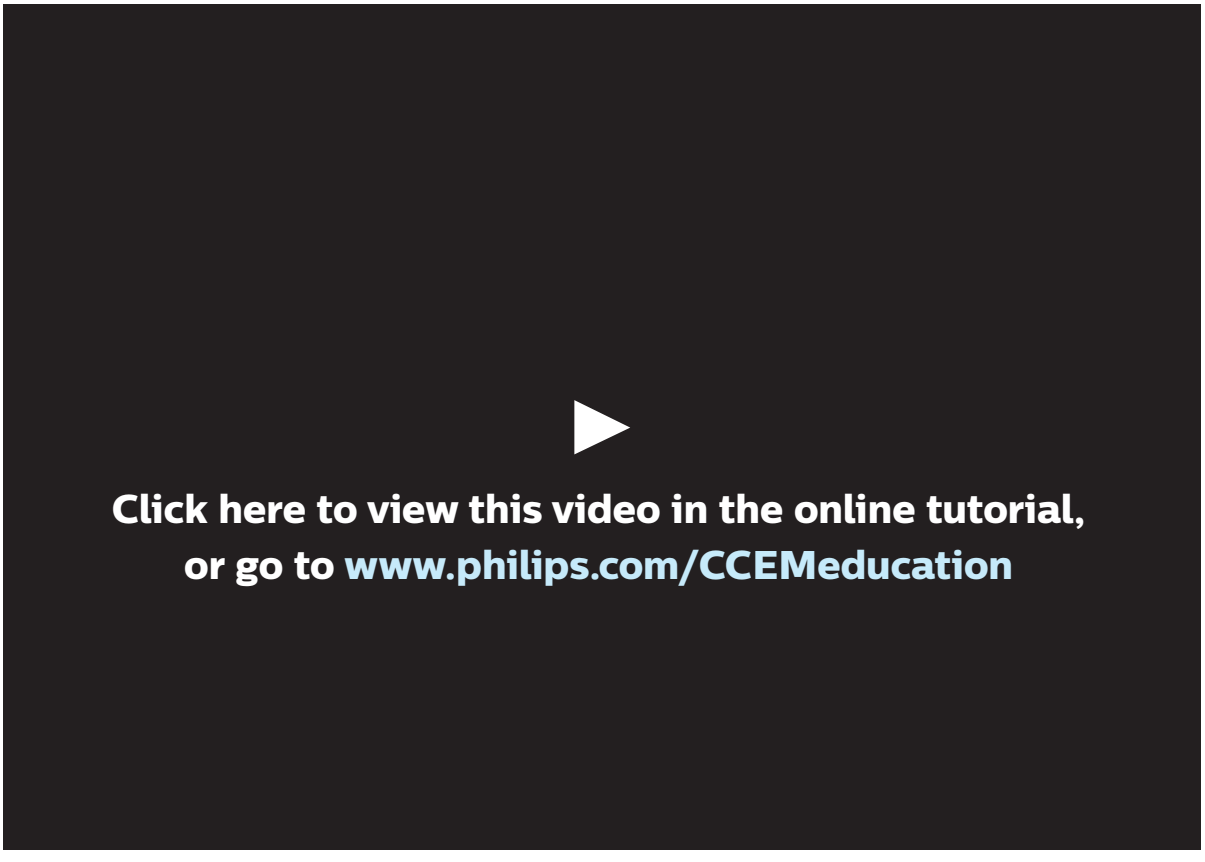
Sagittal sweep of gallbladder demonstrating a large stone plus multiple smaller stones. The gallbladder wall appears thickened.

[Video 11]



Sagittal sweep of gallbladder in a patient with ascites demonstrating thickened GB wall. No gallstones are seen. Note the subtle fold near the neck that could be mistaken for a polyp.

[Video 12]



Sagittal sweep of a gallbladder.
Note the fold in the gallbladder wall.

8 Case resolution

The initial bedside ultrasound demonstrated gallstones in the neck of the gallbladder with a thickened gallbladder wall (6 mm). Surgical consultation was requested along with a comprehensive ultrasound exam that confirmed similar findings to the initial bedside exam. The patient was admitted to the surgical service for cholecystectomy.

9 Summary

Assessment of abdominal pain can be challenging, even for the most experienced clinician. Incorporating POC ultrasound into the evaluation may assist the clinician indetermining the presence of gallstones, biliary colic, and acute cholecystitis. The POC ultrasound exam, in conjunction with clinical and laboratory data, can increase diagnostic certainty.

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Additional resources

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For **feedback** or **comments** regarding this tutorial or the iPad App,
please contact us at **ultrasoundeducation@philips.com**

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go to: **www.philips.com/sparq**

This paper reflects the opinion of the author, not Philips Healthcare. Before performing any clinical procedure, clinicians should obtain the requisite education and training, which may include fellowships, preceptorships, literature reviews, and similar programs. This paper is not intended to be a substitute for these training and education programs, but is rather an illustration of how advanced medical technology is used by clinicians.

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