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Ultrasound of the gallbladder and hepatobiliary system

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Introduction

Biliary system diseases are common pathology in medical practice. After obtaining the patient history and performing a physical examination, conventional B-mode and Colour Doppler imaging (CDI) are the first-line imaging methods of choice. In fact, ultrasound (US) is now a routine examination in daily clinical practice and in many clinical presentations. Additionally, it is used in asymptomatic patients as a screening tool [(1)]. It is an accurate imaging modality when performed by a qualified and experienced operator. Furthermore, it is safe, non-invasive, inexpensive, easily accessible and a repeatable imaging modality, which is highly sensitive and specific for the detection of many biliary diseases.

It is unusual for the biliary tree to be scanned in isolation due to the complexity of the pathophysiology of the hepatobiliary system. Rather, the biliary tree is scanned as part of an upper abdominal ultrasound examination. Therefore, ultrasound imaging can frequently demonstrate an alternate diagnosis as the cause of a patient's symptoms when the biliary system is normal [(2, 3)]. However, it is a highly operator dependent imaging modality and its diagnostic success is also influenced by variables such as non-fasting, obesity, presence of surgical dressings and a distended abdomen due to gastrointestinal (GI) gas. In the hands of an experienced practitioner, ultrasound has become a diagnostic tool equal in importance to endoscopy. However, the limitations of ultrasound must be appreciated by the operator, recognising that successful diagnostics of some hepatobiliary disease requires a multimodality approach [(4)].

Topography and gross anatomy

The gallbladder is a saccular shaped hollow sac that has a pear or teardrop shape in long-axis cross section. Its function is to store and concentrate bile, which is expelled into the duodenum after eating. Topographically, it is commonly located in the right hypochondrium in the mid-clavicular line, just below the right lower costal margin, beneath the anterior abdominal wall. Anatomically, it is situated on the inferior surface of the liver in the gallbladder fossa of the posterior right hepatic lobe, lateral to the second part of the duodenum and anterior to the right kidney and transverse colon.

The gallbladder comprises a fundus, body, infundibulum and neck. The fundus is the rounded, distal portion of the gallbladder that typically projects below the inferior surface of the liver in the mid-clavicular line. The body is the largest portion that tapers to the infundibulum and neck. Sometimes, there is a saccular outpouching from the infundibulum/neck known as Hartmann's Pouch, which is a common location for gallstones to become lodged, causing cholestasis.

The cystic duct (CD) of the gallbladder arises from the superior aspect of the gallbladder neck and transmits bile from and to the main bile duct. The CD contains a spiral series of mucosal folds, referred to as the spiral valves of Heister that prevent collapse or over-distension of the gallbladder due to sudden position changes. The cystic artery, a branch of right hepatic artery, is the main arterial supply to the gallbladder.

Impact of body habitus on gallbladder position

The gallbladder typically lies obliquely within the abdomen. However, its position and orientation vary with differing body habitus. There are four typical body habitus types – hypersthenic, sthenic, hyposthenic and asthenic [Table 1]. It is important for the ultrasound practitioner to understand this variation in the position/orientation of the gallbladder position to correctly align the ultrasound transducer to optimally image the long and short axes of the gallbladder [Figure 1].

Table 1 Variable positions of the gallbladder dependent upon body habitus type.

Body habitus type	Typical gallbladder position and orientation
Hypersthenic 5% population (wide, deep, chest, Wide abdominal cavity)	The diaphragm, liver and gallbladder tend to lie high in the abdomen in the right upper quadrant, under the thoracic cage. Consequently, the liver and gallbladder are often difficult to access using ultrasound, requiring a flexible and adaptable scanning technique. Intercostal approach and decubitus/erect patient positions can facilitate imaging. The stomach is also high, and this can create problems with US imaging access to deeper structures due to overlying gas and food residue. The gallbladder is also often horizontally orientated rather than in its normal oblique orientation.
Sthenic (Average build)	The liver and gallbladder tend to lie as expected in the right upper quadrant with the gallbladder fundus projecting just below the lower costal margin in the mid-clavicular plane and with the gallbladder lying in its typically oblique orientation.

Hyposthenic (Tall, thin, narrow, chest not deep in AP diameter)	The liver and gallbladder tend to lie lower than in hypersthenic/sthenic types; often located in the right lumbar abdominal region and the gallbladder is frequently more vertically orientated.
Asthenic (Extreme variant of above)	The liver and gallbladder tend to lie low down in the abdomen, sometimes as low as the right iliac fossa. The gallbladder tends to lie in a more vertically orientated than above body habitus types.

Impact on Ultrasound Scanning technique

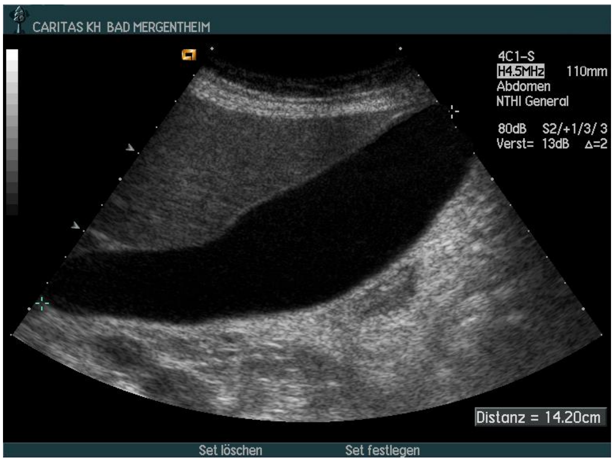
An understanding of these variable positions of structures is essential for successful ultrasound scanning technique. It is suggested that the practitioner looks at the patient as they enter the scan room and assigns them to a body habitus type. This will help the ultrasound practitioner to know where to find the gallbladder and other structures and how to align the ultrasound transducer to show the long and shorts axes of the gallbladder [Figure 1, Table 1].

Gallbladder measurements

The normal gallbladder size is reported to be 7-10 (length) x 2-4 (AP diameter) x 2-4 (transverse diameter) cm, but it obviously depends on the volume of bile present [(5)]. Typical bile volume is normally 40 - 60 ml, measured by a rotating ellipsoid [(5)]. However, volume estimates using ultrasound are unreliable, showing a wide intra- and inter-operator variability [(5, 6)]. Cholecystomegaly in patients with diabetes mellitus or during long standing fasting periods may reveal gallbladder diameters up to 15 x 6 x 6 cm without clinical relevance [Figure 2], in contrast to clinically important hydrops associated with right upper quadrant pain and fever.

Gallbladder volume can be estimated before and after a test meal and this can be used to assess gallbladder function to a limited degree. Contraction of >60 % is regarded as normal. It is difficult to locate the gallbladder after a test meal as it is usually contracted. A useful tip is to mark an X on the abdominal wall at the site of the gallbladder when it is distended to facilitate its location after the test meal. Normal contraction is a requirement before gall stone treatment with, for example, ursodeoxycholic acid. The normal gallbladder wall thickness is ≤ 3 mm on ultrasound.

Figure 1 Long axis section of the gallbladder showing clinically insignificant large, thin walled gallbladder (+…..+). This is often seen in the elderly, known as a physiological atonic gallbladder. A large gallbladder (up to 15 cm in length) might be found in older people, diabetics and many other unspecific disorders [(6)].

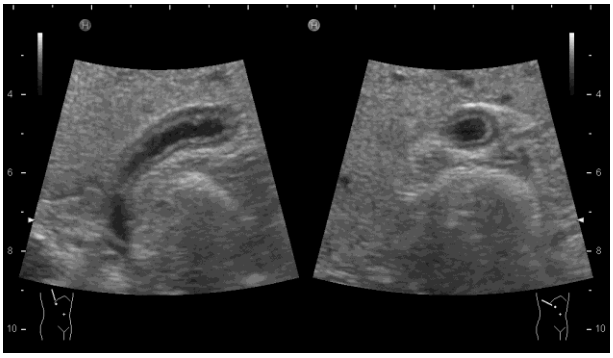


Ultrasound Examination technique

Patient Preparation

It is recommended that a patient undergoes a 6-8 hours period of fasting and non-smoking, prior to imaging of the gallbladder and biliary tree to maximise the distension of the gallbladder. However, a patient may take small amounts of still water by mouth prior to the scan, particularly for taking any medications. Additionally, fasting reduces food residue and gas in the upper gastrointestinal (GI) tract, which may reduce image quality or preclude imaging of the gallbladder and biliary tree due to overlying GI contents. Inadequate fasting and smoking are likely to result in the gallbladder being partially or completely contracted; consequently, the walls will appear thicker than normal mimicking pathological gallbladder wall thickening – a misdiagnosis [Figure 2].

Figure 2 Small contracted gallbladder (left: long axis section; right: short axis section section): gallbladder lumen is very narrow, the layers of the contracted and thickened wall are visible.



In emergency situations, however, ultrasound can be performed without fasting. If a conclusive diagnosis is not reached, a repeat scan after fasting is recommended if the clinical status of the patient permits. Alternately, other imaging modalities such as MRI can be used.

Patient history and physical examination

It is recommended that a short history is taken and that the abdomen is examined/palpated before the ultrasound examination commences. This is to ensure that the ultrasound practitioner has the complete clinical picture and coupled with the ultrasound findings, can be integrated to ensure that the clinical question is addressed.

Ultrasound Examination of the gallbladder and biliary tree

The gallbladder and biliary tree are usually examined as part of a complete upper abdominal survey. However, targeted scanning of these structures is sometimes undertaken where there is a robust history/presentation, typical gallbladder/biliary tree pathology or in follow-up cases. The examination is not confined to the gallbladder. Rather, it must include the ducts of the intra- and extra hepatic biliary tree.

Ultrasound Equipment

Routinely, a convex, wide band, multi-frequency (e.g. 2-6 MHz) transducer is used for the evaluation of the gallbladder. However, lower frequencies may be used when an increased depth of penetration is required, for example in obese patients or when the gallbladder is deep (e.g. hypersthenic patients). In very slim patients (e.g. asthenic/hyposthenic types) [Table 1] where the gallbladder maybe very superficial, a wide band high frequency range convex or linear transducer (e.g. 4-12 MHz) should be used to optimise image quality.

Anatomical Landmarks

Topographically, the gallbladder is usually located in the midclavicular line at the level of the lower costal margin. Useful landmarks to identify the gallbladder on ultrasound are the inferior edge of the right lobe of liver and the liver hilum. In the right subcostal oblique section, the landmark structure to be used is the interlobar fissure and the gallbladder will be found by aligning the probe with the fissure. The gallbladder will be located inferiorly or laterally to the fissure (between liver segments IV and V).

Image acquisition

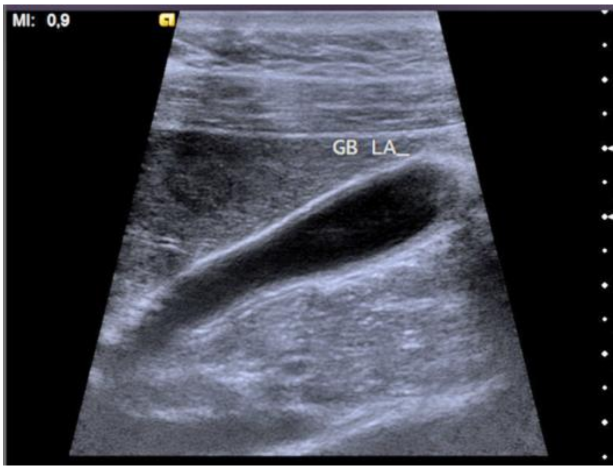
Conventional real-time ultrasound produces images of thin slices of the liver/biliary tree on the screen, and so it is essential that the operator scans the structures systematically, in at least two anatomical planes, to be entirely convinced that the entire volume of the liver and biliary tree and structures has been imaged. The operator must then synthesise this 2-dimensional information to develop a 3-dimensional map of the individual patient`s liver/biliary tree anatomy and pathology. This requires good hand-eye-brain coordination and spatial awareness.

Ultrasound scanning technique of the gallbladder and biliary tree

The gallbladder and biliary tree can be examined initially with the patient in a supine position. This is to be encouraged as a first-line approach to minimise the risks of operator repetitive strain injury to the operator due to overreaching. Successful examination of the gallbladder and biliary tree also often requires the patient to be examined in a left posterior-oblique or left lateral decubitus position. These latter positions cause the liver/gallbladder to rotate antero-medially under the influence of gravity and this may optimise the use of the liver as an acoustic window for imaging the gallbladder or make the gallbladder more readily accessible below the thoracic cage.

In an 'average'/sthenic patient, the transducer can be placed in the right mid-clavicular line on the anterior abdominal wall at the lower costal margin and its position is adjusted until the gallbladder is located, usually just visible beneath the liver. The operator should try to use the liver as an acoustic window and avoid scanning through bowel by angling cranially. The patient may be asked to take a suspended deep breath-in to cause the liver/gallbladder to descend below the lower costal margin. The transducer is then rotated over the gallbladder until the true long axis section of the gallbladder is achieved [Figure 3]. There is often a temptation for novice practitioners to freeze an image as in Figure 3. However, one must remember the gallbladder is a 3-D structure and so the transducer must be angled medially>laterally, to ensure that the ultrasound beam is swept through the gallbladder, ensuring that the whole gallbladder has been imaged in its entire long axis.

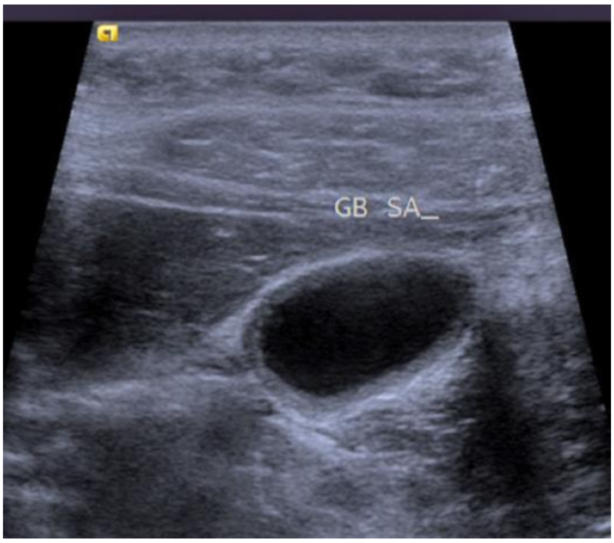
Figure 3 Long axis section of the gallbladder in a sthenic patient. Once this plane is achieved, the transducer must be angled to ensure all the gallbladder has been scanned thoroughly in this plane.



The normal gallbladder wall is thin and measures ≤3mm in the antero-posterior diameter. Many operators do not measure the normal wall thickness as is it difficult to measure such a small structure accurately. If a measurement is made, the gallbladder should be aligned so that the long axis lies horizontally on the screen, with the walls perpendicular to the ultrasound beam [Figure 3]. The anterior wall of the gallbladder should always be measured as it is closer to the transducer; it should be measured 'in line'/parallel with the ultrasound beam to optimise the axial resolution of the ultrasound beam.

In this plane, the fundus of the gallbladder is frequently not seen as it lies parallel to the ultrasound beam; an artefact. An inexperienced practitioner might recognise this apparent 'absence' of the wall as a perforation. This highlights the importance of understanding the physics of ultrasound artefacts and their impact on diagnosis. After scanning the gallbladder in long axis, the transducer should be rotated over the gallbladder, through 90 degrees towards the practitioner, to image the gallbladder in its true short axis section [Figures 3 and 4]. Again, the transducer should be angled (cranial-caudal) to ensure thorough imaging of the gallbladder in this plane from cystic duct to fundus.

Figure 4 Short axis section through the gallbladder. The transducer must be angled from cranially to caudally to ensure that the entire gallbladder has been imaged in this plane.

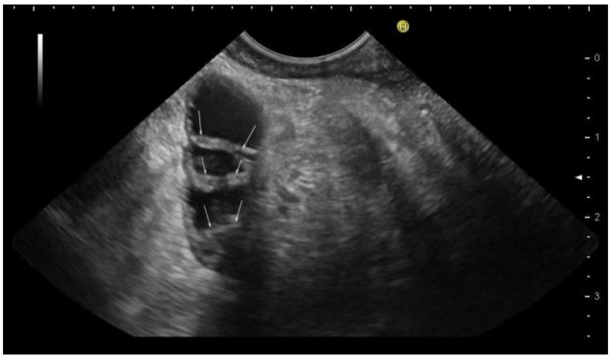


Movement of the patient is essential where there is sludge or stones present in the gallbladder to assess whether they move as the patient moves. Erect imaging is particularly useful to assess whether gallstones are mobile, as they will normally descend into the dependent part of the gallbladder (fundus) with the patient erect, with the assistance of gravity.

The demonstration of the cystic duct is easiest in deep inspiration with the patient in the supine or left lateral decubitus position. It is visualised by tracking the duct from the infundibulum of the gallbladder [Figure 5]. Sometimes the echogenic structures of the spiral valves of Heister may be depicted. This structure is important to recognise on ultrasound as it may be confused with real septae [Figures 6 and 18]. Moreover, it can cause acoustic shadowing, which may sometimes be mistaken for a calculus in the neck of the gallbladder. Scanning from multiple angles and different positions can aid diagnosis [Figure 16]. The distal segment of the cystic duct is best visualised with the patient supine, in the plane through the hepatic portal, anterior to the portal vein.

Figure 5 **Cystic duct, originating at the gallbladder infundibulum (*). The course of cystic duct is marked by arrowheads.**

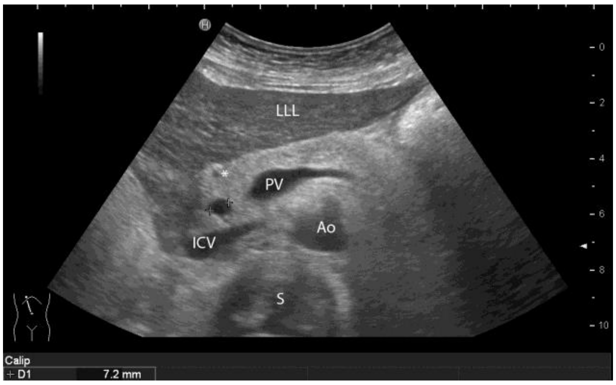
Figure 6 **Spiral valve of Heister in the infundibulum of gallbladder and proximal cystic duct (arrows), visualized by longitudinal endoscopic ultrasound with the transducer positioned in the gastric antrum towards the liver hilum.**



The main bile duct (MBD) with the common hepatic duct (CHD, region of the liver hilum) and the common bile duct (CBD, choledochal duct) in most patients can be easily displayed using transabdominal ultrasound. In supine position a cross section of the CBD may be found in the dorsal part of the pancreatic head [Figure 7].

Figure 7 **Cross section of the CBD in the posterior part of the pancreatic head (between calipers: 7.2 mm diameter). The other cross section of a tubular structure (in**

the ventral part of the pancreatic head) is the gastroduodenal artery (*; Ao: Aorta; ICV: inferior caval vein; LLL: left liver lobe; PV: portal vein; S: spine).



When found in cross section, the course of the MBD may be delineated by rotating the transducer in an oblique position. With the patient in a left posterior oblique or left lateral decubitus position the liver can be used as an acoustic window for imaging the hilar and extra hepatic biliary tree in a longitudinal section. The MBD often lies obliquely and is more lateral superiorly, hence it can usually be imaged by placing the transducer below the right costal margin in the region of the mid-clavicular line; an oblique position is required to align the transducer parallel to the long axis of the bile duct to image it along its length in a single plane ("shoulder – navel – section"). To follow the course of the extrahepatic bile duct requires slight rotation of the transducer in direction to a sagittal plane.

The MBD appears as a tubular structure usually typically situated anterior to the portal vein. Often, the bile duct is imaged with the transducer parallel to the midline. In this section, the hepatic artery will normally appear as a round structure between the MBD and the portal vein [Figures 8 - 10]. However, the practitioner must be mindful of the anatomical variants of the vessels/tubes in this region. Consequently, colour Doppler imaging is useful to ensure that the operator is in fact imaging and measuring the bile duct (no flow) and is not inadvertently mistakenly measuring another vessel, such as the hepatic artery/portal vein (7) [Figures 8 - 11].