Laparoscopic Ultrasound of the Bile Duct for Choledocholithia

Indications

- All patients undergoing laparoscopic cholecystectomy are candidates for laparoscopic ultrasound (LUS) of the biliary tree. This can be performed on a routine basis or selectively on patients with increased risk factors for choledocholithiasis. These risk factors include:
  - Acute cholecystitis
  - Elevated liver function tests
  - Hyperamylasemia
  - Dilated common bile duct

- Additionally, patients with acute or chronic thickening or inflammation around the hepatoduodenal ligament in which the anatomy is obscured will benefit from ultrasound evaluation to help delineate the anatomy.

- Ultrasound is also useful to confirm the integrity of the common bile duct after ligation of the cystic duct, which would rule out injury of the common hepatic or common bile duct.

- LUS is very valuable in the event that gallbladder cancer, cholangiocarcinoma, pancreatic cancer or ampullary tumors are suspected or incidentally found. Under these circumstances, laparoscopic staging with ultrasound provides a more accurate means of evaluating local invasion, vascular involvement, nodal staging, liver metastasis and peritoneal metastasis.

- Relative contraindications to LUS are excessive inflammation, pancreatitis, large amount of fat or many adhesions, which would obscure the anatomy or make it difficult to access the head of the pancreas or duodenum.

PHILIPS

Anatomy

The gallbladder *(Figures 1-4)*

The gallbladder is best visualized just under the liver edge between liver segments four and five. The gallbladder is pear shaped with the fundus extending below the liver edge. Typically the gallbladder has three echo layers. The mucosa is hyperechoic and the muscularis is hypoechoic. The third layer represents the peritoneum or the adventitia surrounding the gallbladder.

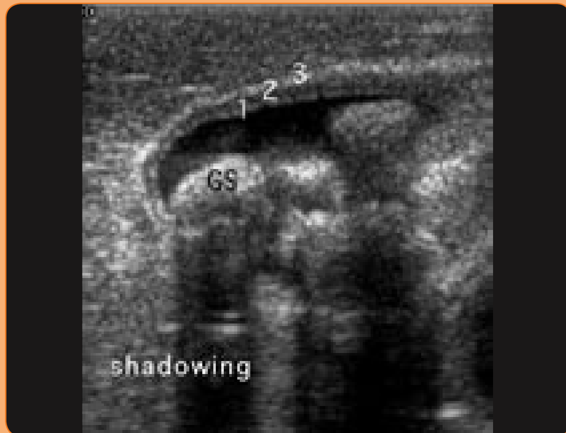

Figure 1. LUS of the gallbladder through segment five of the liver. The mucosa (1), muscularis (2) and adventitia (3) make up the three layers of the gallbladder wall. A gallstone (GS) with a hyperechoic surface and posterior shadowing can be easily identified.

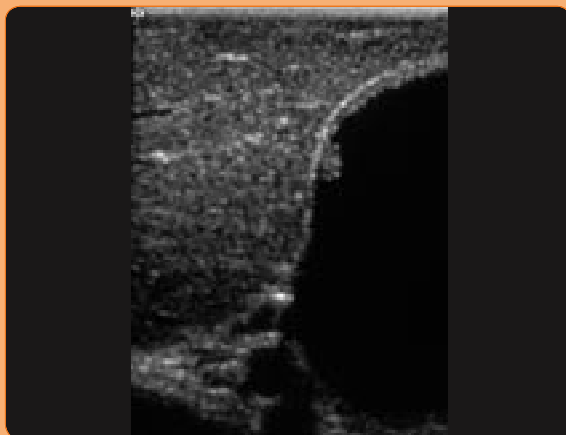

Figure 2. Cholesterol polyp projecting from the gallbladder wall seen through segment five of the liver.

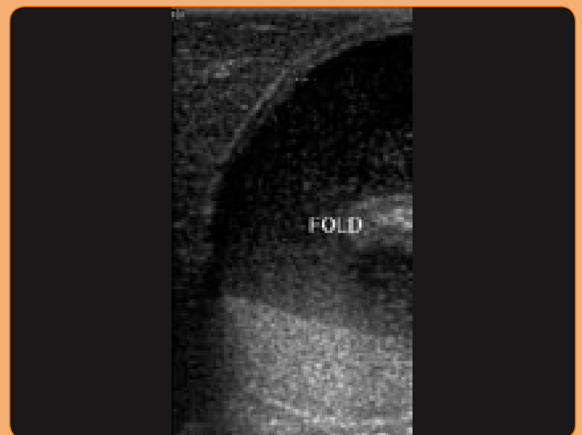

Figure 3. Gallbladder with sludge. Three layers of the gallbladder wall are clearly seen. A prominent fold of the gallbladder wall is also seen.

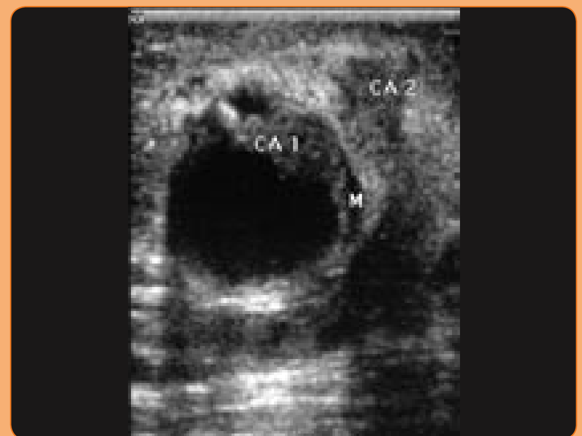

Figure 4. Gallbladder cancer (CA 1) seen as an irregular thickened mucosal layer. The hypoechoic muscularis (M) is for the most part intact. There is extension of the cancer (CA 2) outside of the gallbladder involving the adventitial layer but not invading the liver. This was found at laparoscopic evaluation. The patient underwent open cholecystectomy with wedge resection of segment five and portal lymphadenectomy.

Segment-four liver and intrahepatic biliary tree
(Figures 5-6)

The best view of the common hepatic duct and intrahepatic biliary tree is through segment four of the liver. This is just to the right of the falciform about halfway to the gallbladder (Figure 5). Through this hepatic window, the confluence of the right and left duct is seen to form the common hepatic duct. Deep to this is the hepatic artery, usually seen in a cross-sectional view. Behind this is the portal vein, caudate lobe of the liver and the vena cava. This is the starting point for evaluation of the biliary tree and surrounding structures (Figure 6).

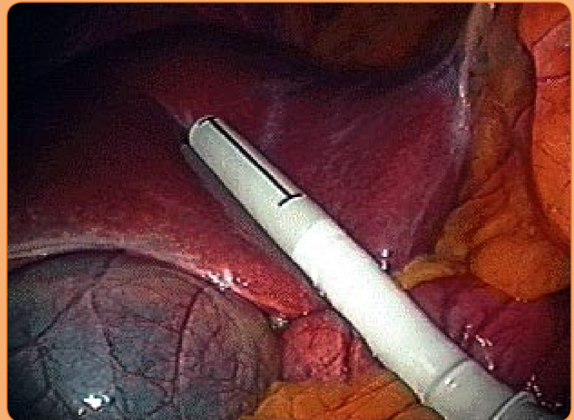

Figure 5. View of the LUS probe over segment four of the liver. The probe is placed through the umbilical port.

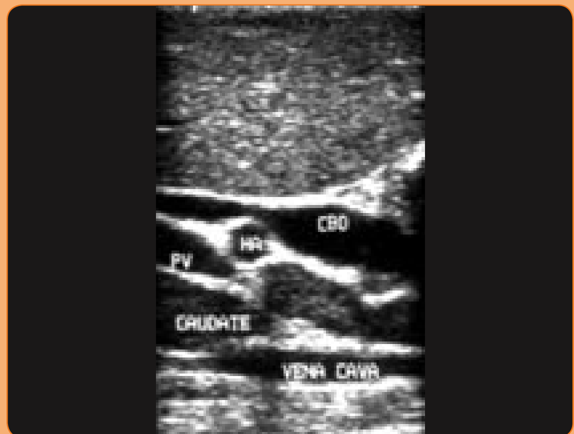

Figure 6. With the probe over segment four parallel with the porta hepatis, the liver parenchyma is first seen followed by the common bile duct (CBD), hepatic artery (HA), portal vein (PV), caudate lobe and vena cava.

Hepatoduodenal ligament *(Figures 7-10)*

Between the liver hilum and the head of the pancreas lies the hepatoduodenal ligament, containing hilar lymph nodes, the extrahepatic biliary tree, hepatic and cystic artery, portal vein and periportal lymph nodes and lymphatics.

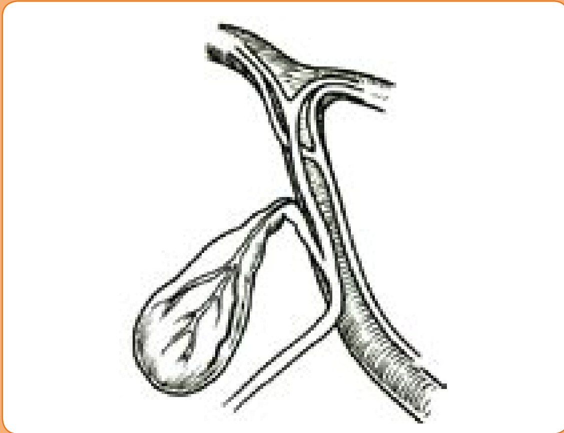

Figure 7. Drawing of the typical relationship of the biliary tree to the hepatic artery and portal vein at the hepatoduodenal ligament.

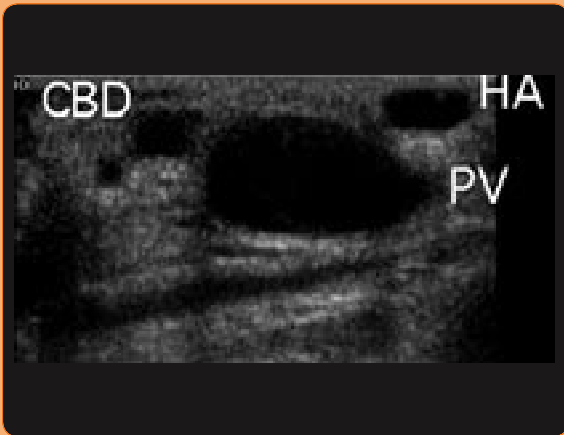

Figure 8. View when probe is placed longitudinally over the hepatoduodenal ligament. The liver is raised to show the position of the probe with the tip high in the hilum.

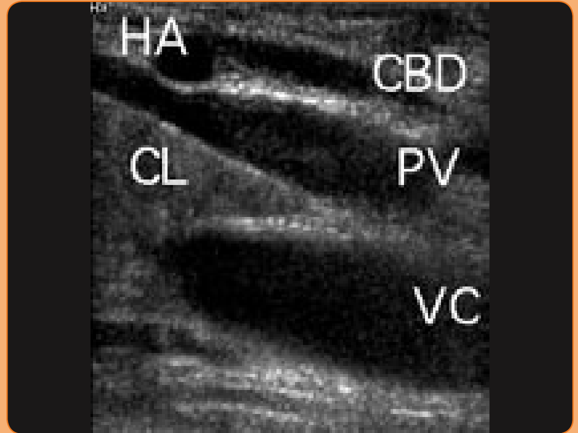

Figure 9. Longitudinal view with probe placement as in Figure 8. Note that the common bile duct (CBD) is very superficial. The hepatic artery (HA) is seen in cross section. The portal vein (PV), caudate lobe (CL) and vena cava (VC) follow.

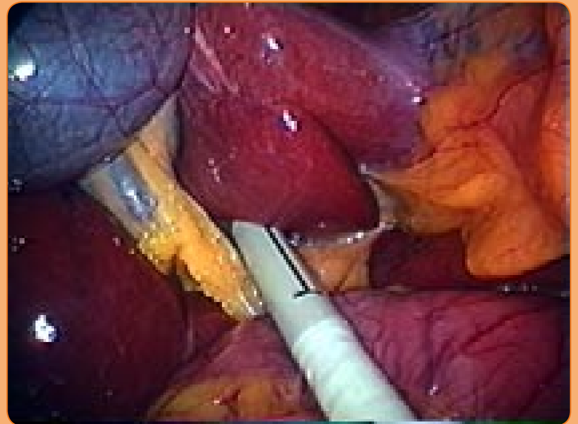

Figure 10. "Mickey Mouse" view of the hepatoduodenal ligament with transverse placement of the probe.

View through head of pancreas *(Figures 11-12)*

The common bile duct enters the head of the pancreas posteriorly. The cystic duct enters at a variable location and often can be seen entering the common bile duct in the head of the pancreas. Anterior to the pancreas, the antrum, pylorus or duodenal bulb serves as the acoustical window to the head of the pancreas. At the cephalad portion of the pancreas, the pancreaticoduodenal artery can be seen anterior to the common bile duct. As the common bile duct courses through the head of the pancreas, it will deviate to the patient's right as it approaches the ampulla. The pancreatic duct can be easily seen as it joins the common bile duct just before it enters the ampulla. Medial to the head of the pancreas, the portal vein can easily be followed coursing posterior to the pancreatic neck. The pancreatic duct can easily be seen just anterior to the portal vein in the middle of the pancreatic parenchyma. From this point to the ampulla, the pancreatic duct can be followed toward the ampulla. Notably, the texture of the pancreas often changes from a hyperechoic to a slightly hypoechoic consistency just before the confluence of the biliary and pancreatic duct. This hypoechoic area is the dorsal portion of the pancreas. The vena cava can be seen posterior to the pancreatic head.

Figure 11. Drawing of the probe's transducer over the second portion of the duodenum giving a lateral to medial view. This gives a better acoustical window.

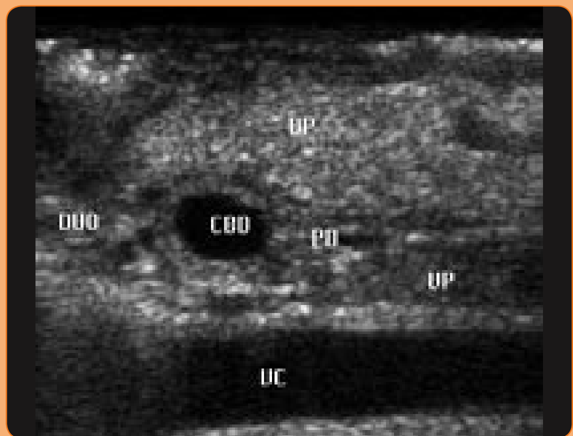

Figure 12. Transduodenal view of the head of the pancreas through the duodenum (DUO). The dorsal pancreas (DP) is hypoechoic relative to the ventral pancreas (VP). The pancreatic duct (PD), common bile duct (CBD) and vena cava are labeled as well.

Transduodenal view *(Figures 13-15)*
As the distal portion of the common bile duct is approached, the ultrasound transmission becomes somewhat obscured in many patients due to overlying parapancreatic omental fat or simply a fatty pancreas. The duodenum, which is usually fluid filled and relatively devoid of bowel gas, provides an excellent acoustical window at this level allowing a better view of the common bile duct, pancreatic duct and ampulla. The image is obtained by placing the probe lateral to the second portion of the duodenum. This allows cross-sectional view of the common bile duct. The ampulla is seen as a target pattern just lateral to the medial duodenal wall.

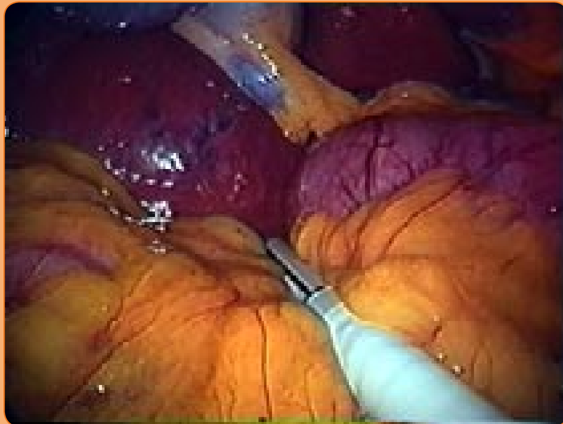

Figure 13. Laparoscopic view of the probe's transducer over the second portion of the duodenum.

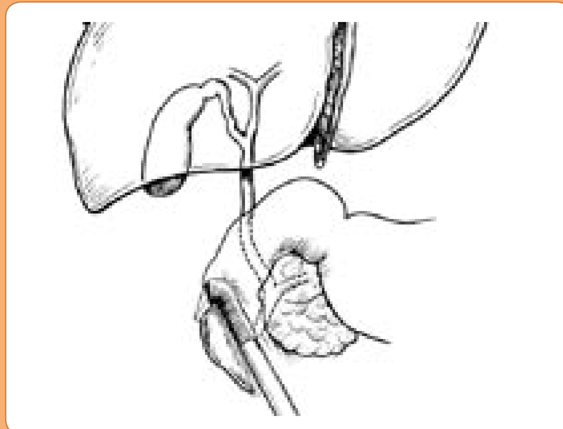

Figure 14. Drawing of the probe placed over the second portion of the duodenum. Note that the tip is deflected to give a transverse view.

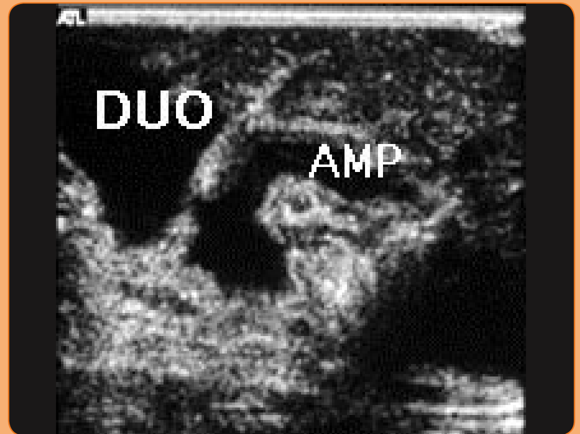

Figure 15. Transduodenal view of the ampulla (AMP) projecting into the duodenum (DUO). This is often seen as a target pattern.

Scanning Technique

- After first placing ligatures on the cystic duct, ultrasound is performed to check the integrity of the common bile duct. A 5-mm laparoscope is inserted through a 5-mm port in the right upper quadrant to visualize the position of the LUS probe. The LUS probe is inserted through the umbilical 10-mm port or, alternatively, a 10-mm epigastric port.

- With the transducer over segment five, first **identify the gallbladder**. If the gallbladder is thickened, look for abnormal mucosal patterns, which may identify a neoplasm. This is a brief view that allows one to see shadowing gallstones, sludge, cholesterolosis, polyps or thickening from acute inflammation.

- To evaluate the proximal biliary tree, first get a **transhepatic view of the confluence of the ducts** by placing the probe over segment four of the liver and aligning the long axis of the probe with the porta hepatis. Next, get a longitudinal view of the common hepatic duct, which is usually just below the liver, and then a cross-sectional cut of the right hepatic artery, which more commonly lies between the common hepatic duct and portal vein. The third structure is the portal vein, which is seen longitudinally. The caudate lobe of the liver is the fourth structure and the vena cava is the fifth structure (Figure 6). Once these structures are identified, further inspection of the proximal biliary tree can be carried out. The right hepatic duct is usually in line with the common hepatic duct and the left is seen to take off at almost a 90° angle.

- Once the transhepatic evaluation is completed, place the probe between the liver and the anterior surface of the hepatoduodenal window to get a **longitudinal view of the structures of the hepatoduodenal ligament** (Figures 8-9). Adjust the depth of the image to magnify the closer structures. Adjust the focus to the near field. Next, place the probe on the common hepatic duct. When the common bile duct is difficult to find, the liver can be lifted to directly visualize the hepatoduodenal ligament and the junction with the cystic duct. If there is still difficulty finding the common hepatic or common bile duct, find the portal vein and slowly move the probe laterally with a rotating clockwise/counterclockwise motion until the bile duct is identified. The duct is confirmed by following it out distally and proximally verifying its normal anatomical path. The non-vascular nature of the common bile duct can also be confirmed with Doppler or color Doppler imaging. After identifying the common hepatic duct, advance the probe caudad toward the pancreatic head and, with clockwise/counterclockwise rotation on the long axis, search for the **cystic duct/common bile duct junction**. This is at a variable location and can sometimes be seen entering near the ampulla. The most common location is just above the pancreas. It may be useful to get a transverse view of the portal structures above the level of the pancreas. In this view the common hepatic duct is lateral to the hepatic artery and the portal vein is posterior and a larger structure. This is often called the "Mickey Mouse" view since the common bile duct and hepatic artery form the ears and the portal vein forms the face (Figure 10).

- Next, proceed distally to the **intrapancreatic common bile duct**. The common bile duct and the portal vein deviate from each other, with the common bile duct heading laterally toward the second portion of the duodenum (Figure 7). To continue getting a longitudinal view, the tip of the probe must be angled medially. At this point, the common bile duct may be obscured by the fat overlying the pancreas or just the sheer bulk of the pancreatic head, especially if it is fatty. It then becomes necessary to get a transduodenal window which provides better acoustical coupling, since it is water rather than fat density. Here, the tip of the probe is deflected laterally and downward over the duodenum.

  This provides a **transduodenal view of the common bile duct and ampulla**. The duct is followed from proximally to distally and is seen in cross section. The pancreas proximally is hyperechoic to isoechoic and as the probe goes more distally, the pancreatic parenchyma usually gets somewhat hypoechoic. Near the level of the ampulla the pancreatic duct can be seen approaching the common bile duct at an almost 90° angle (Figures 11-14). Both ducts can then be seen to enter the ampulla, which often can be seen as a target pattern exiting the medial wall of the duodenum (Figure 15).

- It can be difficult to see the intrapancreatic common bile duct because the duct is small or decompressed. Sometimes it is necessary to place a cholangiocatheter in the cystic duct and infuse saline into the bile duct. This distends the distal duct and provides a fluid interface to give a better image. If the distal duct cannot be seen well, careful inspection for shadowing in the region of the distal duct and ampulla is sought as this may represent a common bile duct stone.

Ultrasound Findings

Gallbladder pathology

The most common finding is cholelithiasis, though patients can have small, non-shadowing stones termed sludge or cholesterolosis (Figures 1-3). This can represent tiny calcium bilirubinate stones in the case of sludge, or adherent soft cholesterol clusters in the case of cholesterolosis. Often when preoperative ultrasound suggests a gallbladder polyp, an adherent soft cholesterol stone is found rather than a true polyp. In acute cholecystitis the gallbladder wall can be thickened due to inflammation and associated edema. Walls thicker than four millimeters are usually associated with very difficult dissections at laparoscopic cholecystectomy. True neoplasms such as polyps or cancer are rarely encountered. Ultrasound is excellent for identifying intraluminal masses and determining the depth of penetration of the gallbladder wall, identifying suspicious lymph nodes and to evaluate for liver metastasis (Figure 4).

Choledocholithiasis

The main reason for performing LUS during laparoscopic cholecystectomy is to look for common bile duct stones. If the duct is large there is a higher chance of encountering stones, with stones ranging in size from one millimeter to several centimeters more commonly found in the distal duct. They may be shadowing or non-shadowing as in the case of small, soft-cholesterol stones. A typical stone will have a hyperechoic surface in the shape of the surface of the stone. Posterior to this is shadowing (Figures 16-17). Small stones in the distal duct are especially hard to find if the pancreas is fatty and the duct is not dilated. A small stone can be lodged in the ampulla. If the distal duct is not readily seen, careful examination of the area of the common bile duct for shadowing is important. If visualization is difficult and a stone is suspected, it is helpful to infuse normal saline through the cystic duct to help outline the stone. If the duct is not dilated, there is no shadowing, and there is a low probability of a stone, the chances of missing a significant common bile duct is small and a cholangiogram is not necessary to confirm a negative exam.

Sludge in bile duct

There is often a small amount of sludge in the common bile duct that is not seen with cholangiography. This is most likely because on cholangiography these particles are small enough that the contrast obscures the sludge or that it passed with the bile before the contrast reaches the distal duct to detect any filling defects. Unless there is a large amount of sludge, this is usually an incidental finding of no clinical significance. At most the patient should be warned that they might have an episode or two of biliary pain should some of this sludge cause partial obstruction in passing.

Anatomy of the biliary tree and surrounding structures

The hepatic duct, cystic duct junction and distal common bile duct are readily seen with ultrasound. The right hepatic and left hepatic duct can also be seen in most cases and certainly when the ducts are dilated. Anomalous branching patterns such as segment six duct off the cystic duct or right hepatic duct are difficult to see, due to their small size, and can be missed. These patterns are best seen with intraoperative cholangiography. The thickness of the bile duct wall and configuration of the cystic duct hepatic duct junction are well seen with ultrasound. The surrounding structures—such as the hepatic parenchyma, lymph nodes, hepatic artery, replaced hepatic artery, portal vein, pancreas, etc.—are seen much better with ultrasound.

Ampullary and pancreatic tumors

Occasionally, a patient will be found to have a dilated bile duct with no stone in the common bile duct. Ultrasound is particularly useful on these occasions, since an ampullary tumor, bile duct tumor or pancreatic tumor may be identified and staged at that time. Ultrasound can be used to help determine the size and location of the tumor. It will also allow identification of vascular encroachment or encasement, assessment of regional and distant nodes for metastasis and evaluation of the liver for metastasis. Biopsies can be performed with ultrasound guidance.

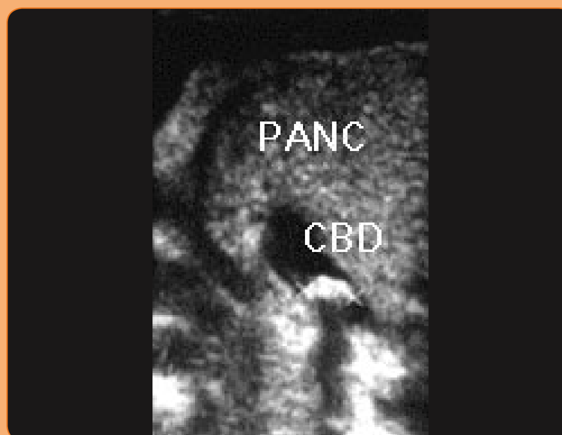

Figure 16. Stone in the distal intrapancreatic common bile duct (CBD).

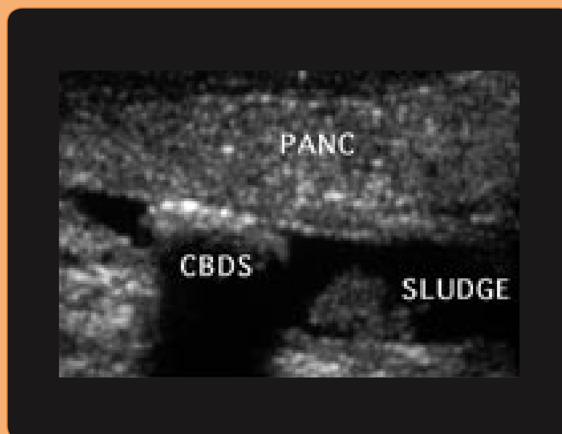

Figure 17. Longitudinal view of a common bile duct stone (CBDS) with shadowing. There is also some non-shadowing sludge.

Pitfalls

Small ducts

These may be very difficult to find especially in thin individuals with minimal periportal fat. It is often helpful to elevate the liver and look directly at the porta hepatis to visualize the location of the common bile duct and place the probe directly on top of it. If there is a question of whether the structure is vascular or biliary, Doppler or color Doppler imaging may be useful. If it remains difficult to find, irrigation of normal saline through the cystic duct will produce distention of the duct and make it easier to identify.

Fatty liver

A fatty liver that is also thick makes it difficult to see the intrahepatic bile ducts and makes the transhepatic window sub-optimal. When this occurs, it is best to just place the probe over the portal structures.

Fatty pancreas

As in the liver, if the pancreas has excessive fatty consistency or there is overlying omental fat, transmission of the ultrasound beam is diminished and visualization of the common bile duct is obscured. Use a transduodenal window, which gives a water-density ultrasound window. The probe should be placed on the lateral duodenal wall facing medially. If this does not give an adequate view and a stone is suspected, infusion of saline through the cystic duct will distend the duct and enhance its contrast with the surrounding pancreatic parenchyma. Careful search must be made for hyperechoic reflection and any shadowing in the pancreatic head. This could represent a stone. Under these circumstances, if the view is sub-optimal, small non-shadowing stones or sludge may be missed. A cholangiogram may be necessary or one can accept that these small stones may be insignificant. Alternately, if the common bile duct is not dilated, there are no indicators suggesting choledocholithiasis and no shadowing is seen, it can be concluded that most likely there is no stone. We have for the most part taken this approach and have not missed a clinically-significant stone in our series.

Para-ampullary duodenal diverticula

This can be misleading. Air in a para-ampullary duodenal diverticulum can create a hyperechoic reflection with posterior shadowing. This appears to be in the pancreatic parenchyma. Care must be taken to follow the duct carefully to check to see if this hyperechoic reflection and shadowing is in or outside of the common bile duct. If it is outside of the common bile duct and extremely hyperechoic, it is most likely due to air in a diverticulum.

Artifacts

Because of overlying structures such as the hepatic artery, posterior enhancement and shadowing at the lateral edges of the artery when overlying the common bile duct can create artifacts of hyperechoic densities in the common bile duct which suggests sludge or a stone. One must be careful to recognize this possible artifact.

REFERENCES

Arregui ME, Surgeon's Guide to Ultrasound. General Surgery & Laparoscopy News, McMahon Publishing Group. December 1997.

Arregui ME, Laparoscopic Cholecystectomy: Ultrasound and Doppler. Carol E. H. Scott-Conner for the SAGES manual. Fundamentals of Laparoscopy and GI Endoscopy, chapter 13.4 pages 162-166 Springer-Verlag. October 1998.

Barteau JA, Castro D, Arregui ME, Tetik C, A comparison of intraoperative ultrasound vs. cholangiography in the evaluation of the common bile duct during laparoscopic cholecystectomy. Surgical Endoscopy 1995; 9:490-498.

Thompson DM, Tetik C, Arregui ME, LUS. Problems in General Surgery, Lippincott-Raven Publishers, Philadelphia 1997 Vol. 14 No. 1, pp. 107-116

Thompson DM, Arregui ME, Tetik C., Madden MT, Wegener M., A Comparison of LUS with Digital Fluorocholangiography for Detecting Choledocholithiasis During Laparoscopic Cholecystectomy, Surgical Endoscopy. 12 (7):929-32, 1998 July.

Thompson DM, Arregui ME, The Role of LUS in Cancer Management, Seminars in Surgical Oncology. 15 (3):166-75, 1998 Oct.-Nov.

Staren ED, Arregui ME (eds.), Diagnostic And Interventional Ultrasound for Surgeons, 1997, Lippincott, Philadelphia, PA.

Wegener ME, Kolachalam RB, Arregui ME, Laparoscopic Intraoperative Ultrasonography. In Operative Strategies in Laparoscopic Surgery Phillips EH, Rosenthal R (eds.). Springer-Verlag, Heidelberg, Germany. 1995; pp39-46

AUTHORMaurice E. Arregui, MDSt. Vincent Hospital and Health Care Center, Indianapolis, Indiana

Philips Medical Systems is part of Royal Philips Electronics

www.medical.philips.com/ultrasound

North America
Tel: 800 229 6417
Asia Pacific
Tel: 852 2821 5888
Europe
Tel: 49 40 5078 4532
Latin America
Tel: 954 835 2600

© Koninklijke Philips Electronics N.V. 2003. All rights are reserved. Reproduction in whole or in part is prohibited without prior written consent of the copyright holder.

Philips Medical Systems Nederland B.V. reserves the right to make changes in specifications or to discontinue any product, at any time without prior notice or obligation, and will not be liable for any consequences resulting from the use of this publication.

Printed in USA G53640r2 6-03