Endoscopic ultrasound (EUS) can demonstrate the detailed anatomy of the liver from the transgastric and transduodenal routes. Most of the liver segments can be imaged with EUS, except the right posterior segments. The intrahepatic vascular landmarks include the major hepatic veins, portal vein radicals, hepatic arterial branches, and the inferior vena cava, and the venosum and teres ligaments are other important intrahepatic landmarks. The liver hilum and gallbladder serve as useful surface landmarks. Deciphering liver segmentation and anatomy by EUS requires orienting the scan planes with these landmark structures, and is different from the static cross-sectional radiological images. Orientation during EUS requires appreciation of the numerous scan planes possible in real-time, and the direction of scanning from the stomach and duodenal bulb. We describe EUS imaging of the liver with a curved linear probe in a step-by-step approach, with the relevant anatomical details, potential applications, and pitfalls of this novel EUS application.

**Key words:** endoscopic ultrasound (EUS), hepatic vein, ligamentum teres, ligamentum venosum, liver, liver segment

**INTRODUCTION**

Radiological description of liver segments has been standardized. However, endoscopic ultrasound (EUS) provides a different perspective of liver anatomy from the familiar computed tomographic (CT) and transabdominal ultrasound (US) images and requires three-dimensional conceptualization of the liver parenchyma. In most of the EUS literature, the liver parenchyma has simply been described as the left and right lobes and a detailed explanation of liver anatomy by EUS is not available. With improving resolution and widespread use of EUS, small liver metastases and other focal lesions in the liver are being increasingly discovered. Some of these small liver lesions are unsuspected by previous imaging tests and often have a connotation of metastatic disease. Hence, these EUS findings have to be co-related with the CT and US scans and need a detailed description, including their location in the respective liver segments.

It is likely that in the future there will be increasing application of EUS-guided interventions including fine-needle injections, tumor ablative therapies, vascular interventions, and complex transhepatic drainage procedures, requiring an amalgamation of cholangiographic and EUS information. We envisage that in the coming years, detailed knowledge about EUS liver segmentation and anatomy will be increasingly needed as a basic roadmap for these interventions. In the present review, we describe a practical step-by-step evaluation of the liver parenchyma and vasculature with a convex EUS probe.

**PROCEDURE**

**Basic principles of endosonographic liver segmentation**

We follow the liver segmentation scheme proposed by the French surgeon and anatomist Claude Couinaud who divided the liver into eight segments based on third order portal vein (PV) distribution (Fig. S1a). All images in the present study have been generated from a detailed review of real-time recordings using the curved linear scanning GF-UCT 260 echoendoscope (Olympus Optical, Tokyo, Japan), coupled with an Aloka Prosound-α10 ultrasound processor (Hitachi Aloka Medical, Tokyo Japan). Our image orientation is with the cranial aspect of the patient directed towards the right side of the screen.
Identification of liver segments by EUS depends upon recognizing certain familiar structures within the liver (Table 1). The branches of hepatic and portal veins, branches of hepatic arteries, and intrahepatic ligaments serve as landmarks for EUS imaging of the liver. The gallbladder (GB) and the liver hilum also serve as useful surface landmarks for orientation. The endosonographer must appreciate that EUS is a dynamic study, and the liver is imaged in innumerable scan planes. Hence, after locating the intrahepatic landmarks, the scan plane must be rolled off these structures to one side to image the demarcated segment. This technique of real-time imaging of the liver is counter-intuitive from the static, cross-sectional imaging modalities such as CT scans. On conventional static, radiological sections, the hepatic vein (HV) and PV branches are shown to circumscribe strictly demarcated segments between them. However, these intrahepatic landmarks are not demarcating structures, and only provide a rough approximation for the relatively avascular planes used by surgeons for hepatic parenchymal dissection.

### Techniques of endosonographic liver segmentation

#### Step 1: Evaluation of the left lateral segments

As the EUS scope is introduced beyond the gastroesophageal junction, the probe usually faces anteriorly towards the left liver lobe if the scope shaft is straight and the knobs are free (Fig. 1; Fig. S1b–e). In the EUS scanning plane, segment 2 (S2) is closer to the probe (upper in the scan field), and S3 farther away. The respective PV branches to the left lobe segments S2 and S3 (henceforth called P2 and P3, respectively) are seen as round anechoic structures with hyperchoic margins. With a very slight clockwise rotation over the left lobe, the HV is seen as a long vascular channel coursing from the upper right to the lower left part of the image (Fig. 2a; Video S1). The plane of the left HV separates S2 (located posteriorly and superiorly in the left lobe) from S3 (located more anteriorly and inferiorly in the left lobe). To line up the S3 ducts, as for hepaticogastrostomy, the EUS probe is pushed in with upward tip deflection. S2 ducts are easier to puncture, but the puncture site is higher, often transesophageal, with risk of mediastinitis and difficult stent deployment.

#### Step 2: Identification of the umbilical part of the left PV and ligamentum teres

With slight further clockwise rotation, the P2 and P3 are seen to converge into an elongated vascular channel with thick hyperechoic walls – the umbilical part (pars-umbilicus) of the left PV. The umbilical part of the left PV describes a smooth arch towards the ligamentum teres (round ligament) (Fig. S2). On EUS, the ligamentum teres is seen as a hyperchoic band extending from the umbilical part of the left PV to the liver surface at the inferior margin of the falciform ligament (Fig. 2b; Video S1).

#### Step 3: Identification of the medial segment of the left lobe

To the right (clockwise rotation of the probe) of the umbilical part of the left PV is the medial segment of the left lobe.
lobe (S4). S4 is bordered by the concavity of the arching umbilical part of the left PV on the left side, and the middle HV on the right side, which separates it from S8. This corresponds to the area between the falciform ligament and the GB, as seen on the liver surface. The S4 extends over the front of the liver hilum, S1 (caudate lobe), and medial portions of the right posterior segments. The transverse portion of the left PV and the ligamentum venosum demarcate S4 from the S1 behind it (Fig. 2; Fig S3; Video S1). S4 is seen in a wedge-shaped profile on transgastric EUS imaging, between rotations from the umbilical part of the left PV until the middle HV (Fig. 2c; Fig. S4).

**Step 4: Identification of ligamentum venosum and the caudate lobe (S1)**

Ligamentum venosum is the obliterated ductus venosus, which shunts blood from the left umbilical vein to the inferior vena cava (IVC) until birth. It runs from the angle between the transverse and umbilical part of the left PV to the IVC at the drainage of the left HV and middle HV. The ligamentum venosum separates S1 from rest of the liver – S2 to the left and S4 to the front. To the right and posteriorly, the S1 is bounded by the IVC. On transabdominal US, the ligamentum venosum is demonstrated between the S1 and S2, but the EUS scan plane from the proximal stomach cannot demonstrate these two segments in one plane. Instead, on EUS, the ligamentum venosum is seen as a thick hyperechoic band between S1 under the probe, and S4 deep to it (Fig. 2c; Fig. S3).

**Step 5: Identification of the IVC and right liver lobe from the stomach**

The middle HV separates S4 from the right anterior segments (S5 and S8). As the scan plane rotates over the middle HV, part of S8 is seen deep to the upper IVC. S8 occupies a wide area under the diaphragmatic dome. However, the right liver lobe is generally not seen except in small parts, as it is farther away from the probe (Figs S4,S5). In addition, there may be prominent branches of the middle HV giving the impression of two separate draining veins in the IVC and should not be confused as the right HV. The right diaphragm is seen as a thick hyperechoic muscle bundle over the superior liver surface.

If the probe is rotated by a few more degrees, along with slight withdrawal, we can demonstrate the upper part of the IVC through S1 and its termination into the right atrium (Video S1). The IVC is not related directly to the upper stomach, and S1 is usually seen interposed between the probe and the IVC in the scan plane (Fig. 2d; Fig S1b).

**Step 6: Evaluation of the liver hilum from the stomach**

The hilum of the liver is below and behind S4 and can be seen by pushing the probe in. The PV trunk is seen in a longitudinal orientation from the stomach with the bile duct behind it. The cystic duct is seen below the bile duct and the GB below and counter-clockwise (to the right anatomically). A part of S5 may be seen farther in the field below the GB in patients with optimal scanning conditions (Fig. S6). The
transverse part of the left PV rises close to the probe in the scan plane and can be traced down into the PV trunk at the hepatic hilum (Fig. 2d). The left HA follows the transverse part of the left PV and can be traced back to its branches by counter-clockwise rotation and slight upward tip angulation (Fig. S7a; Video S1). The right PV branch dips down almost vertically in this view and cannot be further traced from the stomach. The right HA also follows the right PV (Fig. S7b).

Further clockwise rotation from the hilum directs the scan plane off the liver and the probe now faces the abdominal aorta posteriorly. At the level of the aortic hiatus, the aorta is slightly to the left of the midline. The common hepatic artery (CHA) can be traced from the celiac trunk by rotating back in a counter-clockwise direction and a little withdrawal towards the liver hilum. The CHA gives off the right gastric artery that is usually not seen, and the gastroduodenal artery (GDA) at the upper part of the pancreatic neck. Variations in HA anatomy are common and can be recognized during the EUS study. A replaced right HA or CHA is seen best from the stomach, and can be traced to its origin from the superior mesenteric artery. During transgastric imaging, the replaced right HA is seen to course ‘below’ the elongated image of the PV instead of the normal crossing down from an upward direction in the scan plane. It is important to recognize this anomaly before an intraductal ultrasound (IDUS) examination, as a replaced right HA cannot be seen during IDUS examination. A replaced left HA can be seen to originate from the left gastric artery and traced along the left PV into the hilum.
Step 7: Identification of the hepatoduodenal ligament structures, and PV and hepatic artery branches from the duodenal bulb

As the scope passes the pylorus it is pushed into the apex of the bulb, forming a J-shaped configuration. The scope tip is directed superiorly and the probe now faces posteriorly. Clockwise rotation directs the scanning plane down to the pancreatic head and counter-clockwise rotation directs the scanning plane upwards to the liver hilum (Fig. S8).

The bile duct and PV are demonstrated in long axis from the bulb, with the former closer to the probe. When the PV is traced upwards to the hilum its bifurcation can be displayed with the right PV branch directed upwards and the left branch downwards in the image (Fig. 3a; Video S2). The common HA is seen to indent the PV as it crosses it. It then divides into the GDA and the proper hepatic artery (henceforth called the HA) at the superior margin of the pancreatic head. The HA usually courses along the posterior aspect of the common bile duct in 80% of cases and divides into its right and left branches earlier than the branching of the PV and bile duct. The right HA is thus usually seen in cross-section between the bile duct and the PV, indenting these structures. It then passes upwards into the hilum, while the left HA extends down on the screen (Fig. 3b). The arterial branch to S4 (A4) is variable and has two patterns. It can originate from the left HA near the umbilical portion/fissure, best seen by transgastric imaging while tracing the left HA. The A4 branch can also arise from the loop of the extrahepatic HA (PHA) as a third branch between the left HA and right HA, coursing cephalad. This trifurcating branch to
S4, arising from the PHA, is called the middle hepatic artery.  

The inferior vena cava (IVC) may be seen as a posterior structure with S1 interposed between it and the PV at the hilum. The S1 may also be seen to project behind the IVC when the scan plane is directed to the left and posteriorly. The right adrenal may be seen behind the IVC with the right crus of the diaphragm interposed. Medial rotation of the scan plane sometimes brings the aorta into view.

**Step 8: Understanding the liver hilar orientation from the duodenal bulb**

As the scope is rotated counter-clockwise, the liver progressively moves from the right half of the screen to the lower half of the field (Video S2). The GB is situated in the inferior aspect of the liver between S4 and S5 with its neck on the left, and the fundus seen towards the right of the screen. Usually the hepatic parenchyma seen below the GB from the duodenal bulb is S4, as the scan plane is angled towards the left side from the duodenal bulb (Figs S8a,S9). Terminal branches of the middle HV are seen deep to the GB bed. Focal hyperechoic areas, the so-called focal fatty sparing are common in the GB bed and should not be confused with neoplastic changes.

Further counter-clockwise rotation scans higher into the liver hilum, with the scanning plane gradually directed upwards and posteriorly. In most instances, the confluence of the right and left hepatic ducts lies anterior to the right HA. The PV is usually posterior to the bile duct and HA at the hilum, with the right and left PV branches behind the respective arteries in the scan plane. The left PV and left HA are seen as elongated structures going down and to the left, running vertically towards the umbilical fissure in the distance (Fig. S10a; Video S3). Only a very limited view of the medial sector (S4) of the left lobe is seen from the duodenal bulb. The

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*Figure 4* Branching of the right portal vein (RPV) and right hepatic artery (RHA) seen from the duodenal bulb. For demonstration of segmental bifurcation of the right-sided portal and hepatic vein branches, some leftward movement of the scope tip (small-wheel down) is needed besides maximal counter-clockwise torque, along with slight withdrawal against the pylorus. (a) Close-up view of the branching of the RPV under the probe. (b) The RPV bifurcates into its anterior division (Ant. RPV) and posterior division (Post. RPV). S5 is close to the probe. (c) An elongated representation of the right portal vein branches. Branches of hepatic vein as seen in this section are usually perpendicular to the portal vein radicals. (d) The segmental divisions of the RPV and RHA can be further traced. A5,8, anterior branch of right hepatic artery to segments 5 and 8; A6,7, posterior branch of right hepatic artery to segments 6 and 7; P5,8, anterior branch of right portal vein; P6,7, posterior branch of right portal vein.
right HA and right PV branches are seen extending upwards and to the left of the screen (Fig. 3c; Video S2). The cystic artery is usually a branch of the right HA and passes caudal and forward along the neck of the GB. It can usually be identified.

Variations in hilar biliary anatomy are common but are very difficult to identify by EUS when the ducts are non-dilated and probably should not be commented upon. The hepatic ducts are more easily seen and traced when obstructed and dilated (Fig. S10b). The bile duct dimension should not be measured from the cross-sectional profile of the common hepatic duct at the hilum. This transverse section is almost always a slightly oblique plane through the duct, and overestimates the true duct diameter. We measure the bile duct diameter when the duct is displayed in longitudinal section, and consider 6 mm as the normal upper limit (up to 9 mm after cholecystectomy).

Step 9: Identification of segmental divisions of right PV and HA from the duodenal bulb

The right PV and right HA can be further traced into their anterior (S5 and S8) and posterior (S6 and S7) segmental divisions by a counter-clockwise scope rotation (Fig. 4; Figs S11,S12; Videos S2,S3). As we scan away from the hilum, these relationships of the vessels and ducts no longer hold true, and Doppler evaluation may be needed to identify the tubular structures.

DISCUSSION

Fat, calcium and air remain the enemy of EUS examinations. EUS evaluation of a hyperechoic fatty liver is difficult as a result of increased attenuation of the ultrasound beam. Comparison of the hepatic echotexture with that of the left kidney or the spleen during EUS examination will ensure that the gain settings are not in error. Calcified lesions obscure deeper parenchyma, and multiple large gallstones may limit evaluation of S5 and S4, and also of the hilar structures. Aerobilia after endoscopic biliary sphincterotomy, or surgical or spontaneous bilio-enteric fistulas may severely limit EUS evaluation of the intrahepatic structures. However, sometimes a biliary stent may actually serve as a useful landmark at the hilum. Anatomical description using EUS can be difficult after liver resection. Thick fibrotic bands in the liver parenchyma as a result of scarring, extensive liver parenchymal diseases, cirrhosis, and extensive liver metastatic disease will make EUS evaluation of the intrahepatic anatomy difficult, if not impossible. In most of these conditions, however, there is usually no clinical indication for a detailed hepatic evaluation by EUS. Pre-procedure recognition of these pitfalls will help avoid a long frustrating EUS examination.

CONCLUSION

With careful technique a detailed EUS evaluation of the liver is possible, as we have illustrated. EUS examination of the liver should be part of upper abdominal EUS studies. All intrahepatic findings should be localized in detail. A thorough understanding of the liver anatomy by curved linear EUS probe will form the backbone of future transhepatic EUS-guided interventions.

CONFLICT OF INTERESTS

Authors declare no conflict of interests for this article.

REFERENCES

**SUPPORTING INFORMATION**

Additional supporting information may be found in the online version of this article at the publisher’s web-site:

**Figure S1** (a) Depiction of liver segments, as seen from below. Note the relationship of S1, S4, and the liver hilum. (b) A cut-away schematic representation for understanding the liver segments and vascular landmark structures, as seen during linear EUS imaging from the proximal stomach and duodenal bulb. The left lobe segments S2 and S3 have been removed in the figure. Note the falciform ligament on the anterior liver surface, ligamentum teres (l.t.) in the umbilical fissure, and ligamentum venosum (l.v.) extending from the left portal vein (LPV) to the inferior vena cava (IVC) approximately at the entry of the left and middle hepatic veins (LHV and MHV). The S1 (caudate lobe) is also seen to the left and front of the IVC. It is easy to understand why the EUS scans show the S1 just below the probe, and IVC and S4 farther away in the scan planes. (c) Position of EUS scope on fluoroscopy, after passing the gastroesophageal junction, facing the left liver lobe anteriorly. Note that the gastric air does not indicate the fundus in left lateral patient position. (d) Clockwise rotation now directs the scan plane through the inferior vena cava. (e) Fluoroscopic image of the EUS scope, with clockwise rotation and upwards angulation to scan through the spleen.

**Figure S2** Schematic representation of the relative positions of S1 and S4 liver segments. Scan-A passes through S2 and S3 to the left of the umbilical part (UP) of the left portal vein. Scan-B cuts through the UP, and also through part of ligaments teres and venosum. GB, gallbladder; IVC, inferior vena cava; LHV, left hepatic vein; l.t., ligamentum teres; MHV, middle hepatic vein; P2, portal vein branch to S2; P3, portal vein branch to S2; UP, umbilical part (of left portal vein).

**Figure S3** P2 and P3 merge to form the left portal vein (PV). The hyperechoic ligamentum venosum (l.v.) is seen extending to the right of the image and the ligament teres (l.t.) (round ligament to the left of the image) from the left PV. Between the probe and the ligamentum venosum is S1 (caudate lobe). S4 is beyond the ligamentum venosum. On the left side of S1, the fissure for the ligamentum venosum separates S2 from S1. However, on EUS, we cannot demonstrate S1 and S2 in one plane, unlike on transabdominal ultrasound scanning.

**Figure S4** Further clockwise rotation and slight pushing in of the EUS probe traces the portal vein (PV) towards the liver hilum. Note a branch to segment 4 (P4) arising from the junction between the umbilical and transverse segments of the left PV. Deep to the middle hepatic vein (MHV) some S8 parenchyma is seen. l.v., ligamentum venosum.

**Figure S5** Continued clockwise rotation for a few degrees takes the scanning plane off the middle hepatic vein. The expanding profile of the upper (terminal) part of the suprahepatic inferior vena cava (IVC) is seen as it enters the right atrium. The transverse part of the left portal vein is still seen in the lower part of the liver. The S1 (caudate) remains close to the probe. Deep to the IVC are either of segments S8 or S7. It is difficult to identify the right hepatic vein (RHV) emptying into the IVC from deep in the image and variation of venous anatomy is also common. The RHV normally extends further away from the scan plane and is usually not seen by transgastric imaging. Hence, it is not possible to distinguish between the superior segments of the right lobe deep to the IVC by transgastric imaging.

**Figure S6** (a) Slight pushing in of the probe lands it on the hilum of the liver, which is seen in a longitudinal profile. The portal vein (PV) is seen as the superior-most structure from the stomach. The bile duct (not seen in this image) is seen behind the PV, as the scan plane is directed towards the right and forwards (looking from left and behind the hepatoduodenal ligament). The hepatic artery (HA) and its branches course between and over the bile duct and PV trunk. S4 (quadrate lobe) is located over the liver hilum. The right PV and right HA dip down on the screen and cannot be traced further from the stomach. Part of the right lobe (S5) is seen in the lower half of the image with the globular gallbladder (GB) on its underside. (b) Further pushing in of the probe slides it along the liver undersurface now. The scan plane shows the GB along the liver undersurface with S5 on top. We are now scanning from below-upwards.

**Figure S7** (a) Doppler identifies and allows the tracing of the left hepatic artery (LHA) from the hilum into its branches in the left lobe by counter-clockwise rotation along the inferior liver margin. The left portal vein (LPV) follows the same path. (b) The right hepatic artery (RHA) indents the portal vein (PV) and bile duct, and courses from above the PV in the scan plane, before dipping down in the scan field. A replaced RHA arising from the superior mesenteric artery would come from below the PV in the scan plane.

**Figure S8** (a) Schematic diagram illustrating the orientation of the scan planes while imaging the hilum and liver from the duodenal bulb. Structures shown in this figure are not necessarily at the same level, but have been illustrated for ease of understanding. The scan planes have been shown to origi-
nate from a single point. In reality, we scan the hilum and liver in numerous planes from different areas in the duodenal bulb. However, the scan lines illustrated here give a framework for understanding the generated EUS images. The scope is pushed into the apex of the duodenal bulb. As the scope is progressively rotated counter-clockwise, the operator attempts to sweep the scan plane from A to D. Very slight inward or outwards displacement of the probe may be needed. GB, gallbladder; IVC, inferior vena cava; LPV, left portal vein; PV, portal vein; RPV, right portal vein. (b) Fluoroscopic images of a curved linear EUS scope during imaging of the hilum and right liver from the duodenal bulb. The small metal stent was previously placed in the minor papilla and is unrelated to the present study. The scope is looped in the stomach and pushed in the duodenal bulb. The scan plane is directed downwards, medially, and backwards towards the upper part of the pancreatic head and hepatoduodenal ligament structures (scan plane A). (c) With counter-clockwise rotation of the probe, the scan plane is directed to image the gallbladder along the underside of the liver, corresponding to the area between planes A and B. (d) Maximal counter-clockwise rotation of the probe directs the scan plane deep into the right liver lobe. The scan plane corresponds to planes C to D and visualizes the right-sided vasculature and parenchyma.

Figure S9 Counterclockwise rotation takes the scan plane towards the liver hilum. The bile duct is traced towards the hilum, and the cystic duct take-off is identified. The cystic duct is identified by its spiral mucosal folds and slightly wavy outlines, and is usually closer to the probe than the bile duct. The cystic duct takes a turn towards the neck of the gallbladder (GB). A few degrees of further rotation counter-clockwise and slight manipulation of the probe demonstrate the cystic duct turning towards the GB neck. The globular profile of the GB can be lined up on the undersurface of the liver. The neck is to the left of the screen and the fundus to the right. Segment 4 of the liver is seen below the GB.

Figure S10 (a) The looping left hepatic artery (LHA) is seen. The umbilical part (UP) of the left portal vein can be made out in the distance. The liver parenchyma close to the probe probably belongs to S4. The branches of the LHA can usually be further traced from the stomach, but not from the duodenal bulb. CHD, common hepatic duct; RHA, right hepatic artery; RPV, right portal vein. (b) The dilated left hepatic duct (LHD) is seen extending away from the EUS probe. A small part of the left liver lobe can also be seen from the duodenal bulb. CHD, common hepatic duct.

Figure S11 Right portal vein (RPV) and right hepatic artery (RHA) are seen close to the probe. S5 is towards the probe. Superior aspect of the liver is towards the left of the scan plane, and S8 is seen deep in the scan plane with good imaging conditions. S6 lies behind (posterior) S5, and is seen down in the scan plane, below S5. However, there is no clear demarcation between S5 and S6.

Figure S12 Right hepatic artery and vein branching. The posterior division of the PV is seen. The posterior branches of the right portal vein and hepatic artery course away from the probe to S6 and S7, which are not seen. The dilated right hepatic duct (RHD) is now behind the vascular structures. A5,8, anterior branch of right hepatic artery to segments 5 and 8; A6,7, posterior branch of right hepatic artery to segments 6 and 7; P5,8, anterior branch of right portal vein; P6,7, posterior branch of right portal vein.

Video S1 Transgastric imaging of the liver. The linear EUS probe is positioned in the upper gastric body. The left lobe and hilar structures are viewed by rotation, and some in-and-out movements. This video demonstrates the liver anatomy as seen from the stomach.

Video S2 Transduodenal imaging of the liver. The EUS probe is introduced in the duodenal bulb with a gastric loop. The probe is directed upwards and posteriorly. This video demonstrates the structures of the hepatoduodenal ligament, liver hilar anatomy, and traces the right lobe ducts and vessels to their segmental divisions.

Video S3 Intrahepatic branching of the ducts and vessels in a 75-year-old man with hilar cholangiocarcinoma. The biliary confluence is patent. The dilated intrahepatic ducts make understanding the anatomical relationships easier.