Radial EUS imaging of the liver: A pictorial guide

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ABSTRACT

Systematic radial EUS imaging can provide a detailed evaluation of most of the liver segments, liver hilum, and hilar and intra-hepatic vascular and ductal anatomy. Innumerable scan planes are possible, and the endosonographers must reference the intra-hepatic vascular structures and ligaments, surface landmarks such as the gallbladder, and adjacent organs such as cardiac chambers and kidneys to define the liver segments. There is no strict demarcation between the adjacent segments, and all estimates are rough approximations. Radial EUS cannot sample detected lesions but can comprehensively evaluate the liver for any pathology. In particular, the superior part of the right anterior sector (S8), S4, and S6 are better seen with the radial than linear EUS probe. Unlike common belief, the liver hilum can also be well evaluated with the radial EUS probe from the mid and upper gastric body, similar to linear probe EUS imaging. Radial EUS imaging of the liver is carried out from three stations: gastroesophageal junction, upper-mid gastric body, and antrum-duodenal bulb. We describe a step-by-step approach to radial EUS description of liver anatomy in this pictorial review.

Key words: Falciform ligament, ligamentum teres, ligamentum venosum, liver segments, radial EUS

INTRODUCTION

Imaging of the liver by trans-abdominal ultrasound and cross-sectional imaging by computed tomography and magnetic resonance imaging is standardized. There is a need to associate cross-sectional liver anatomy with the trans-luminal views of the liver demonstrated by EUS. The endosonographer may need to localize liver lesions described on radiological studies during an EUS examination, and also describe the anatomical locations of small liver lesions picked up during an EUS study. A comprehensive evaluation of the liver and hilar structures should form part of a complete EUS study of the upper abdomen. In particular, liver metastasis needs to be systematically looked for in upper abdominal malignancies. Furthermore, the description of perihilar tumors needs an understanding of the hilar and intra-hepatic ductal and vascular anatomy.

We have previously described segmental and vascular anatomy of the liver using a linear EUS probe.[1] A radial EUS probe provides a different perspective of liver anatomy. Like the linear EUS probe, innumerable scan planes are possible. Real-time imaging requires "rolling-over" intrahepatic landmarks, including, portal veins (PV), hepatic veins (HV), hepatic arteries (HA), and ligaments (teres and venosum ligaments). The

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surface reference landmarks for liver segments include the gallbladder (GB) which straddles segment 4 (S4) and S5 and the falciform ligament which divides S3 and S4. These "EUS landmarks" have been described in our previous work.[1] Finally, adjacent anatomical structures such as cardiac chambers and kidney can also serve as a rough guide to the abutting liver segments.

With a radial EUS probe, the liver is evaluated from three stations: (1) around the gastro-esophageal junction (GEJ), (2) gastric body, and (3) gastric antrum and duodenal bulb. In this tutorial, we will understand the anatomy of the liver with the perspective of radial EUS imaging.

IMAGE ORIENTATION FROM THE UPPER STOMACH

At the GEJ, the image is electronically rotated to display the aorta at 5–6 o'clock position on the screen. The spine is now seen behind and slightly to the left of the aorta on the screen, and the hypoechoic fibers of diaphragmatic crus between the probe in the esophagus and the aorta behind [Figures 1 and 2]. The diaphragmatic crus is the sonographic demarcation between the thoracic and abdominal cavity, with the aortic hiatus located at the level of the twelfth thoracic vertebra (T12). The right crus fibers pass behind the inferior vena cava (IVC). Air artifacts and fluid in the gastric fundus are seen in the right upper quadrant of the screen at this level. The gastric fundus can be better defined by water instillation in the gastric lumen. The spleen which is seen in the right lower quadrant of the screen defines the greater curvature of the stomach. The liver is displayed in the right half of the screen, and the gastric wall which abuts the liver is the lesser curvature of the stomach. The anterior wall of the stomach is seen superiorly, and posterior wall inferiorly.

IMAGING STEPS FROM UPPER STOMACH

At the GEJ, the IVC is seen as a crescent-shaped anechoic structure at 7–9 o'clock position, with respiratory alterations in caliber. Slight withdrawal from the IVC leads to the right atrium, which is then seen to extend forward into the larger right ventricle [Figure 3].

Pushing the probe in and angulating the scan direction toward the liver at the GEJ (big-wheel down) from below, displays an elongated contour of the left lobe of the liver. The liver parenchyma is intersected obliquely by the radial scan plane, with the diaphragmatic muscles and the cardiac chambers deep to it. The right ventricle is seen as a large pulsating structure on top of the liver; a small part of the left ventricle can also be seen in the right upper quadrant of the screen [Figure 4].

The superior aspects of the left and right lobes are well seen with the radial EUS probe. The left HV and middle HV can be seen converging at their drainage into the IVC; usually, the right HV can also be seen. The HVs

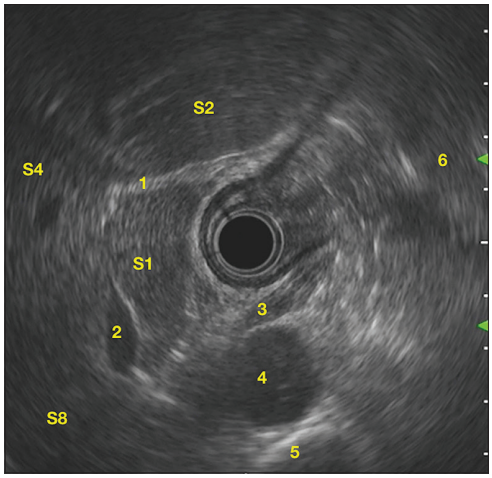

Figure 1. Radial EUS imaging at the gastroesophageal junction. The diaphragmatic crus forms the sonological demarcation between the thorax and the abdominal cavity. The caudate lobe is located to the front and left of the inferior vena cava. The fissure for *ligamentum venosum* separates S1 from S2 and S4. The gastric fundus is seen as a large area of air-artifacts on the right side of the screen. 1: *Ligamentum venosum*; 2: Inferior vena cava; 3: Diaphragmatic crus; 4: Aorta; 5: Spine; 6: Gastric fundus

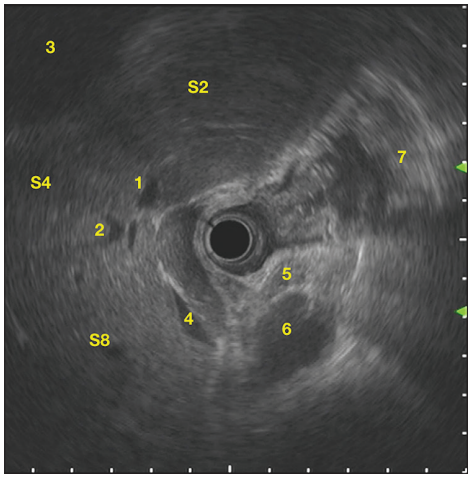

Figure 2. The left and middle hepatic veins drain into the inferior vena cava, where the *ligamentum venosum* joins it at the superior surface of the liver. At this superior level, S4 is adjacent to S2. A large part of S8-the superior-medial segment of the right lobe of the liver is seen lateral of the middle hepatic veins. 1: Left hepatic veins; 2: Middle hepatic veins; 3: Right atrium; 4: Inferior vena cava; 5: Crus; 6: Aorta; 7: Fundus of stomach

can be used as a rough demarcation between segment (S) 2, the superior aspect of S4, and S8 [Figure 5].

From the GEJ and upper gastric body, lateral sector of the left lobe comprising S2 and S3 is well seen, along with a long axis display of the left HV. Since the radial scan plane can intersect the left lobe in multiple planes, it is not possible to strictly demarcate between S2 and S3. Roughly speaking, S2 is behind/toward the probe and S3 is seen more anteriorly and at a lower level, as the probe is pushed down. Since S2 is superior, as we pull up and image the top of the left lobe, more of S2 is seen. Between the cardia and the IVC is the caudate lobe. We can see the hyperechoic *ligamentum venosus*, demarcating the caudate lobe (S1) from S2 and S4 [Figure 2].

Slight rotation of the probe counter-clockwise and clockwise, with variable pressure on the big-wheel dial, and simultaneous in-and-out movements of the probe can display most of the lateral and medial segments of the left lobe, and the caudate lobe from the upper stomach.

IMAGING THE LIVER HILUM FROM THE STOMACH

Like the linear EUS probe, liver hilum, and hepatoduodenal ligament structures can also be demonstrated by the radial EUS probe from the stomach.

The PV confluence ("club-head") is first displayed. Then, the scope is rotated anti-clockwise, with upward probe pressure (big wheel down), and withdrawn a few millimeters to display an elongated contour of the PV extending upward from the portal-confluence to the liver hilum [Figure 6]. The left PV can be followed in the long axis from the PV bifurcation by continued rotation of the probe. The HA and its branches can also be traced from the "whale-tail" appearance of the celiac trunk division. IVC can often be seen behind the elongated display of the PV trunk [Figure 7]. This imaging complements the imaging of hepatoduodenal structures from the duodenal bulb, described later.

IMAGING FROM THE ANTRUM

The balloon on the radial probe is inflated, and the probe is pushed up into the antrum, without crossing the pylorus. The liver and GB are seen on the left of the screen and mark the anterior wall of the antrum; the lesser curve is inferior. A cross-section through the long axis of GB at this level displays the parenchyma of S5 or S4 deep to it. The fundus of the GB is dependent in this position and is an important site to look for small gallstones, which can be missed by trans-duodenal imaging alone. However, a distended GB can have a variable relationship to the antrum and duodenal bulb. Beyond the liver parenchyma, the thick anterior abdominal wall muscles are seen.

IMAGING FROM DUODENAL BULB AND SUPERIOR DUODENAL ANGLE

The liver is displayed from the duodenal bulb in the upper and left half of the image. The left lobe is displayed toward the left, and right lobe in the right

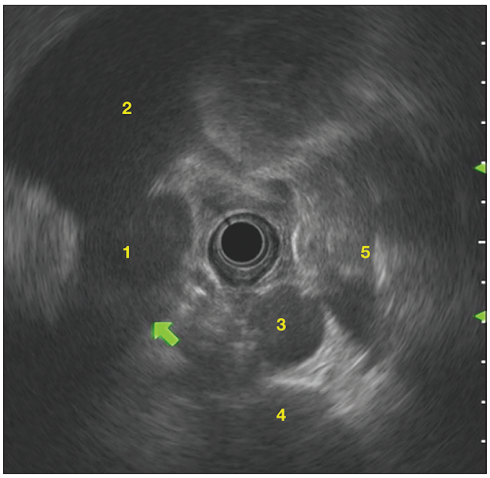

Figure 3. Pulling up on the inferior vena cava leads to its widening into the right atrium. The right atrium then extends forward into the larger right ventricle. The right sided cardiac chambers are at a lower level than the left ventricle. 1: Right atrium; 2: Right ventricle; 3: Aorta; 4: Spine; 5: Left lung

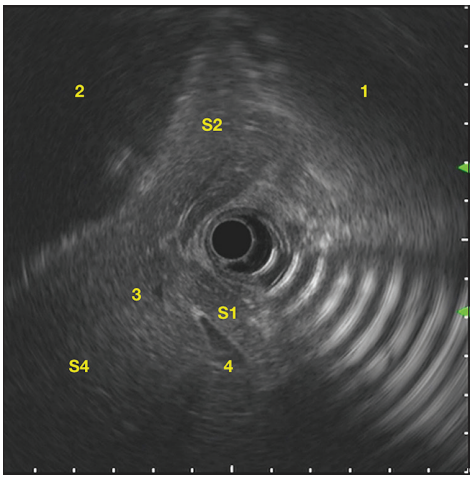

Figure 4. The probe is pushing on the left wall at the cardia. The scan plane is directed obliquely upward, and the pulsating right ventricle is seen on top of the left lobe (S2). S2 is closer to the probe, and S3 further away. 1: Left ventricle; 2: Right ventricle; 3: Left hepatic vein; 4: Inferior vena cava

upper image quadrant. The orientation of the scan plane changes when the probe is pushed inward with maintained gastric greater-curve loop (push-position), and when the imaging is done with the probe directed down toward the descending duodenum (D2). In the former position, the probe is directed superiorly, whereas in the latter position, the probe is directed inferiorly. Thus, the 360° scan planes can have multiple orientations. The IVC can be displayed either on the right side of the probe on the screen in a long or cross-sectional orientation [Figure 8a and b], or on the left side deep to the PV [Figure 8c] depending on the probe orientation.

Deep to the IVC on the right side of the screen, we can often see the right kidney and right renal vein [Figures 9 and 10]. The liver segment adjacent to the right kidney is S6 [Figure 11]. The PV is always

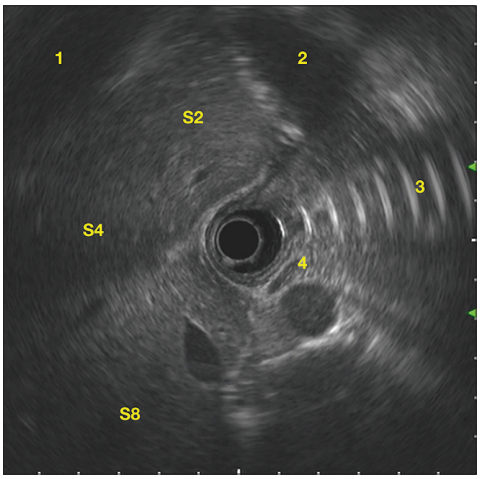

Figure 5. By angulating the imaging plane upward, we can see the larger contour of the right ventricle, and smaller contour of the left ventricle, close to S2 of the liver. 1: Right ventricle; 2: Left ventricle; 3: Gastric fundus; 4: Diaphragmatic crus in front of the aortic hiatus

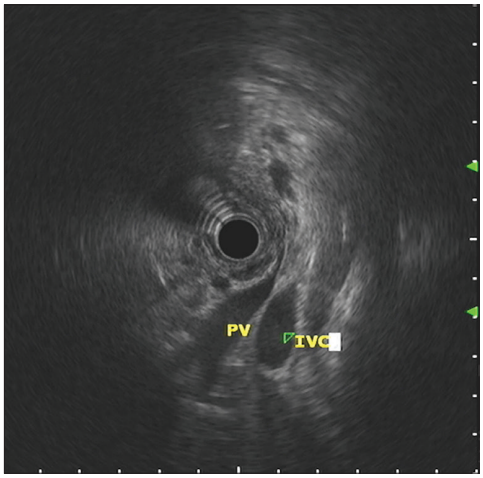

Figure 7. The portal vein and inferior vena cava can be seen in long orientation, along with the rounded cross-section of the hepatic artery, from mid-body, lesser curvature of stomach. Note that an evaluation of the liver hilum is possible with the radial probe from the stomach, like the linear probe

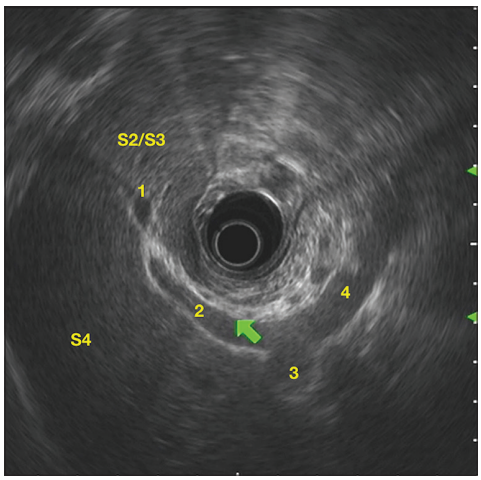

Figure 6. By rotating the probe counter-clockwise and pushing it against the anterior abdominal wall, the portal vein can be traced up from the "club-head confluence." The portal vein can be demonstrated in a long axis, along with the hepatic artery arising from the celiac trunk. In this figure, the left portal vein is seen to extend upward and round off in its umbilical portion. Distinction between S2 and S3 is difficult in this orientation. 1: Umbilical part of left portal vein; 2: Transverse segment of left portal vein; 3: Right portal vein; 4: Portal vein trunk

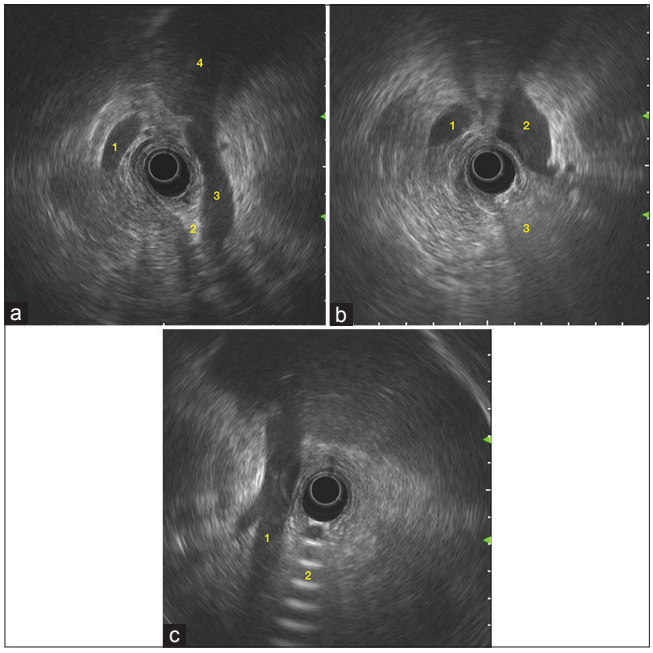

Figure 8. (a) Portal vein and inferior vena cava-both posterior structures, are seen on opposite side of the duodenal lumen. The inferior vena cava is seen in long axis on the right side of the screen. See the schematic depiction [Figure 8] to understand this orientation. The duodenal folds converge at the bottom of the screen. 1: Portal vein trunk; 2: Descending duodenal lumen; 3: Inferior vena cava; 4: Right atrium. (b) The portal vein and inferior vena cava are seen in cross-section from the duodenum. 1: Portal vein; 2: Inferior vena cava; 3: Descending duodenal lumen. (c) The inferior vena cava is displayed in long axis on the left side of the screen unlike the previous images. The descending duodenum is seen in the midline below the probe. 1: Inferior vena cava; 2: Descending duodenum

displayed on the left side of the screen deep to the pancreatic head [Figure 12]. Figure 13 explains the variable orientation of the PV and IVC-both posterior structures to the duodenum [Figure 13].

Rotation counter-clockwise directs the imaging plane toward the liver hilum and traces the PV trunk upward. The PV divisions can be seen, with the left PV branch extending toward the left side of the screen, and right PV branch to the right. By dropping the wrist down, and continued counter-clockwise rotation, the left PV can be traced and displayed along its length [Figure 14]. S4 is seen deep to the left PV. Probe manipulation can trace the left PV to its umbilical portion (UP), where it is seen to round off. The hyperechoic *ligamentum teres* is seen directed to the surface of the left lobe, from the UP [Figure 15]. The inferior part of S4 (Quadrate lobe) is close to the probe. The upper part of S4 is deep to the left PV, and the anterior abdominal wall is seen further away to the left. The cross sections of thinner left HV, and its branches can be seen alongside the much bigger left PV branches.

The GB is seen in the upper half of the screen and can be displayed with fundus left or fundus right, depending on whether the probe is oriented superiorly or downward [Figure 16a and b]. The common HA division into the proper HA and gastroduodenal artery can be seen from the duodenal bulb. The proper HA

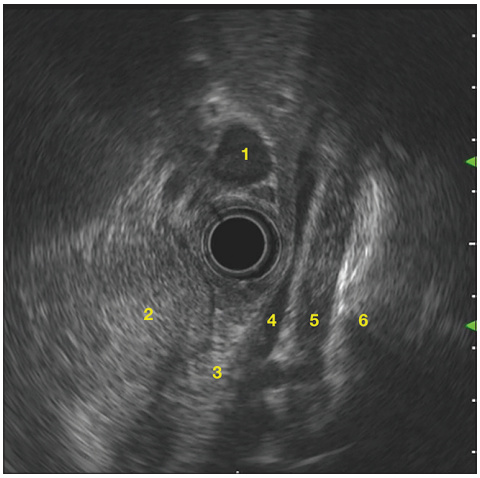

Figure 9. A long section of the inferior vena cava is seen on the right of the screen. Note the psoas muscle and the spine behind the vein. Descending duodenal lumen extends below; the duodenal lumen can be better defined by water instillation. 1: Gallbladder; 2: Head of pancreas; 3: Descending duodenum; 4: Inferior vena cava; 5: Psoas muscle; 6: Spine

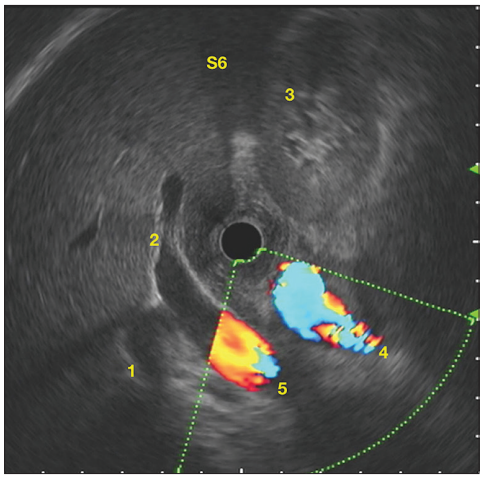

Figure 11. The portal vein trunk and inferior vena cava are seen on opposite sides of the descending duodenal folds. The portal vein division into the left and right branches is well seen. Note the right kidney; the adjacent liver segment would be S6. 1: Left portal vein; 2: Right portal vein; 3: Right kidney; 4: Inferior vena cava; 5: Portal vein trunk

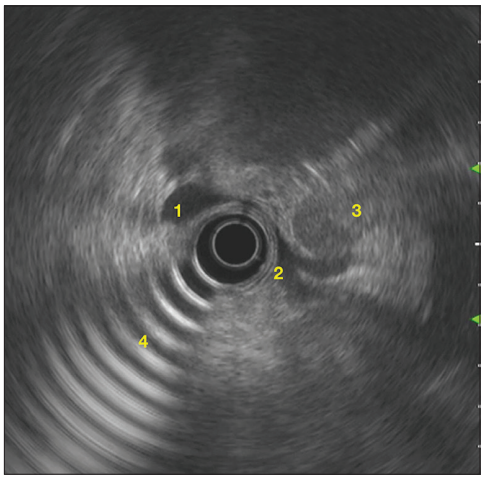

Figure 10. The right kidney and right renal vein arising from the inferior vena cava are seen. 1: Inferior vena cava; 2: Right renal vein; 3: Right kidney; 4: Descending duodenal lumen

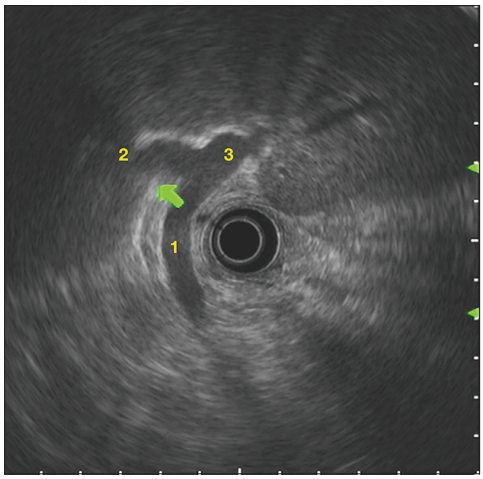

Figure 12. The portal vein trunk is depicted from the duodenal bulb. The left portal vein extends to the left of the screen, and the right branch on opposite side. 1: Portal vein trunk; 2: Left portal vein; 3: Right portal vein

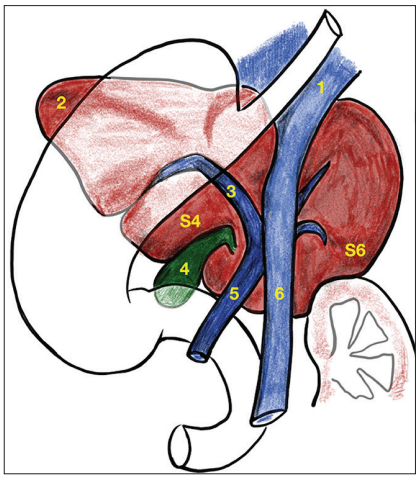

Figure 13. Schematic depiction of relevant anatomical structures to understand radial EUS imaging of the liver from first and second parts of duodenum. This image explains how portal vein and inferior vena cava-both posterior structures, are depicted on either side of the duodenum. It is also clear that the normal gallbladder and left portal vein trunk are approximately oriented at right angles on the undersurface of the liver. Rotation of the probe between these structures, can show S4, part of S1, and *ligamentum teres* from the duodenal bulb. The fusiform expansion of the upper inferior vena cava into the right atrium can be seen from the duodenal bulb; part of the right kidney, right adrenal gland, and posterior muscles of abdominal wall can also be seen from these positions. These structures are depicted in the following figures. 1: Right atrium; 2: Left lobe of liver; 3: Left portal vein; 4: Gallbladder; 5: Portal vein trunk; 6: Inferior vena cava

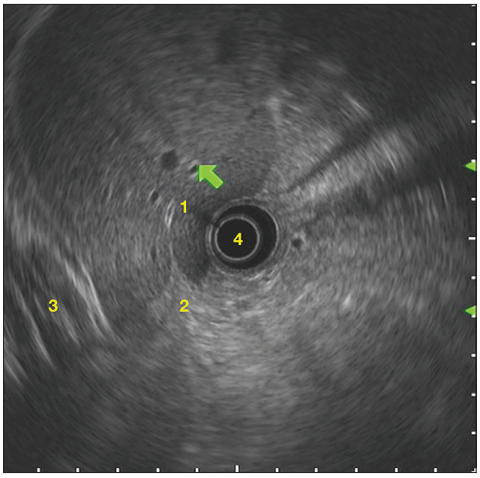

Figure 15. The left lobe is seen from the duodenal bulb. Most of the segment seen from this direction is S4. The fan-shaped hyperechoic *ligamentum teres* is seen in an oblique section. The thick anterior abdominal wall muscles are seen abutting the anterior surface of the left lobe. 1: Left portal vein; 2: *Ligamentum teres*; 3: Anterior abdominal wall; 4: Probe in duodenal bulb

is seen to loop upward, and the right HA can be traced between the PV and the bile duct coursing upward.

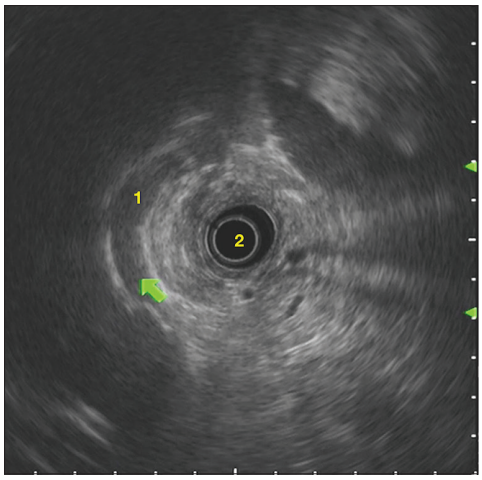

Figure 14. Rotating the probe counter-clockwise from portal vein bifurcation can trace the left portal vein in long-axis. 1: Left portal vein trunk; 2: Probe in duodenal bulb

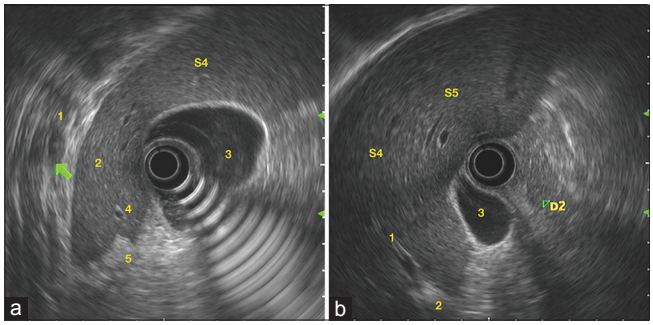

Figure 16. (a) Depending on the probe orientation, the gallbladder can be depicted with "fundus right" or "fundus left." 1: Anterior abdominal wall; 2: Left lobe liver; 3: Gallbladder; 4: Left portal vein; 5: *Ligamentum teres*. (b) The gallbladder is seen of the liver under-surface. The imaging is directed from the right-to-left, and back-to-front. Most of the liver parenchyma seen in this orientation is S4. A cross section of the umbilical portion of portal vein is seen, with fan-like extension of *ligamentum teres* extending away. The *ligamentum teres* extends from the umbilical portion of left portal vein to the inferior surface of the liver, and is the obliterated remnant of the umbilical vein, which carries blood from placenta to the fetus. S4 is located to the right of *ligamentum teres* and umbilical portion of left portal vein, and S3 to the left. The *ligamentum teres* divides S3 from S4. 1: Umbilical portion of portal vein; 2: *Ligamentum teres*; 3: Gallbladder

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Conflicts of interest

There are no conflicts of interest.

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