

EUS anatomy of the liver segments

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ABSTRACT

Clinical applications of EUS for the liver have been recently increasing. They include the screening and diagnosis of liver parenchymal disease and malignant tumors as well as EUS-guided interventions such as hepaticogastrostomy, tumor ablation therapy, and portal pressure gradient measurement. Although the segmental localization of the targeted tumor, bile duct, and vessel in the liver is important to complete these procedures, little information is available regarding hepatic segmental anatomy on EUS. The liver can be visualized with EUS by transgastric and transduodenal scanning, and the EUS determination of segmental location can be achieved using various anatomical landmarks. Identification of the right posterior segments is, however, technically difficult because they are located far from the stomach and duodenum. In the present review, we describe the normal anatomy of liver segments using linear EUS.

Key words: Anatomy, EUS, liver segment

INTRODUCTION

EUS has become an important imaging modality for the evaluation of various gastrointestinal (GI) and pancreatobiliary diseases. Since the addition of EUS-FNA provides diagnostic cytopathological samples, EUS is essential for the diagnosis and staging of malignant GI tumors such as esophageal and gastric cancers as well as pancreatic cancer. EUS also has an important role in the evaluation of common bile duct stones, pancreatic cystic lesions, and subepithelial tumors in the GI tract.

Conventionally, EUS was not used for the evaluation of the liver, but the interest in clinical application of EUS

on the liver has increased since we reported the efficacy of EUS and EUS-FNA for focal liver lesions in 1999.^[1] EUS is very useful to detect small liver lesions, which are not identified by transabdominal ultrasound (US) and computed tomography. The reported series on EUS for liver tumors, however, did not describe their location in the liver segments, probably because EUS liver segment anatomy was regarded as less important.^[1-3] From a clinical management perspective, the precise location of the tumors in the liver is vitally important, especially when conducting surgical resection or locoregional treatments (*e.g.*, percutaneous radiofrequency ablation). From a diagnostic perspective, systematic EUS examination of each segment is needed

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to increase the detection rate of lesions in the liver, the largest organ in the body. In addition, comprehension of liver segments on EUS is a prerequisite for the success of EUS-guided interventions including EUS-guided hepaticogastrostomy and EUS-guided portal pressure gradient measurement (PPGM).^[4,5] Furthermore, EUS liver segment anatomy will become increasingly important when locoregional treatments under EUS guidance such as radiofrequency ablation, photodynamic therapy, and ethanol injection are widely available for liver tumors.^[6,7] In this review, we describe the normal linear EUS anatomy of liver segments.

LIVER SEGMENTATION

Liver segmentation is usually described according to the Couinaud classification, which divides the liver into eight functionally independent segments (S1–S8) based on third-order portal vein distribution. Center of each segment has the hepatic artery branch, portal vein branch, and bile duct (portal triad). The liver is also functionally divided into the left lobe and right lobe by Cantlie's line, which runs from the middle of the gallbladder fossa anteriorly to the inferior vena cava (IVC) posteriorly. The left lobe is further divided into the medial (S4) and lateral segments (S2 and S3) by falciform ligament. The right lobe is divided into the anterior (S5 and S8) and posterior segments (S6 and S7) by the right hepatic vein. The caudate lobe of the liver (S1) is located posteriorly between the fissure for the ligamentum venosum and the IVC.

IDENTIFICATION OF LIVER SEGMENTS BY EUS

In this review, all images of liver segments were obtained using the curved linear scanning echoendoscope (GF-UCT260, Olympus Medical Systems, Tokyo, Japan), connected to a high-quality compact US processor (EU-ME2 Premier Plus, Olympus Medical Systems, Tokyo, Japan). The EUS image orientation in this review was with the cranial aspect of the patient displayed toward the right side of the screen unless otherwise noted.

Various anatomical landmarks are used in the EUS determination of segmental location. They include the portal veins, hepatic veins, IVC, ligamentum teres, ligamentum venosum, gallbladder, and right

kidney. In the left lobe, the important landmarks are the left hepatic vein and middle hepatic vein, which separate S2 from S3 and S4 from the right anterior segments (S5 and S8), respectively. The left portal vein, ligamentum teres, and ligamentum venosum are also useful landmarks for the determination of segments in the left lobe. The IVC and the ligamentum venosum mark the boundary between the caudate lobe (S1) and the left lobe. In the right lobe, the main landmark is the right hepatic vein, which separates the right anterior segment (S5 and S8) from the posterior segment (S6 and S7). The gallbladder is located in the gallbladder fossa on the inferior surface of the liver between S4 and S5. The right kidney will serve as a landmark to identify S6.

IDENTIFICATION OF LIVER SEGMENTS BY EUS FROM THE STOMACH

EUS from the stomach can provide images of the caudate lobe (S1) and left lobe (S2, S3, and S4). Part of the right anterior segment (S5 and S8) might be also identified in some patients. Various landmarks will make it easy to recognize liver segment during EUS from the stomach.

Left lateral segments

When the EUS scope is gently advanced into the stomach through the gastroesophageal junction and then is slightly rotated counterclockwise, the left lobe is visualized. In this position, the left lateral segment (S2 and S3) is scanned with clockwise and counterclockwise rotations of the scope. The left hepatic vein can be seen as a long vascular channel with thin walls, running from the top right to the bottom left of the screen [Figure 1a]. Color Doppler examination shows a triphasic pattern [Figure 2a]. The left hepatic vein divides the left lateral segment into S2 and S3; during EUS from the upper stomach, S2 is located between the probe and the left hepatic vein and S3 is situated below the left hepatic vein. Round vessels with echogenic (bright) walls are the portal vein in each segment. Color Doppler evaluation of the normal portal vein demonstrates an undulating (monophasic) pattern [Figure 2b]. The endosonographer should rotate the EUS scope clockwise and counterclockwise repeatedly to perform a complete examination of the left lateral segments [Figure 3a and b]. When performing EUS-guided hepaticogastrostomy, the intrahepatic bile duct in S3, not S2, is considered as the preferred puncture site to avoid potential

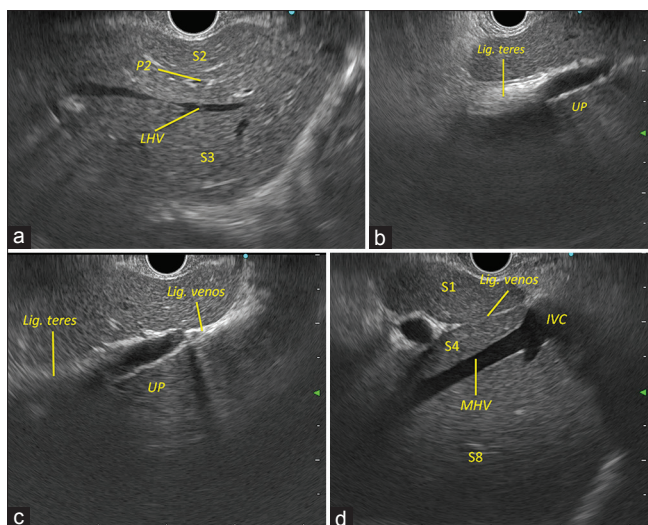


Figure 1. (a) As the EUS scope is passed through the gastroesophageal junction and then is rotated counterclockwise, the left lobe of the liver is identified. The left hepatic vein (LVH) can be seen as a long vascular channel with thin hyperechoic walls. Its course divides segments 2 and 3; in this image, segment 2 is located closer to the probe. The portal vein branch is also seen in each segment as round vessels with thick hyperechoic walls. P2, the portal vein branch in segment 2. (b) When following the respective portal vein branches in the left lateral segments by rotating clockwise and slightly pushing the EUS scope, the umbilical portion (UP) of the left portal vein is visualized. A thick hyperechoic band, expanding from the UP to the anterosuperior surface of the liver, is the ligamentum (lig) teres. (c) On clockwise rotation, the ligamentum venosum (lig. venos) is seen as a thick hyperechoic band, running from the umbilical portion (UP) to the inferior vena cava (*i.e.*, going toward the probe). (d) On further clockwise rotation and withdrawal of the EUS scope, the middle hepatic vein (MHV) can be seen, entering into the inferior vena cava (IVC). Three liver segments (segments 1 [the caudate lobe], 4, and 8) can be identified in this image. The caudate lobe (segment 1) is located between the probe and the ligamentum venosum (lig. venos). The MHV separates segment 4 from segment 8

severe complications such as mediastinitis or pneumomediastinum.

When rotating the scope clockwise, the portal vein branches to S2 and S3 (P2 and P3, respectively) and converges to form the umbilical portion of the left portal vein. By slightly pushing the scope, a high echoic band is seen extending from the umbilical portion of the left portal vein. This band is the ligamentum teres (the round ligament, the obliterated left umbilical vein), which exists in the free edge of the falciform ligament [Figure 1b]. The ligamentum teres reaches the anterosuperior liver surface and separates medial (S4) from lateral segments (S2 and S3).

Left medial segment

After identifying the umbilical portion of the left portal vein and the ligamentum teres, the scope is rotated clockwise so that the left medial segment (S4)

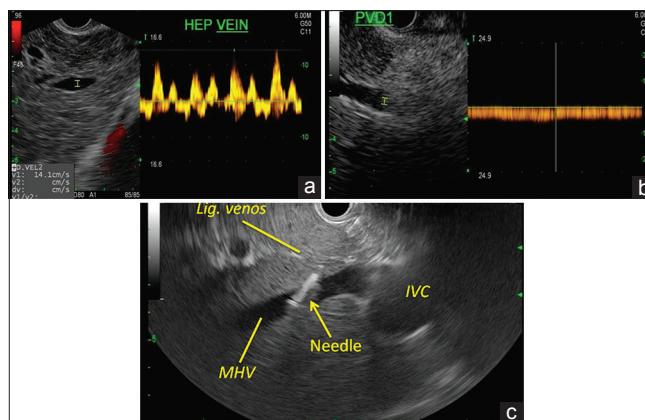


Figure 2. (a) Doppler ultrasound of the hepatic vein shows the triphasic waveform (scope: GF-UCT180, Olympus Medical Systems, Tokyo, Japan; ultrasound processor: Aloka ProSound Alpha10, Aloka Co., Ltd., Tokyo, Japan). (b) Doppler ultrasound of the portal vein shows the undulating (monophasic) pattern (scope: GF-UCT180, Olympus Medical Systems, Tokyo, Japan; ultrasound processor: Aloka ProSound Alpha10, Aloka Co., Ltd., Tokyo, Japan). (c) EUS-guided portal pressure gradient measurement. The middle hepatic vein (MHV) is punctured by a 25G FNA needle via the transgastric route. IVC, inferior vena cava; Lig. venos, ligamentum venosum (scope: GF-UCT180, Olympus Medical Systems, Tokyo, Japan; ultrasound processor: Aloka ProSound Alpha10, Aloka Co., Ltd., Tokyo, Japan)

can be seen below the ligamentum teres. On further clockwise rotation and withdrawal of the scope, the ligamentum venosum, the obliterated fetal remnant of the ductus venosum, is seen as a thick high echoic band [Figure 1c]. The ductus venosum connects the umbilical vein with the IVC in the fetal circulation and closes after birth. The ligamentum venosum courses from the transverse and umbilical portions of the left portal vein to the IVC at the entrance of the left hepatic vein and middle hepatic vein [Figure 1d]. These two hepatic veins form a common trunk in 60%–80% of cases.^[8,9] We usually puncture the left or middle hepatic vein when performing EUS-guided PPGM [Figure 2c]. The ligamentum venosum lies between the caudate lobe (S1) of the liver posteriorly and the left lobe anteriorly [Figure 1d]. On EUS from the stomach, the caudate lobe can be seen between the probe and the ligamentum venosum. S4 is also identified between the ligamentum venosum and the middle hepatic vein, which separate S4 from the right anterior segments (S5 and S8). In general, the right hepatic vein cannot be identified easily from the stomach on EUS, and thus the right posterior segments (S6 and S7) will not come into view.

The caudate lobe

The caudate lobe (S1) is demarcated by the groove of IVC and the fissure for the ligamentum venosum. As mentioned above, the caudate lobe is seen between

the probe and the ligamentum venosum while scanning from the stomach [Figure 1d]. By rotating clockwise and slight withdrawal of the scope after identification of the ligamentum venosum, the IVC can be visualized in a short-axis orientation on the right side of the screen. Further clockwise rotation and adjustment of the scope tip will bring the IVC into view in a long axis. We puncture the IVC in this view for EUS-guided PPGM in cases where it is impossible to access the hepatic vein safely. Liver parenchyma seen between the probe and the IVC is the caudate lobe.

The hepatic hilum

The hepatic hilum can be identified when rotating clockwise and pushing the scope once the ligamentum venosum is recognized. Anatomically, the bile duct and the portal vein are located anteriorly and posteriorly, respectively, at the hepatic hilum. The hepatic artery usually runs between the bile duct and the portal vein. On EUS from the stomach, however, the main portal vein is seen between the probe and the common hepatic/bile duct [Figure 4a]. Counterclockwise rotation will bring the gallbladder and cystic duct into view.

As the main portal vein is followed to its bifurcation, the transverse part of the left portal vein is seen close to the probe. In this scan plane, the liver parenchyma surrounded by the left portal vein, the middle hepatic vein, and the ligamentum venosum is S4 [Figure 4b]. The portal vein branch to S4 (P4) is visualized arising off from the main left portal vein. The right portal vein is seen going away from the probe. Although S5 might be seen as a liver parenchyma surrounded by the gallbladder, the main portal trunk, the right portal vein, and the diaphragm, the right lobe is usually difficult to visualize on EUS by transgastric scanning because it lies farther away from the probe.

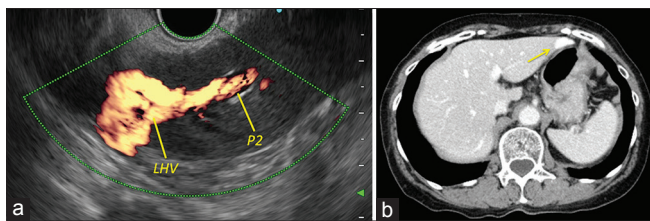


Figure 3. (a) A 75-year-old female who underwent EUS for the evaluation of abdominal pain. Color Doppler EUS demonstrates aneurysmal communication between the portal vein branch to segment 2 (P2) and left hepatic vein (LHV). (b) Subsequent contrast-enhanced computed tomography scan shows intrahepatic portal venous shunt in segment 2

IDENTIFICATION OF LIVER SEGMENTS BY EUS FROM THE DUODENUM

The left medial segment (S4) and the right lobe can be observed by transduodenal scanning. The small and tortuous duodenal lumen might preclude scanning the entire right lobe. In addition, as compared with the left lobe and caudate lobe, the right lobe has fewer reliable landmarks on EUS, making it difficult to identify precise segmentation of the right lobe.

The hepatic hilum

The scope is passed through the pylorus and advanced to the apex of the duodenal bulb, pressing the probe against superior duodenal angle and thus forming a J-shaped position. The orientation of EUS image is reversed in this scope position, with the caudal aspect of the patient displayed on the right side of the screen. By rotating the probe clockwise, the bile duct and main portal vein can be seen in the long axis. In this view, the bile duct is close to the probe; Color Doppler helps differentiate the bile duct from the portal vein [Figure 5a]. The hepatic artery is also identified in the short or long axis between the bile duct and portal vein. Further clockwise rotation and gently pushing the scope can trace the bile duct down to the pancreas. The splenic vein and superior mesenteric vein are seen merging into the portal vein confluence.

By counterclockwise rotation, the portal vein can be followed up to the level of the bifurcation. In this view, the left portal vein is seen going downward, while the right portal vein is directing toward the upper left of the screen [Figure 5b]. The ligamentum venosum might be visualized as a high echoic band extending from the left side of the portal vein. Part of S4 is seen in the

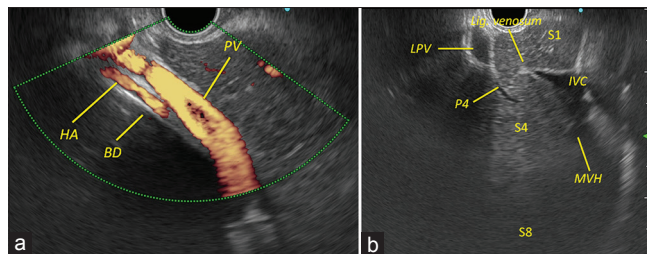


Figure 4. (a) After identifying the ligamentum venosum and then pushing the scope, the hepatic hilum can be seen. On EUS from the stomach, the portal vein (PV) lies the closest to the probe at the hepatic hilum. The hepatic artery (HA) runs between the PV and bile duct (BD). (b) The transverse part of the left portal vein (LPV) can be seen close to the probe by tracing the main portal vein. The liver parenchyma surrounded by the LPV, ligamentum (lig.) venosum, and middle hepatic vein (MHV) is segment 4. The portal vein branch to segment 4 (P4) is identified arising off from the main LPV

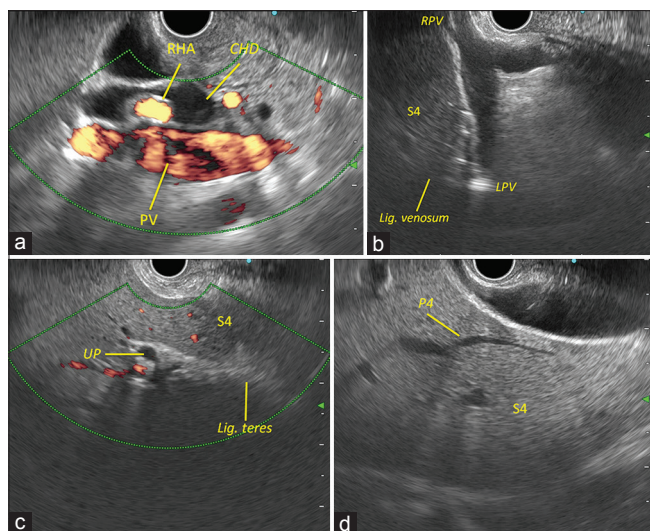


Figure 5. (a) The hepatic hilum can be identified by clockwise rotation after pushing the probe against superior duodenal angle. Contrary to the EUS imaging of the hepatic hilum from the stomach, the bile duct is located the closest to the probe. The right hepatic artery (RHA) is identified between the common hepatic duct (CHD) and the main portal vein (PV). Note that the caudal aspect of the patient is displayed on the right side of the screen. (b) The main portal vein can be followed to its bifurcation; the right portal vein (RPV) directs upward and the left portal vein (LPV) goes downward in the image. The ligamentum (lig.) teres is seen, extending from the UP. The ligamentum (lig.) venosum is sometimes seen, attached to the LPV. The liver parenchyma surrounded by the RPV, LPV, and lig. venosum belongs to segment 4. (c) The left portal vein can be further traced to the umbilical portion (UP) of the left portal vein. The ligamentum (lig.) teres is seen, extending from the umbilical portion. (d) By clockwise rotation in a J-shaped scope position in the duodenal bulb, the gallbladder can be visualized, with the gallbladder neck located in the right side of the screen. The liver parenchyma below the gallbladder is segment 4. P4, the portal vein branch to segment 4

left side of the screen. The left portal vein is further traced to its umbilical portion. A high echogenic band extending from the right side of the portal vein is the ligamentum teres [Figure 5c].

Left medial segment

As mentioned above, part of S4 is seen from the duodenal bulb while tracing the portal vein entering into the liver. The other way to identify S4 is by identification of the gallbladder as a landmark. In a J-shaped position of the scope in the bulb, a counterclockwise rotation will bring the gallbladder into the image; the left side and right side of the image are the neck and the fundus of the gallbladder, respectively. The liver parenchyma below the gallbladder is usually S4 [Figure 5d].

Right anterior segments

From the duodenal bulb, the portal vein branches of the right anterior (S5 and S8) and posterior (S6 and S7) segments can be followed by a counterclockwise rotation

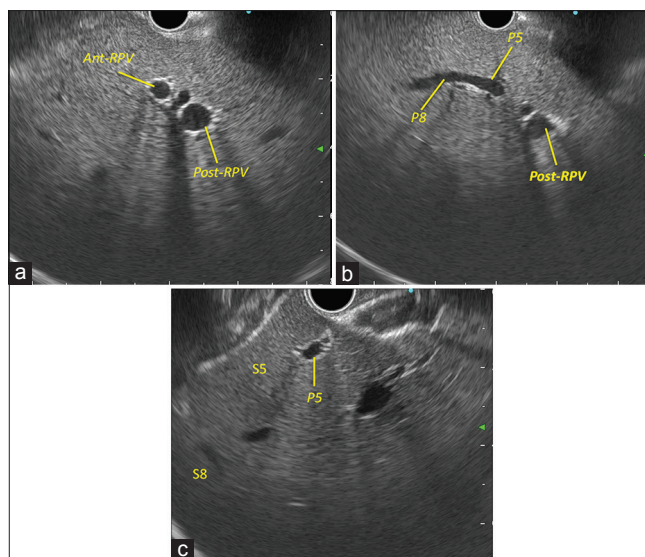


Figure 6. (a) The right portal vein can be traced to the anterior portal vein (Ant-RPV) and posterior portal vein (Post-RPV). (b and c). The anterior portal vein can further direct upward of the screen and then divides into the branches to segments 5 and 8 (P5 and P8, respectively). The P5 is seen closer to the probe

after identification of the main portal vein [Figure 6a]. While the anterior segmental branch runs close to the probe, the posterior segmental branch goes down in the image [Figure 6b]. By carefully following the anterior segmental branch, S5 will be seen in the upper left of the image [Figures 6c]. S8 might be observed in the lower left of the image. S6 and S7 are located next to S5 and S8, respectively, but it might be difficult to recognize the right posterior segments with this maneuver.

Right posterior segments

EUS examination of the right posterior segments (S6 and S7) is challenging because they are the most right of the segments and therefore are situated far from the stomach and duodenum.^[10,11] The right kidney is a good landmark to identify S6. The right kidney can be seen from the duodenal bulb with a J-shaped position of the scope. After visualization of the portal vein, the IVC will be seen in a long axis by a clockwise rotation. On further clockwise rotation and elevation of the tip of the scope, the right kidney will come into the view. The liver parenchyma (S6) will be seen on the left side of the right kidney [Figure 7a-c].

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient has given her consent for her images and other clinical information to be reported in the journal. The patient understand that her name and initial will not be

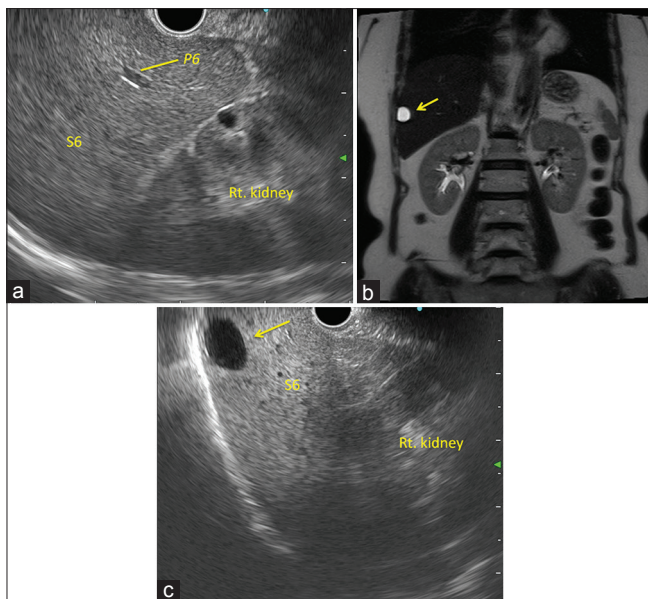


Figure 7. (a) In a J-shaped position in the duodenal bulb, the right kidney can be seen by clockwise rotation and slightly pushing the EUS scope after identification of the portal vein and inferior vena cava. The liver parenchyma belonging to segment 6 is identified next to the right (Rt)kidney. P6, the portal vein branch to segment 6. (b) A 71-year-old female who underwent magnetic resonance cholangiopancreatography for pancreatic cystic lesions. Magnetic resonance cholangiopancreatography shows a cyst in segment 6 (arrow). (c) EUS demonstrates the same cyst in segment 6 (arrow)

published and due efforts will be made to conceal her identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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