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EDITORIAL

- 322 Screening for colorectal cancer in patients with inflammatory bowel disease. Should we already perform chromoendoscopy in all our patients?

Huguet JM, Suárez P, Ferrer-Barceló L, Iranzo I, Sempere J

REVIEW

- 326 Stepwise evaluation of liver sectors and liver segments by endoscopic ultrasound

Sharma M, Somani P, Rameshbabu CS, Sunkara T, Rai P

ORIGINAL ARTICLE

Observational Study

- 340 Polysomnographic assessment of respiratory disturbance during deep propofol sedation for endoscopic submucosal dissection of gastric tumors

Urahama R, Uesato M, Aikawa M, Yamaguchi Y, Hayano K, Matsumura T, Arai M, Kunii R, Isono S, Matsubara H

Prospective Study

- 348 Submucosal injection of platelet-rich plasma in endoscopic resection of large sessile lesions

Lorenzo-Zúñiga V, Moreno de Vega V, Bartolí R, Marín I, Caballero N, Bon I, Boix J

META-ANALYSIS

- 354 Endoscopic retrograde cholangiopancreatography in cirrhosis - a systematic review and meta-analysis focused on adverse events

Mashiana HS, Dhaliwal AS, Sayles H, Dhindsa B, Yoo JW, Wu Q, Singh S, Siddiqui AA, Ohning G, Girotra M, Adler DG

CASE REPORT

- 367 Tight near-total corrosive strictures of the proximal esophagus with concomitant involvement of the hypopharynx: Flexible endoscopic management using a novel technique

Dhaliwal HS, Kumar N, Siddappa PK, Singh R, Sekhon JS, Masih J, Abraham J, Garg S

Contents

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Stepwise evaluation of liver sectors and liver segments by endoscopic ultrasound

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Abstract

The liver has eight segments, which are referred to by numbers or by names. The numbering of the segments is done in a counterclockwise manner with the liver being viewed from the inferior surface, starting from Segment I (the caudate lobe). Standard anatomical description of the liver segments is available by computed tomographic scan and ultrasonography. Endoscopic ultrasound (EUS) has been used for a detailed imaging of many intra-abdominal organs and for the assessment of intra-abdominal vasculature. A stepwise evaluation of the liver segments by EUS has not been described. In this article, we have described a stepwise evaluation of the liver segments by EUS. This information can be useful for planning successful radical surgeries, preparing for biopsy, portal vein embolization, transjugular intrahepatic portosystemic shunt, tumour resection or partial hepatectomy, and for planning EUS guided diagnostic and therapeutic procedures.

Key words: Endoscopic ultrasound; Hepatic vein; Liver sectors; Portal vein; Liver segments; Caudate lobe; Cantlie's line; Falciform ligament; Gallbladder

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Core tip: Standard anatomical description of the liver segments is available by computed tomographic scan and ultrasonography. A stepwise evaluation of the liver segments by endoscopic ultrasound (EUS) has not been described. In this article, we have described a stepwise evaluation of the liver segments by EUS. This information can be useful for planning successful radical surgeries, preparing for biopsy, portal vein embolization, transjugular intrahepatic portosystemic shunt, tumour resection or partial hepatectomy, and for planning EUS guided diagnostic and therapeutic procedures.

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INTRODUCTION

The French surgeon and anatomist Claude Couinaud described "two lobes" (right and left), "two hemilivers" (right and left), "four sectors," and "eight segments" of the liver. The two lobes are separated by the falciform ligament, the two hemilivers are separated by the Cantlie's line, the four sectors are separated by the planes of three hepatic veins (portal fissures or scissurae), and the eight segments are separated by an imaginary transverse plane passing by the portal vein bifurcation (Figure 1 and Table 1)^[1]. Each of the segments is an independent segment and has its own vascular inflow, outflow, and biliary drainage. The segments are referred to by number or by names^[2,3]. The numbering of the segments is done in a counter-clockwise manner starting from Segment I (the caudate lobe). The segments II to IV belong to the left and segments V to VIII belong to the right hemiliver (Table 1)^[2-4]. Standard anatomical description of the liver segments is available by computed tomographic (CT) scan^[5]. A stepwise evaluation of the liver segments is also described by ultrasonography^[6,7]. Endoscopic ultrasound (EUS) has been used for detailed imaging of many intra-abdominal organs and for the assessment of intra-abdominal vasculature^[8-11]. A stepwise evaluation of the liver segments by EUS has not been described. In this article, we describe a stepwise evaluation of the liver segments by EUS.

APPLIED ANATOMY AND THE HOME BASES FOR IMAGING

The home bases of liver imaging are given in the figure and the table (Figure 2A and Table 2). The main key of the imaging is following the hepatic vein tributaries and the portal vein branches. The three hepatic veins

Table 1 The sectors and the segments of liver

Four hepatic sectors	Eight hepatic segments
Left lateral sector	Segment I - the caudate lobe Segment II - posterosuperior Segment III - anteroinferior
Left medial sector	IVa - superior segment IVb - inferior segment
Right anterior sector	Segment V - inferior segment Segment VIII - superior segment
Right posterior sector	Segment VI - inferior segment Segment VII - superior segment

This table shows the relationship of hepatic sectors and hepatic segments. The four segments of left liver are: I (caudate); II (left lateral superior); III (left lateral inferior); and IV (left medial) [subdivided into superior (IVa) and inferior parts (IVb) by Bismuth]. The four segments of right liver are: V (right anteroinferior); VI (right posteroinferior); VII (right posterosuperior) and VIII (right anterosuperior). The caudate lobe is often called an independent segment.

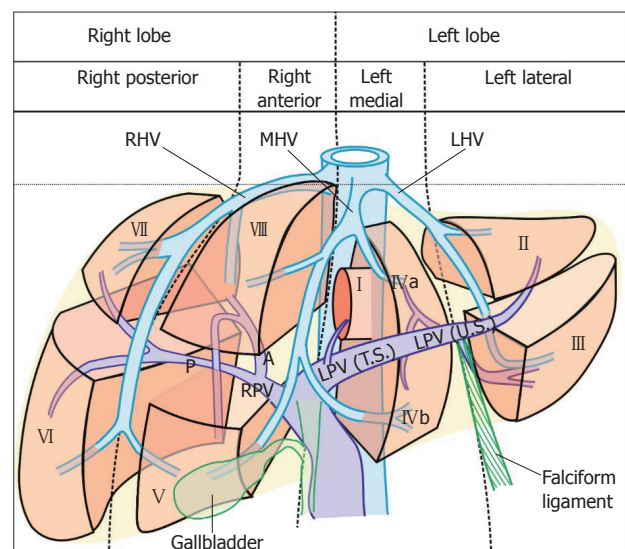


Figure 1 Three vertical planes and a transverse plane divide the liver into four sectors and eight segments. The vertical planes divide the liver into four sectors. The transverse plane divides the liver into superior and inferior segments. LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; LPV: Left branch of the portal vein; RPV: Right branch of the portal vein.

divide the liver into four vertical sectors: right anterior, right posterior, left medial and left lateral (Figure 1). The plane of portal vein bifurcation creates a transverse plane that crosses the vertical planes and divides the four sectors into eight segments (Figures 1 and 2A, and Table 1). The right hepatic vein lies in the right portal fissure and separates the right hemiliver into anterior and posterior sectors. The left hepatic vein lies in the left portal fissure and separates the left hemiliver into medial and lateral sectors. The middle hepatic vein lies in the main portal fissure and separates the anterior division of right liver from the medial division of the left liver. The main portal vein bifurcates into the right and the left branches, which travel in an imaginary transverse plane of the transverse fissure. The extrahepatic part of the left branch of the portal vein is known as the

Table 2 The home bases of imaging for liver segments

Home bases	Defining of segments
Hepatic veins	LHV separates II and III from IV (a and b) MHV separates IVa from VIII and IVb from V RHV separates V from VI and VIII from VII
Portal vein and its branches	Superior segments lie above and inferior segments lie below the transverse fissure The LPV supplies segments II to IV The RPV supplies segments V to VIII
IVC	IVC passes through the bare area of the liver and is related to superior segments in the upper part, segment I for most of its course, and with segment VI close to the lower most part above the right kidney
IVC suprahepatic part	A transverse plane defines the upper limit of superior segments (II, IV, VIII, and VII)
Ligamentum teres	Separates segment III from IVb
Ligamentum venosum	Separates I from IVa and II
Gallbladder	Neck lies close to segment V and fundus close to segment VI, from stomach IVb comes between the gallbladder and probe

IVC: Inferior vena cava; LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; LPV: Left branch of the portal vein; RPV: Right branch of the portal vein.

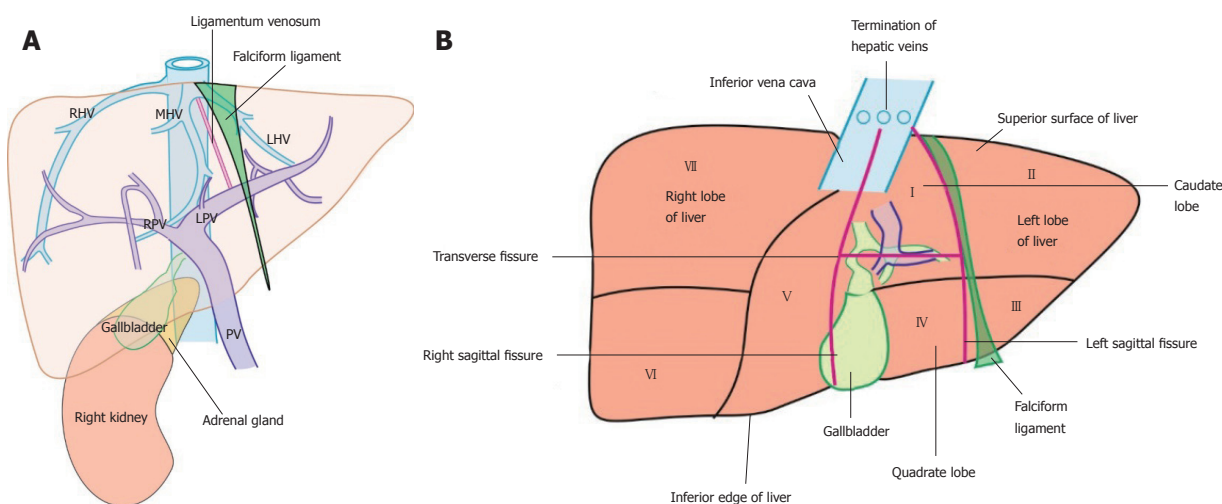


Figure 2 The home bases of imaging and visceral surface of liver. A: The endoscopic ultrasonography home bases of imaging for liver segments include the inferior vena cava (IVC) during its course behind the liver up to the right atrium, three hepatic veins in portal fissures and their joining point into the IVC, the portal vein and its branches in transverse fissure, the right kidney, the ligamentum teres, the ligamentum venosum, and the gallbladder; B: The caudate lobe lies between the stomach and IVC. The hepatic veins join the IVC. The ligamentum venosum and ligamentum teres are attached to the upper and lower border of the left branch of the portal at the angulation between the transverse and umbilical part. The visceral surface of the liver comes in contact with all segments except segment VIII. PV: Portal vein; LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; LPV: Left branch of the portal vein; RPV: Right branch of the portal vein.

transverse part and the intrahepatic part of left branch of the portal vein is known as the umbilical part. The extrahepatic part of left branch of portal vein lies in the gastrohepatic ligament on its inferior surface. The umbilical part of portal vein is surrounded on all sides by the liver (Figure 1). The right portal vein divides into two branches after entering the liver. The anterior branch supplies the anterior sector of the right lobe, and the posterior branch supplies the posterior sector of the right lobe (Figures 1 and 2A, and Table 2). The gallbladder, the right kidney, the fissures on the under surface of liver, and the ligaments of liver are acting as additional home bases of imaging for liver segments.

The inferior surface of the liver has an H-shaped fissure where the right and left limbs of the H are made by the right and left sagittal fissures, and the transverse limb is formed by the porta hepatis. The left sagittal fissure has upper and lower limbs, which are formed

by the fissure for the ligamentum venosum and the fissure for the ligamentum teres. The upper part of the ligamentum venosum is attached to the inferior vena cava (IVC). The lower part of the ligamentum teres extends to the inferior surface of liver (Figure 2B and Table 2). The relationship of the caudate lobe is crucial in understanding the segments of liver. When seen from the stomach the caudate lobe lies between the stomach and the IVC. The hepatic veins join the IVC (Figure 2B).

POSITION OF THE PATIENT AND THE POSITIONS OF OPERATOR

EUS can be done with the patient in a prone, left lateral, or supine position, and the descriptions in this article have been done with the patient in a prone position. The position of the operator can change with the movement of the body (or hand), which transfers the

Table 3 A difference in the segments of imaging from the three positions

Station	Comment	Segments visualized
Abdominal part of the esophagus and stomach	Probe in the esophagus lies close to the left lobe of the liver and in the stomach close to the visceral surface of the liver	Superior segments and caudate lobe are in direct contact with the lower end of esophagus All segments except segment VIII on the visceral surface of liver are in contact with the stomach
Duodenal bulb	Probe lies close to the hilum of the liver	Direct contact with segment I and right lobe liver segments Left side segments are seen through caudate lobe, caudate process, and IVC
Second part of duodenum	Probe lies close to the hilum of the liver	Direct contact with segment I and right lobe liver segments Left side segments are seen through caudate lobe, caudate process, and IVC

IVC: Inferior vena cava.

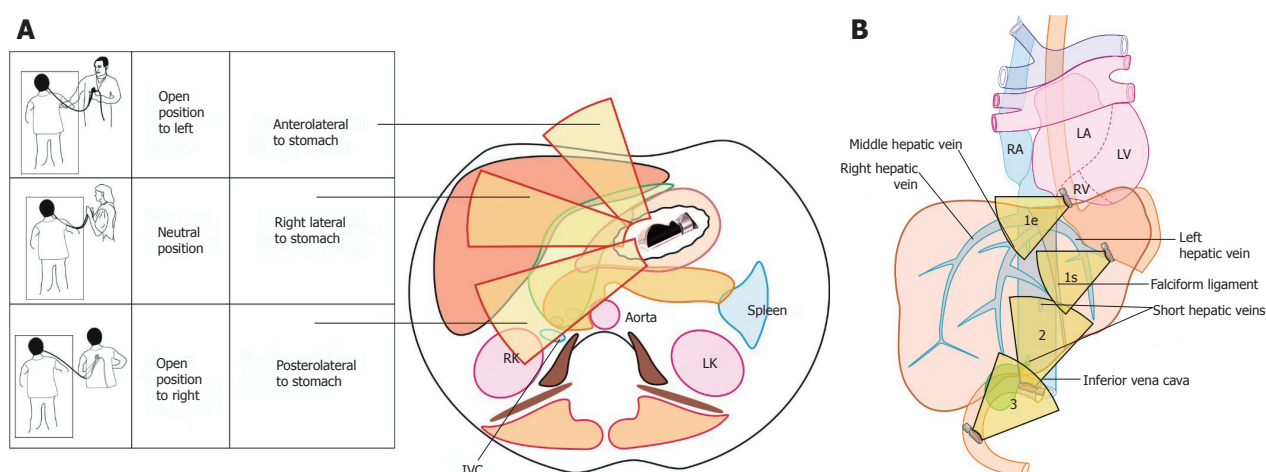


Figure 3 Different operator positions during imaging and three stations of imaging. A: Rotation is the key movement and should be done in a straight position to transfer the effect of rotation to the tip of the ultrasonic transducer. During imaging from the stomach, the open position to left starts imaging structures placed dorsal to the probe in the esophagus and stomach and primarily screens the left lobe of the liver. The neutral position screens the structures near the liver hilum and the open position to right screens the right lobe of liver; B: The three stations of imaging for liver segments: (1) abdominal part of esophagus (1e) and stomach (1s); (2) duodenal bulb; and (3) second part of the duodenum. IVC: Inferior vena cava; RK: Right kidney; LK: Left kidney; RA: Right atrium; LA: Left atrium; RV: Right ventricle; LV: Left ventricle.

effect of rotation towards the tip of the scope when the scope is maintained in a straight position. The three positions are open position to left, neutral position, and an open position to right. In an open position to left, the operator faces the patient's feet. In a neutral position, the operator faces the body of the patient. In an open position to right, the operator faces the head of the patient. A clockwise rotation from an open position to left in the stomach moves the imaging axis of the probe from a dorsal to a lateral and subsequently to a ventral position (Figure 3A). A reverse of this happens when the scope is rotated counterclockwise after seeing the right kidney.

THREE STATIONS OF IMAGING

The imaging is possible from three stations. Station 1: abdominal part of esophagus and stomach; station 2: duodenal bulb; and station 3: 2nd part of duodenum (Figure 3B and Table 3). Each station shows the segments in different anatomical relationships, and the differences in the segmental assessment of imaging are described in the table.

Station 1: Imaging from the lower end of the esophagus and stomach

This station of imaging is the most convenient method of imaging and is discussed in detail. Generally, it requires a rotation of the scope in three positions (Figure 3A) and a shift of the scope in and out to the four different levels (Figure 4A). During this rotation the sectors come close to the probe in the following order left lateral, left medial, right anterior, and right posterior (Table 4).

Imaging from open position to left: From the open position to left, the portal vein branches going to segment II and III are identified (Figure 5A). Imaging of the intrahepatic part of the left branch of the portal vein (umbilical part) within the umbilical fissure gives a fisheye appearance as it is completely surrounded on all sides by the liver parenchymal tissue (Figure 5B). The fisheye appearance indicates the left edge of the H of the transverse fissure from where the upper and lower limbs of the left sagittal fissure can be followed by slight in and out movement to trace the ligamentum venosum and ligamentum teres (Figures 5B and 5C). Further

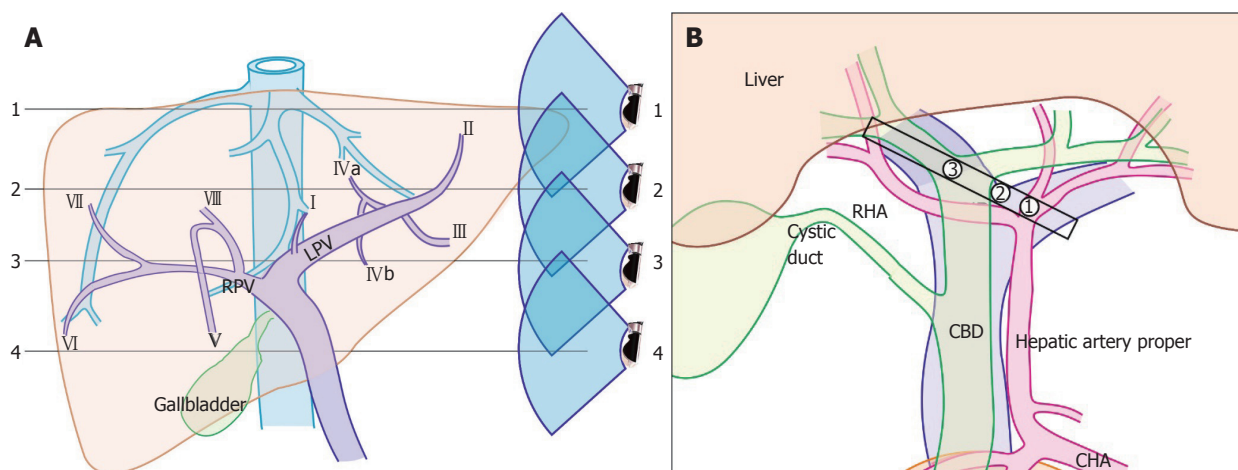


Figure 4 Hepatic vein tributaries with portal vein branches and hilar structures during rotation from left to right edge of transverse fissure. A: The imaging of hepatic vein tributaries and portal vein branches as the home bases during imaging from the abdominal part of the esophagus and stomach; B: The hilar structures with the divisions during a rotation from the left edge of the transverse fissure to the right edge. (1) hepatic artery into two branches; (2) the union of the right and left branch of the portal vein; (3) the division of the common hepatic duct into right and left branches. LPV: Left branch of the portal vein; RPV: Right branch of the portal vein; CHA: Common hepatic artery; RHA: Right hepatic artery; CBD: Common bile duct.

rotation traces the transverse fissure from the left edge of the H towards the right edge of the H and follows the umbilical part of the left branch of the portal vein towards the transverse part of the left branch. During this rotation from the left edge to the right edge, the appearance of the hepatic artery into two branches, the union of right and left branch of the portal vein and the division of the common hepatic duct into right and left branches appear one by one in the transverse fissure (Figures 4B and 5D).

Imaging from the neutral position: Further rotation traces the course of the extrahepatic part of the left branch of the portal vein (transverse part) within the transverse fissure (Figure 6A). At this point the union of right and left branches of the portal vein is seen (Figure 6B). Near the union point the extrahepatic part of the right branch of the portal vein can be seen to join the transverse part of the portal vein from a direction coming from 6 o'clock within the transverse fissure. The right branch of the portal vein is often seen traveling close to the neck of gallbladder. Near the right edge of the transverse fissure, the union of right and left ducts is seen in front of the right branch of the portal vein (Figure 6C). The imaging of the right branch of the portal vein is easy through the caudate process of the liver in the area above the transverse fissure and below the IVC (Figure 6D).

Imaging from an open position to right: Further rotation with slight upward angulation traces the extrahepatic part of the right branch of the portal vein towards the intrahepatic part. Imaging of the intrahepatic part of the right branch of the portal vein usually requires a decrease in frequency to increase penetration depth and an increase in the depth of the

imaging to include the entire right lobe of the liver along with the hyperechoic diaphragm, which is seen beyond the convex upper surface of the liver (Figure 7A). Imaging of the right part of liver is easy due to the window made by the IVC and the caudate process (Figure 7B). The right branch of the portal vein can be followed to the division into an anterior and a posterior branch. Usually, with a linear scope the vision of the anterior branch is best seen when the middle hepatic vein is seen on the far side of the screen (Figure 7C). A relatively more posterior view of the course of posterior division of the right portal vein branches is possible through the caudate process between the porta hepatis and the IVC. It is usually possible to see the segmental branches to segment VI and VII (Figure 7D).

Station 2: Imaging from duodenal bulb

Neutral position: Imaging from duodenal bulb shows a view of the liver hilum (transverse fissure) where the portal vein is easily identified, with right and left angulation, up and down movements, and in and out adjustments.

Open position to left: The portal vein bifurcation defines the line between superior and inferior segments. A counterclockwise rotation traces the transverse fissure towards the gallbladder and the right edge of the transverse fissure where the right lobe segments are seen.

Open position to right: A clockwise rotation after tracing the portal vein bifurcation traces the transverse fissure towards the left edge of the transverse fissure where the left lobe segments are seen. The lower border of the caudate lobe lies above the bifurcation and above the transverse part of the left branch of the

Table 4 The structures from three positions from station 1

Clockwise rotation from an open position to left	Part of portal vein	Part of hepatic vein	Other home base structures	Main sector of liver visualized	Main segments of liver visualized	Figure number for segment
Open position to left	P II and P III	LHV	Diaphragm and heart	Left medial closer to left lateral ¹	II, III, and IV	2A, 2B, 3A, 5A
Neutral position after approximately 60° to 75° clockwise rotation	Fisheye appearance of LPV	MHV	Left edge of transverse fissure attached to ligamentum venosum and ligamentum teres	Left medial closer to probe than right anterior	I and IV	3A, 5B
Open position to right after further approximately 60° to 75° clockwise rotation	RPV dividing into anterior and posterior branches	RHV	Right edge of transverse fissure, IVC, gallbladder, and caudate process	Right anterior closer to probe than right posterior	V, VI, VII, and VIII	3A, 7A, 7C, 7D

¹When the scope is in maximum open position only the left lateral segment is seen. IVC: Inferior vena cava; LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; LPV: Left branch of the portal vein; RPV: Right branch of the portal vein.

portal vein.

Station 3: Imaging from descending duodenum

An open position to right places the scope in a parallel axis with the superior mesenteric vein from the descending duodenum. From this position a counterclockwise rotation traces the course of the IVC from a 10 o'clock position to a 4 o'clock position and sequentially brings the hilum of the right kidney, the right lobe of liver, the hilum of the liver and gallbladder, and lastly the left lobe of the liver into view (Figure 8). In this process the segments belonging to the posterior surface and bare area of the liver are easily followed close to the IVC. The first segment close to the lower most part of the IVC just above the adrenal gland and right kidney belongs to segment VI (Figure 8A). Once the gallbladder is seen segment V lies close to the upper surface of the gallbladder. Near the hilum of the liver segment I is identified between the portal vein and the IVC. On maximum counterclockwise rotation the probe lies close to the upper most part of the IVC near the joining of the hepatic veins where the superior segments (VII, VIII, IVa, and II) are visualized.

SYSTEMATIC APPROACH TO IDENTIFY LIVER SEGMENTS

The imaging of segments is done in eight steps: (1) identify lobes; (2) identify sectors (right and left portal fissures); (3) identify the plane of superior and inferior segments (transverse fissure/liver hilum); (4) identify left sagittal fissure and the liver ligaments; (5) identify caudate lobe (posterior to transverse fissure); (6) identify left lobe segments; (7) identify quadrate lobe (anterior to transverse fissure); and (8) identify right lobe segments.

Identify lobes (Cantlie's line)

Applied anatomy: The Cantlie's line passes through the middle hepatic vein (main portal fissure) superiorly. It also corresponds to a vertical plane passing diagonally from the middle of the gallbladder fossa anteriorly and inferiorly to the left side of the IVC posteriorly (Figure 2B).

Technique of examination: Identify the IVC. The middle hepatic vein is identified merging into IVC (Figures 9A and 9B).

Identify sectors

Applied anatomy: Each right and left hemiliver is subdivided by the left and right hepatic veins lying in the left and right portal fissures. The course of the left hepatic vein divides the left lobe into the medial and lateral sectors. The course of the right hepatic vein divides the right lobe into the anterior and posterior sectors.

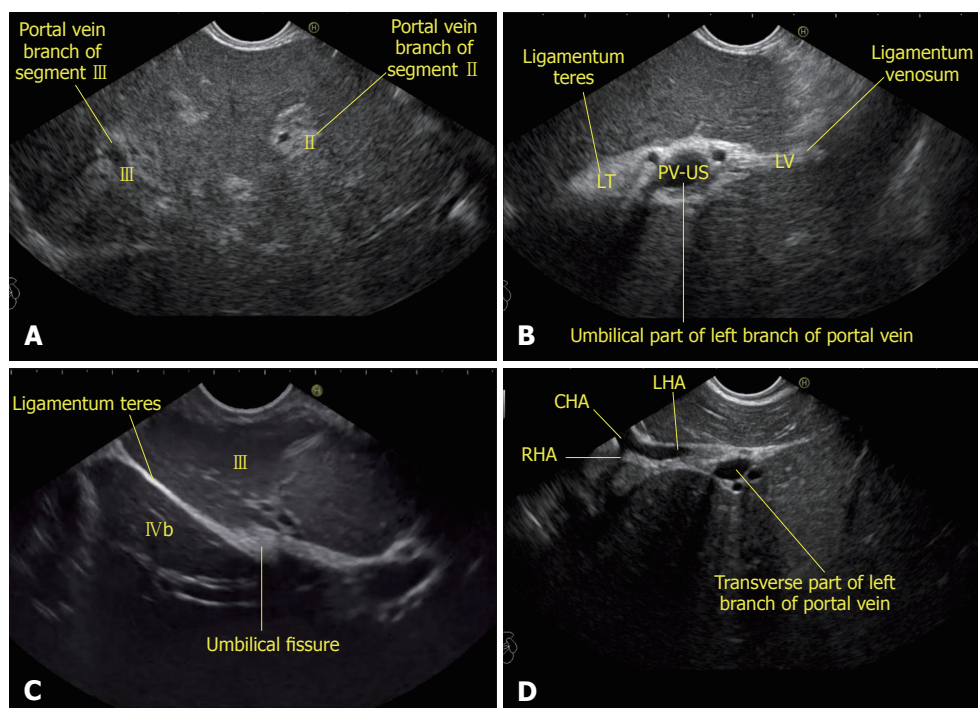


Figure 5 Imaging of liver segments from station 1. A: Imaging from the abdominal part of esophagus showing segments II and III portal vein branches; B: The fisheye appearance of the umbilical part of the left branch of the portal vein as seen from the abdominal part of esophagus; C: Imaging from the visceral surface of the liver showing that the ligamentum teres is attached to the lower part of the umbilical vein; D: On clockwise rotation near the left edge of the porta hepatis, the umbilical part enters the transverse fissure. At this point the bifurcation of the common hepatic artery can be seen towards the left edge of the transverse fissure. This image shows the entry of the left branch of the common hepatic artery into the transverse fissure. CHA: Common hepatic artery; RHA: Right hepatic artery; LHA: Left hepatic artery.

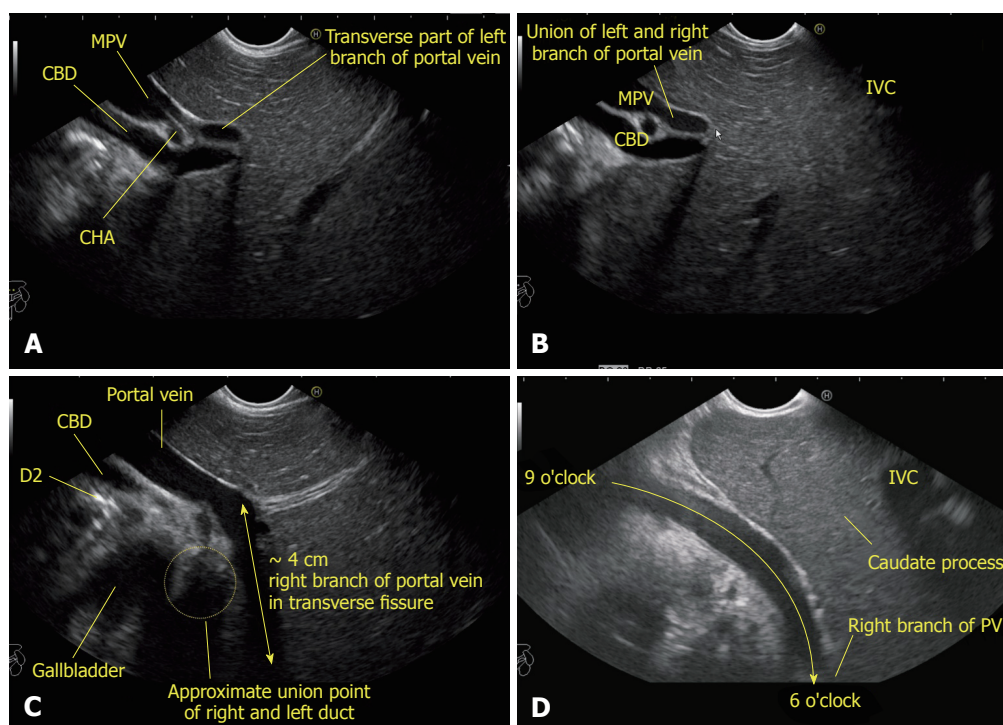


Figure 6 Imaging from neutral position from station 1 showing the tracing of the portal vein and its branches during clockwise rotation from the left to right edge of the transverse fissure. A: Further clockwise rotation traces the course of the left branch of the portal vein (PV) in the transverse fissure; B: Further rotation shows the union of the right and left branch of the PV; C: The approximate 4 cm breadth of the transverse fissure within which the right branch of the PV joins the left branch; D: The imaging of the right branch of the PV is easy through the caudate process of the liver. With slight up angulation, the right branch of the PV is seen in the transverse fissure going from a 6 o'clock to a 9 o'clock position. CHA: Common hepatic artery; IVC: Inferior vena cava; PV: Portal vein; CBD: Common bile duct; MPV: Main portal vein.

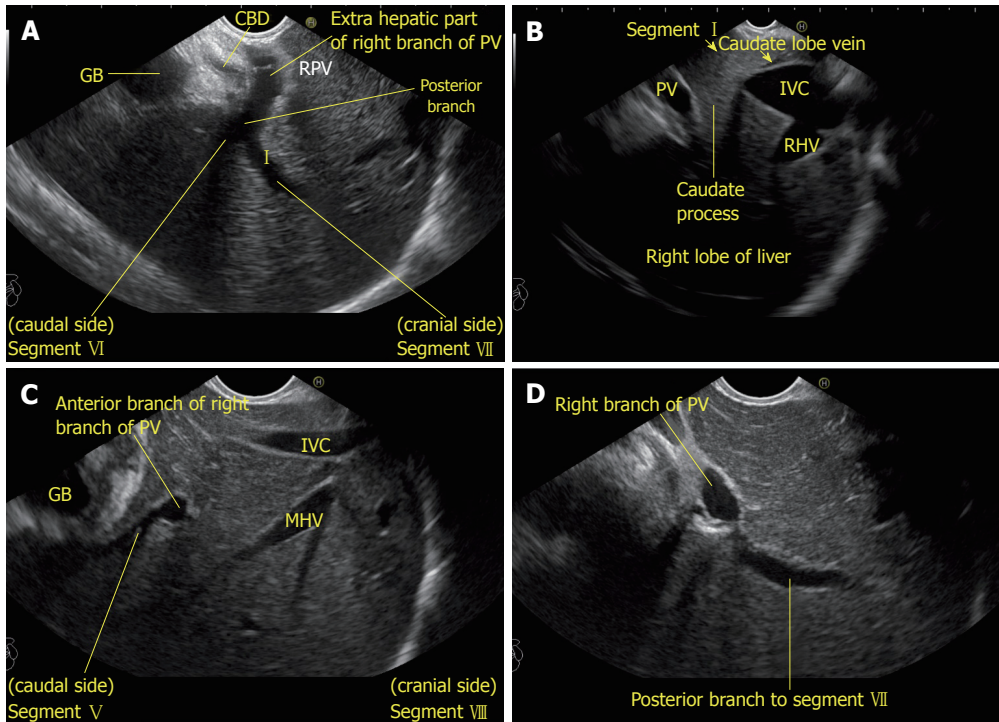


Figure 7 Imaging from station 1 showing the right portal vein and its branches in relation to liver segments. A: Imaging of the intrahepatic/extrahepatic part of the right branch of the portal vein is seen along with the right lobe of the liver and the hyperechoic diaphragm; B: The inferior vena cava and caudate process provide a good window of imaging for the right lobe of the liver (The caudate lobe is connected with the right lobe of liver through the caudate process). In this location, presence of the inferior vena cava may also provide a satisfactory window of imaging; C: A view of the divisions of the right branch of the portal vein is possible through the caudate process. In this case, the anterior branch is supplying segments V and VIII of the liver; D: The division of segment VI and VII branches is visualized. The upper part of the posterior branch goes towards segment VII. CBD: Common bile duct; GB: Gallbladder; PV: Portal vein; RHV: Right hepatic vein; MHV: Middle hepatic vein; IVC: Inferior vena cava.

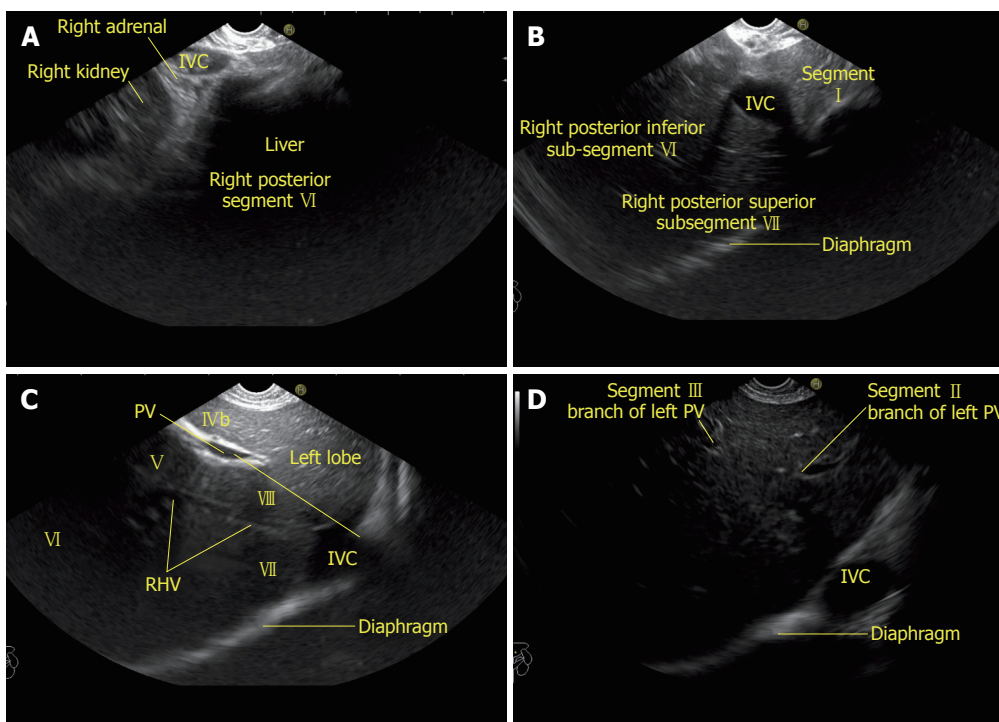


Figure 8 Imaging from the descending duodenum showing the structures visualized during counterclockwise rotation from open position to right. A: Imaging from the descending duodenum showing the right kidney and inferior vena cava (IVC). The right adrenal gland is seen behind the IVC; B: Imaging from the descending duodenum showing the IVC moving towards the diaphragm. The caudate lobe is seen between the probe and the IVC. The caudate lobe indicates the approximate place of the transverse part of the left branch of the portal vein (PV); C: Imaging from the descending duodenum showing the right hepatic vein. It divides the segments of the right lobe. A line between the cranial end of the IVC and the PV gives approximate locations of the right and left half of the liver; D: The segmental branches (II and III) of the umbilical part of the PV are seen with the IVC at a 4 o'clock position. RHV: Right hepatic vein; IVC: Inferior vena cava; PV: Portal vein.

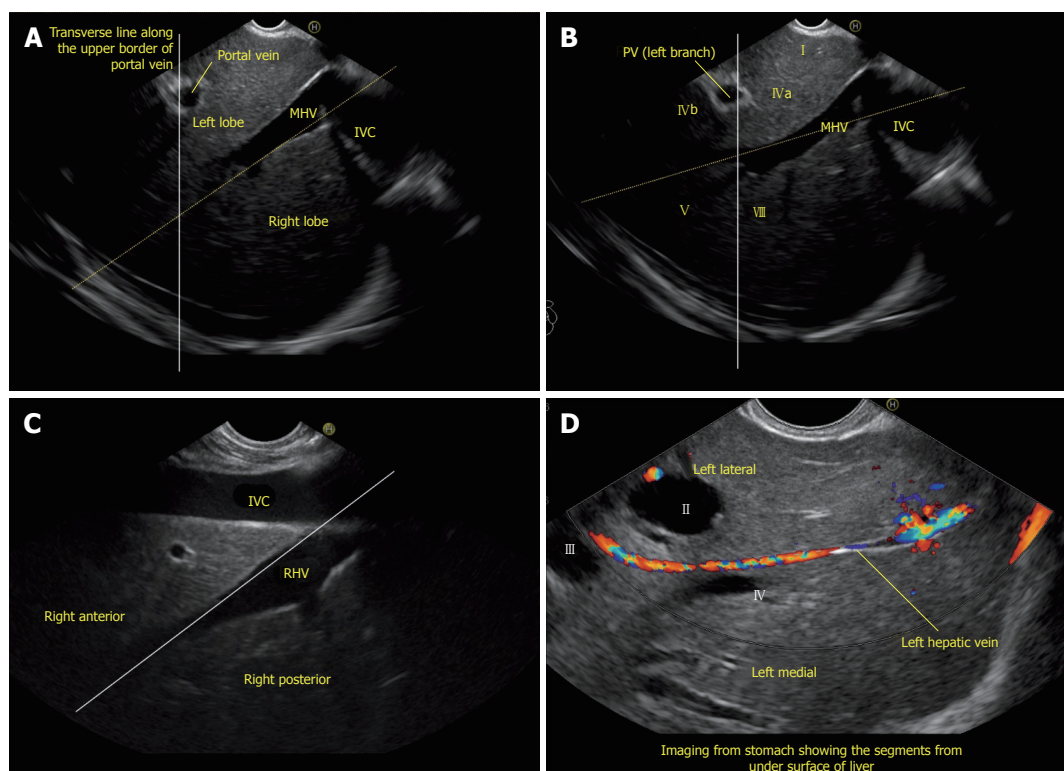


Figure 9 Imaging from station 1 showing hepatic vein branches and their relationship to liver segments. A: The middle hepatic vein lies in the course of the Cantlie's line and separates the left and right lobe of the liver; B: The segmental division is shown for segment I, IVa, IVb, V, and VII; C: The right hepatic vein separates the right anterior and right posterior sectors; D: The left hepatic vein separates the left medial and left lateral sectors. MHV: Middle hepatic vein; RHV: Right hepatic vein; IVC: Inferior vena cava; PV: Portal vein.

Technique of examination: Identify the merger of the left and right hepatic veins into the IVC (Figures 9C and 9D).

Identify the plane of superior and inferior segments

Applied anatomy: The portal vein and its branches in the transverse fissure acts as a guide to divide the liver into superior (VII, VIII, IVa and II) and inferior segments (III, IVb, V and VI). The applied anatomy of fissures and ligaments was already discussed in the home bases section. The joining of the three hepatic veins into the supra hepatic part of the IVC determines the uppermost margin of superior segments related to the IVC.

Technique of examination: The umbilical fissure is identified within the left lobe of the liver. Clockwise rotation along the umbilical fissure traces the transverse plane of the transverse fissure within which the left and right branches of the portal vein are seen (Figures 6C, 6D, and 10).

Identify the left sagittal fissure and the liver ligaments

Applied anatomy: The applied anatomy of fissures and ligaments was already discussed in the home bases section.

Technique of examination: The umbilical fissure is identified within the left lobe of the liver. The ligaments are attached to the upper and lower part of the um-

bilical fissure (Figure 5C).

Identify the caudate lobe

Applied anatomy: Anatomy texts describe the caudate lobe as a midline, vertically oriented hepatic lobe seen on the posterior aspect of the liver separating a portion of the right and left hepatic lobes in an H configuration. The horizontal bar of the H configuration represents the transverse fissure of the porta hepatis, which includes the horizontal portion of both portal veins. Above the bar is the caudate lobe of the liver and below the bar is the medial segment, or quadrate lobe, of the left lobe of the liver^[12].

Technique of examination: The caudate lobe may be imagined as a midline wedge in a sagittal plane with its tip extending cephalad up to the insertion of the left and middle hepatic veins into the IVC and its base or posterior border facing the IVC (Figures 11A and 11B). The right (or medial border) of the pyramid is continuous with the parenchyma of the right lobe of the liver *via* the caudate process (Figure 11C). The anterior border of the caudate lobe is separated from the medial segment of the left lobe of the liver superiorly by the fissure for the ligamentum venosum and inferiorly by the left portal triad and portal bifurcation (Figure 11D). A clockwise rotation after identification of the left lobe of the liver from an open position to left will help in identification of the ligamentum venosum (Figure 11D).

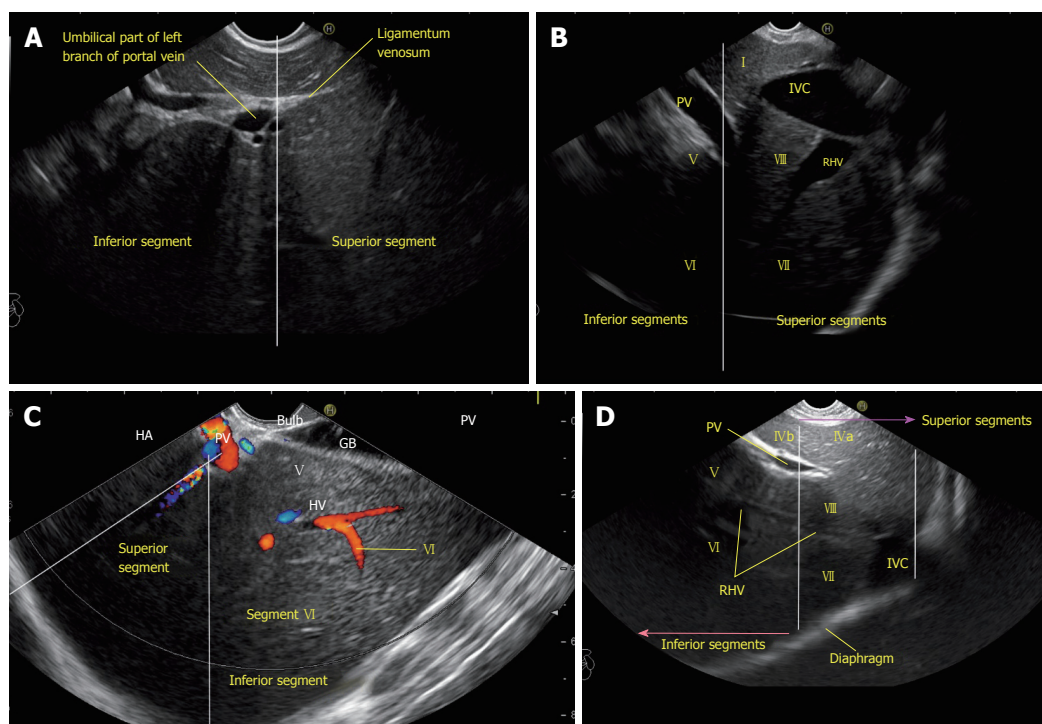


Figure 10 The division of superior and inferior liver segments by the portal vein and its branches. A: Line at the level of the upper border of the umbilical segment of the portal vein dividing the superior and inferior segments; B: The white line divides the superior and inferior segments. This diagram from the esophagus shows the right side of the liver through the caudate lobe of the liver and the inferior vena cava. The presence of hepatoduodenal ligament around the portal vein may not allow a similar quality of visualization of the inferior segments (V and VI); C: This image from station 2 (duodenum bulb) shows the right and middle hepatic veins. The right hepatic vein is parallel to the surface of the gallbladder, and the middle hepatic vein is towards the neck of the gallbladder. Only the right lobe is seen through the gallbladder; D: The right hepatic vein drains segments VI and VII and a variable portion of segments V and VIII. Segment I has direct drainage into the intrahepatic/retrohepatic part of the inferior vena cava. RHV: Right hepatic vein; IVC: Inferior vena cava; PV: Portal vein.

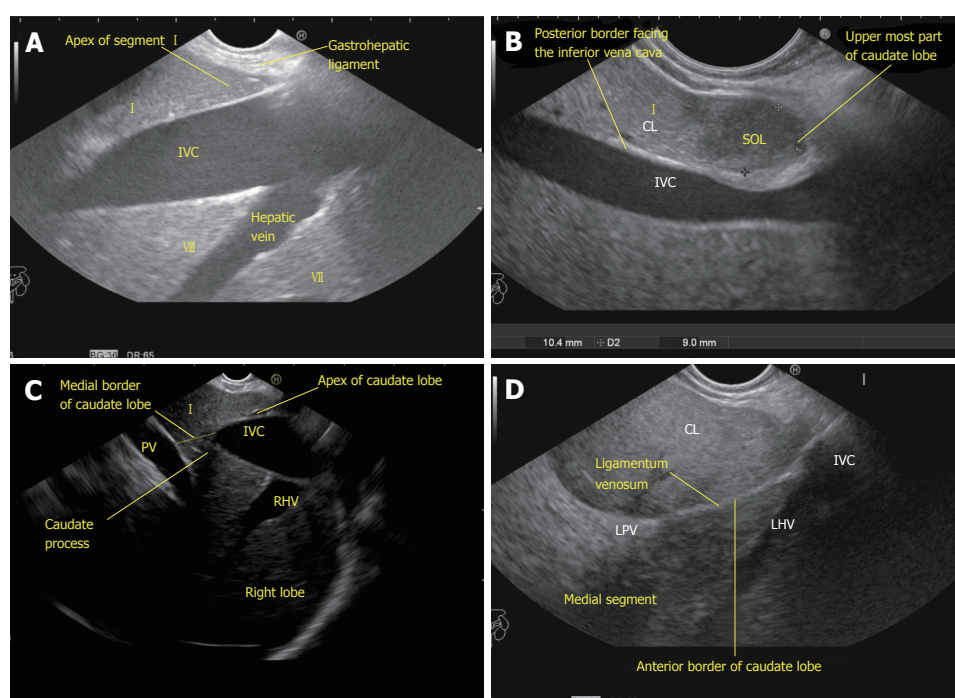


Figure 11 The caudate lobe, its boundaries, and its relationships. A: The apex of the caudate lobe lies like a wedge near the joining of the hepatic veins. The base faces the inferior vena cava; B: A small metastatic space-occupying lesion is seen near the tip of the caudate lobe of the liver near the diaphragm between the probe and the inferior vena cava. Anterior margin of lesion is limited by the fissure for the ligamentum venosum; C: The continuity of the caudate lobe into the right lobe of the liver via the caudate process; D: The ligamentum venosum proceeds towards the umbilical part of the portal vein and divides the left medial segment from the caudate lobe. The ligamentum venosum is the anterior border of a pyramidal shaped caudate lobe. The attachment of the ligamentum venosum demarcates the lowest limit of the anterior border. SOL: Space-occupying lesion; LHV: Left hepatic vein; LPV: Left branch of the portal vein; RHV: Right hepatic vein; IVC: Inferior vena cava; PV: Portal vein.

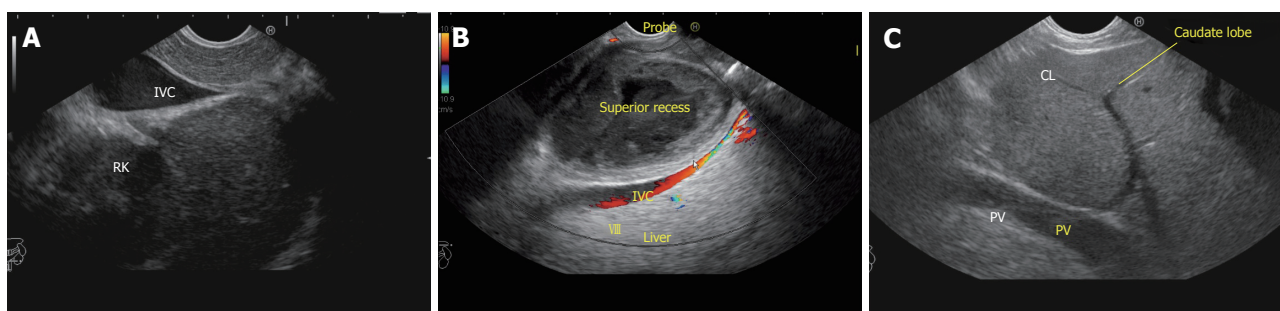


Figure 12 The caudate lobe, its boundaries, and its relationships. A: The exit of the inferior vena cava from the liver demarcates the lowest limit of the posterior border. The right kidney is seen through the inferior vena cava. Segment VI lies above the right kidney; B: The left border of the caudate lobe lies close to superior recess of the lesser sac, which is filled with fluid in this case; C: The vascular supply of the caudate lobe from the right branch of the portal vein. The right and left lobes of the liver lie on either side of the right and left sagittal fissures, and the caudate and quadrate lobes lie posterior and anterior to the transverse fissure. RK: Right kidney; IVC: Inferior vena cava; PV: Portal vein.

The upper border of the umbilical part of the left branch of the portal vein is attached to ligamentum venosum and serves as an accurate anatomic boundary of the lowermost limit and anterior margin of the caudate lobe (Figure 11D).

The caudal margin of the caudate lobe forms the cephalad margin, or lintel, of the foramen of Winslow and projects into the lesser sac where it is related to the right crus of the diaphragm and inferior phrenic artery. The left (or lateral border) of the caudate lobe projects into the superior recess of the lesser peritoneal sac and is covered anteriorly by the gastrohepatic ligament (lesser omentum), which separates it from segments II and III anteriorly and segment VIII in the right lateral wall (Figure 12B). The vascular inflow and biliary drainage to the caudate lobe comes from both the right and left pedicles. The right side of the caudate, the caudate process, largely derives its portal venous supply from the right portal vein or the bifurcation of the main portal vein (Figure 12C). The left portion of the caudate derives its portal venous inflow from the left portal vein.

Caudate process a two-way window for imaging of the right and left lobe of the liver in EUS: The caudate lobe, caudate process, and the IVC act as a window of imaging from the left side to the right side of the liver and vice versa. While imaging from the abdominal part of the esophagus and stomach the window allows left to right visualization. While imaging from the duodenal bulb and the second part of the duodenum the window allows right to left visualization (Figures 11C, 11D, 12A, 12C, and 13).

Identify the left lobe

Applied anatomy: The left lobe lies anterior to the esophagogastric junction and the fundus of stomach.

Technique of examination: The segments of the left lobe are best visualized with slight up tilting of the scope from the fundus of stomach. In this position, the left part of the heart is visualized through the diaphragm and the left hepatic vein is easily identified as the border

between the left medial and two left lateral segments (segment III anterior-inferior and segment II posterior-superior). Further demarcation of segment II as the upper segment and segment III as the lower segment is possible by the plane passing by the portal vein bifurcation (Figures 14A and 14B). This plane is not usually visualized during imaging of the left lateral segments (II and III) in an open position to left where the fisheye appearance of the umbilical part is not visualized. A line can be extrapolated from the upper border of the fisheye appearance of the left branch of the portal vein for proper demarcation (Figure 14B). The visualization of the left medial segment is seen between the probe and the middle hepatic vein (Figure 14C). The presence of the middle hepatic vein and of the upper border of the left branch of the portal vein indicates the area where segment I communicates with segment IV (Figure 14D).

Identify segment IVa and IVb (quadrate lobe)

Applied anatomy: Segment IV is located between the plane passing by the middle hepatic vein on the right and the axis of the umbilical scissura on the left. This segment can be divided into an upper (IVa) and a lower (IVb) segment by a horizontal line passing through the umbilical portion of the left branch of the portal vein. The IVb segment (quadrate lobe) is demarcated on the visceral surface anteriorly by the inferior edge of the liver, on the right side by the gallbladder fossa, posteriorly by the porta hepatis, and on the medial side by the fissure for the ligamentum teres (Figures 14B and 14D).

Technique of examination: Segment IV is easily identified near the middle hepatic vein. The identification of the gallbladder, ligamentum teres, and umbilical fissure also helps in identification of the liver segments (Figure 14D).

Identify right lobe segments

Applied anatomy: The right liver consists of anterior and posterior segments, divided by the presence of

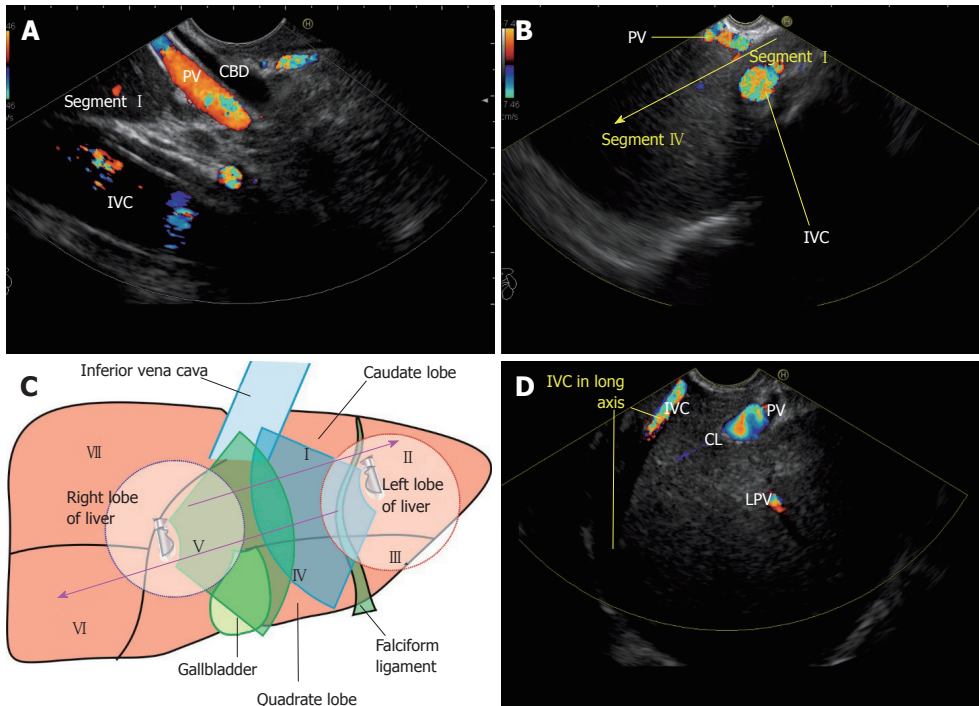


Figure 13 The caudate lobe from different stations of imaging. A: An image of the caudate lobe through the portal vein in front of the inferior vena cava from the duodenal bulb; B: An image of the caudate lobe between the portal vein and the inferior vena cava from the descending duodenum; C: The caudate process acts as a two-way window for imaging of the right and left lobes of the liver in endoscopic ultrasonography. The red circle shows the approximate area of gastric impression on the visceral surface of the left lobe of the liver and shows that the imaging of the right lobe is possible through the caudate lobe and caudate process. The blue circle shows the approximate area of duodenal impression on the visceral surface of the right lobe of the liver and that the imaging of the left lobe is possible through the caudate lobe and caudate process; D: An image of the left lobe of the liver through the caudate lobe from the duodenal bulb. IVC: Inferior vena cava; PV: Portal vein; CBD: Common bile duct; CL: Caudate lobe; LPV: Left branch of the portal vein.

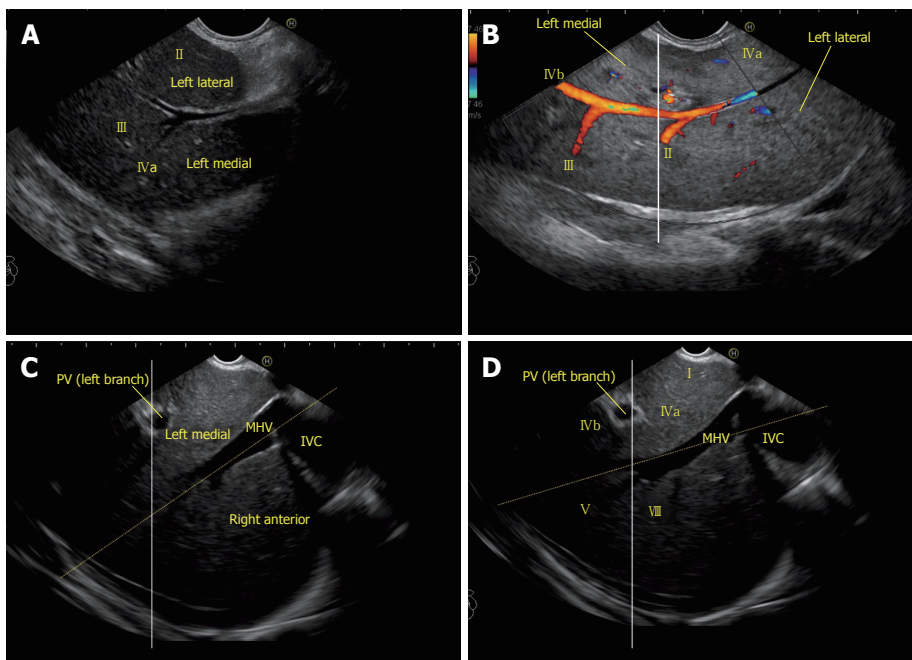


Figure 14 Hepatic veins dividing liver segments. A: Image showing left lobe segments; B: The upper and lower tributaries of the hepatic vein indicate the upper and lower segments of the left lateral and left medial sectors. Segments II, III, IVa, and IVb veins are seen. In this case, the imaging is done from the visceral surface of the liver and from an area close to the antrum and body. Hence, segment IV appears closer to the probe than segment III. It must be clear that while imaging from the lower end of the esophagus that the left lateral segment is closer while during imaging from the visceral surface of the liver that the orientation of a segment may vary depending on the location of probe (for example, near the antrum segment IV is closer than segment III, and near the fundus and proximal body segment III is closer than segment IV). The white line is an extrapolated line that has been drawn in an approximate axis from the upper part of the umbilical part of the left branch of the portal vein; C: A line going through the middle hepatic vein separates the left medial and right anterior sectors; D: A line along the upper part of the transverse fissure (along the upper edge of the portal vein) subdivides the upper and lower segments of the left medial (segments IVa and IVb) and right anterior (segments VIII and V) segments. MHV: Middle hepatic vein; IVC: Inferior vena cava; PV: Portal vein.

Table 5 The representation of liver segments

Home base structure	Comment	Figure No.
Hepatic veins	The main left hepatic vein drains the two lateral segments of the left lobe (segments II and III)	9D
	The middle vein drains segment IV and the anterior sector of the right lobe (segments V and VIII)	9B
	The right vein drains the remainder of the right lobe (segments VI and VII) and a variable portion of segments V and VIII	9C
Hepatic vein tributaries	The higher tributary of LHV going towards the diaphragmatic and costal surface belongs to segment II	9D
	The higher tributary of MHV going towards the diaphragmatic and costal surface belongs to segment VIII	9B, 14C, 14D
	The higher tributary of RHV going towards the diaphragmatic and costal surface belongs to segment VII	15A, 15C
	The tributary of LHV going towards the liver hilum drains segment IVa	14B
	The tributary of MHV going towards the liver hilum drains segment IVb	14D
	The tributaries of RHV going towards the liver hilum drains segments V and VII	9C
Right and left branches of the portal vein	The right branch of the portal vein supplies the right liver (segments V to VIII)	7A, 7B, 7C, 7D
	The left branch of the portal vein supplies the left liver (segments II to IV)	5A, 5B, 5C, 5D, 6A, 6B
	The caudate lobe receives direct branches from both the right and left branches	12C
Segmental branches of the portal vein	The extrahepatic part supplies segment I	11D
	The anterior branch of the RPV supplies segments V and VIII	7C
	The posterior branch of the RPV supplies segments VI and VII	7D
Right kidney	Lies lateral to the infrahepatic part of the IVC	8A
Caudate lobe	Forms an important anatomical landmark	10A, 10B, 10D, 11A, 11B, 11C

IVC: Inferior vena cava; LHV: Left hepatic vein; MHV: Middle hepatic vein; RHV: Right hepatic vein; LPV: Left branch of the portal vein; RPV: Right branch of the portal vein.

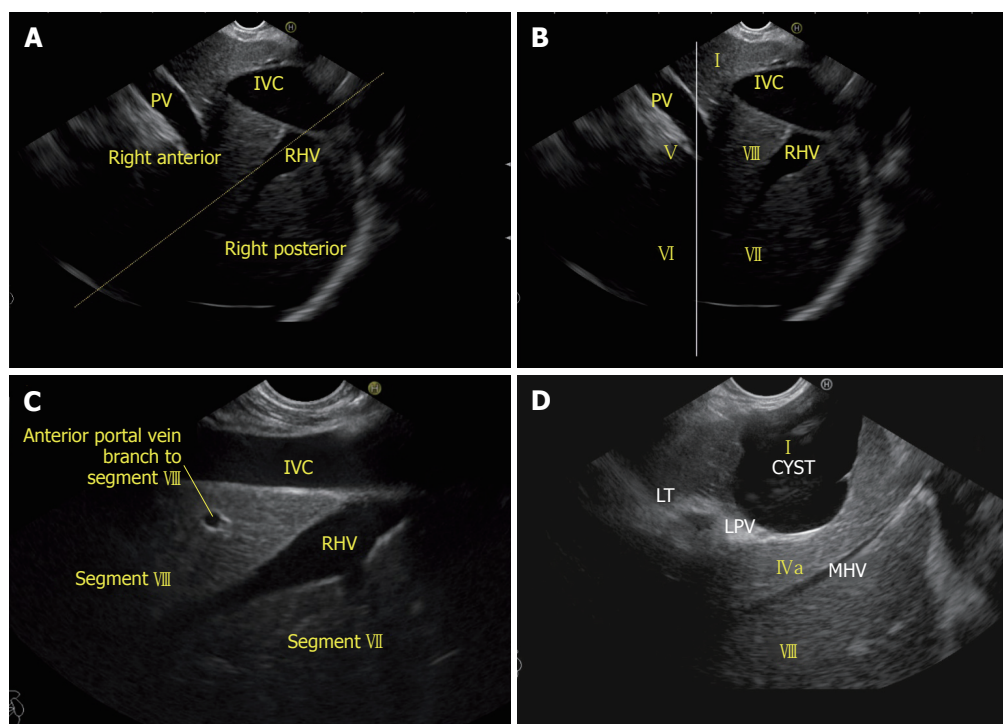


Figure 15 Liver sectors and liver segments are visualized. A: The inferior vena cava (IVC) runs parallel to the probe in a long axis. A line along the right hepatic vein divides the liver into anterior and posterior sectors; B: The right lobe of the liver contains segments V to VIII. The segments are seen through the caudate process. The white line is drawn along the upper border of the curving part of the portal vein; C: The right hepatic vein is seen joining the IVC at an angle of around 60°. Segment VII is seen above the hepatic vein and segment VIII is seen between the hepatic vein and the IVC; D: The middle hepatic vein drains segment IV, segment V, and segment VIII. RHV: Right hepatic vein; LPV: Left branch of the portal vein; IVC: Inferior vena cava; PV: Portal vein.

the right hepatic vein in the right portal fissure (Figure 15A).

Technique of examination: A simple crossover of lines passing through the upper border of the left branch of the portal vein and along the axis of the right hepatic

vein will divide the right hemiliver into four segments (Figure 15).

CONCLUSION

Table 5 summarizes the evaluation of different liver

segments from different positions by EUS. Routine use of Couinaud's liver segmentation may be important in planning successful radical surgery. This description will allow better preparation for biopsy, portal vein embolization, transjugular intrahepatic portosystemic shunt, tumour resection, or partial hepatectomy for transplantation. Such advance planning will reduce intra- and post-operative difficulties and complications. In this article, we have given a detailed description of EUS anatomy of the liver and liver segmentation. This information may be useful in planning EUS guided diagnostic and therapeutic procedures involving liver pathologies^[13,14].

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