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PICTORIAL ESSAY

16-Slice CT hepatic venography

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The liver has a dual blood supply, but it has only one drainage outflow, i.e., the hepatic veins. Imaging studies about the hepatic veins, especially noninvasive imaging studies, are scarce [1]. With the increase of living-donor liver transplantation (LDLT), more attention is being paid to the vascular anatomy and its variants. In addition, more entities can occur in the hepatic vein, such as Budd-Chiari syndrome (BCS), stenosis of the hepatic veins, hepatic venous congestion, and invasion by malignant masses. Computed tomography (CT) has played an important role in the evaluation of liver diseases, especially with the advent of the multidetector CT (MDCT) scanner. Spatial resolution of the current 16-slice CT is nearly isotropic, and temporal resolution is about 250 ms, thus allowing performance of multiple phase scanning of the liver and different image reformations. However, reports about hepatic venography using a 16-slice CT scanner are few. This pictorial essay describes the technology and uses of hepatic venography with a 16-slice CT scanner.

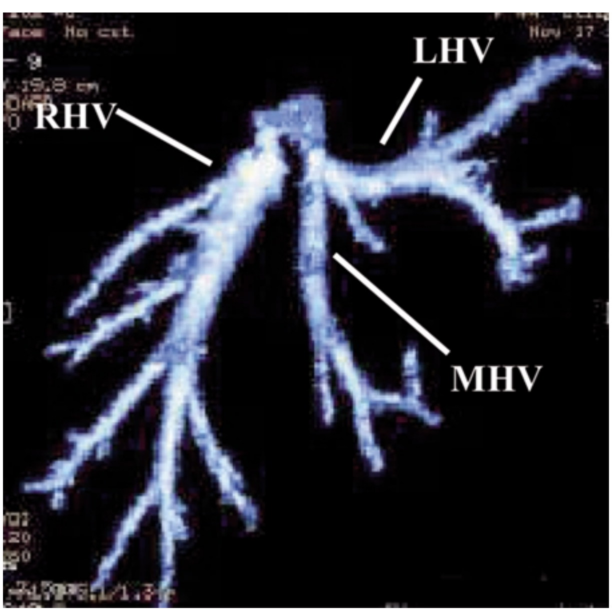

Fig. 1. A 44-year-old woman with normal anatomy of the hepatic veins. Surface shadow display (SSD) image shows the right hepatic vein (RHV) joining the IVC; the middle hepatic vein (MHV) and the left hepatic vein (LHV) share a common trunk into the IVC.

Techniques

All CT scans in this essay were obtained with a 16-MDCT scanner (GE Medical Systems). Scanning conditions were as follows: slice collimation 2.5 mm × 4 detectors; slice thickness, 2.5 mm; reconstruction interval, 1.3 mm; helical pitch 1.375, 120 kVp, and 240 mAs. All datasets acquired by helical scanning were reconstructed to isotropic voxel datasets. Reconstructed data

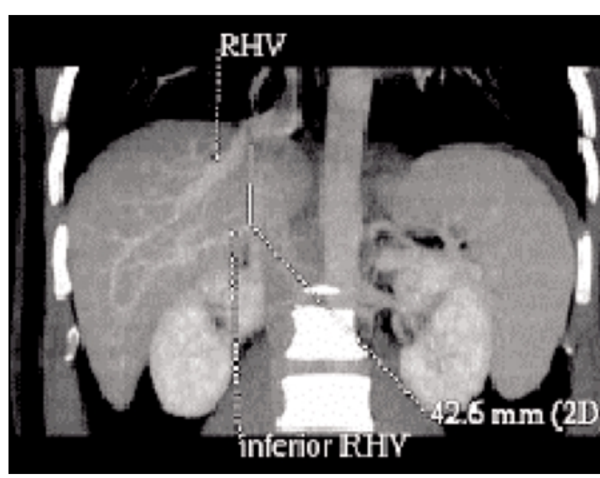

Fig. 2. A 54-year-old woman with an inferior right hepatic vein. Coronal maximum intensity projection (MIP) image displays the inferior right hepatic vein (IRHV) draining into the IVC. The distance between the IRHV and the RHV, and the diameter of inferior right hepatic vein were measured and are depicted.

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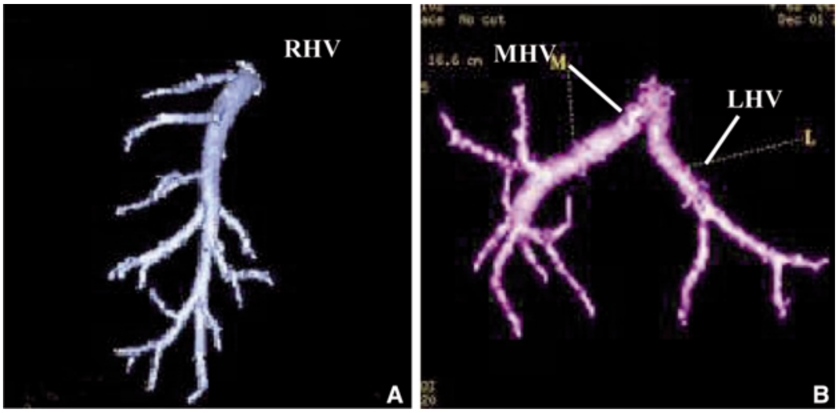

Fig. 3. A 64-year-old woman with an IRHV. **A** and **B** are SSD images that show the RHV, MHV and LHV, respectively.

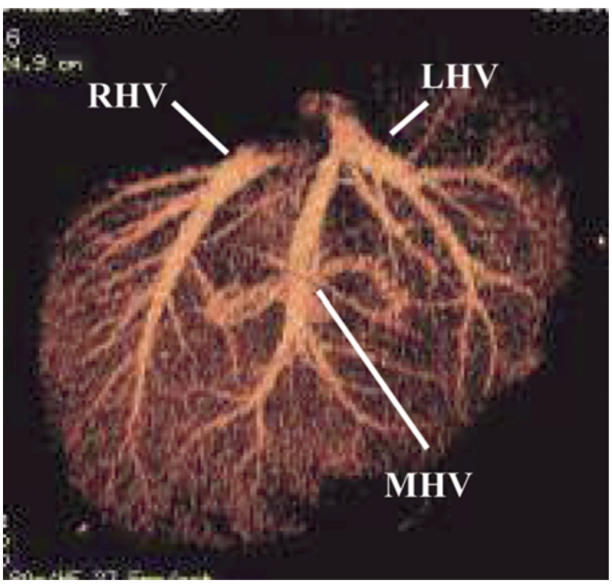

Fig. 4. A 73-year-old woman with a normal hepatic venous anatomy. Volume-rendering (VR) reformation displays normal MHV distribution.

were transferred from the scanner to a three-dimensional workstation (ADW4.2). One hundred milliliters of Omnipaque 300 (iohexol, Amersham) was injected as contrast medium through the right antecubital vein at a flow rate of 3.0 to 3.5 mL/s. Data acquisition for three-dimensional CT hepatic venography started 70 s after injection of contrast medium [2–4]. Maximum intensity projection (MIP) and volume rendering (VR) were used for all cases, and surface shadow display (SSD) was used for some cases. All postprocessing techniques were performed by one radiologist; the average postprocessing time was 5–10 min for each case.

Anatomy of the hepatic vein

The three main branches of the hepatic vein—right, left, and middle—drain into the inferior vena cava (IVC). The right hepatic vein (RHV) enters the IVC separately, but the middle (MHV) and left (LHV) hepatic veins may share a common trunk in 65% to 85% of patients (Fig. 1) [1]. Common anatomic variants include an accessory inferior right hepatic vein (IRHV) that drains Couinaud segment VI (Fig. 2) and a middle right hepatic vein that drains segment V. In one study, these variants were seen in 18% and 5.5% of patients, respectively [5]. If present, the distance from the right hepatic vein should be measured in the coronal plane. If the distance between the RHV and the accessory IRHV is longer than 4 cm, it may be difficult to surgically implant both veins with a single partially occluding clamp on the recipient's IVC [6, 7]. In addition, these veins should be preserved to reduce the risk of graft malfunction, especially if the veins are larger than 3 mm in maximum diameter.

Liver transplantation

The number of LDLTs has been increasing because cadaveric livers are not readily available. In adult LDLT, preoperative evaluation of hepatic venous anatomy is crucial for decreasing surgical complications [8–10]. Hepatic resection is typically performed in a plane parallel to the MHV. The hepatic venous system can display a number of anatomic variations, and surgical procedures without prior knowledge of the venous anatomy can lead to serious consequences. Therefore, it is very important to be familiar with the hepatic venous anatomy before the operation. CT hepatic venography is an excellent modality for the depiction of normal and variant hepatic venous anatomies (Figs. 3 and 4) [2]. The following section lists the classification of hepatic venous drainage patterns at the right liver lobe and middle hepatic vein, respectively. The classification of Nakamura and Tsuzuki [11] shows the hepatic venous drainage pattern of the right liver lobe. In type 1 (with an incidence of 50.9%), the RHV is large and drains the lateral sector and dorsal or lateral part of the paramedian sector. The MHV drains the ventral or medial part of the paramedian sector. In type 2 (incidence of 47.1%), the RHV is of medium size and thick, and some inferior hepatic veins

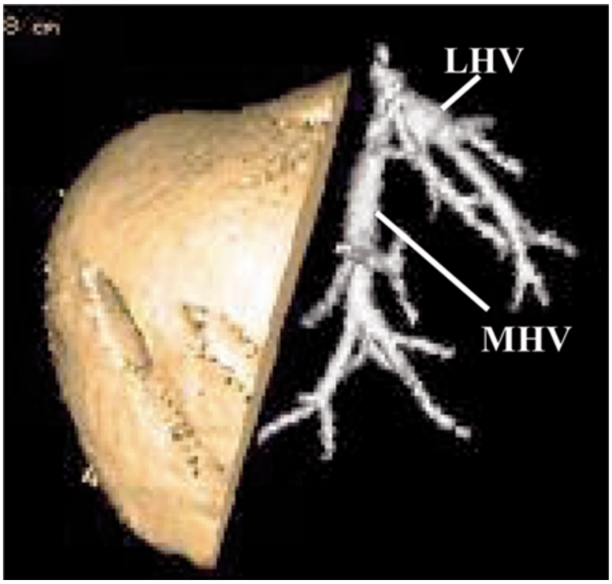

Fig. 5. A 73-year-old woman with a normal hepatic venous anatomy. SSD image displays the middle and left hepatic veins and the right hemiliver, which clearly display the surgical plane of LDLT, about 1 cm from the MHV.

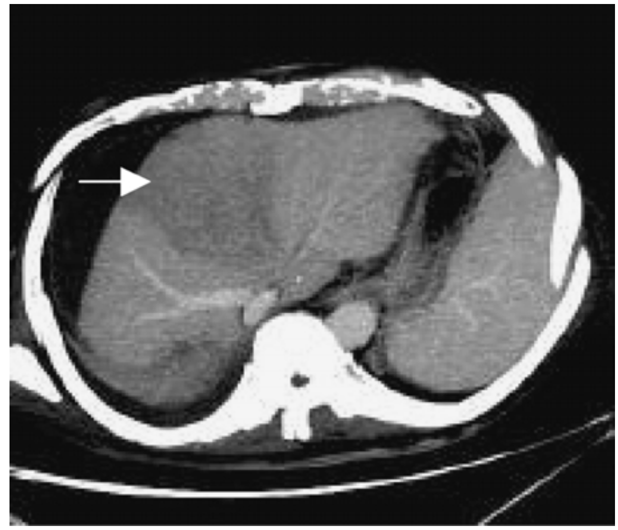

Fig. 6. A 53-year-old man with orthotopic liver transplantation (OLT). Axial maximum intensity projection (MIP) images display the absence of the MHV.

are present. The inferior hepatic veins drain the inferior part of the lateral sector, and the drainage area depends on peripheral development of the inferior hepatic vein. The RHV drains the residual superior part of the lateral sector. In type 3 (incidence of 2%), the large MHV is present and drains the paramedian sector and the inferior part of the lateral sector. The RHV is small and drains the superior part of the lateral sector. Also, a thick inferior hepatic vein is present [2]. The classification of Marcos et al. [12] categorizes the peripheral branching pattern of the MHV. In type 1 (incidence of 67.9%), the thick veins that drain segments IVa and V are branches with equal size and almost equal drainage areas. In type 2 (17%), the segment V vein is small and short. Segment IVa veins are thin and have a relatively larger drainage area than the segment V vein. In type 3 (15.1%), early proximal branching occurs and some medium-size branches are present in segments IVa and V [2].

Postoperative venous congestion can occur unexpectedly in regions covered by the thin branch of the MHV, especially in the dorsal area of the anterior sector. In patients with a hepatic venous branch covering a wide drainage area, venous reconstruction is needed to prevent postoperative liver dysfunction, even if the branch is thin [13]. Detailed preoperative evaluation for peripheral hepatic venous anatomy and hepatic veins traversing the surgical plane is necessary (Fig. 5) [14]. Hepatic venous congestion on CT images can appear as low attenuation that corresponds to the area of hepatic venous drainage with or without hepatic venous opacification [13]. CT venography can better display these changes.

Hepatic venous stenosis has emerged as an important vascular complication of LDLT. The incidence of hepatic venous stenosis after LDLT was reported to be 5% [15]. In our center the rate of hepatic venous stenosis for orthotopic liver transplantation (OLT) is about 1% (13 of 1300; unpublished data). The higher incidence of hepatic venous stenosis in patients who undergo LDLT may due to surgical procedures that include anastomosis between the hepatic vein of the graft and the IVC of the recipient. The relative position of the hepatic veins is fixed so that even slight movement of the graft results in buckling of the vessels and poor flow in the hepatic veins [15]. Early detection of hepatic venous stenosis is important because it can lead to timely intervention, such as hepatic vein stent placement, and thus improvement of the patient's chance for a successful outcome. CT hepatic venography can demonstrate nonvisualization or stenosis of the hepatic veins (Figs. 6, 7), mosaic heterogeneous enhancement, and hepatomegaly, which are characteristic of Budd-Chiari syndrome.

Budd-Chiari syndrome

Obstruction of hepatic venous outflow results in a clinical phenomenon known as Budd-Chiari syndrome, consisting of congestive hepatomegaly, abdominal pain (from hepatic capsular distention), and ascites. Budd-Chiari syndrome is also a rare but important cause of portal hypertension [1, 16]. Thrombosis is by far the leading cause of obstruction of the major hepatic veins [1]. In the intrahepatic IVC, obstruction may also be caused by a membrane or web, which is actually a sequel of thrombosis (Fig. 8A). Newer liver transplantation techniques such as LDLT and OLT with

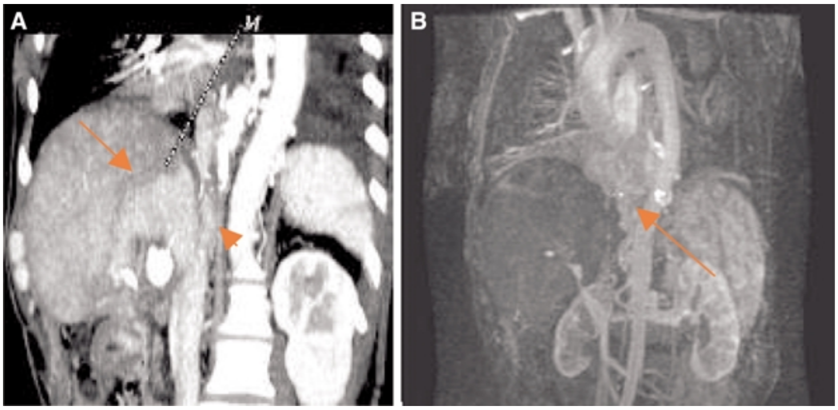

Fig. 7. A 62-year-old woman with OLT presenting with outflow obstruction. **A** Coronal MIP shows the absence of the MHV and stenosis of IVC (*arrow*). Note the esophagus varix. **B** Magnetic resonance angiography with coronal MIP image displays an absence of all major hepatic veins and stenosis of retrohepatic IVC. Also note the dilated, serpentine left gastric vein (*arrow*).

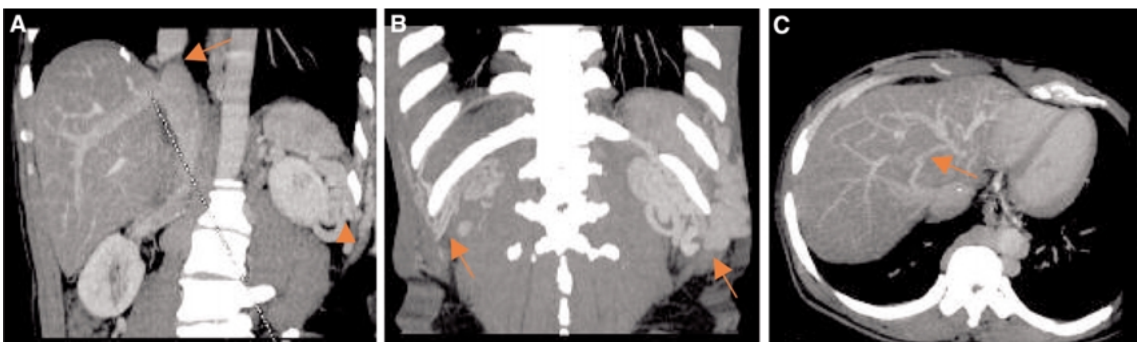

Fig. 8. A 47-year-old man with Budd-Chiari syndrome (BCS). **A** Coronal MIP shows thrombosis in the retrohepatic IVC (not shown) and suprahepatic IVC (*arrow*). **B** is also a coronal MIP image showing the serpentine varix in the posterior abdominal wall (*arrow*). **C** Axial MIP image displays the absence of the proximal MHV and a collateral vessel between the MHV and RHV (*arrow*) can be seen, a typical finding in BCS.

piggyback anastomosis may increase the risk of hepatic venous anastomotic stricture.

Budd-Chiari syndrome can be diagnosed on color Doppler sonography when color flow is absent in the main hepatic veins. Contrast-enhanced CT and magnetic resonance imaging may show nonvisualization of the major hepatic veins and a mosaic heterogenous perfusion pattern diffusely involving the liver. Intrahepatic veno-venous collaterals (Fig. 8B) can been seen when the IVC or the hepatic veins are obstructed [1, 16, 17]. One common collateral pathway connects intrahepatic venous collaterals to systemic venous pathways via subcapsular veins and may be identified on the surface of the liver. Alternatively, blood may be shunted away from an obstructed hepatic vein and toward a patent one. Prominent collaterals, typically the ascending lumbar, azygos, and hemiazygos veins, may be seen in patients with BCS because of obstruction of the intrahepatic IVC (Fig. 8C). The other routes are the left renal-hemiazygos pathway, inferior phrenic-pericardiophrenic collaterals, and superficial collaterals of the abdominal wall. Magnetic resonance angiography cannot display the superficial collaterals of the abdominal wall because of the limited size of the selected imaging volume [17]; however, CT hepatic venography can better show all the routes in this syndrome, including the superficial collaterals. Enlargement of the normally small accessory hepatic veins may also occur.

Transjugular intrahepatic portosystemic shunt

Transjugular intrahepatic portosystemic shunt (TIPS) creation has proved to be effective in the treatment of variceal bleeding and refractory ascites due to portal hypertension. Shunt stenosis is a frequent complication that, if not treated, can lead to shunt thrombosis and recurrent bleeding or ascites. Early detection and treatment of shunt dysfunction decreases the incidence of these complications. Patients with a TIPS develop shunt dysfunction at rates of 17% to 50% every year [18]. Therefore, regular follow-up is mandatory for the early detection and correction of shunt dysfunction to prevent recurrent variceal bleeding. Although portography is the standard for the diagnosis of shunt dysfunction, it is an invasive procedure that is more suitable for the definitive diagnosis and treatment of shunt dysfunction than for screening. Helical CT angi-

Fig. 9. A 47-year-old man with TIPS. Coronal MIP image shows filling of contrast agent in both ends of the stent, indicating patency of the shunt.

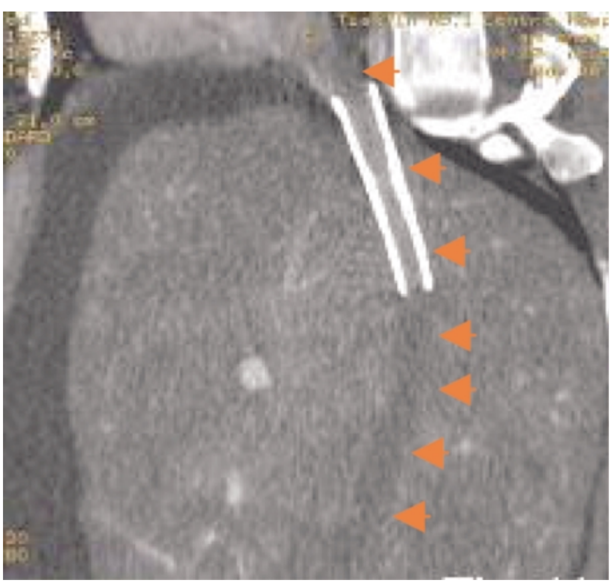

Fig. 10. A 29-year-old man with TIPS. Curved planar reformation image displays no contrast agent filling the stent (*arrowheads*), suggesting the obstructed shunt.

ography is a useful screening modality for the detection of TIPS stenoses or occlusions, especially with the use of MDCT. A study using helical CT angiography reported sensitivities, specificities, and accuracies of 97%, 89%, and 94% for the detection of all abnormalities and 92%, 77%, and 84% for the detection of significant abnormalities, respectively [18]. Although no reports for the diagnosis of TIPS complications using 16-slice CT have been published until now, it should have better results (Figs. 9, 10).

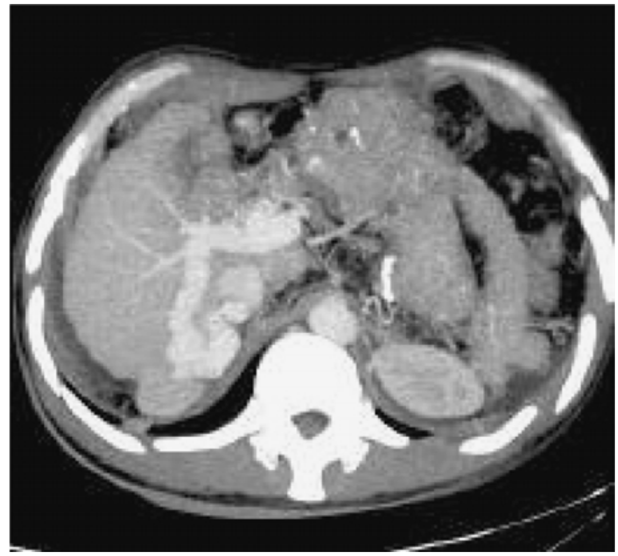

Fig. 11. A 56-year-old man with portal hypertension. Axial MIP image shows communication of the right portal vein and the IVC through the hepatic surface.

Intrahepatic vein shunts

Shunts between the hepatic arteries and the hepatic veins are rare but may occur in cavernous lymphangiomatosis or in Rendu-Osler-Weber syndrome [1, 19]. More commonly, arteriosystemic shunts occur in the setting of hepatocellular carcinoma with hepatic venous invasion. They may also develop after liver biopsy or with penetrating trauma. Arterioportal shunts are the most typical vascular communications associated with hepatocellular carcinoma, but portosystemic venovenous shunts are more common; these shunts provide collateral pathways for venous drainage of the liver in the setting of portal hypertension. Although the most commonly identified portosystemic shunts are extrahepatic, large intrahepatic portosystemic collaterals may be identified in the subcapsular area of the liver or may drain directly into the IVC (Fig. 11) [1]. Intrahepatic venous collaterals have also been reported as an important finding that indicates hepatic venous or IVC obstruction, but these have also been associated with other conditions, such as liver tumors, metastatic adrenal tumors invading the IVC, diaphragmatic hernia, Osler-Weber-Rendu disease [19], congestive liver disease, and so on (Fig. 12). With regard to the diagnosis of intrahepatic venous collaterals, hepatic venography has not been the sole tool; it has been replaced gradually by noninvasive medical imaging techniques such as CT venography, magnetic resonance imaging, and color Doppler sonography. Figure 8C shows the classic finding of chronic BCS: the MHV is obstructed proximally and connected to the RHV by a collateral vessel [1, 16, 17].

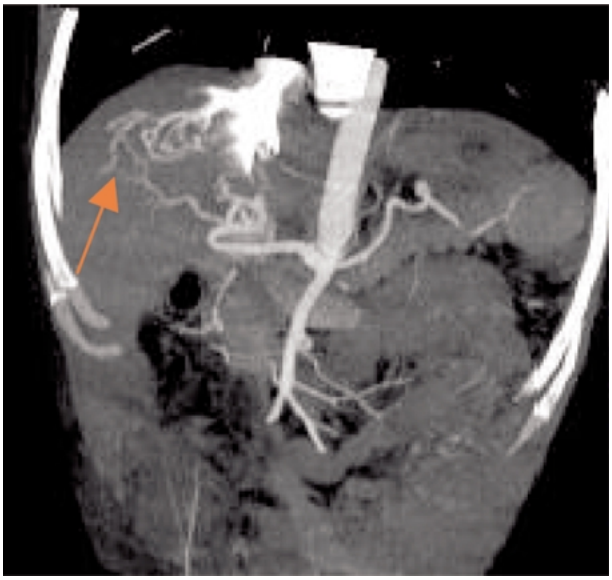

Fig. 12. A 31-year-old man with recurrence of tumor after OLT. After radiofrequency ablation of the mass, oblique MIP images display communications between the RHV and the right hepatic artery (*arrow*).

Fig. 14. A 46-year-old woman with hemangioma. Coronal MIP image displays the superior RHV involved by a small tumor consistent with cavernous humangioma (*arrow*) in the multiphase contrast-enhanced CT of the liver.

Fig. 13. A 54-year-old man with hepatocellular carcinoma. Coronal maximum intensity projection image display the right hepatic vein involved.

Others

Malignant liver tumors may obstruct or compress major hepatic veins or the IVC directly or in company with a tumor thrombus (Fig. 13). Some benign hepatic tumors around the hepatic veins can compress them (Fig. 14) [20]. Signs of vascular invasion of hepatocellular carcinomas are filling defects in the portal and hepatic veins, enhancement of the malignant thrombus on arterial phase images, and expansion of the vein lumen.

Conclusions

Overall, as a useful tool in the evaluation of the hepatic vein, hepatic CT venography can provide important and detailed anatomic information about both the donor and the recipient before LDLT. It can also show whether patients have hepatic venous congestion and stenosis. In addition, it can detect other entities such as BCS, TIPS, intrahepatic venous shunts, and hepatic venous involvement by different tumors. With these benefits, CT hepatic venography has become a routine protocol to evaluate hepatic vein anatomy before and after liver transplantation in our institution.

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