Ultrasound examination of the liver: Normal vascular anatomy

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Abstract Various treatments for liver diseases, including liver transplant (particularly partial liver resection from a living donor), treatment of liver tumors, and TIPS, require detailed knowledge of the complex vascular anatomy of the liver. The hepatic artery and portal vein provide the organ with a double blood supply whereas venous drainage is furnished by the hepatic veins.

Multislice computed tomography and magnetic resonance imaging provide undeniably excellent information on these structures. On ultrasound, the inferior vena cava, the openings of the hepatic veins, and the main branch of the portal vein can always be visualized, but intra-segmental vessels (portal, arterial, accessory hepatic venous branches) can be only partially depicted and in some cases not at all.

In spite of its difficulty and limitations, hepatic sonography is frequently unavoidable, particularly in critically ill patients, and the results are essential for defining diagnostic and therapeutic strategies. For this reason, a thorough knowledge of the sonographic features of hepatic vascular anatomy is indispensable.

Sommario Vari interventi terapeutici sul fegato, in particolare il trapianto, con maggior rilevanza per la resezione parziale da donatore vivente, il trattamento dei tumori epatici e le TIPS, richiedono la conoscenza dettagliata dell'architettura vascolare epatica, che è complessa; arteria epatica e vena porta forniscono al fegato una doppia vascolarizzazione, mentre il drenaggio venoso è assicurato dalle vene sovrepatiche.

TC multistrato e RM forniscono sicuramente dati eccellenti mentre ecograficamente sono costantemente evidenziabili la vena cava inferiore, lo sbocco delle sovrepatiche e i rami principali della vena porta; la vascolarizzazione intrasegmentale (rami portal, rami arteriosi e vene sovrepatiche accessorie) lo è solo parzialmente e saltuariamente.

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La necessità di eseguire esami ecografici, spesso in pazienti critici, i cui risultati sono essenziali per definire l'iter diagnostico e terapeutico rendono tuttavia, nonostante i limiti, l'ecografia di primaria importanza e la conoscenza dell'anatomia ecografica vascolare epatica essenziale.

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Introduction

Intimate knowledge of the vascular anatomy of the liver is essential for planning and follow-up of liver transplants (particularly those involving partial resection of a living-donor organ), treatment of liver tumors, TIPS, and less frequently the management of other liver diseases [1]. For the most part, multislice computed tomography (CT) and magnetic resonance imaging (MRI) have now replaced angiography in the study of hepatic vascularization. There are, however, a few exceptions. Evaluation of the arterial vascularization of the IV segment is not easy with CT or MRI. The blood supply of this segment comes mainly from the right hepatic artery, and this has important surgical implications for living-donor transplants [2,3]. Therefore, in this situation, angiography is still required.

In many patients, however, CT and MRI are simply not feasible. Ultrasonography is the only possible solution although the information it furnishes is inferior. The sonographer performing the examination must have an excellent knowledge of the hepatic vascular anatomy as it appears on sonography [4] (Fig. 1).

The hepatic artery

The celiac trunk (Fig. 2B) arises from the anterior aspect of the abdominal aorta, right below the diaphragm, and proceeds forward and to the right for approximately 1.5 cm before dividing into the following three branches: the left gastric artery, the hepatic artery (Fig. 2A), and the splenic artery [5,6].

The hepatic artery runs horizontally to the right and forward along the upper edge of the pancreas; at the level of the proximal portion of the duodenum, it gives rise to the gastro-duodenal artery and then continues toward the liver as the proper hepatic artery. It passes in front of the portal vein and rises within the hepatoduodenal ligament, together with the portal vein and common bile duct. In the hilum of the liver, it divides to form the right and left hepatic arteries [7] (Fig. 2). It gives rise to collateral branches: the right gastric artery, which furnishes part of the blood supply of the stomach, and the cystic artery. The latter artery normally arises from the right branch of the hepatic artery. It passes between the cystic and hepatic ducts, and when it reaches the neck of the gall bladder, it

Fig. 1 Hepatic vascularization is complex: the hepatic artery (a branch of the celiac trunk) and the portal vein (formed by the union of the splenic and superior mesenteric veins) provide two blood supplies; venous drainage is handled by the hepatic veins (A). The inferior vena cava, the openings of the hepatic veins, and the main branch of the portal vein can always be visualized sonographically, but sometimes the intrasegmental vessels (branches of the portal vein, arteries, and accessory hepatic veins) cannot be visualized at all (B: Three-dimensional reconstruction of the hepatic vascularization).

Fig. 1 La vascolarizzazione del fegato è complessa: arteria epatica, ramo del tripode celiaco e vena porta, costituita dalla confluenza delle vene splenica e mesenterica superiore, forniscono una doppia vascolarizzazione, mentre il drenaggio è assicurato dalle vene sovrepatiche (A). Ecograficamente sono costantemente evidenziabili la vena cava inferiore, lo sbocco delle sovrepatiche e i rami principali della vena porta; la vascolarizzazione intrasegmentale (rami portalì, rami arteriosi e vene sovrepatiche accessorie) lo è solo saltuariamente (B: ricostruzione tridimensionale della vascolarizzazione epatica).

Fig. 2 The hepatic artery (A) arises from the celiac trunk (B: three-dimensional reconstruction), which in turn originates from the anterior aspect of the abdominal aorta, right below the diaphragm. It runs forward and to the right for approximately 1.5 cm and then divides into the following three branches: the left gastric artery, the hepatic artery, and the splenic artery. The hepatic artery (white arrows) passes in front of the portal vein and ascends within the hepatoduodenal ligament, together with the portal vein (black arrows) and common bile duct. In the hilum of the liver, it divides into right and left branches. On an intercostal color Doppler scan, the normal portal vein appears red-orange (hepatopetal flow) and the hepatic artery is yellow (indicating higher flow velocity).

Fig. 2 L'arteria epatica (A) origina dal tripode celiaco (B: ricostruzione tridimensionale) che a sua volta nasce dalla faccia anteriore dell'aorta addominale, subito al di sotto del diaframma, si porta in avanti verso destra, per circa 1,5 cm, quindi si divide in tre rami: arteria gastrica sinistra, arteria epatica e arteria splenica. L'arteria epatica (frecche bianche) passa davanti alla vena porta, risale tra i foglietti del legamento epato-duodenale assieme alla vena porta (frecche nere) e al coledoco, e nell'ilo epatico si divide nei rami destro e sinistro. All'esame con color Doppler, con scansione intercostale, la vena porta, in condizioni fisiologiche, appare rosso-arancione (flusso epatopeto) e l'arteria epatica di colore giallo (indica la maggiore velocità).

divides into two branches that supply the upper and lower portions of this organ [8].

The left branch (Fig. 3) divides into three branches that supply the anterior and posterior portions of the liver and that quadrate lobe.

At the intrahepatic level, the right branch (Fig. 4), which is larger in caliber than the left branch, gives rise to the cystic artery and then divides within the hepatic parenchyma to form two or three branches that supply the caudate lobe and the anterior and posterior segments.

Fig. 3 After division, the left branch divides again to form branches for the anterior portion of the liver, the posterior portion, and the quadrate lobe. These branches run together with the portal branches (A). They are easy to examine on ultrasound (B) (white arrows), and color Doppler allows them to be distinguished from the portal branches. More complicated is the sonographic evaluation of the small-caliber, terminal branches that supply the large vessels themselves, the bile ducts, and the capsule of the liver; even more difficult are the interlobar branches, which run through the portal spaces and merge with the sinusoids of the liver as perilobular arterioles. In a patient who has received a liver transplant, it is not always easy to recognize and examine the hepatic artery at the hilum, and studies of the intrahepatic branches can assume particular importance in these cases.

Fig. 3 Dopo la divisione il ramo sinistro si suddivide in rami per la porzione anteriore, per quella posteriore e per il lobo quadrato che decorrono assieme ai rami portal (A); sono facilmente valutabili ecograficamente (B) (frecche bianche) e distinguibili con color Doppler rispetto ai rami portal. Non sono invece valutabili ecograficamente gli esili rami terminali destinati all'irrorazione degli stessi vasi maggiori, delle vie biliari e della capsula del fegato né tanto meno i rami interlobari che decorrono negli spazi portal e vanno poi a gettarsi come arteriole perilobulari nei sinusoidi epatici. Nei pazienti dopo trapianto il riconoscimento e la valutazione dell'arteria epatica all'ilo non è sempre agevole e lo studio dei rami intraepatici può avere particolare importanza.

Fig. 4 At the intrahepatic level, the right branch, which is larger than the left, gives rise to the cystic artery and then divides within the hepatic parenchyma, forming two or three branches (for the caudate lobe and for the anterior and posterior segments). Like the left branches, the right branches are easy to examine sonographically (B–C) (white arrows) and can be distinguished on color Doppler from the portal branches; in contrast, it is not possible to identify their subdivisions.

Fig. 4 A livello intraepatico il ramo destro, di calibro maggiore rispetto al sinistro, dopo aver dato origine all'arteria cistica, si divide all'interno del parenchima epatico in due o tre rami (arteria per il lobo caudato, per i segmenti anteriori e per quelli posteriori). Come avviene per i rami sinistri anche i destri sono facilmente valutabili ecograficamente (B–C) (freccie bianche) e distinguibili con color Doppler rispetto ai rami portalì, mentre non appaiono riconoscibili le loro diramazioni.

Each of these first subdivisions gives rise to small branches that supply blood to the larger vessels themselves, the bile ducts, and the capsule of the liver. Above all, they continue as the interlobar arteries that run through the portal spaces and merge (as perilobular arterioles) with the sinusoids of the liver.

The portal vein

The portal vein is formed by the union of all of the veins draining the intestine, spleen, pancreas, and gall bladder. It arises behind the head of the pancreas, to the left of the inferior vena cava, at the level of the II lumbar vertebra

from the confluence of the superior mesenteric vein, the splenic vein, and the inferior mesenteric vein (which usually empties into the splenic vein right before the latter's confluence with the superior mesenteric vein). The portal vein is around 8 cm long and has a diameter of 15–18 mm [9]. It is in contact with the head of the pancreas and the duodenum.

It runs obliquely, upward and to the right, and reaches the hilum of the liver, accompanied by the hepatic artery (which is anterior to it) and the common bile duct. After receiving the coronary veins of the stomach, the right gastric vein, and the cystic vein, the portal vein divides at the hilum, giving rise to its right and left terminal branches [10,11] (Fig. 5A,B).

Fig. 5 Behind the head of the pancreas, to the left of the inferior vena cava at the level of the II lumbar vertebra, the superior mesenteric and splenic veins merge to form the portal vein, which measures around 8 cm in length and has a diameter of 15–18 mm [9]. It runs obliquely, upward and to the right, and when it reaches the hilum (A,B), it divides in a T formation to form its right and left terminal branches.

Fig. 5 La vena porta si forma posteriormente alla testa del pancreas, a sinistra della vena cava inferiore, all'altezza della II vertebra lombare, dalla confluenza delle vene mesenterica superiore e splenica; è lunga circa 8 cm, e ha un calibro di 15–18 mm [9]. Si dirige obliquamente in alto e verso destra per raggiungere l'ilo epatico (Fig. A,B) dove si divide a T dando origine ai suoi rami terminali, destro e sinistro.

Fig. 6 The left branch of the portal vein runs horizontally and crosses over the round ligament (umbilical segment) (O P of P V), where it gives rise to a branch for the II segment and one for the III before terminating in two branches for the IV segment, which is generally the largest segment of the left lobe (A,B).

Fig. 6 Il ramo sinistro della vena porta ha decorso orizzontale, attraversa il legamento rotondo (tratto ombelicale) (O P of P V) dove dà origine a un ramo per il II segmento e a uno per il III, quindi termina con due rami per il IV segmento, generalmente, il più voluminoso del lobo sinistro (A,B).

The left branch runs horizontally, crosses the round ligament (umbilical segment), where it gives rise to one branch for the II segment and one for the III and then terminates in two branches supplying the IV segment [12–14] (Fig. 6), which is generally the largest segment of the left lobe.

The right branch gives off a branch to the caudate lobe and then an anterior and a posterior branch, which in turn divide into two superior and two inferior branches for the four segments (A, B); the right branch of the portal vein divides the V segment from the VIII [6] (Fig. 7).

The hepatic veins

The major hepatic veins (2–3 vessels) drain blood from the hepatic parenchyma and have a mean diameter of 15 mm [15] (Fig. 8A).

The right hepatic vein drains segments V and VII, the middle hepatic vein drains segment IV, part of segment V, and segment VIII (Fig. 8B, C), and the left hepatic vein drains the left lobe of the liver (II and III segments) [16] (Fig. 8D).

The left hepatic vein separates the II segment from the III (Fig. 8D), the middle hepatic vein divides the V and VIII segments from the IV, and the right hepatic vein separates the V and VIII from the VI and VII segments (Fig. 8A–C).

In 60% of the cases, the middle and left hepatic veins merge to form a common trunk [17] (Fig. 8B,C). They then emerge in the cranial part of the retrohilar fossa and empty into the segment of the inferior vena cava lying between the liver and the diaphragmatic orifice.

The minor hepatic veins [10–15] emerge in the lower portions of the retrohilar space and immediately empty into the inferior vena cava, draining the territories

Fig. 7 The right branch of the portal vein gives rise to a branch supplying the caudate lobe and then anterior and posterior branches that subdivide producing two superior and two inferior branches for the four segments (A,B). Its course divides the V and VIII segments (C).

Fig. 7 Il ramo destro della vena porta dà origine a un ramo per il lobo caudato quindi a un ramo anteriore e a uno posteriore che a loro volta si suddividono in due rami superiori e inferiori per i quattro segmenti (A,B); nel suo decorso divide il V dall’VIII segmento (C).

Fig. 8 The major hepatic veins (generally three in number) drain the hepatic parenchyma (A). In 60% of cases, the middle and left hepatic veins merge to form a common trunk (B,C) before emptying into the inferior vena cava. The left hepatic vein divides the II segment from the III (D), the middle hepatic vein separates the V and the VIII segments from the IV, and the right hepatic vein divides the V and the VIII segments from the VI and VII (D).

Fig. 8 Le vene sovrepatiche maggiori, generalmente tre, drenano il sangue refluo dal parenchima epatico (A). Nel 60% dei casi la media e la sinistra si uniscono formando un tronco comune (B,C) prima di confluire nella vena cava inferiore. La vena sovrepatica sinistra divide il II segmento dal III (D), la vena sovrepatica media divide il V e l'VIII segmento dal IV, la sovrepatica destra il V e l'VIII dal VI e dal VII (D).

immediately adjacent to it. They are propulsive veins that are equipped with valves in the adult [18].

Conclusions

The vascular anatomy of the liver is complex. The hepatic artery and portal vein furnish a double blood supply and venous drainage is handled by the hepatic veins [19,20]. It is important to add that, whereas the inferior vena cava, the openings of the hepatic veins, and the main branch of the portal vein can always be visualized sonographically, the intrasegmental vessels (branches of the portal vein, arteries, and accessory hepatic veins) can be visualized only partially or sometimes not at all, and they are also characterized by endless anatomic variants [21].

Despite their limitations and the difficulties that can arise, serial ultrasound studies of the liver are an inevitable part of current therapies, liver transplant, TIPS, radio-frequency ablation procedures, etc., especially in critically ill patients. The results of these studies are essential for defining diagnostic and therapeutic strategies, and a thorough knowledge of the vascular anatomy of the liver is currently indispensable.

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