REVIEW ARTICLE

Isolated Arteries Originating from the Intrahepatic Arteries: Anatomy, Function, and Importance in Intervention

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ABSTRACT

Isolated hepatic arteries are defined as hepatic terminal arterioles that are not accompanied by portal venules or bile ductules and penetrate the liver parenchyma and distribute to the hepatic capsule and intrahepatic hepatic veins. Abundant communications exist between intra- and extrahepatic arteries through isolated arteries and capsular arterial plexus. They play a principal role in the development of subcapsular hemorrhage and arterial collateral formation following transcatheter arterial chemoembolization for liver cancers. The anatomy, function, and clinical importance of isolated hepatic arteries in interventional radiology, especially regarding subcapsular hemorrhage and arterial collateral formation, are highlighted in this article.

An isolated hepatic artery is a characteristic hepatic terminal arteriole that is not accompanied by a portal venule or bile ductule and penetrates the liver parenchyma and distributes to the hepatic capsule and intrahepatic hepatic veins (1). Although the existence of isolated arteries has been documented in the anatomy field, their clinical importance required still greater recognition by interventional radiologists to achieve the optimal diagnosis and treatment of hepatic diseases. However, few reports have yet described the importance of the isolated artery in interventional radiology (1–3). In this review, the microanatomy, function in the microcirculation, and importance in interventional radiology of the isolated artery in the liver are discussed, with special emphasis placed on its role in the development of subcapsular hemorrhage of the liver and arterial collateral formation following transcatheter arterial chemoembolization for liver cancers. Treatment for subcapsular hemorrhage by means of interventional technique and effective performance of transcatheter arterial chemoembolization while taking into consideration the presence of isolated arteries are also highlighted.

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Figures E1 and E2 are available online at *www.jvir.org*.

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MICROANGIOARCHITECTURE OF THE LIVER

In general, the liver receives a dual blood supply from the hepatic artery and portal vein; 75%–80% of blood inflow originates from the portal vein and the remainder from the hepatic artery. The portal blood flow enters the sinusoidal blood vessel and finally drains into the hepatic vein through a central vein. Most hepatic arteries run along the portal vein and bile duct in the Glisson sheath (portal tract) from the hepatic hilum to the interlobular area, serving as the nutrient system of the biliary system, portal vein, hepatic vein, and other structures. The microcirculatory system of the Glisson sheath is extremely complicated. The portal vein ramifies along the way to termination more than 12 times and ends in the preterminal and terminal portal venule. Tiny branches (inlet venules) ramify from these preterminal or terminal venules and connect with the hepatic sinusoids. On the other hand, the hepatic artery clings closely to the portal vein and terminally distributes to the peribiliary area, forming a peribiliary plexus (PBP), which ensheathes the intrahepatic biliary ducts (4,5). Moreover, the hepatic terminal artery also ends in the periportal plexus (PPP), portal vein vasa

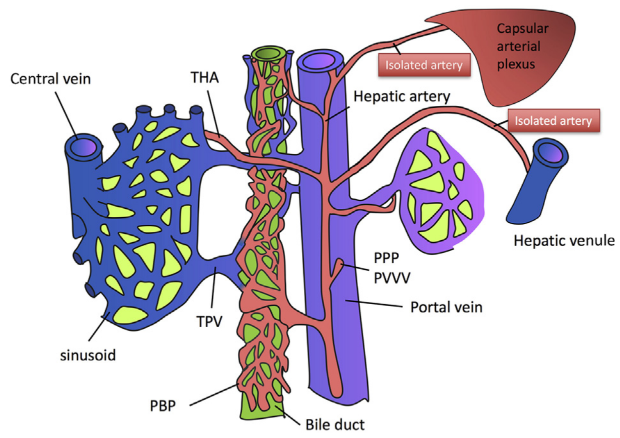

Figure 1. Microangioarchitecture of the liver. PBP = peribiliary plexus; PPP = periportal plexus; PVVV = portal vein vasa vasorum; THA = terminal hepatic arteriole; TPV = terminal portal venule. Adapted and reprinted, with permission, from Miyayama and Matsui (6).

vasorum, and interlobular artery. The PBP and PPP connect to each other and finally enter the portal venules and sinusoids directly or indirectly (**Fig 1**) (4–7). The interlobular artery runs along the interlobular area and finally enters the sinusoid as well.

DEFINITION AND MICROANATOMY OF ISOLATED ARTERY IN THE LIVER

In 2000, Ekataksin documented the presence of isolated arteries unaccompanied by portal veins or bile ducts in the livers of several pigs and other mammals, including humans (1). In that article, "isolated artery" was defined as follows: an arterial vessel that is not associated with a portal vein (venule) or paired with a bile duct (ductule) and that, after dissociating itself from the portal tract, runs an independent course toward the target structure to supply an isolated vascular bed (**Fig 1**).

Figure E1 (available online at *www.jvir.org*) shows the distribution of terminal hepatic arterioles described by Ekataksin. There are two groups, one of which terminates at portal tracts as described above, and the other connecting to the hepatic capsular arterial plexus and hepatic venule penetrating the liver parenchyma without accompanying portal venule or bile ductule (shown as isolated artery in **Fig 1**).

Another report confirmed the presence and microanatomy of isolated arteries in human autopsy liver with the use of vascular casts of hepatic arteries and reported their importance for understanding the mechanism of subcapsular hemorrhage (2). In an autopsy liver casting model, in which silicon rubber was injected into the hepatic artery, fixed, and the tissue cleared with the use of methyl salicylate, many tiny arterial branches were found to penetrate the liver parenchyma toward the surface of the liver and connect with the hepatic capsular arterial plexus, suggesting isolated arteries (**Fig 2**) (1,2). In cadaver dissection, moreover, a larger isolated artery can sometimes be found as a tiny vessel penetrating the liver parenchyma, communicating to the capsular arterial plexus in the subcapsular area (**Fig 3**). Thus, such isolated arteries are common anatomic structures in human liver and serve physiologically as an intermediary between the hepatic artery and hepatic capsular arterial plexus.

The hepatic capsule is present at not only the peritoneal surface of the liver, but also all the parenchymal walls, including the nonperitonealized liver surface (bare area), hilar area, fissures for the ligamentum venosum and ligamentum teres hepatis, and caval groove for the inferior vena cava with the proximal portion of the hepatic veins (8). Thus, the hepatic capsular arterial plexus can communicate with arteries feeding these regions. Among them, the extrahepatic arteries distributing to the bare area and surrounding ligaments of the liver, such as inferior phrenic, internal thoracic, intercostal, and adrenal arteries, are considered to be the major group of feeding arteries to the hepatic capsular arterial plexus (9,10). **Figure 4** (11) shows the distribution of the left inferior phrenic artery to the hepatic capsule of the right lobe through the bare area and falciform ligament and connection to the hepatic capsular arterial plexus in a cadaver dissection. Owing to the presence of these microanatomic communications, intrahepatic arteries can communicate diffusely with major extrahepatic arteries through the isolated arteries and capsular arterial plexus (6). In some older studies, hepatic arterial vascular casts made by injection from the proper hepatic artery showed visualization of the inferior phrenic arteries, although the exact route of the communications was not specified (12).

On conventional dynamic computerized tomography (CT) and magnetic resonance imaging, isolated arteries are invisible, but they can be identified indirectly on selective arterial angiography or angiography-assisted CT from the intra- or extrahepatic artery.

FUNCTION AND IMPORTANCE OF ISOLATED ARTERY

Subcapsular Hemorrhage in the Liver

The pathophysiology of subcapsular hemorrhage is complicated, often making transcatheter intervention for challenging (2). The etiology of subcapsular hemorrhage includes rupture of hepatic tumors, especially hepatocellular carcinoma (HCC) and nontumorous conditions, such as iatrogenic bleeding due to liver biopsy or puncture, blunt trauma, HELLP (hemolysis, elevated liver enzymes, and low platelets) syndrome, amyloidosis, and vasculitis (2). Subcapsular hemorrhage is often localized in this area, with occasional secondary rupture to the peritoneal space. When rupture occurs, urgent surgical intervention may be required (13). On dynamic CT, subcapsular hemorrhage often shows multiple extravasations from a broad surface area, due to interruption of the numerous isolated arteries between the liver parenchyma and hepatic capsule (**Fig 5**). In addition, it