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Liver Transplant Anatomy: Basics for Interventional Radiologists

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Abstract

Liver transplantation is becoming increasingly common in the United States, with very favorable 1- and 5-year survival rates. With increasing long-term survival rates, postprocedural vascular complications can occur with increased frequency. Familiarity with posttransplant vascular anatomy is essential for interventional radiologists dealing with this patient population. This article discusses the posttransplant venous, arterial, and biliary anatomy and the implications for minimally invasive interventions.

Keywords
- ► interventional radiology
- ► liver
- ► liver transplantation
- ► vascular anatomy
- ► bile duct

Liver transplantation is the second most frequently performed major organ transplant with current 1-year patient survival rates of 91 to 93% and 5-year survival rates of 75 to 84%.[1] Significant advances in both surgical technique and medical management of rejection have contributed to a steady increase in transplant volumes.[2] Interventional radiologists must recognize the variability in pre- and post-liver transplant anatomy as well as the surgical techniques employed. During liver transplantation, hepatic arterial, hepatic venous, and/or inferior vena cava (IVC), portal venous, and biliary ductal anastomoses must be performed.[3] Knowledge and recognition of this anatomy is crucial for identifying and managing postoperative complications. This article focuses on deceased donor liver transplantation, highlighting the anatomical appearances of various anastomoses through multimodality imaging. It will briefly mention split liver and living donor transplants but not cover them in depth.

Anatomy

A comprehensive understanding of both the normal and variant hepatic anatomy, as well as the anatomy of the liver posttransplantation, is essential to having expertise in this space. Both the typical and atypical posttransplantation anatomy of the hepatic arterial, portal venous, hepatic venous/IVC, and bile ducts are outlined below including a few examples of potential complications that may be encountered.[4]

Arterial

A variety of arterial anastomotic surgical techniques have been described and are routinely implemented depending on the donor/graft artery and the recipient/native artery. These anastomoses can be end-to-end, with or without the use of conduits and/or interposition grafts, and may include more than one anastomosis with possible sacrifice/ligation of adjacent arteries.[5,6] End-to-end anastomosis without any additional intervening segments performed with a direct single-point attachment of the recipient hepatic artery to the graft hepatic artery is the most common type (►**Fig. 1a**).[7] Donor or recipient anatomical variant, that is, replaced right hepatic artery arising off the superior mesenteric artery (►**Fig. 1b**), can affect the surgical anatomy and points of attachment (►**Table 1**).[8]

Alternative anastomosis between the donor and the recipient is at times needed and can be made via a conduit or an interposition graft. These may be synthetic or a

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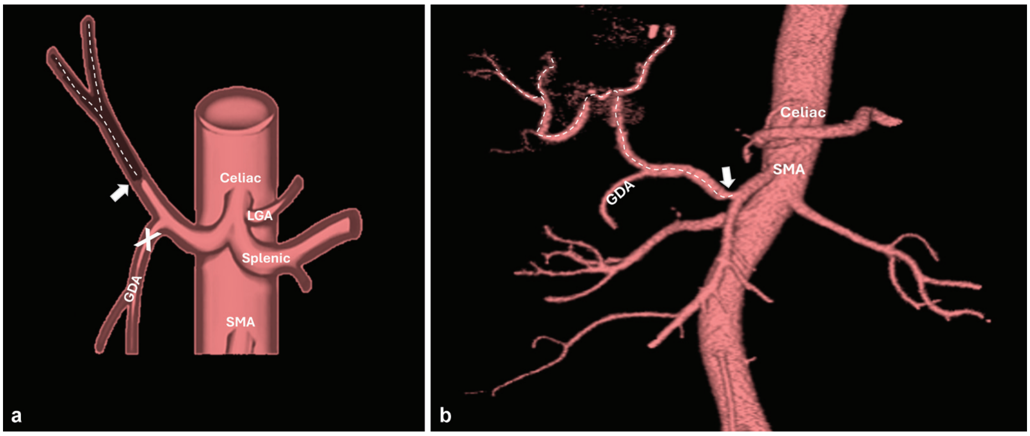

Fig. 1 Conventional end-to-end hepatic artery anastomosis (**a**) with the recipient proper hepatic artery anastomosed (white arrow) to the donor proper hepatic artery and its branches (dotted white lines). Note the recipient, as depicted in this illustration (or conversely the donor), gastroduodenal artery (GDA) may or may not be ligated (*X*). (**b**) Example of a surgical variation for a recipient with a replaced hepatic arising off the superior mesenteric artery (SMA), with anastomosis (white arrow) to the donor common hepatic artery (dotted white lines) at this level. LGA, left gastric artery.

Table 1 Relevant hepatic arterial variants in both recipients and living donors with notable surgical implications are summarized

Hepatic arterial variants	Implication for transplantation
Variants relevant to recipients	
• Short common/proper hepatic artery	• May need interposition graft. Can lead to redundancy, kinking, stenosis, complex anastomosis
• Celiac artery stenosis	• Increase chances of biliary complications and graft dysfunction
• Replaced/accessory right or left hepatic artery. Entire hepatic arising off the superior mesenteric artery	• Can make surgery more technically challenging. Complex anastomosis, stenosis
Variants relevant to living donors	
• Right hepatic artery giving rise to the middle hepatic artery	• May compromise arterial supply to the left lobe of the liver
• Hepatic artery trifurcation or having right/left hepatic artery arising prior to the origin of the gastroduodenal artery	• Gastric or duodenal hypoperfusion if clamping or ligating common hepatic artery

harvested autologous vessel from either the recipient or the donor. Direct aortohepatic conduits are typically infrarenal but can rarely arise from a supraceliac location and often have multiple sites of attachment (►**Fig. 2**). In cases of revision, retransplantation, insufficient arterial stump length, as well as bypassing an infected or inflamed arterial segment, an interposition graft may be used between the donor and recipient.[4,6,7]

Note with an increased number of anastomoses, studies have shown an increase in the incidence of anastomotic arterial complications such as hepatic artery stenosis. Patients receiving a living donor transplant have an almost twofold risk of hepatic arterial complications. When hepatic arterial complications occur at an early stage, it may result in ischemia/necrosis of the graft. In contrast, when they occur at a later time point, it can lead to biliary complications with relative preservation of graft function.[9]

Portal Venous

The portal venous system has fewer anatomic variants than the hepatic artery. In greater than 55% of cases, the joint trunk of the splenic vein (SpV) and the inferior mesenteric vein (IMV) join the superior mesenteric vein to form the main portal vein. The second variant, occurring in ~25% of patients, is a joint trunk of the SMV and IMV joining the SpV to form the main portal vein. The least common variant involves all three veins—SMV, IMV, or SpV, joining at one common confluence to become the main portal vein.[10] When the portal vein is free of thrombus or disease, an end-to-end anastomosis may be performed between the donor portal vein and the recipient portal vein and is the preferred surgical anastomosis (►**Fig. 3a**).

If the portal vein of either the donor or recipient is too short, thrombosed, diseased, or traumatized prior to or during surgery, a graft (synthetic interposition graft or

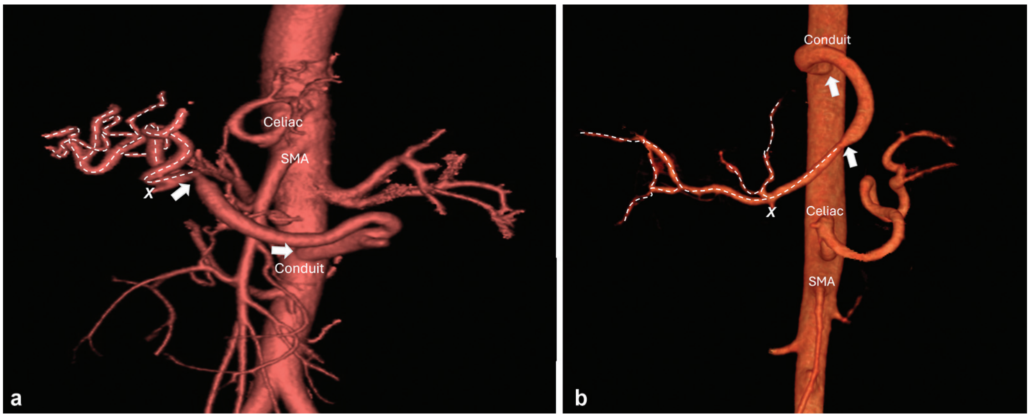

Fig. 2 Demonstration of two different types of aortohepatic conduits. (**a**) An infrarenal conduit with two anastomoses (white arrows), one below the level of the renal arteries and the other with the donor common hepatic artery. (**b**) An uncommon supraceliac conduit with two anastomoses (white arrows). The dotted white lines represent the donor hepatic artery and its branches. The *X* represents a ligated/sacrificed donor gastroduodenal artery. SMA, superior mesenteric artery.

cadaveric vein graft) can be used to bridge the anastomosis. For example, a bypass conduit may be required between the recipient SMV and portosplenic confluence to the donor portal vein in the setting of acute or chronic native portal vein thrombosis (►**Fig. 3b**). When the recipient's portal vein is of smaller caliber and/or bifurcated, it is typically dissected at the bifurcation to match a larger donor portal graft thereby minimizing the size discrepancy between the two, commonly referred to as a branch-patch angioplasty technique.[11]

Portal venous complications are rare but may be related to the patient's clinical status prior to liver transplantation, including a history of portal hypertension, portal venous thrombosis, and splenectomy. Acute complications may involve hepatic failure and its clinical manifestation, while late-stage presentations include portal hypertension and its sequelae.[4,12]

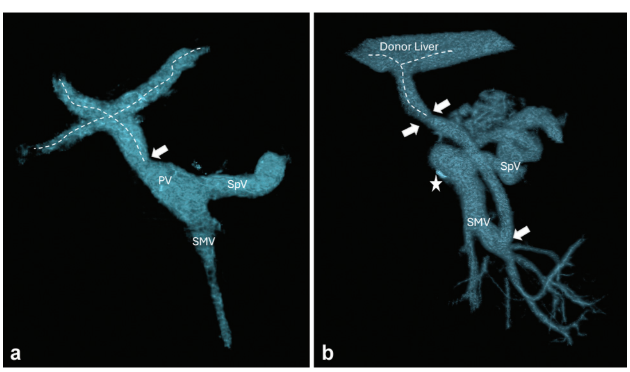

Fig. 3 Conventional end-to-end portal venous anastomosis (**a**) between the recipient main PV anastomosed (white arrow) to the donor portal vein and its branches (dotted white lines). (**b**) Patient with a bypass conduit/graft between the recipient SMV anastomosis (single white arrow) and the donor portal vein (dotted white lines) anastomosis (double white arrow) in the setting of chronic recipient portal vein thrombosis. Note the calcification (white star) and the obliteration of the recipient main PV with varices arising off the splenic vein. PV, portal vein; SMV, superior mesenteric vein; SpV, splenic vein.

Hepatic Venous/Inferior Vena Cava

Hepatic vein and IVC anastomosis in liver transplantation can be categorized mainly into two categories: either whole grafts or split grafts. Split graft anastomosis is made by connecting only the hepatic vein branches of the donor graft to either the IVC or directly to the hepatic veins by end-to-end anastomosis.[5] While whole graft anastomosis occurs most commonly with a piggyback technique (►**Fig. 4a**) or via a cavocavostomy (►**Fig. 4b**), when the donor outflow venous system is anastomosed into part of the recipient's outflow system. Less commonly, an intercaval donor venous outflow connection can be made with two anastomoses at the superior and inferior aspects of the recipient intrahepatic IVC (►**Fig. 4c**).[3,11,13]

Hepatic venous outflow obstruction, though rare, can occur at the level of the IVC or the hepatic veins. Early complications are often due to surgical techniques resulting in torsion, kinking, or stenosis. In general, factors such as compression, inflammation, fibrosis, or neointimal hyperplasia contribute to later-term complications with endovascular techniques, including balloon angioplasty and/or stent placement, being the mainstay therapy.[4]

Biliary

Biliary surgical anastomosis can be either biliary–biliary (choledocho-choledocostomy) or biliary-enteric (►**Fig. 5**). With a choledocho-choledochostomy anastomosis, the recipient common bile duct (CBD) or the common hepatic duct (CHD) is anastomosed directly with the donor CBD or CHD. With biliary-enteric anastomosis, the CHD or CBD is anastomosed to a loop of the bowel. This is often achieved by performing an end-to-side biliary-enteric anastomosis, where the end of the CBD or CHD is connected to the side of either a Roux-en-Y jejunal loop or an interposition jejunal loop attached to the recipient duodenum.[14,15]

Biliary complications, such as strictures and leaks, occur in approximately 15% of deceased donor transplants and up to 40% of living donor transplants. Symptoms can vary significantly, ranging from elevated cholestatic enzymes in

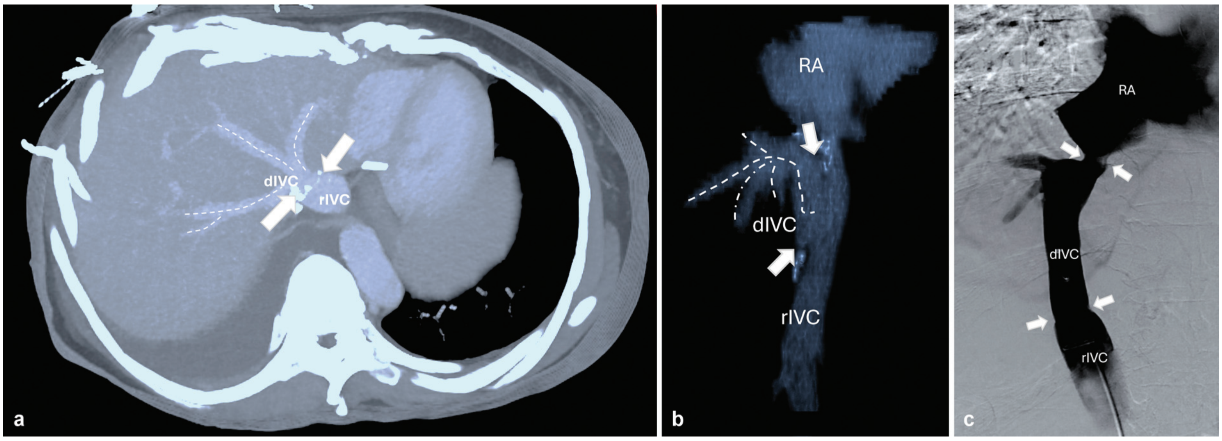

Fig. 4 Whole graft venous outflow connection. (**a**) Axial contrast-enhanced MIP CT images demonstrate a piggyback caval donor IVC (dotted white lines) anastomosis (white arrows) to recipient IVC. (**b**) 3D-rendered side-to-side cavocavostomy anastomosis (white arrows) between the recipient and donor IVC. Dotted white lines represent the branches of the hepatic veins from the dIVC. (**c**) Donor caval interposition connection (dIVC) can be made with two anastomoses (white arrows) at the superior and inferior aspects of the recipient IVC. RA, right atrium; dIVC, donor inferior vena cava; rIVC, recipient inferior vena cava. (**a**) Cholangiogram depicting an end-to-end, duct-to-duct, choledocho-choledochostomy biliary anastomosis (white arrows) from injection performed after cannulation of the rCHD. (**b**) Cholangiogram demonstrating an end-to-side biliary-enteric anastomosis (white arrows) with a hepaticojejunostomy biliary reconstruction between the dCBD and the recipient Roux-en-Y jejunal loop. dCHD, donor common hepatic duct; rCHD, recipient common hepatic duct; dCBD, donor common bile duct.

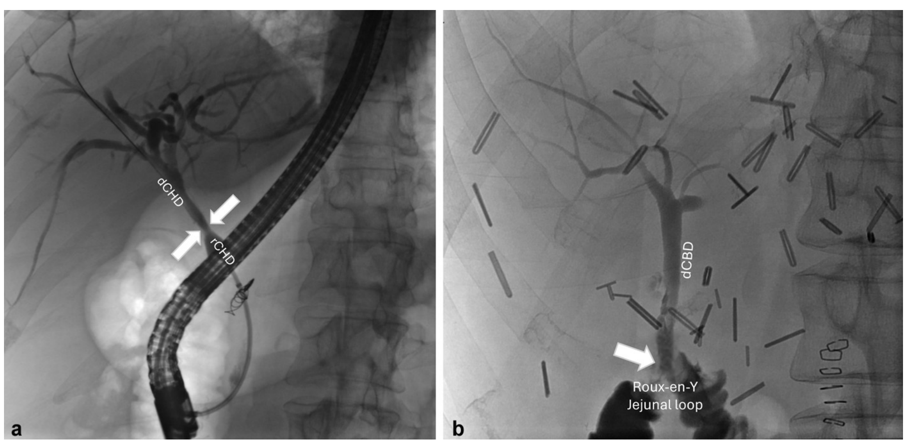

Fig. 5 (**a**) Cholangiogram depicting an end to end, duct-to-duct, choledocho-choledochostomy biliary anastomosis (white arrows) from injection performed after cannulation of the rCHD. (**b**) Cholangiogram demonstrating an end-to-side biliary-enteric anastomosis (white arrows) with a hepaticojejunostomy biliary reconstruction between the dCBD and the recipient Roux-en-Y jejunal loop.
dCHD, donor common hepatic duct; rCHD, recipient common hepatic duct; dCBD, donor common bile duct.

asymptomatic patients to severe cases of septic shock due to bacterial cholangitis.[16]

Conclusion

This article illustrates vascular and biliary anatomical structures following hepatic transplantation. Surgical vascular and biliary anastomosis techniques vary based on donor and recipient anatomy including diameter mismatch, the presence of underlying pathology, the need to undergo retransplantation or revision, and ultimately the preference of the transplant surgeon. Interventional radiologists need to understand these anatomical variations and surgical techniques for accurate diagnosis leading to safe and effective interventions.

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Conflict of Interest
None declared.

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