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Basic knowledge of interest

Anatomy of the hepatic hilar area: the plate system

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Abstract To surgically manage hilar bile duct carcinoma successfully, it is important to be familiar with the principal anatomical variations of the biliary and vascular components of the plate system in the hepatic hilar area, because all the variations in the bile ducts and vessels occur in the plate system. The plate system consists of bile ducts and blood vessels surrounded by a sheath. There are three plates in the hilar area: the hilar plate, the cystic plate, and the umbilical plate. The bile duct and blood vessel branches penetrate the plate system and form Glisson's capsule in all segments of the liver, except for the medial segment. The right hepatic duct is usually (in 53%–72% of individuals) formed by the union of the anterior segmental duct and the posterior segmental duct in the hilar area. However, three other variations have been found in which these segmental ducts do not form the right hepatic duct. Few anatomical variations have been identified in the left hepatic duct, but confusion arises because of the variations in the medial segment ducts (B4) which join the left hepatic duct at different sites. In 35.5% of individuals they join the hepatic duct in the vicinity of the hilar confluence (type I B4 anatomy), and in 64.5% of individuals they join the left hepatic duct some distance away from the confluence (type II B4 anatomy). Because B4 is very close to the hilar confluence in type I, hilar bile duct carcinoma can easily invade B4 and, for that reason, for curative resection of hilar bile duct carcinoma, resection of S4a (the inferior part of the medial segment) should be considered along with the resection of extrahepatic bile duct and caudate lobe. Variations in the portal vein and hepatic artery are found in 16%–26% and 31%–33% of individuals, respectively. Because a considerable number of anatomical variations in the bile ducts and vessels persist in the hilar area, and the reported proportions of the different variations vary, it is necessary to have a good knowledge of the plate system and the variations in the bile ducts and blood vessels in the hilar area to perform safe and curative surgery for hilar bile duct carcinoma.

Key words Hilar plate · Cystic plate · Umbilical plate

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Introduction

Anatomical variations in the bile ducts and blood vessel branches are most common in the plate system of the hilar area. In this review, special attention has been devoted to the plate system and the normal variations in its components, which sometimes cause confusion during surgical resection of hilar bile duct carcinoma.

Plate system

The plate system consists of bile ducts and blood vessels surrounded by a sheath that is continuous with Glisson's capsule, intrahepatically, and the hepatoduodenal ligament, extrahepatically. This system also contains a large number of lymphatics, nerves, and a small vascular network. Couinaud[1,2] states that the bile ducts and hepatic artery are located within the plate system, but that the portal vein is covered with a separate sheath of loose connective tissue, and that is why the plate containing the extrahepatic bile duct and hepatic artery can be easily separated from the portal vein. Three plates are found in the hilar area: the hilar plate, the cystic plate, and the umbilical plate (Fig. 1).

Hilar plate

The hilar plate is located in the hilar area of the liver. It is bounded above by S4a (the inferior part of the medial segment), on the right by the Rouviere sulcus (a landmark demarcating the division between S6 and S5) and the cystic plate, and on the left it is continuous with the umbilical plate. The anterior Glisson's sheath generally runs behind the junction between the cystic plate and the hilar plate, and the posterior-inferior Glisson's sheath runs behind the Rouviere sulcus. As a result, the bile ducts and blood vessels of the right side can be dissected easily without widely opening the hilar plate.

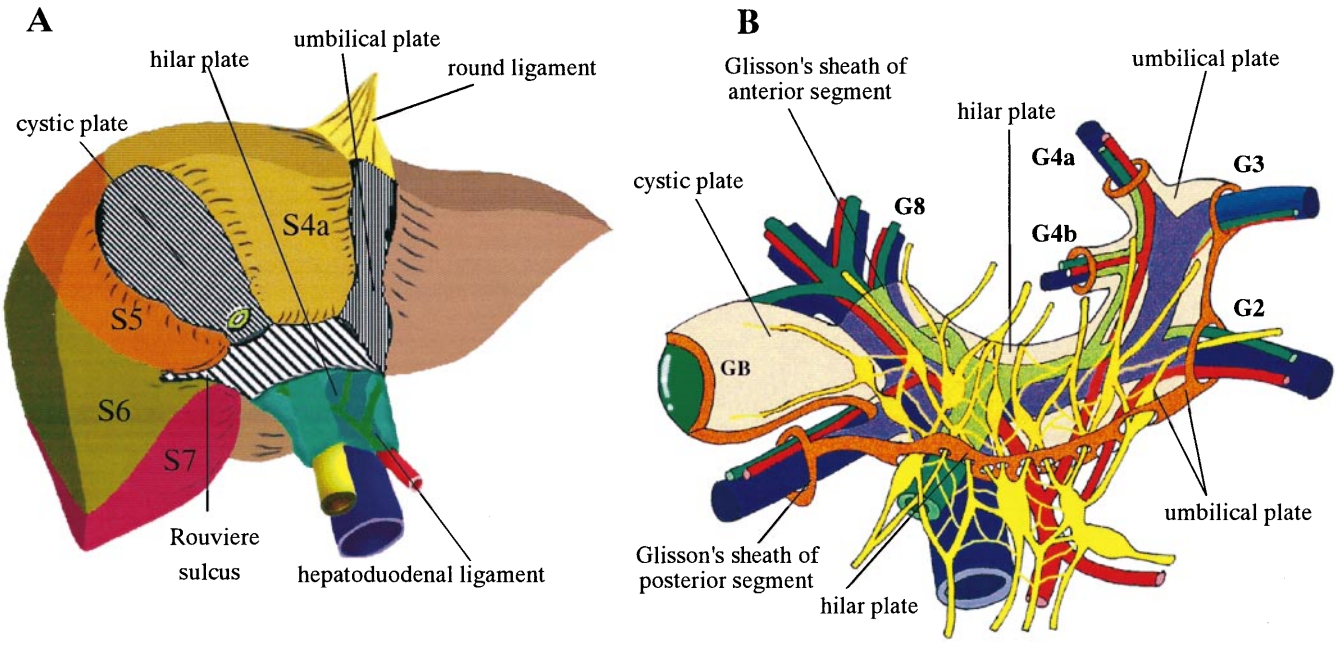


Fig. 1A,B. Plate system. **A** Location of the different plates; **B** components of the plate system. *GB*, Gallbladder, *G*, Glisson's sheath

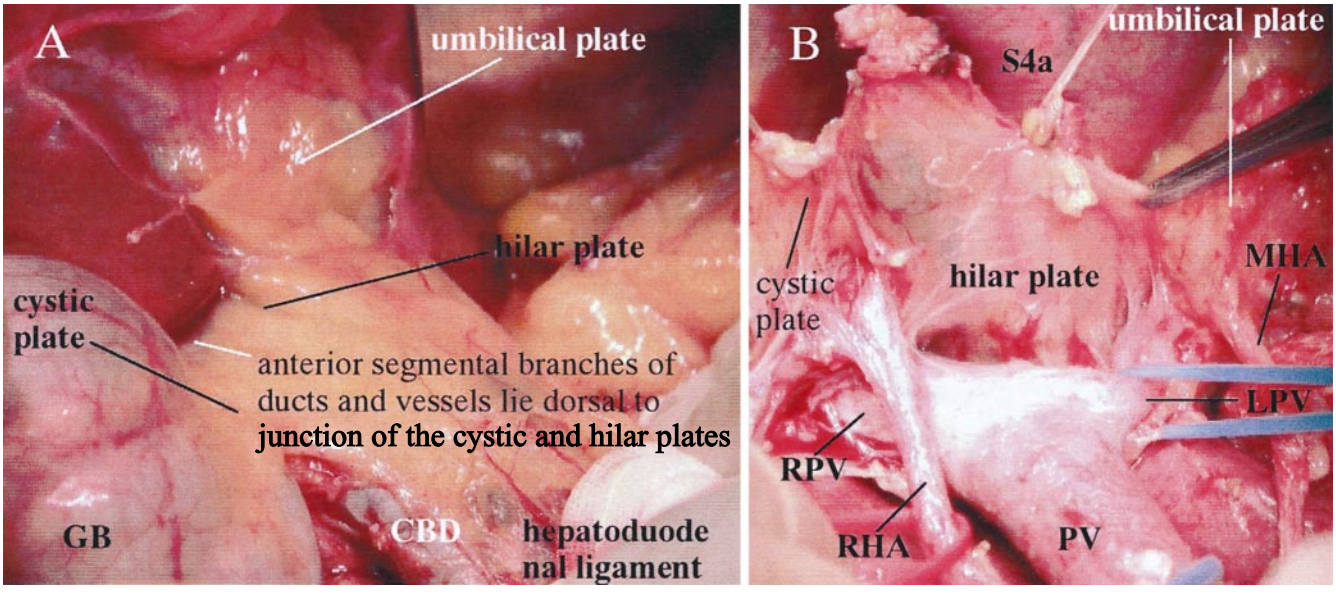


Fig. 2A,B. Hilar bile duct carcinoma in a 62-year-old man: en-bloc resection of S4a + S5 + S1 with the plate system. **A** Anterior segmental branches of vessels and ducts course dorsal to the junction of the cystic and the hilar plate. **B** Plate system (dorsal view). The bile duct has been cut caudally and turned cranially. *GB*, Gallbladder; *CBD*, common bile duct; *RPV*, right portal vein; *LPV*, left portal vein; *RHA*, right hepatic artery; *MHA*, middle hepatic artery; *PV*, portal vein; *S4a*, inferior part of the medial segment

Cystic plate

The cystic plate is located in the gallbladder bed and is continuous with the capsule of S5, S4a, and the Glisson's sheath of the anterior segment of the liver. The posterior edge of the cystic plate lies above the Cantlie line in the hilar area. It has also been observed that, in most individuals (83%), the posterior edge of the cystic plate is located on the right side of the right portal vein branch.[2]

Umbilical plate

The umbilical plate is located along the inferior edge of the ventral surface of the umbilical fissure. It contains the ducts and blood vessels of S2, S3, and S4, and is continuous with the round ligament inferiorly. Thus, the segmental branches of the left lobe divide or fuse within the umbilical plate. The upper margin of the umbilical plate can be reached by incising the superior border of the round ligament.

Lymphatics in the plate system

The lymphatics of the hilar area are distributed in a very complex manner. The superficial and deep lymphatics (lymphatics of Glisson's sheath) of the liver course through the plate systems of the hilar area.[3] The superficial lymph vessels travel through the junction between the upper edge of the hilar plate and the capsule of S4a. Histological examination of transverse sections of the hilar area has revealed a thick layer of connective tissue between S4a and the portal vein, and this layer contains numerous lymph vessels. In contrast to the connective tissue on the ventral aspect of the portal vein, the connective tissue between the dorsal aspect of the portal vein and the caudate lobe is thin and contains very few lymph vessels.

Anatomy of the hilar region

The hilar bile duct confluence is located in the hilar plate. It is important to dissect the hilar duct confluence and the plate en bloc, because carcinoma of the hilar bile ducts can easily spread to the plate tissue. On the right side of the hilar plate, the right hepatic artery courses between the cystic plate and the hilar plate, and the branches of the right portal vein travel dorsal to the artery and then enter Glisson's sheath. On the left side, the middle hepatic artery courses through the umbilical plate, and the left branch of the portal vein lies dorsal to the artery (Fig. 2A). In fact, the hilar ducts can be separated easily from the portal vein by dividing the common bile duct caudally and lifting it cranially (Fig. 2B).

Caudate lobe and medial segment branches

Because the ducts and blood vessels usually course through the plate system and form Glisson's sheath intrahepatically, the plate system is continuous with Glisson's sheath. The arrangement of the ducts and blood vessels in the caudate lobe and the medial segment of the liver, however, is different. The bile ducts and arteries of the caudate lobe ramify in the hilar plate, but the branches of the portal vein run directly to the caudate lobe. Thus, while the caudate lobe artery and bile duct branches form Glisson's sheath within the liver, the portal veins do not (Fig. 3). The intrahepatic bile duct branches of the medial segment make a J-shaped turn, pierce the umbilical plate, and ultimately join the left hepatic duct. The middle hepatic arteries make a U-shaped turn and enter the middle segment. By contrast, the portal vein branches arise from the medial segment and enter the right side of the umbilical portion (UP) of the portal vein in a straight line. The vessels and ducts of the medial segment do not form a Glisson's sheath immediately to the right of the UP (Fig. 4). These anatomical differences in the ducts and blood vessels of the medial segment are attributable to the fact that this segment develops later than the other segments of the liver and that the medial segment portal vein branches develop from the tertiary level of the portal system in the embryo.

Anatomy of the portal vein branches in the hilar area

Because the portal vein develops during the very earliest part of the gestational period, few variations are found in the portal vein branches,[1,6,13,14] and variations in the anterior segmental branches of the portal vein (P5 + P8) are very rare. Reports by different investigators have revealed three principal portal vein branching patterns in the hilar area: the common type, in which the anterior segmental branch joins the posterior segmental branch to form the right branch of the portal vein, in 74%–84% of patients; the three-branch type, in which the anterior segmental branch joins the portal vein confluence, in 8%–12% of patients; and the left-branch type, in which the anterior segmental branch joins the left branch of the portal vein, in 9%–17% of patients (Fig. 5). Kida et al.[6] reported that variations in the anatomy of biliary tract are mostly (81%) associated with variations in the anatomy of the portal vein.

Anatomy of the bile duct branches in the hilar area

Right hepatic duct

The reported percentages of each of the anatomical variations of the right hepatic duct and hilar bile duct confluence patterns vary.[2–7] Because surgeons usually enter the hilar area through the right side during radical operations for hilar carcinoma of the bile duct, it is important for them to know the anatomical arrangement of the right hepatic duct, the anterior segmental duct, and the posterior segmental duct in the hilar area. A review of studies of casts of normal liver revealed that the junction of the anterior segmental duct and the

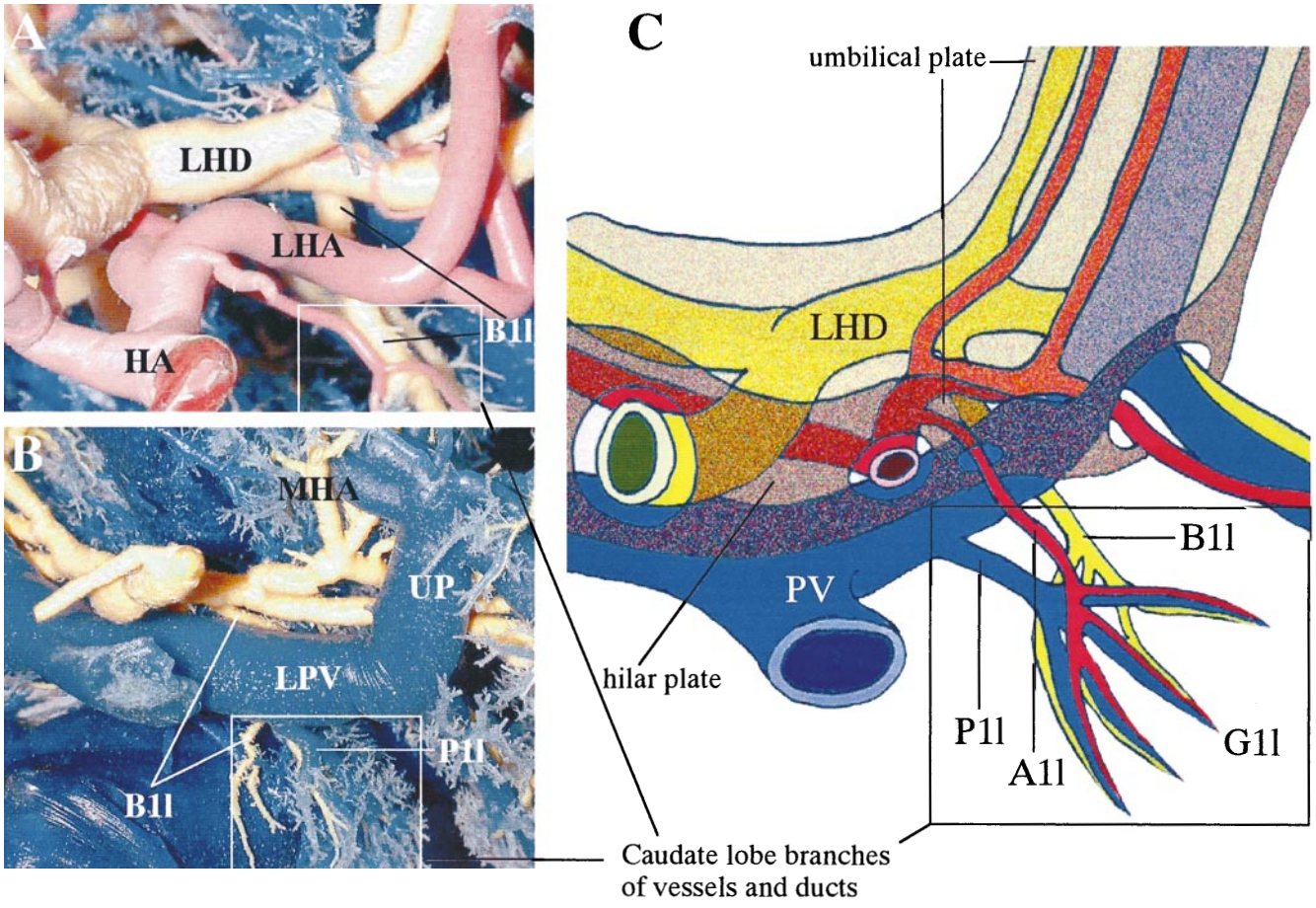


Fig. 3A–C. Structure of the caudate lobe vessels and ducts. **A** and **B** (liver casts) and **C** (schema). *LHD*, Left hepatic duct; *PV*, portal vein; *LPV*, left portal vein; *HA*, hepatic artery; *LHA*, left hepatic artery; *MHA*, middle hepatic artery; *P11*, portal vein branch of S1 (*left side*); *A11*, hepatic artery branch of S1 (left side); *B11*, bile duct branch of S1 (left side); *G11*, Glisson's sheath of S1 (left side); *UP*, umbilical portion

posterior segmental duct to form the right hepatic duct, and the right hepatic duct, in turn, joining the left hepatic duct in the hilar confluence, is the most common variation in the anatomy of the right hepatic duct (53%–72%). However, there are three anatomical variations in which the anterior and posterior segmental bile ducts do not form the right hepatic duct: (1) the posterior segmental duct joins the left hepatic duct (9%–27%), (2) the anterior segmental duct joins the hilar confluence and forms and three-branch type hilar confluence (7%–14%), and (3) the anterior segmental duct joins the left hepatic duct (6%–9%) (Fig. 6). Absence of the right hepatic duct is an anatomical variation that results from the persistent presence of the proximal portion of the left vitelline vein during development.

Analyses of the relation between the hepatic ducts and portal vein branches have revealed a "north-turning bile duct branch", in which the posterior segment bile duct runs superiorly, dorsally, and then inferiorly (Hjortsjo curve) to the right branch of the portal vein, in most individuals (83%–89%), and a "south-turning bile duct branch", in which the posterior segment bile duct courses ventrally and inferiorly to the right branch of the portal vein, in a few individuals (11%–17%).[2,6,7]

Left hepatic duct

There are relatively few variations in the anatomy of the left hepatic duct, but the wide anatomical variation in the bile duct branches of the medial segment causes considerable problems during the surgical treatment of hilar bile duct carcinoma.[8–10] The courses of the medial segment bile ducts (B4), and blood vessels (P4, A4) are different from the courses of the bile ducts and vessels in the other segments of the liver. In a study of 171 liver specimens (100 normal liver casts and 71 cadaver livers), Onishi et al.,[11] of our department, found numerous variations in the anatomy of B4. The anatomy of B4 was classified into two main types (and a third, mixed type), depending on the pattern of the junction

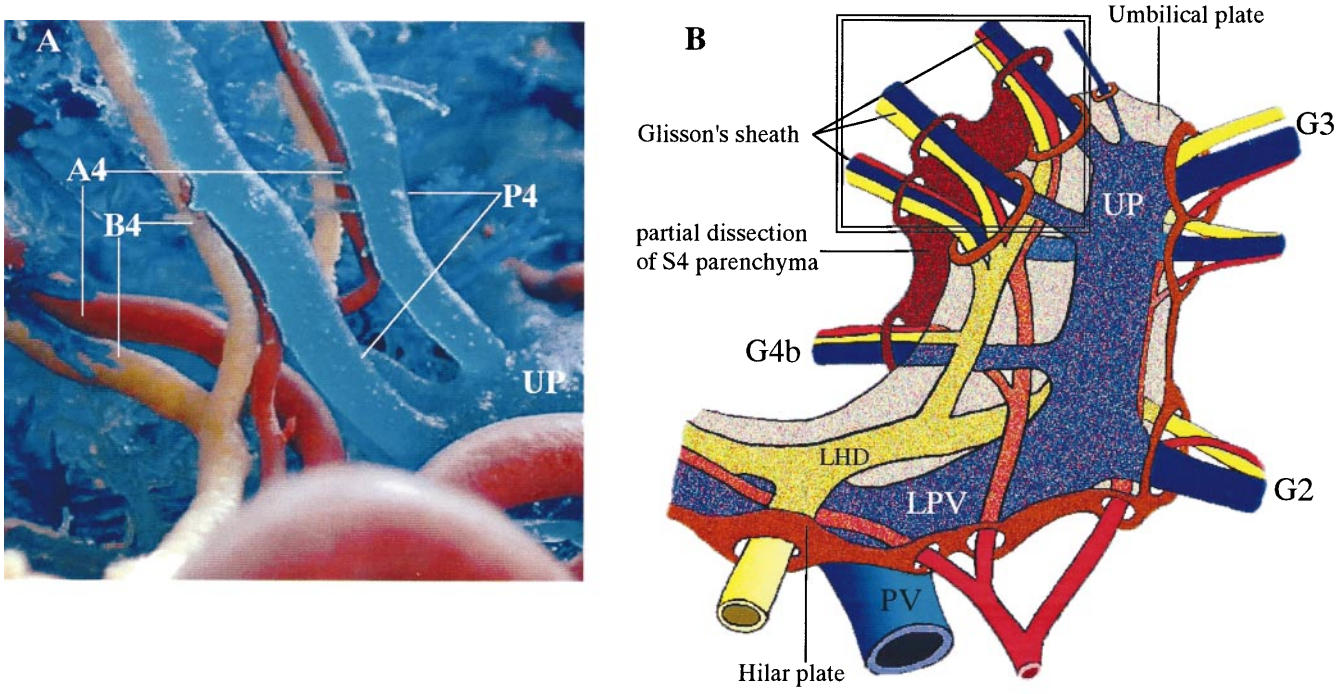


Fig. 4A,B. Distribution of the bile duct (*B4*), hepatic artery (*A4*), and portal vein (*P4*) of the medial segment. **A** Liver cast; **B** schema. *LHD*, Left hepatic duct; *PV*, portal vein; *UP*, umbilical portion; *G*, Glisson's sheath

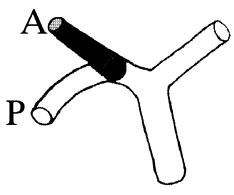
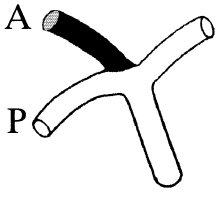
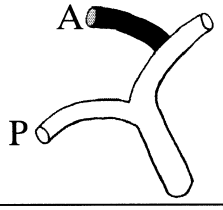
	Presence of a right portal vein	Absence of a right portal vein	
Variations in the anatomy of the anterior segment portal vein	common type 	3-branch type 	anterior segmental duct joining to the left hepatic duct type 
Couinaud (1981)[1] (n=111)	83.5%	7.7%	8.8%
Kumon (1985)[13] (n=23)	73.9%	8.7%	17.4%
Kida (1987)[6] (n=104)	79.8%	11.5%	8.7%

Fig. 5. Variations in the anatomy of the right portal vein and their incidence (analysis of liver casts). *A*, Anterior branch; *P*, posterior branch

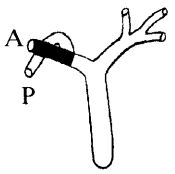
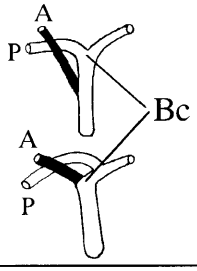
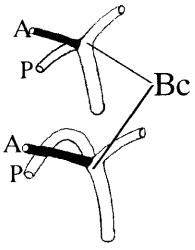
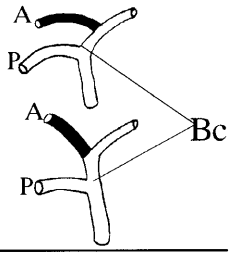
	Presence of a right hepatic duct	Absence of a right hepatic duct		
	common type	posterior segmental duct joining to the left hepatic duct	3-branch type	anterior segmental duct joining to the left hepatic duct
Variations in the anatomy of the anterior segment bile duct				
Healey (1953)[4] (n=96)	72.0%	22.0%	-	6.0%
Couinaud (1981)[1] (n=102)	53.3%	24.3%	14.0%	8.4%
Kida (1987)[6] (n=104)	71.2%	8.7%	11.5%	8.6%
Ishiyama (1999)[7] (n=41)	58.5%	26.9%	7.3%	7.3%

Fig. 6. Variations in the anatomy of the right hepatic duct and their incidence, based on analysis of liver casts. *A*, Anterior branch; *P*, posterior branch; *Bc*, bile duct confluence

of B4 with the left hepatic duct between the hilar confluence and the confluence between B2 and B3, and the position of the UP. In type I, B4 joins the left hepatic duct close to the hilar confluence, and in type II, B4 joins the left hepatic duct laterally, close to the UP. The incidence of type I, type II, and the mixed type is 35.5%, 54.6%, and 9.9%, respectively. Because B4 is very close to the hilar confluence in 35.5% of individuals, for curative resection of hilar bile duct carcinoma, it may be necessary to remove S4a along with the caudate lobe bile duct branch.[12]

Anatomy of the hepatic artery branches in the hilar area

Embryologically, the hepatic artery develops late in the gestational period, and, thus, variations are found in a large proportion of the population (33%–45%). More than ten variations in the anatomy of the hepatic artery, including an accessory or replaced artery, have been identified. In addition to the presence of an accessory hepatic artery, based on published reports,[15,16] the patterns of the hepatic artery in the hilar area have been divided into the following types: the common type, in which the right, middle, and left hepatic artery arise from the common hepatic artery (found in 71%–72% of the population); a type in which the right hepatic artery arises from the superior mesenteric artery (SMA) (found in 13%–14% of the population); a type in which the left hepatic artery arises from the left gastric artery (LGA; found in 11%–12% of the population); and a type in which the common hepatic artery arises from the SMA (found in 2%–5% of the population) (Fig. 7).

Analysis of the anatomical relationship between the hepatic artery and the portal vein and hepatic duct branches has revealed that the hepatic artery usually courses dorsal to the hepatic duct (in 76% of the population) and sometimes ventral to it (in 24% of the population). In addition, in 9% of the population, the right hepatic artery runs dorsal to the portal vein,[17] making it necessary to pay special attention to the anatomy of the vessels and ducts of the hilar area.

Summary

Many investigators have reported on the anatomy of the hilar area in detail in different periods, but the purposes of their studies varied with the needs and advances in surgical procedures of the time. Because many variations in the anatomy of the ducts and blood vessels in the hilar area persist in humans, knowledge of the plate system, i.e., (1) the hilar plate, (2) the cystic plate, and

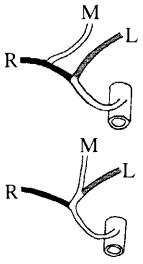
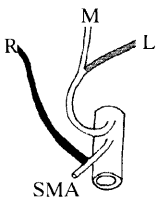
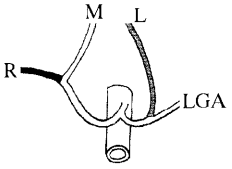
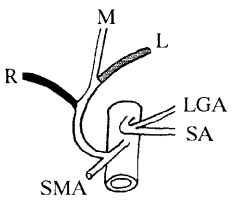
	common type	rt. hepatic a. from the SMA	lt. hepatic a. from the LGA	common hepatic a. from the SMA
				
Michels (1966)[15] (n=200)	71.0%	13.0%	11.0%	5.0%
Suzuki (1982)[16] (n=100)	72.0%	14.0%	12.0%	2.0%

Fig. 7. Variations in the anatomy of the main hepatic arteries exclusive of accessory hepatic arteries. *R*, Right hepatic artery; *M*, middle hepatic artery; *L*, left hepatic artery; *SMA*, superior mesenteric artery; *LGA*, left gastric artery; *SA*, splenic artery

(3) the umbilical plate, and of where the vessels and ducts pass through the plates, is essential for successful surgical resection in the hilar region. Surgeons should therefore understand and review the three plate systems, as well as the anatomy of the hilar bile ducts, before performing surgical resection of hilar bile duct carcinoma.

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