Chapter 30.1

Surgical anatomy of the liver and biliary tree

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Development

The liver and biliary tree develops as a hollow endodermal bud, the hepatic diverticulum, from the distal foregut in the 3-week embryo. The rapidly proliferating cells of the bud penetrate the septum transversum and eventually develop into the liver, while the connection between the hepatic diverticulum and the foregut is preserved to form the bile duct. A ventral outgrowth of the bile duct gives rise to the gallbladder and cystic duct. With the rotation of the gut, the opening from the bile duct into the intestine migrates to a posterior position and the common bile duct comes to lie behind the duodenum and pancreas.

Surgical anatomy of the liver

The external appearance of the mature liver shows its division into two lobes by the umbilical fissure and falciform ligament. Further subdivisions are made on other superficial features. The quadrate lobe is a subdivision of the right lobe and lies to the left of the gallbladder fossa and to the right of the umbilical fissure. The transverse hilar fissure forms the posterior boundary of the quadrate lobe and divides it from the caudate lobe posteriorly (Fig. 1).

Fig. 1. Divisions of the liver by its external features.

The internal architecture of the liver bears only a superficial relation to its external appearance. Cast studies of the biliary tree and portal venous radicles show that the liver is divided into right and left halves, according to the territories of drainage of the right and left hepatic ducts and the areas of supply of the right and left branches of the portal vein and hepatic artery. This principal division is called Cantlie's line, after its first description in 1898, but it is not readily visible on external examination. It runs from the medial edge of the gallbladder fossa to the inferior vena cava posteriorly. The nomenclature of hepatic anatomy has become confused by the use of the term ‘lobe’, which has been applied to both the division of the liver by its external features and the territories of drainage of the right and left hepatic ducts.

Glisson's capsule, a peritoneal and fibrous covering, invests the liver. The reflections of the capsule on to the right hemidiaphragm form the coronary ligament and right triangular ligament, and the reflection from the left liver on to the left hemidiaphragm forms the left triangular ligament. Glisson's capsule is also reflected over the falciform ligament. The structures at the hilum of the liver are invested in dense fibrous tissue continuous with Glisson's capsule; here this covering is known as the hilar plate. The hilar plate is continuous with the peritoneal layers investing the common hepatic and common bile duct, cystic duct, and gallbladder.

The liver is supplied by blood 80 per cent of which comes via the portal vein and 20 per cent via the hepatic artery. Venous drainage is by three, large, short, hepatic veins that pass posteriorly to the inferior vena cava, which lies on the posterior surface of the liver. Drainage of bile occurs from the left and right hepatic ducts to the common hepatic and bile duct, and then to the second part of the duodenum.

The portal vein is formed by the confluence of the superior mesenteric vein and the splenic vein in front of the inferior vena cava and behind the neck of the pancreas. The portal vein runs behind the pancreas to the free border of the lesser omentum, where it traverses

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to the hilum of the liver in the hepatoduodenal ligament behind the common bile duct and to the right of the hepatic artery. At the hilum of the liver, the portal vein divides into left and right branches. The vein, with its accompanying branches of the biliary tree and hepatic artery, is invested in a fibrous sheath continuous with the hilarplate.

The common hepatic artery usually arises from the coeliac axis and travels across the posterior abdominal wall to lie just above the pylorus. Here it gives off the gastroduodenal artery before continuing as the hepatic artery proper, which then runs in the gastroduodenal ligament medial to the common bile duct and anterior to the portal vein to the hilum of the liver. The hepatic artery divides into the left and right hepatic artery well below the hilum of the liver. Sixteen per cent of individuals have an aberrant right hepatic artery arising from the superior mesenteric artery that runs in the groove to the right of the portal vein and common bile duct. Less commonly, the arterial supply to the left half of the liver comes from the left gastric artery.

The venous radicles in the liver give rise to three hepatic veins, the right, middle, and left, which are short and large. The middle hepatic vein usually joins the left hepatic vein before entering the inferior vena cava. In addition, a number of unnamed short veins enter the inferior vena cava directly. These arise in the caudate lobe, which, because of its embryological development form the dorsal mesogastrium, has a different venous drainage

Segmentation of the liver

The three hepatic veins divide the liver into four sectors, each of which is further subdivided into two segments. The whole liver is therefore divisible into eight segments: four are in the right half, and three in the left half (Fig. 2). The remaining segment is the caudate lobe, which should be considered separately because of its different embryological origin, variable blood supply, and venous drainage. Two differing descriptions of the segmentation of the liver are in common use, that of Couinaud and that of Goldsmith and Woodburne. These differ mainly in nomenclature, and the description of Couinaud will be used here.

Fig. 2. Schematic representation of the segmentation of the liver.

The segments are numbered anticlockwise I to VIII, starting with the caudate lobe (Fig. 3). Each segment is supplied by a named portal venous radicle and is drained by a segmental bile duct, forming the smallest anatomical unit of hepatic resection. Removal of segments II to IV is described as 'left hepatectomy' and removal of segments V to VIII, 'right hepatectomy'. Removal of segment IV (the quadrate lobe) in addition to right hepatectomy is described as extended right hepatectomy. The use of this nomenclature avoids the confusion inherent in the use of the terms 'hepatic lobectomy' and 'trisegmentectomy'.

Fig. 3. The segments of the liver, showing the segmental biliary tree and venous drainage.

The intrahepatic bile ducts

The interlobular bile canaliculi join to form segmental bile ducts that eventually drain into the right or left hepatic ducts. On the right, ducts from segments VI and VII join to form the right posterior sectoral duct, which runs horizontally across the gallbladder fossa, where it is surgically accessible after localization by needle puncture or intraoperative ultrasonography. The right anterior sectoral duct runs more vertically and is formed by the confluence of the ducts from segments V and VIII.

Segmental ducts from segments II, III, and IV merge to form the left hepatic duct at the base of the umbilical fissure. Although there are variations in the exact anatomy of this confluence of bile ducts, these are of little clinical relevance. The duct from segment III is surgically accessible by dissection in the groove to the left of the umbilical ligament, where it lies anterior to its accompanying branch of the portal vein and hepatic artery. The left hepatic duct runs from the base of the umbilical fissure to the hilum in the transverse hilar fissure, invested by the fibrous tissue of the hilar plate with the left portal vein lying posterior and the left hepatic artery lying inferior. The left duct is surgically accessible by division of the peritoneal fold under the quadrate lobe (segment IV), a procedure known as lowering the hilar plate.

At the hilum of the liver, the right and left hepatic ducts join to form the confluence of the bile ducts. Anatomical variations of both the intrahepatic and extrahepatic biliary tree are so common that a 'normal' pattern is seen in less than 60 per cent of individuals (Fig. 4). In 57 per cent, the right anterior and posterior sectoral ducts join to form a right hepatic duct, whereas in the remainder, the right anterior and posterior sectoral ducts join the confluence individually. One important variation is the presence of an anomalous subvesical duct, the duct of Luschka, which runs in the gallbladder fossa. It is found in 12 to 50 per cent of individuals, drains a variable portion of the right liver, and is potentially vulnerable during cholecystectomy.

Fig. 4. Anomalies of the confluence of the bile ducts: ra, right anterior sectoral duct; rp, right posterior sectoral duct; lh, left hepatic duct; roman numerals refer to hepatic segments.

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The gallbladder

The gallbladder, a pear-shaped reservoir 5 to 12 cm in length, lies in a fossa on the lower surface of the liver. Four parts of the gallbladder are described: the fundus, the body, the infundibulum, and the neck. In addition, a Hartmann's pouch often develops as a pathological feature in the neck and infundibulum of the gallbladder in the presence of gallstones. Various congenital abnormalities have been described, including double, bilobed, and intrahepatic gallbladder, and congenital absence. The occasional presence of a long mesentery is of significance since it may allow torsion. The gallbladder drains by the cystic duct to the junction of the common hepatic duct and common bile duct. The wall of the cystic duct contains muscle fibres that form the sphincter of Lutkens, while the mucosa of the cystic duct forms crescentic folds known as the spiral valve of Heister.

Calot's triangle

Calot's triangle is formed by the common hepatic duct to the left and the cystic duct below. Although the original description of this area gave the cystic artery as the superior border, the inferior surface of the liver is now accepted as this border. The cystic artery usually arises from the right hepatic artery behind the common hepatic duct and runs behind the right hepatic duct and through Calot's triangle to the gallbladder. In 20 per cent of individuals the cystic artery arises from a right hepatic artery that runs anterior to the common hepatic duct, and the right hepatic artery forms a loop or ‘caterpillar hump’ with the cystic artery originating from the apex in 7 per cent of individuals. In the latter case, the right hepatic artery may be mistaken for the cystic artery during cholecystectomy. In 10 per cent of individuals the cystic artery arises proximally from the right hepatic artery and runs anterior to the common hepatic duct, while the right hepatic artery runs posterior to this duct.

There are no discrete veins draining the gallbladder and bile duct, although all arteries are normally accompanied by a small vein or

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venous plexus. Some veins drain directly from the gallbladder into the liver. Lymphatic drainage is first to the cystic lymph node, which is usually seen adjacent to the cystic artery during cholecystectomy, and thence to the retroduodenal lymph nodes. Some lymphatic channels from the fundus drain to the lymphatic channels in the liver capsule. Motor and sensory sympathetic nerves from the coeliac plexus reach the gallbladder along the hepatic artery, and the parasympathetic motor supply comes from the right and left vagus nerves.

Two other major anomalies may be encountered during the course of dissection in Calot's triangle for cholecystectomy. An aberrant right hepatic artery from the superior mesenteric artery occurs in 16 per cent of individuals, running in the groove between the common hepatic duct and the portal vein. It can be seen in the medial border of Calot's triangle in 90 per cent of these individuals. The right posterior or anterior sectoral ducts may also run through Calot's triangle and may be mistaken for the cystic duct.

The bile ducts

From the confluence of the bile ducts, the common hepatic duct runs for some 2.5 to 3.5 cm down to its confluence with the cystic duct, resulting in the formation of the common bile duct. This junction is variable. In 5 per cent of people the cystic duct spirals behind the common hepatic duct and enters the bile duct low down within the pancreas. In 2 per cent the cystic duct opens directly into the confluence of the bile ducts (Fig. 5). The common bile duct is normally 10 to 12 cm in length and about 6 mm in diameter in anatomical specimens. In life, the upper limit of normal measured by ultrasonography is 7 mm, whilst on direct cholangiography, when the duct is deliberately distended, it may be 10 mm in diameter.

Fig. 5. The relations of the extrahepatic biliary tree.

The common hepatic and bile ducts are supplied by adjacent arteries that supply two axial arteries that run at 3 o'clock and 9 o'clock along the bile duct wall. Other small arteries run in the mesentery around the bile duct to form a plexus. About 60 per cent of blood flow to the duct arises inferiorly from the retroduodenal and gastroduodenal arteries, while 38 per cent comes from the cystic and hepatic arteries superiorly.

The common bile duct passes behind the first part of the duodenum. It may be exposed by division of the peritoneal fold over the superior aspect of the first part of the duodenum and by drawing the duodenum downwards. It then runs either in a groove in the back of the head of the pancreas or in the loose areolar tissue behind the head of the pancreas. Here it may be exposed by Kocher's manoeuvre, that is, division of the peritoneum lateral to the duodenum and reflection of the duodenum and head of the pancreas medially. It curves to the right to enter the medial duodenal wall about 2 cm below the duodenal cap, where it is joined by the main pancreatic duct of Wirsung to form the sphincter of Oddi, which discharges into the duodenum through the ampulla of Vater.

Some 2 cm of the terminal portion of the common bile duct lies within the wall of the duodenum, where it is surrounded by the smooth muscle fibres of the sphincter of Oddi. The pancreatic duct may be closely applied to the common bile duct at this point and may similarly be invested in smooth muscle of the sphincter of Oddi (Fig. 6). The exact anatomy of the terminal common bile duct and pancreatic duct follows one of three patterns. They may unite outside the wall of the duodenum and traverse the duodenal wall to the papilla as a common channel; they may join within the duodenal wall and have a short common terminal channel; and separate orifices have been described.

Fig. 6. Anatomy of the sphincter of Oddi.

Further reading

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