Anatomy of the gallbladder and bile ducts

Vishy Mahadevan

Abstract

The biliary system or biliary tract denotes the elaborate system of coalescing channels which serves to transport bile from the liver to the second part of the duodenum. Bile is an alkaline liquid produced by the hepatocytes, partly as a secretion and partly as an excretory product. The biliary system commences within the substance of the liver as narrow intercellular channels between adjacent hepatocytes. These channels, termed canaliculi, coalesce with their neighbours to form larger channels termed ductules. The latter join other ductules to form ducts. These unite with other ducts to form larger ducts which eventually emerge from the liver as the right and left hepatic ducts. The latter unite to form the common hepatic duct which, after being joined by the cystic duct, continues as the common bile duct and empties into the second part of the duodenum. For descriptive purposes the biliary tract is subdivided into two parts: intrahepatic and extrahepatic. The former is situated within the substance of the liver while the latter lies entirely outside the hepatic substance. This article is confined to a description of the clinical and surgical anatomy of the extrahepatic biliary tract. The extrahepatic biliary tract comprises the right and left hepatic ducts, common hepatic duct, gallbladder and cystic duct and the common bile duct. Diseases of the extrahepatic biliary tract account for a considerable volume of abdominal surgical practice. These include metabolic, inflammatory, neoplastic and congenital conditions. A detailed knowledge of the anatomy of the gallbladder and bile ducts and an awareness of the anatomical variations to which these structures are subject are essential to the conduct of safe and effective surgery involving the biliary tract, besides being of crucial importance to the accurate interpretation of radiological and ultrasound images of the extrahepatic biliary tract.

Keywords Ampulla of Vater; anatomical variations; bile ducts; blood supply; Calot's triangle; gallbladder; sphincter of Oddi

The biliary ducts (Figure 1)

The right and left hepatic ducts emerge from the liver and unite at the right end of the porta hepatis (the transverse fissure on the visceral surface of the liver, also known as the hilum of the liver) to form the common hepatic duct. The common hepatic duct is, on average, 4 cm in length and approximately 4 mm wide. It is joined on its right side, at an acute angle, by the cystic duct. The latter connects the gallbladder to the common hepatic duct. (Figure 1)

The cystic duct is 3–4 cm in length and approximately 3 mm wide. From its commencement at the neck of the gallbladder, it passes posteriorly, inferiorly and medially to join the common hepatic duct to form the common bile duct (Figure 1). The mucous lining of the cystic duct is often raised into a spiral fold called the spiral valve of Heister (see Figure 2). The fold consists of a variable number of turns and is continuous with a similar mucosal fold in the neck of the gallbladder.

The common bile duct is 7.5–11 cm in length with an internal diameter of 6–8 mm under normal physiological pressure. Commencing about 2.5 cm superior to the first part of the duodenum, the common bile duct descends to lie successively behind and then below, the first part of the duodenum before coursing obliquely through the medial wall of the second part of the duodenum to open into the lumen of the latter. Given this fairly constant relationship of the common bile duct to the *first part of the duodenum*, the common bile duct may, for descriptive purposes, be divided into the following four segments: (Figure 1)

i) supraduodenal (above the first part of duodenum)
ii) retroduodenal (posterior to the first part of duodenum)
iii) infraduodenal (below the first part of duodenum and behind the head of the pancreas)
iv) intramural (within the wall of the 2nd part of duodenum).

The retroduodenal segment, which is 2–3 cm in length, deviates laterally from the hepatic artery and portal vein to continue as the infraduodenal segment.

The infraduodenal part of the common bile duct lies in a groove on the posterior surface of the head of the pancreas. On occasion this segment of the common bile duct may be embedded in the head of the pancreas. Usually, the termination of the common bile duct joins the termination of the main pancreatic duct (the duct of Wirsung) to form a common vestibule, the hepatopancreatic ampulla (ampulla of Vater). The ampulla itself opens at the summit of the major duodenal papilla, a small inward mucosal projection from the posteromedial wall of the second part of the duodenum, typically 10 cm distal to the pyloroduodenal junction in the adult. The ampulla as well as the intramural segments of the common bile duct and main pancreatic duct are each surrounded by sphincteric smooth muscle. The ampullary sphincter is better known as the *sphincter of Oddi*. The smooth muscle constituting these sphincters is anatomically distinct and functionally independent of the circular and longitudinal smooth muscle in the wall of the duodenum. The natural tonus in the smooth muscle of the sphincters causes them to remain closed. However, gastric contents, upon entering the duodenum, cause the duodenal mucosa to secrete cholecystokinin, a peptide hormone. This hormone causes contraction of the gallbladder and simultaneous relaxation of the pancreatic, biliary and ampullary sphincters permitting bile and pancreatic secretions to enter the duodenum.

The ampulla of Vater is, almost invariably, depicted in textbooks as a distinct sac-like structure. However, inspection of a normal retrograde cholangio-pancreatogram shows that, in the majority of individuals, the junction forms a simple tube without any obvious sac-like appearance. Sometimes, the common bile duct and the main pancreatic duct open separately into the second part of the duodenum.

The common hepatic duct and the supraduodenal part of the common bile duct lie within the free edge (right edge) of the lesser omentum (Figure 3), where the two leaves of the lesser omentum become continuous with each other. This free edge, where the two leaves of the lesser omentum become continuous

Vishy Mahadevan MBBS PhD FRCS (Ed & Eng) is the Barbers' Company Professor of Anatomy at the Royal College of Surgeons of England, London, UK. Conflicts of interest: none.

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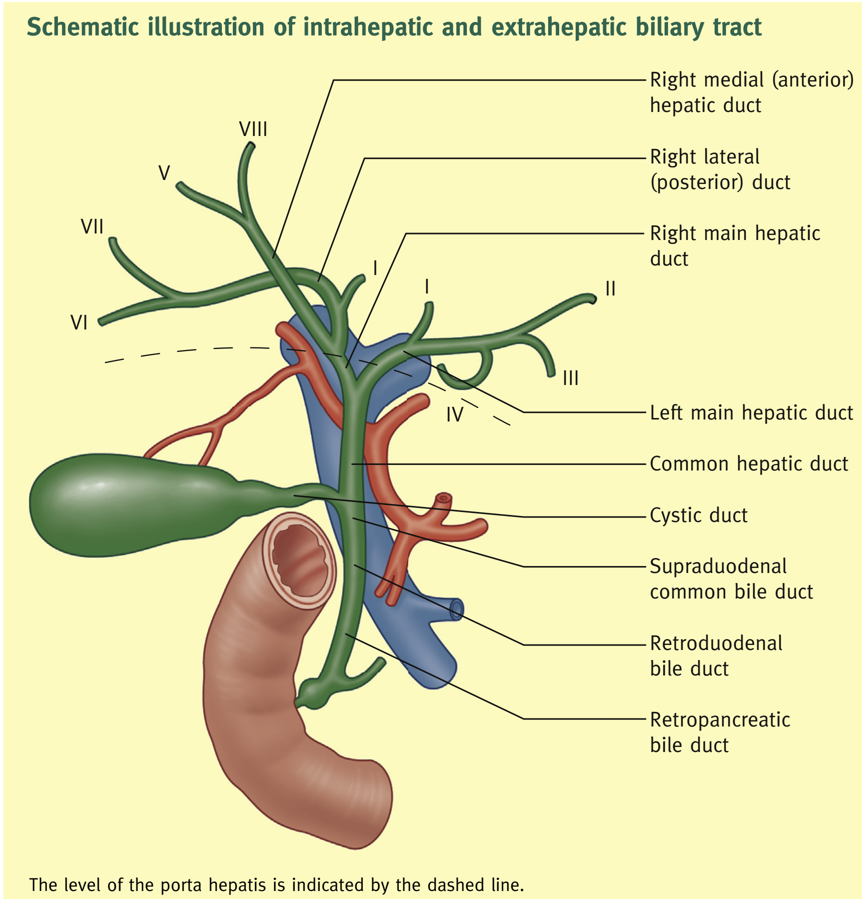

Figure 1

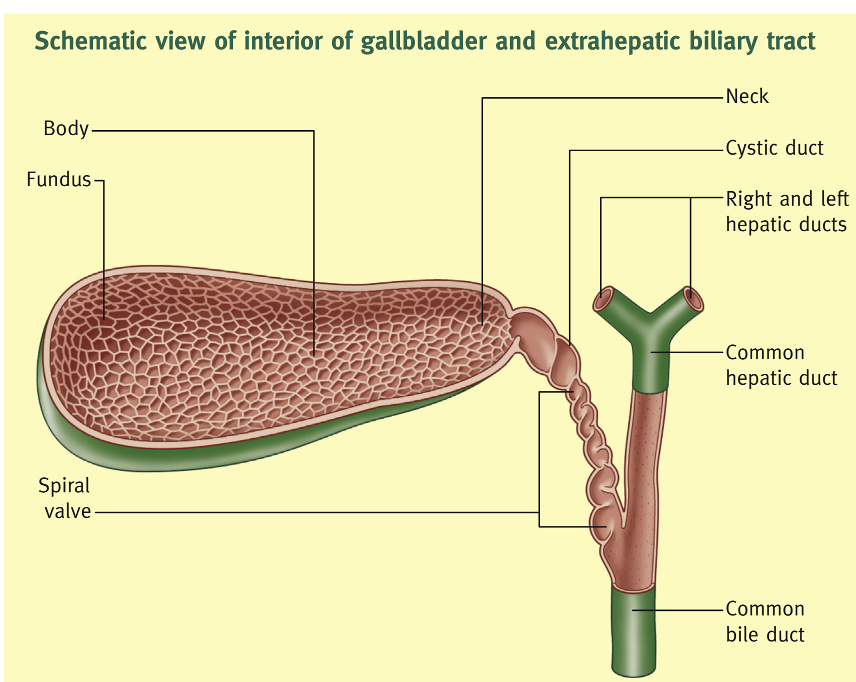

Figure 2

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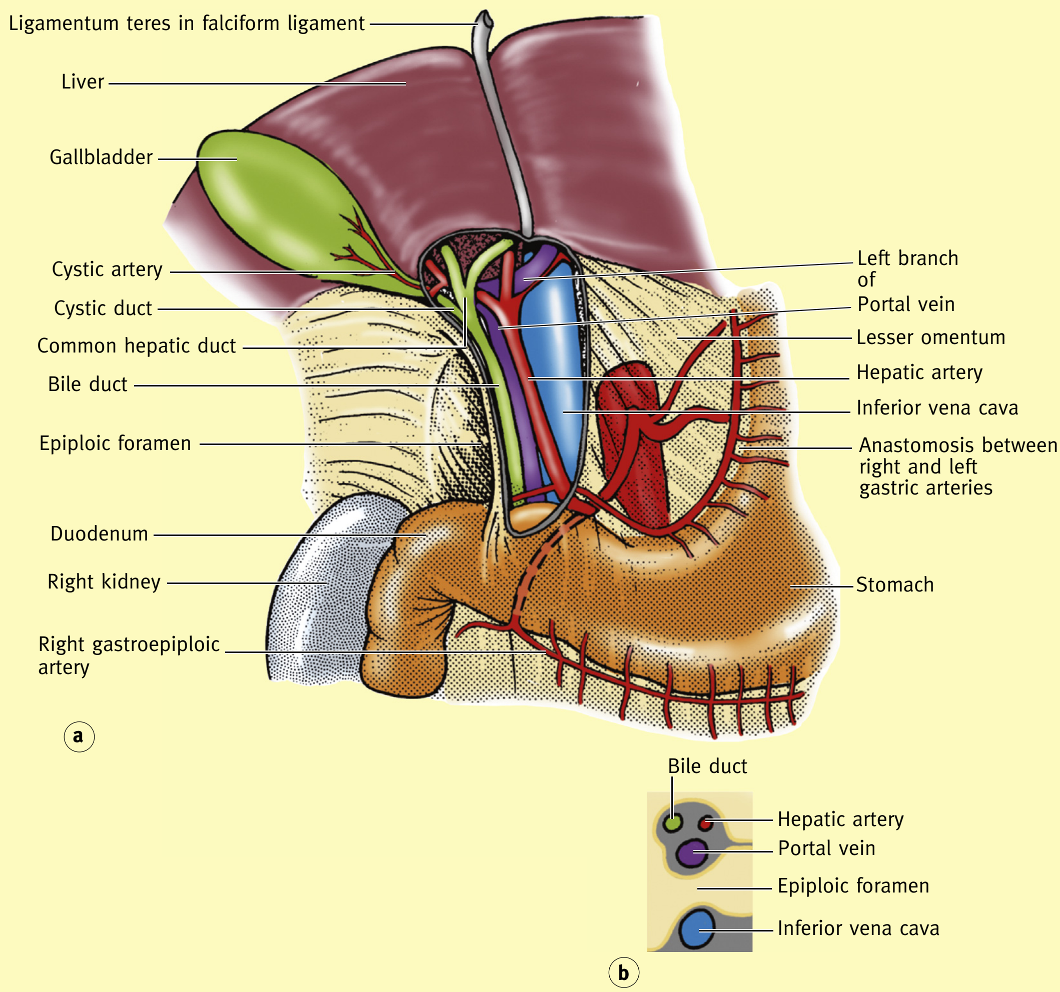
Illustration showing Calot's triangle, epiploic foramen and structures in the hepatoduodenal ligament



Epiploic foramen and its boundaries seen in transverse section.

Figure 3

with each other, is more commonly known in the surgical literature as the hepatoduodenal ligament. The arrangement of structures within the free edge of the lesser omentum is as follows. The common hepatic duct and its distal continuation the common bile duct lie immediately to the right of the hepatic artery. Lying immediately posterior to the hepatic artery and biliary tract and parallel to both is the portal vein. Accompanying these structures within the free edge of the lesser omentum are lymphatics, lymph nodes and autonomic nerve fibres. Superiorly the two leaves of the lesser omentum are attached to the margins of the porta hepatis (Figure 3). The free edge of the lesser omentum with its contents forms the anterior boundary of the epiploic foramen (of Winslow), while the peritoneum lying in front of the inferior vena cava forms the posterior boundary. The epiploic foramen is a natural intraperitoneal opening between the general peritoneal cavity (greater sac) and the lesser sac (Figure 3b). Haemorrhage during open surgery of the gallbladder or liver may be controlled by temporarily occluding the portal vein and hepatic artery by compressing the free edge of the lesser omentum with a vascular clamp, or by passing a finger through the epiploic foramen and compressing the artery and portal vein between the finger and the thumb (Pringle's manoeuvre).

Running within the free edge of the lesser omentum, the hepatic artery and the portal vein reach the porta hepatis, and each divides into a right branch and left branch for the corresponding hemilivers. The right and left hepatic ducts emerge from the porta hepatis and unite to form the common hepatic duct.

The gallbladder (Figures 1–4)

The gallbladder is a pear-shaped, thin-walled, distensible sac with a capacity of approx. 50 mL. The gallbladder lies on the visceral surface of the liver in a narrow fossa, termed the cystic fossa, which runs from the anterior margin of the inferior surface of the liver, posterosuperiorly towards the inferior vena cava (Figure 4). The cystic fossa lies immediately to the right of the quadrate lobe of the liver. The peritoneum that covers the visceral surface of the liver is continued over the inferior surface of the gallbladder. The superior surface of the gallbladder,

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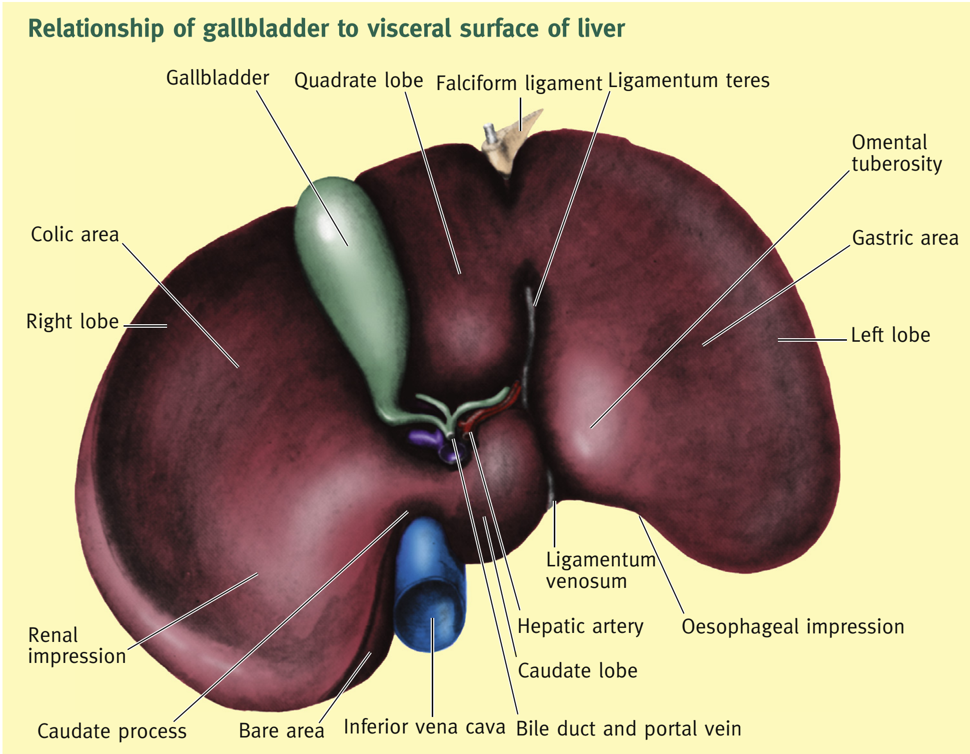

Figure 4

however, is directly related to the liver without any intervening peritoneum. Occasionally the gallbladder may be completely enveloped in visceral peritoneum and suspended from the liver by a mesentery. Such an anomaly may predispose the gallbladder to torsion. The gallbladder is divided for descriptive purposes into a fundus, body and neck, the latter opening into the cystic duct (Figure 2). The fundus is the rounded end which projects beyond the anterior margin of the visceral surface of the liver and lies behind the tip of the 9th costal cartilage. The body and neck are directed superomedially towards the porta hepatis (Figure 4).

Inferiorly, the gallbladder relates to the first and second parts of the duodenum and to the hepatic flexure of the colon. An inflamed gallbladder may adhere to any of these structures, and on occasion may erode their walls. A large gallstone may thus drop into the lumen of the duodenum and may become impacted in the distal small intestine causing intestinal obstruction (i.e. gallstone ileus).

Bile as it leaves the liver is 97% H_2O, 1% pigment and 1–2% bile salts. The principal function of the gallbladder is to act as a reservoir for bile. It also concentrates bile by a factor of nearly 10 by a process of active reabsorption of H_2O, NaCl and HCO_3, and makes the bile viscous by secretion of mucus.

Histological structure

The gallbladder and the sphincter of Oddi contain involuntary muscle, but there are only scattered muscle fibres in the remaining parts of the biliary tract. The mucosa of the gallbladder and biliary tract has a lining columnar epithelium. The gallbladder mucosa features numerous mucus-secreting goblet cells.

Imaging of the extrahepatic biliary tract

Oral cholecystography and intravenous cholangiography are now practically obsolete in the developed world. The imaging methods that are currently used to delineate the biliary tract and which provide the greatest amount of anatomical information are ultrasonography, ERCP (endoscopic retrograde cholangiopancreatography), PTC (percutaneous transhepatic cholangiography) and MRCP (magnetic resonance cholangiopancreatography). The last named is non-invasive, does not involve the use of contrast media and yields a most impressive degree of anatomical detail.

Blood supply and venous drainage of the extrahepatic biliary tract

The gallbladder derives its blood supply from the cystic artery. Commonly, this vessel arises from the right hepatic artery within the hepatoduodenal ligament, and usually passes behind the common hepatic duct to reach the neck of the gallbladder and then to branch over the surface of the body of the gallbladder (Figure 3). However, variations in the origin of the cystic artery are frequent. The cystic artery may arise from the left hepatic artery or from the trunk of the hepatic artery, or even from the gastroduodenal artery. Furthermore the cystic artery may pass in front of, instead of behind, the bile ducts, to reach the gallbladder. Nevertheless, the cystic artery, whatever its origin, is almost invariably situated within Calot's triangle (or cystohepatic trigone). This triangle is situated very deeply. It is bounded superiorly by the visceral surface of the liver adjacent to the porta hepatis; medially by the common hepatic duct and inferolaterally by the cystic duct and neck of the gallbladder (Figure 3) In addition, the gallbladder receives numerous arterial twigs from

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the right hepatic artery via the gallbladder bed in the liver. These are sometimes seen at laparoscopy. The blood supply to the common hepatic duct and common bile duct is from the cystic and hepatic arteries, and from the gastroduodenal and superior pancreaticoduodenal arteries. These vessels contribute to longitudinal anastomotic channels which lie on the wall of the bile ducts along the lateral and medial borders.

Venous drainage of the gallbladder is by numerous veins which accompany the arterial twigs to the gallbladder in its bed, and which are visible at laparoscopy, provided the gallbladder is not grossly inflamed or thickened. They drain into the radicles of the right portal vein in the liver bed. Rarely, one or more cystic veins are present and drain from the neck of the gallbladder to the right branch of the portal vein.

Lymphatic drainage of the extrahepatic biliary tract

Lymphatics from the gallbladder drain into the hilar nodes (i.e. lymph nodes in the porta hepatis) and to the cystic lymph node (of Lund) that is situated in Calot's triangle. Lymph from the common hepatic duct and upper part of common bile duct drains into the hilar nodes while lymph from the lower half of the common bile duct travels inferiorly to drain into the superior pancreaticoduodenal and retroduodenal lymph nodes. Eventually all these nodes drain into the coeliac group of lymph nodes which lie around the origin of the coeliac artery (coeliac trunk).

Innervation of the extrahepatic biliary tract

The efferent, motor innervation of the gallbladder and bile ducts is by sympathetic and parasympathetic fibres. The latter are derived from the anterior and posterior vagal trunks and accompany the hepatic and cystic arteries to reach the biliary tract. The sympathetic fibres run in the splanchnic nerves, pass through the coeliac ganglion and then reach the biliary tract. Visceral afferent fibres for pain run with the sympathetic efferents.

Embryology and developmental anomalies

The gallbladder and the bile ducts are subject to numerous variations, and these are best understood by considering their embryological development. As early as the third week of development, an endodermal outgrowth, termed the hepatic diverticulum, develops from the ventral wall of the very distal end of the embryonic foregut. This grows in a ventrocranial direction to meet the septum transversum within which it proliferates to give rise to cords of liver cells. The lower part of the hepatic diverticulum narrows to form the bile duct. A ventral outgrowth from the bile duct primordium differentiates into the gallbladder and cystic duct. Variations in anatomy include: (i) a long cystic duct which joins the common hepatic duct behind the duodenum; (ii) a short, or even absent, cystic duct; (iii) the cystic duct opening into the left side of the common hepatic duct; and (iv) the presence of accessory hepatic ducts.

Developmental anomalies of the gallbladder include agenesis of the gallbladder, bilobed gallbladder and multiple gallbladders. ◆

FURTHER READING

Ellis H, Mahadevan V. Clinical anatomy. 13th edn. WILEY Blackwell, 2013; 106–9.

Keplinger KM, Bloomston M. Anatomy and embryology of the biliary tract in Surgical Clinics of North America April 2014; 203–17. 94: 203–17.

Langman's medical embryology. 12th edn. TW Sadler Wolters Kluwer/Lippincott Williams & Wilkins, 2012; 217–21.

Moore KL, Dalley AF, Agur AMR. Clinically oriented anatomy. 7th edn. Wolters Kluwer/Lippincott Williams & Wilkins, 2014; 277–80.

Vakili K, Pomfret EA. Biliary anatomy and embryology in Surgical Clinics of North America Dec. 2008; 1159–73. 88: 1159–73.

Williams NS, Bulstrode CJK, O'Connell Hodder Arnold PR, eds. Bailey and Love's short practice of surgery. 25th edn 2008; 1111–9.

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