1 Surgical Anatomy of the Hepato-Biliary System

Vinay K. Kapoor

1.1 Gallbladder

Gallbladder (GB) is a pyriform organ lying on the undersurface of segments IV and V of liver. It has a fundus (the part protruding beyond the edge of the liver) (Fig. 1.1), body, and neck. The gallbladder neck narrows into the cystic duct at the infundibulum. Gallbladder neck often has an outpouching on its inferior border called Hartmann's pouch (Fig. 1.2). A large stone in the Hartmann's pouch may cause extrinsic compression of the common bile duct (Mirizzi's syndrome). Retraction of the gallbladder fundus elevates the liver to expose the subhepatic area and retraction of the gallbladder neck exposes the Calot's triangle. Repeated attacks of cholecystitis may cause fibrotic thickening of the gallbladder wall resulting in a small contracted thimble gallbladder which is difficult to hold and retract. The first part of the duodenum lies very close to the gallbladder; a cholecysto-duodenal fold (Fig. 1.3) of peritoneum may also be present. An attack of acute cholecystitis may cause the gallbladder to get adhered to the adjacent duodenum and colon; the gallbladder may even fistulate into these organs.

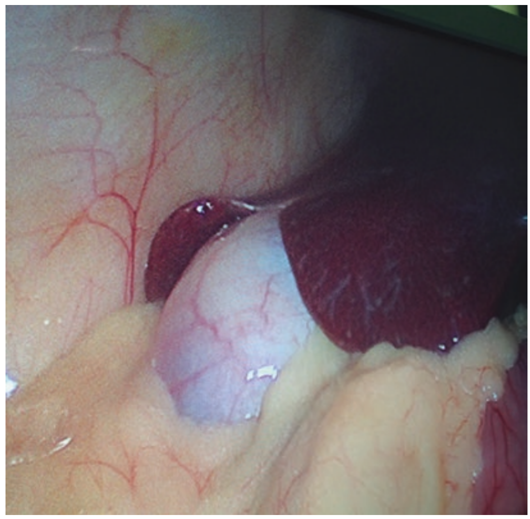

Fig. 1.1 Fundus of the gallbladder

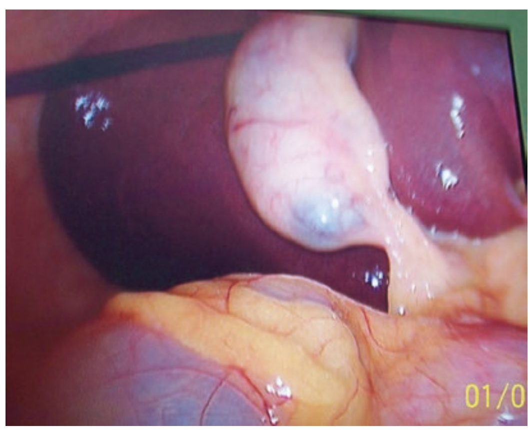

Fig. 1.2 Hartmann's pouch—an out pouching of the gallbladder neck

Please also see an Invited Commentary on Surgical Anatomy of the Hepato-biliary System by Daniel J Deziel (pp 9–10)

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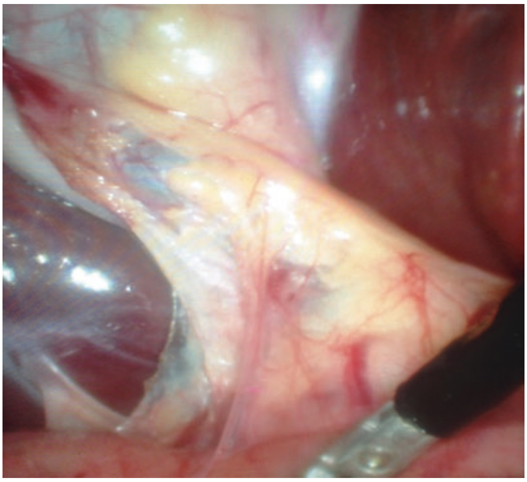

Fig. 1.3 Cholecysto-duodenal fold

1.2 Liver

The antero-superior surface of the liver is attached to the upper part of the anterior abdominal wall and the under surface of the anterior part of the diaphragm by the falciform ligament. Care should be taken when inserting the epigastric port so as not to cause injury to the falciform ligament which can result in bleeding. Ligamentum teres (round ligament) is the obliterated umbilical vein which lies in the free edge of the falciform ligament. The falciform ligament is attached to the inferior surface of the liver between segment IV and segment III. Ligamentum venosum is the obliterated ductus venosus which lies between the caudate lobe and the left lateral sector on the inferior surface of liver.

The postero-superior surface of the liver is attached to the diaphragm by the right and left coronary ligaments. The anterior layers of the coronary ligaments are continuous with the layers of the falciform ligament. The anterior and posterior layers of the coronary ligaments join to form the triangular ligaments; left triangular ligament is well formed. Hepato-renal ligament is the posterior layer of the right coronary ligament.

The surface of the liver is covered by a capsule which if torn can cause diffuse bleed from the exposed parenchyma. Based on the branches of the hepatic artery and portal vein, liver is divided into a larger (60%) right lobe and a smaller (40%) left lobe by the Cantlie's line on the inferior surface of the liver extending from the gallbladder fossa anteriorly to the inferior vena cava (IVC) fossa posteriorly. Hepatic veins do not follow lobar distribution—the middle hepatic vein lies in the Cantlie's line; right hepatic vein divides the right lobe into anterior and posterior sectors and the left hepatic vein divides the left lobe into medial and lateral sectors. There is no surface anatomical marking between right anterior and posterior sectors but the falciform ligament on the anterior surface and the umbilical fissure on the inferior surface demarcate left medial and lateral sectors.

Blood supply to the liver (about 1500 mL/min) is dual—from the hepatic artery (20–40%) and from the portal vein (60–80%). Normal liver can tolerate absence of the arterial blood supply, e.g., after injury, ligation, embolization, etc., without clinically significant deleterious effects.

1.3 CT Anatomy of Liver

On computed tomography (CT), liver sectors can be identified by the hepatic veins. Right posterior sector lies posterior to the right hepatic vein; right anterior sector lies between the right hepatic vein and middle hepatic vein; left medial sector (segment IV) lies between the middle hepatic vein and left hepatic vein; and left lateral sector (segment) lies posterior to the left hepatic vein. Sectors are divided into segments by portal veins. Right portal vein divides right posterior sector into segments VII (superior) and VI (inferior) and right anterior sector into VIII (superior) and V (inferior). Left portal vein divides left medial sector (segment IV) into subsegments A (superior) and B (inferior) and left lateral sector into segments II and III.

NOTE: *In Japan, the superior subsegment of segment IV is called IVB while the inferior subsegment is called IVA.*

1.4 Bile Ducts

The liver is divided into eight segments each having its own segmental bile duct (and hepatic artery and portal vein). Intrahepatic bile ducts, along with the branches of the hepatic artery and the portal vein, are enclosed in extensions of the Wallerian sheath (portal pedicles). Fortunately, the bile duct lies anteriorly and is easily exposed when this sheath is opened, e.g., for an intrahepatic cholangio-jejunostomy. Bile ducts of segments VI and VII unite to form the right posterior sectoral duct and those of segments V and VIII unite to form the right anterior sectoral duct inside the liver; these two sectoral ducts then unite to form the right hepatic duct (RHD) which has a short vertical largely intrahepatic course. Bile ducts of segments II, III, and IV unite variably to form the left hepatic duct (LHD) which has a long horizontal mainly extrahepatic course at the base of the quadrate lobe (segment IV) in a groove between the quadrate (segment IV) and the caudate (segment I) lobes. Hilum is a transverse fissure (slit) on the inferior surface of the liver between the base of segment IV (quadrate lobe) in front and segment I (caudate lobe) behind it. The hepatic artery and portal vein branches enter and the right and left hepatic ducts exit the liver at the hilum. The bilio-vascular pedicle at the hilum of the liver is called porta hepatis. At operation, the right anterior sectoral bilio-vascular pedicle is located in the gallbladder fossa—it has a vertical course (towards the right shoulder of the patient). The right posterior bilio-vascular pedicle is located in the Rouviere's sulcus (Fig. 1.4)—it has a horizontal course (towards the right elbow of the patient). Rouviere's sulcus is a useful but often ignored landmark [1]; it lies anterior to the caudate lobe to the right of the hepatic hilum and contains the right posterior sectoral portal pedicle. Dissection in the Calot's triangle during cholecystectomy should remain anterior to (in front of) the Rouviere's sulcus.

The union of right and left hepatic ducts in the porta hepatis is called the biliary ductal confluence. The caudate lobe drains directly by multiple small bile ducts into the left hepatic duct or

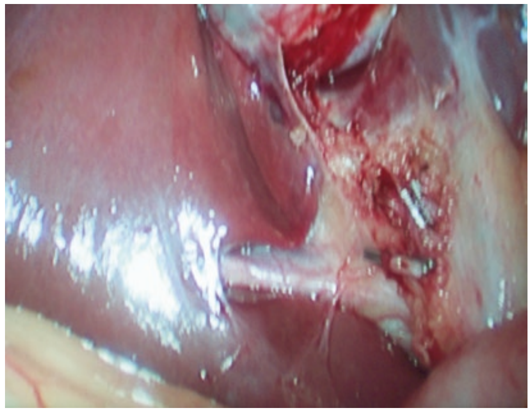

Fig. 1.4 Right posterior sectoral bilio-vascular pedicle in the Rouviere's sulcus

the biliary ductal confluence. Confluence of the right hepatic duct (RHD) and the left hepatic duct (LHD) is an important radiological landmark in the evaluation of a benign biliary stricture. If the biliary ductal confluence is patent (Bismuth Type I, II, and III biliary stricture), repair is easier and results are better. If the biliary ductal confluence is involved (Bismuth Type IV biliary stricture), repair is technically difficult and results are poorer. The right and left hepatic ducts unite outside the liver parenchyma in the hilum of the liver to form the common hepatic duct (CHD) which is joined by the cystic duct to form the common bile duct (CBD). All (even if the stricture is Bismuth Type I or II, i.e., a common hepatic duct stump is present) bilio-enteric anastomoses for benign biliary stricture should be performed at the hilum including the biliary ductal confluence (as the blood supply is richest here) and should be extended to the left hepatic duct—hilo-jejunostomy [2]. The cystic duct has irregular mucosal folds, called valves of Heister, which may make the passage of a catheter (for intraoperative cholangiography) or balloon (for dilatation of the cystic duct before trans-cystic duct choledocholithotomy) difficult. The common hepatic duct and the common bile duct run down vertically in the free edge of the lesser omentum (hepato-duodenal ligament) which contains these ducts to the right anterior, the hepatic artery to the left anterior, and the portal vein behind. The right end of the base of the quadrate lobe marks the hilum of the liver and is another useful landmark during cholecystectomy [3]. At operation, the line joining the hilum of liver to the first part of the duodenum indicates the hepato-duodenal ligament; all dissection should remain to the right of the hepato-duodenal ligament. The common bile duct runs behind the first part of the duodenum and behind or through the head of the pancreas to be joined by the pancreatic duct to form a dilated common channel, the ampulla of Vater, which opens on the medial wall of the second part of duodenum at a nipple-like projection, the papilla of Vater surrounded by the sphincter of Oddi. The common bile duct, thus, has supraduodenal, retroduodenal, retro (or intra) pancreatic and intraduodenal parts.

1.5 Calot's Triangle

Calot's triangle (Fig. 1.5) is the most important area—*the sanctum sanctorum*—during cholecystectomy. The "surgical" Calot's triangle (also called hepato-cystic triangle) lies between the undersurface of the liver on the top, the common hepatic duct on the left and the cystic duct below. The cystic artery, along with the cystic lymph node of Lund which lies along it, usually lies in the Calot's triangle as it arises from the right hepatic artery and crosses the triangle to enter the gallbladder. Division of the peritoneum on the anterior and posterior surfaces of the Calot's triangle opens the triangle for dissection of the cystic artery.

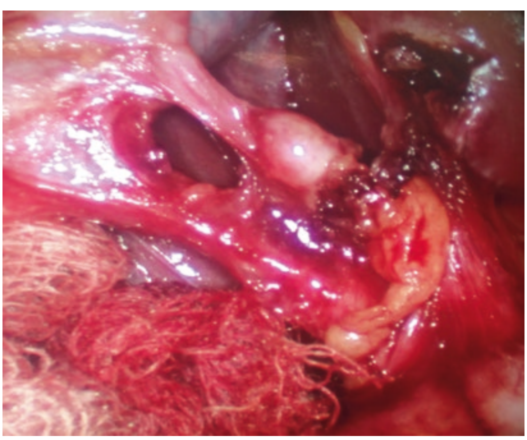

Fig. 1.5 Calot's triangle showing cystic duct, cystic artery and cystic lymph node

Repeated attacks of cholecystitis may cause inflammatory fibrosis in the Calot's triangle resulting in obliteration of the Calot's triangle and the gallbladder neck getting adherent to the common hepatic duct; in later stages, a cholecysto-choledochal fistula (Mirizzi's syndrome) may form.

1.6 Subvesical Ducts

There is a lot of confusion in the literature about the nomenclature of small bile ducts which are present in the gallbladder bed. They have been variously called subvesical ducts, cholecysto-hepatic ducts, and ducts of Luschka [4]. Usually, these ducts are small and get obliterated by the electrocautery or ultrasonic energy used for dissecting the gallbladder from its bed in the liver during cholecystectomy. An unnoticed duct in the gallbladder bed may get injured during dissection of the gallbladder from its bed in the liver and may cause bile leak in the postoperative period (Strasberg Type A bile duct injury). As many as 15% of 270 cases of bile duct injury were a consequence of an injury to these ducts [5].

The author is of the opinion that any bile duct present in the gallbladder bed should be called a subvesical duct. There are two types of subvesical ducts present in the gallbladder bed. One, small aberrant ducts which drain some (small) volume of the liver parenchyma around the gallbladder bed in segments IV and V into the gallbladder (they should rightly be called hepato-cholecystic NOT cholecysto-hepatic ducts; Fig. 1.6); they do not communicate with the intrahepatic bile ducts. Injury to these ducts results in small amount of transient bile leak which usually resolves on its own after the biloma has been drained; endoscopic intervention is not required (in fact, endoscopic intervention will not work as the injured open duct is not in communication with the main ductal system). The other type of subvesical ducts is small aberrant ducts

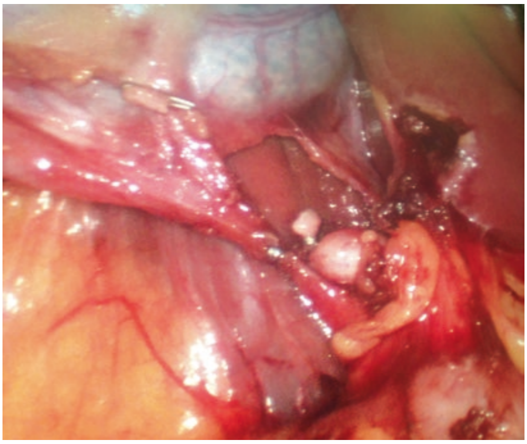

Fig. 1.6 Hepato-cholecystic duct in the Calot's triangle

which connect an intrahepatic bile duct to the gallbladder; these are the subvesical ducts originally described by Luschka. Injury to these ducts also results in postoperative bile leak which usually stops after endoscopic stenting because the injured open duct is in continuity with the main ductal system.

1.7 Hilar Plate

Most of the surface of the liver (except the bare area on the top) is covered by the visceral peritoneum, underneath which lies the Glisson's capsule. Hilar plate is the visceral peritoneum as it reflects from the inferior surface of the segment IV (quadrate lobe) of the liver to the hepatic hilum and then to the lesser omentum (gastrohepatic ligament) and the hepato-duodenal ligament. Hilar plate separates the liver parenchyma from the bilio-vascular pedicle in the hilum of the liver. Hilar plate continues with the cholecystic plate on the right and with the umbilical plate on the left. Cholecystic plate (Fig. 1.7) separates the gallbladder from the liver parenchyma in the gallbladder bed. Glisson's capsule continues as sleeve-like sheaths along the right and left portal pedicles into the liver parenchyma. The left bilio-portal pedicle runs a horizontal course at the base of segment IV (quadrate lobe) and has longer extrahepatic length than the right pedicle. Hilar plate needs to be lowered (using sharp dissection) to expose the anterior surface of the left hepatic duct at the base of the segment IV (quadrate lobe) for performing a high (hilar) bilio-enteric anastomosis.

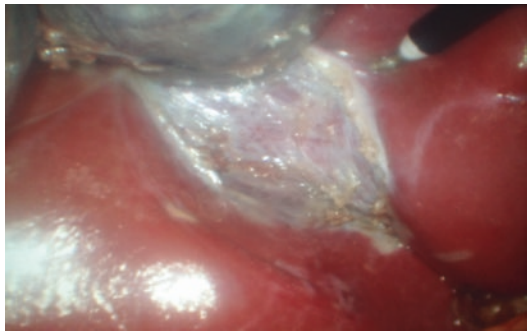

Fig. 1.7 Cholecystic plate

1.8 Aberrant (Anomalous) Anatomy

Anomalies are common in the anatomy of the bile ducts—both intrahepatic and extrahepatic—so common that some surgeons (including the Author) believe that there is nothing called "normal" biliary anatomy and all patients have variations of anatomy. During cholecystectomy, the anomalies of the extrahepatic biliary tree are important (cf. during hepatectomy, where anomalies of the intrahepatic biliary tree are more important). The surgeon should always keep in mind the common anatomical anomalies or variations (aberrations) of the biliary anatomy. Ignorance of these anatomical anomalies or variations may lead to their non-recognition/misinterpretation and an iatrogenic bile duct injury during cholecystectomy.

One of the common anomalies of the extrahepatic bile ducts which is of importance during cholecystectomy is an aberrant right subsegmental, segmental (usually V), or even sectoral (usually posterior) duct. These anomalous ducts lie in the Calot's triangle and join the common hepatic duct; they may rarely join the cystic duct or even the gallbladder. These ducts may be mistaken for the cystic duct and clipped and divided. If they are not identified during the operation, they can get injured during dissection in the Calot's triangle—this will produce a Strasberg type B or C bile duct injury and Bismuth type V benign biliary stricture.

The common anomalies of the cystic duct are short or even absent (a sessile gallbladder opening directly into the common bile duct) cystic duct and a long tortuous cystic duct which crosses the common bile duct either in front or behind to open low on its left border. A short cystic duct results in a narrow Calot's triangle making the dissection difficult. It may result in inadvertent clipping of the lateral wall of the common hepatic duct or the common bile duct; in a sessile gallbladder, the common bile duct (especially if it is normal and undilated) may be mistaken for the cystic duct and dissected, clipped and excised (the classical laparoscopic bile duct injury). The long tortuous cystic duct may be fused with the common bile duct and attempts to dissect it along its entire length may cause injury to the common bile duct.

It is safer to leave a few mm of the cystic duct than to remove or clip even one mm of the common bile duct.

The cystic duct also may be aberrant and join the right hepatic duct; in such a case, the right hepatic duct may be mistaken for the cystic duct and clipped and divided—this will result in an isolated right hepatic duct injury (left hepatic duct, common hepatic duct, and common bile duct are in continuity and are normal).

The gallbladder may be absent (agenesis) or double (duplication).

ANECDOTE: *A patient had symptoms suggestive of gallstones; ultrasonography (US) revealed "contracted gallbladder." At operation, the gallbladder was about to be grasped in an instrument when it was fortunately realized that it was actually the dilated common bile duct which looked like the gallbladder. The gallbladder fossa was empty. Postoperative isotope hepato-biliary scintigraphy confirmed the diagnosis of agenesis of gallbladder.*

1.9 Vascular Anatomy

Celiac axis (trunk) arises from the abdominal aorta on its anterior surface at T12-L1 level between the two crura of the diaphragm. It is only about 2 cm long; soon after its origin from the aorta, it divides into 3 branches—common hepatic artery, splenic artery, and left gastric artery. Common hepatic artery runs towards the right along the superior border of the proximal body of the pancreas. It gives off the gastroduodenal artery and then continues as the proper hepatic artery. Proper hepatic artery runs upwards in the free edge of the lesser omentum (hepatoduodenal ligament) lying to the left of the common bile duct and in front of the portal vein. Below the hepatic hilum it divides in a Y-shaped manner into a right and a left hepatic artery.

Right hepatic artery usually (80–90% of cases) runs behind the common bile duct but may (in 10–20% of cases) cross in front of the common bile duct to enter the hilum of the liver. A long tortuous right hepatic artery may form a Moynihan hump (Fig. 1.8) which lies in the Calot's triangle or even on the anterior surface of the neck of the gallbladder. The right hepatic artery may get injured during dissection in the Calot's triangle resulting in a major bleed, desperate attempts to control which may in turn cause a bile duct injury. An incomplete injury,

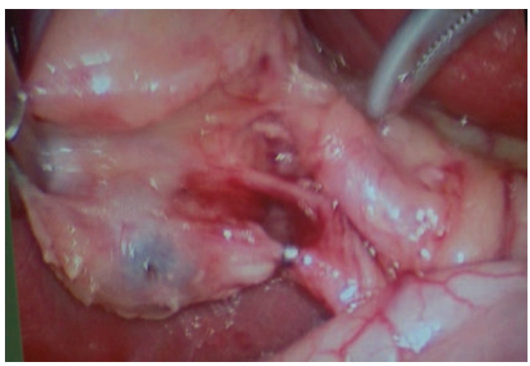

Fig. 1.8 Moynihan hump of the right hepatic artery

e.g., thermal, to the right hepatic artery may result in a pseudoaneurysm. An aberrant right hepatic artery arises from the superior mesenteric artery, instead of from the proper hepatic artery. It may be accessory (in addition to a normally placed right hepatic artery) or replaced (no normally placed right hepatic artery). The aberrant right hepatic artery travels on the right posterior aspect of the common bile duct behind the cystic duct. It may get injured during cholecystectomy resulting in profuse bleeding, attempts to control which may in turn cause a bile duct injury.

Cystic artery arises from the right hepatic artery. It runs in the Calot's triangle along the cystic lymph node of Lund. Dissection in the Calot's triangle should be kept to the right of the cystic lymph node in order to safeguard the common bile duct. In most cases, the cystic artery divides into two branches—anterior (Fig. 1.9) and posterior (Fig. 1.10)—before it enters the gallbladder. The posterior branch of the cystic artery lies inside the posterior peritoneal fold of the Calot's triangle and may get injured when this fold is opened. Cystic artery gives a small twig to the cystic duct which may get injured when a plane is being developed between the cystic artery and the cystic duct.

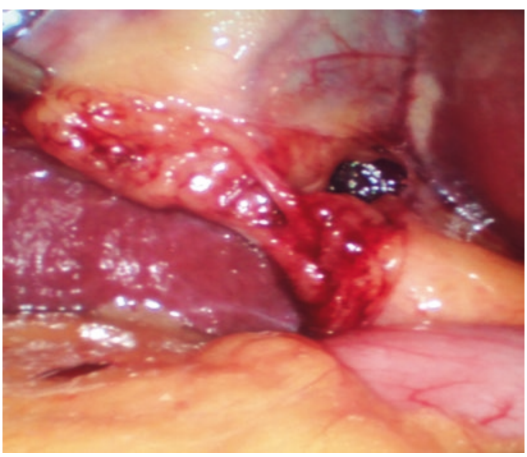

Fig. 1.9 Anterior branch of the cystic artery

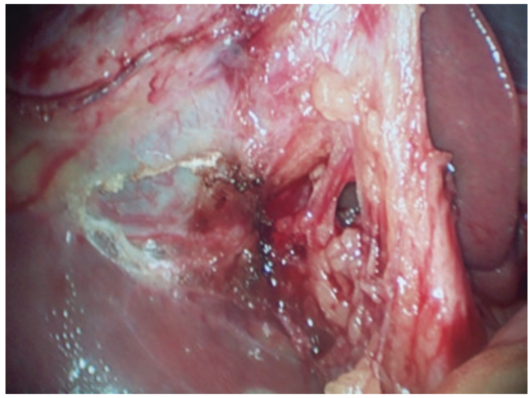

Fig. 1.10 Posterior branch of the cystic artery seen from behind

Common bile duct has an axial blood supply which comes from below as well as from above. The blood supply to the common bile duct comes from the hepatic artery (and its right and left branches), gastro-duodenal artery, anterior and posterior branches of the superior pancreatico-duodenal artery, and the cystic artery. The blood supply is two-thirds from below (gastro-duodenal and pancreatico-duodenal arteries) and one-third from above (cystic artery, and right and left hepatic arteries). The wall of the common bile duct usually has two longitudinal arteries running vertically at 3 and 9 o'clock positions with a periductal arterial plexus. Complete circumferential mobilization of the common bile duct, therefore, should not be done during common bile duct exploration as it may cause ischemia of the bile duct and may result in a delayed (after months or even years) benign biliary stricture without a bile duct injury and bile leak. Upper part of the common hepatic duct receives its blood supply from the caudate artery and medial subsegmental artery of segment IV via an arterial network (hilar plexus) present in the hilum of the liver inferior to the hilar plate—they should be preserved when lowering the hilar plate during hepatico-jejunostomy.

Superior mesenteric vein and splenic vein join at a right angle behind the pancreatic neck to form the portal vein. Portal vein runs upwards in the free edge of the lesser omentum (hepatoduodenal ligament) lying behind the common bile duct and the proper hepatic artery. At the hepatic hilum it divides in a T-shaped manner into a right and a left portal vein.

A few cholecystic veins (Fig. 1.11) may drain from the gallbladder directly into the portal vein; few cholecysto-hepatic veins (Fig. 1.12) drain from the gallbladder into the intrahepatic branches of the portal vein.

The common bile duct is surrounded by peri- and epi-choledochal venous plexuses of Sappe which enlarge in presence of extrahepatic portal venous obstruction (EHPVO) causing portal biliopathy, an uncommon cause of benign biliary obstruction. Inadvertent injury to one of these veins during cholecystectomy may result in profuse and difficult to control, even fatal, bleeding due to high portal venous pressure in these patients.

CAUTION: *Cholecystectomy in presence of EHPVO is one of the most challenging procedures and should be attempted only by a very experienced surgeon preferably a few months after a porta-systemic shunt.*

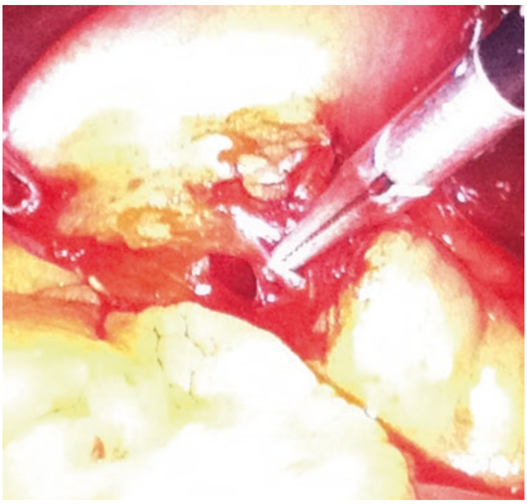

Fig. 1.11 Small cholecystic vein from the gallbladder draining directly into the portal vein

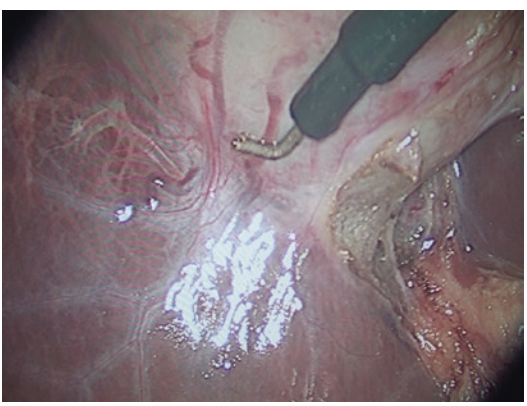

Fig. 1.12 Cholecysto-hepatic veins

1.10 Umbilicus

At the umbilicus, all fibro-aponeurotic layers of the parietes fuse into the umbilical scar. The nick for open insertion of the first trocar for laparoscopic cholecystectomy is made at the angular junction between the infraumbilical parietes (linea alba) and the umbilical scar.

1.11 Big Vessels

Major abdominal vessels, e.g., aorta, inferior vena cava, and iliac vessels, may be at a very small distance from the anterior abdominal wall in a thin built patient and are liable to injury by the Veress needle or the trocar (in case of blind insertion).

1.12 Abdominal Wall

The wound in linea alba after a midline laparotomy should be closed with a continuous suture. Subcostal incision should be closed in two layers—transversus, internal oblique and posterior rectus sheath as one layer and external oblique and anterior rectus sheath as the second layer. Incisions for 10 mm ports should be closed with a few (2 or 3) interrupted sutures to prevent a port site incisional hernia. Heavy (0 or 1) long acting absorbable suture, e.g., polydioxanone (PDS^{R}) should be used for closure. Non-absorbable sutures, e.g., polypropylene (Prolene^{R}) are not preferred as they can be associated with stitch abscess/sinus, more so in a thin built patient with little subcutaneous fat.

1.13 Jejunum

For the preparation of a Roux-en-Y limb during hepatico-jejunostomy, the jejunum can be identified by locating the duodeno-jejunal junction to the right of the inferior mesenteric vein. Jejunum should be divided about 30 cm from the duodeno-jejunal junction so as to preserve the proximal jejunum, which has important absorptive functions, in the enteric limb.

Invited Commentary on Surgical Anatomy of the Hepato-Biliary System

Daniel J. Deziel

Our detailed understanding of the hepato-biliary anatomy comes from classic studies of cadaver dissection and resin casts, from studies of direct cholangiography, and from more contemporary imaging studies using 3D computed tomography (CT) and magnetic resonance imaging (MRI) reconstructions. Professor Kapoor has provided a succinct introductory overview of the salient anatomic features that have practical significance for performing safe operations including laparoscopic cholecystectomy. Since "typical" anatomy is only present in about one-half of individuals, one may quibble with the use of the term "aberrant" to describe the frequent variations that exist. Anatomic variations are present natively, and also result from the effects of inflammatory fibrosis and fusion.

The roughly triangular area bounded by the cystic duct and the gallbladder neck, the common hepatic duct, and the edge of the liver is the crucial region where bile duct and vascular injuries often occur during cholecystectomy. This is most properly referred to as the hepato-cystic triangle, rather than Calot's triangle, which is bound by the cystic artery (instead of the cystic duct). Calot's triangle is neither consistently present nor anatomically precise as the term is commonly used. We might advocate that "Calot's triangle" be deleted from the nomenclature, other than for historical purposes. But, alas, it is undoubtedly so well ensconced in the lexicon that it will continue to roll off of the tongues of surgeons.

One of the most common and most important variations in right duct anatomy occurs when the right anterior sectional (sectoral) duct and right posterior sectional (sectoral) duct do not join to form a main right hepatic duct. Rather, each of these ducts has a separate junction with the common hepatic duct, or even with the left hepatic duct. Some version of this occurs in one out of four individuals. When the right sectional (sectoral) ducts join the common hepatic duct independently, the distance between the junction of the lower right sectional (sectoral) duct with the common hepatic duct and the cystic duct junction is variable. A separate right posterior sectional (sectoral) duct tends to join lower down on the common hepatic duct than does a separate right anterior sectional (sectoral) duct. Hence, this posterior sectional (sectoral) duct can be in close proximity to the gallbladder and the cystic duct and it is particularly vulnerable to injury if it is not recognized. In 2% of individuals, or one out of 50 cholecystectomies, the cystic duct actually joins a separate right posterior sectional (sectoral) duct.

Professor Kapoor importantly emphasizes the presence of subvesical ducts which are the most common source of bile leak from the gallbladder bed following cholecystectomy. There have been somewhat different interpretations of the anatomic studies regarding these structures. Subvesical ducts are best understood as segmental or accessory segmental ducts that are located superficially under the Glisson's tunic in the gallbladder bed. They usually join the right anterior sectional (sectoral) duct or right hepatic duct or, occasionally, the common hepatic duct. True hepatico-cystic ducts have been described, but they are rare, certainly much rarer than the other subvesical ducts, which are common and may be present in up to one-third of individuals. None of these subvesical ducts are "ducts of Luschka." The German anatomist, Hubert von Luschka, did not describe ducts going directly from the liver into the gallbladder (hepatico-cystic ducts) as is commonly misunderstood. Luschka described two tubular microscopic structures in the gallbladder wall that were present on both the peritoneal and the hepatic sides of the gallbladder; these were likely intramural glands and lymphatics.

There are two variations in cystic duct anatomy that are particularly dangerous for causation of bile duct injury during laparoscopic cholecystectomy. The first is when the cystic duct is fused to the common hepatic duct: the "hidden cystic duct." This can occur naturally when the structures share a common sheath. However, this more frequently is the result of inflammatory fusion. The second is when the cystic duct is "short," meaning that it is fused with the common bile duct. This can essentially result in a cholecystocholedochal fistula. Surgeons sometimes refer to the cystic duct as being "absent." Almost certainly, this situation is the result of inflammatory fusion. I have not found a study based on anatomic dissection that has described true "absence" of the cystic duct.

Variations in arterial anatomy add to the risk for bleeding or vascular injury. The cystic artery is characterized by anatomic diversity: it can branch at variable distances from the gallbladder wall, 25% individuals have multiple cystic arteries, 30% of cystic arteries arise from someplace other than the right hepatic artery, 10% of the time there is no cystic artery within the hepatocystic triangle (so that a true Calot's triangle does not exist). The right hepatic artery can be closely applied to the gallbladder for various lengths, either natively or due to inflammation.

When performing cholecystectomy, the cystic artery or its branches should be ligated and divided directly on the gallbladder wall. There are two reasons for this. First, to avoid compromising the right hepatic artery which may be in close proximity. Second, to avoid compromising either a hepatic arterial branch or a recurrent arterial branch to the common bile duct originating from the cystic artery. Professor Kapoor has highlighted the features of the blood supply to the extrahepatic bile ducts. There are anatomic variations in this pattern as well. On occasion, the marginal anastomotic vessels that anchor the epicholedochal plexus are essentially absent and an important component of the blood supply to the common bile duct is provided by an artery that feeds back from the cystic artery.

As a final comment, I would add the falciform ligament to the list of landmarks that are valuable for maintaining orientation during cholecystectomy. The common hepatic duct lies in the midplane of the liver between segments IV and V. If dissection is near the plane of the falciform ligament, which lies between segments III and IV, the surgeon is too far to the patients' left side and on the wrong side of the common bile duct.

For those who have interest, the vascular and ductal variations in biliary anatomy were elegantly detailed by the classic dissections of Nicholas A Michels in the 1950s and 1960s [6–8].

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