Surgical Significance of Variations in Anatomy in the Biliary Region

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ABSTRACT

A good knowledge about the incidence and types of variations is of fundamental importance to the surgeries in the biliary region. Ignorance of these anomalies can be of serious consequences to the patient in case of both the new laparoscopic procedures as well as old open surgeries performed in this region and any surgeon should be fully aware of the great number of problems in this region as far as the variation from normal anatomic patterns is concerned. The benefit of encountering these variations can be passed on to the surgical trainees who can also get accustomed to the significant number of variations in this potentially dangerous region. The importance of these anomalies is further enhanced by the fact that in modern day surgeries like bile duct resection, hepatic duct resection or liver transplantation requires serious recognition to the normal and abnormal.

Keywords: Biliary anatomy, Anomaly, Surgical significance, Vasculature.

INTRODUCTION

A thorough background of normal anatomic knowledge of biliary tract cannot be underestimated. However, a surgeon can encounter multiple anomalies in the form of absence, aplasia, abnormal vascular pattern, and abnormal drainage of ducts which he should be aware of. Absence of the gallbladder is not a common phenomenon and can have a genetic predisposition.[1] Patients with gallbladder agenesis fall into three categories.[2] Some are born with other congenital anomalies, including biliary atresia and cardiovascular or other gastrointestinal malformations. They often die in infancy. Others are asymptomatic throughout life. Slightly more than half have symptoms suggestive of biliary tract disease; in these patients, dilatation of the bile duct system or choledocholithiasis is a frequent finding. This is an interesting correlation because the associated anomalies can confer high mortality.

Agenesis of the gallbladder is rarely diagnosed preoperatively in patients with symptoms of biliary tract disease, because the mostly an USG is interpreted as showing a small, contracted gallbladder, and oral cholecystography and scintigraphy show nonvisualization of the gallbladder, all of which suggest the presence of gallbladder disease.

A thorough search for the gallbladder in possible ectopic locations should be made during operation. If none is found, an operative cholangiogram is indicated.

An ectopic location of the gallbladder is also rare. An intrahepatic location on the right side makes cholecystectomy hazardous, and a cholecystostomy with removal of the stones is the preferred treatment of cholelithiasis in patients with this anomaly. A left-sided gallbladder is located to the left of the falciform ligament and is usually partially embedded in the substance of the left lobe of the liver. The cystic duct may drain into the left hepatic duct or the common hepatic duct. In retrodisplacement of the gallbladder, the organ is located beneath the posterior and inferior surfaces of the liver. Torsion may occur in a floating gallbladder, in which the organ is completely peritonealized and free from the liver or attached to the liver by a long mesentery.

Double and triple gallbladders have been reported, the latter being extremely rare. Double gallbladders may share a common cystic duct and be completely separated, or they may be divided by a septum. When they do not share a common outlet, the cystic ducts of double or triple gallbladders open separately into the common bile duct or, less commonly, into the right hepatic duct.[3]

Cysts of the biliary duct system are also uncommon. Most of them are diagnosed during childhood, and the remainder become apparent in adulthood. Originally, they were described as cystic dilatations of the extrahepatic duct system, which Alonso-Lej and colleagues[4] classified with regard to their location and their fusiform or diverticular configuration. Subsequently, Todani extended this classification to include the frequent association with cystic dilatation of the duct system within the liver, a condition described in 1958 and now known as Caroli's disease.[5-7] The fusiform dilatation may extend proximally to involve the entire common hepatic duct, there may be multiple extrahepatic cysts, and intrahepatic cysts may occur alone or be unilateral, bilateral, cystic or fusiform. The solitary fusiform type accounts for approximately 80% of cases. The etiology is uncertain, but some evidence suggests that fusiform dilatation results from distal obstruction and destruction of the proximal bile duct epithelium by pancreatic juice, because the pancreatic duct enters proximal to the ampulla in most of these patients, and distal obstruction and damage to the epithelium cause cysts in puppies.[8] Choledochal cysts should be treated by complete excision and Roux-en-Y hepaticojejunostomy

whenever possible. The results are excellent.[9] The long-term results of procedures in which the cyst remains *in situ* are not good because of recurrent pancreatitis in about one-third of patients and the development of carcinoma in the cyst in about one-fourth of them.[10] Recent evidence suggests that excision of the extrahepatic portion of the cyst alone eliminates the risk of subsequent cholangiocarcinoma in patients who have both intrahepatic and extrahepatic cystic disease, perhaps because the reflux of pancreatic juice is prevented.

The latest division of liver into various segments has revolutionized the concept of hepatic resection, hepatic transplant and microsurgical techniques. Normally, it is assumed that liver is divided into eight compact segments. The Couinaud's segmentation of liver dividing the liver into eight functional segments itself does not follow a totally uniform pattern in all individuals. It is based on the basis of distribution of portal vein and hepatic vein. Liver segmentation proposed by Healey and Schroy[11] in 1953 is based on the distribution of bile ducts, which follows the distribution of portal vein branches. According to this simple classification a right liver and a left liver are described.[12] Topographically, the division between these halves (called functional lobes) follows a plane (called the principal plane, median fissure, Rex's line, or Cantlie's line) extending forward from the left side of the gallbladder fossa to the left side of the inferior vena cava (IVC). The change in the concept of hepatic segments according to Couinaud is better appreciated and forms the basis of hepatic segmental resection.

EXTRAHEPATIC AND INTRAHEPATIC VASCULATURE

The liver has a dual blood supply from the portal vein and common hepatic artery with a unique feature that mostly the portal vein is responsible for approximately 70% and the hepatic artery for 30% of the blood flow of the liver.[13] Knowledge of the hepatic artery anatomy is essential to have the correct identification, preservation and management of many anatomical variations in hepatic artery supply, which determinate the success of liver transplants, resection of the major organs located in the supramesocolic region and the reduction of postoperative complications.

COMMON HEPATIC ARTERY

The common hepatic artery takes origin from the celiac trunk in most of the cases but anomalous sources of origin can be from the superior mesenteric artery (2.9%), the aorta (1.1%), and, very rarely, the left gastric artery. The common hepatic artery then runs horizontally along the upper border of the head of the pancreas covered by the peritoneum of the

posterior wall of the omental bursa. This can be a problem for a surgeon in case of nonawareness and can result in iatrogenic injury. Within the hepatoduodenal ligament, the proper hepatic artery lies to the left of the common bile duct and anterior to portal vein. The portal vein, however, is located posteriorly or deeper to the proper hepatic artery and the common bile duct. Within the ligament the proper hepatic artery divides into right and left branches, called right and left hepatic arteries. Arterial distribution to different functional segments is identical to the distribution of portal vein.[14] All these anatomical variations should be accounted for as failure to recognize them during surgical procedures can result in unnecessary confusion and injury.

RIGHT HEPATIC ARTERY

In about 17% of subjects, the right hepatic artery branches from the superior mesenteric artery.[15] The right hepatic artery passes to the right behind (or occasionally in front of) the hepatic duct in front of the portal vein. Before entering the liver, the right hepatic artery gives off the cystic artery in the hepatocystic triangle located between the cystic duct and the common bile. The right hepatic artery occasionally forms a sinuous tortuosity called as caterpillar hump or Moynihan's hump, which occupies the major portion of Calot's triangle. Due to this variation, inadvertent injury to right hepatic artery may occur during surgical procedures. The knowledge of caterpillar hump of right hepatic artery is essential for the surgeons to avoid the risk of ischemic necrosis of right lobe of liver.

LEFT HEPATIC ARTERY

In 25 to 30% of cases, the left hepatic artery arises from the left gastric artery.[16] In 40% of subjects, the left hepatic artery branches into a median and a lateral segmental artery.

Other patterns often occur, however, aberrant hepatic arteries are found in about 45% of subjects.[17] If the arteries arise entirely from some source other than the celiac arterial distribution, they are called 'replacing' arteries and can supply an entire lobe of the liver or even the entire liver. Although, atypical hepatic arteries are commonly called 'accessory' arteries if they arise from some aberrant source and are additive to lobar branches, it is evident that they provide the primary arterial supply to a specific part of the liver (lobe, segment or subsegment); therefore, they are not 'accessory' arteries.

Variations in the branching of the left hepatic artery can be in the form of bifurcation into medial and lateral segmental arteries or division of the lateral segmental artery into laterosuperior and lateroinferior branches to the right of median fissure.

In intra-arterial chemotherapy pump placement, preoperative mapping of the hepatic arterial anatomy is mandatory because it aids in deciding whether the patient is suitable for the procedure itself and whether modifications of the technique are required. It is important to place the intra-arterial infusion pump within the dominant hepatic artery, as proximal as possible but distal to the origin of the gastroduodenal artery. In patients with variant vascular anatomy, the location of the pump varies according to the origin of the gastroduodenal artery and to the relationships between the dominant artery perfusing the liver and accessory hepatic arteries.

HEPATIC VEINS

Knowing the variations of hepatic veins before surgery is useful during both partial hepatectomy and donor operations for living related liver transplantation.

In the classic hepatic venous anatomy, three main hepatic veins drain into the IVC. The left hepatic vein drains segments II and III, the middle hepatic vein drains segments IV, V and VIII, and the right hepatic vein drains segments V to VII. In approximately 60% of the population, the middle and left hepatic veins join to form a common trunk, which drains separately into the IVC. The normal portal venous anatomy consists of the main portal trunk branching, at the porta hepatis, into the right and left portal veins, with the right portal vein subsequently dividing into anterior and posterior branches.

The three major hepatic veins have an extrahepatic length of 0.5 to 1.5 cm. In contrast to hepatic arteries, portal veins, and bile ducts, these veins are found intrahepatically within the (intersegmental) planes separating lobes and segments (intersegmental). They drain adjacent segments and subsegments. The right hepatic vein is the largest. It lies in the right fissure, draining the entire posterior segment (superior and inferior subsegments) and the superior subsegment of the anterior segment of the right lobe. It serves segments V, VI, VII and part of VIII.

The middle hepatic vein lies in the median fissure and drains the inferior subsegment of the anterior segment of the right lobe and the inferior area of the medial subsegment of the left lobe. The middle hepatic vein also drains the right anterior superior subsegment.[14] This vein mainly serves the left liver, together with the left hepatic vein. The middle hepatic vein serves mainly segments IV, V and VIII.

The left hepatic vein lies in the upper part of the left fissure. It drains the superior area of the medial subsegment (segment IV) and the left anterior superior and inferior subsegments (segments II and III). In about 60% of individuals, the left and middle veins unite to enter the IVC as a single vein.

A venous anomaly relevant in donors is an accessory inferior right hepatic vein draining directly into the IVC, usually draining segment VI or VII, rarely segment V. The anomaly may be seen in as many as 47% of cases. Sometimes more than one vessel may be found. In preoperative planning, it is important to highlight not only the presence and number of these accessory veins but also their size and their distance from the main hepatic venous drainage site along the IVC. When this distance is more than 40 mm, it may be technically difficult to implant both veins into the recipient's IVC.

The most important point in successful living donor liver transplantation is to maintain the balance between the blood supply and venous drainage of the graft. Venous congestion can seriously damage the graft, causing its failure; therefore, even small hepatic venous branches, which run along the parenchymal dissection plane, need to be left intact or reconstructed.

INTRAHEPATIC BILIARY TRACT

Bile canaliculi are formed by parts of the membrane of adjacent parenchymal cells, and they are isolated from the perisinusoidal space by junctions. Bile flows from the canaliculi through canals of Hering into the interlobular bile ducts found in portal pedicles. In the segmental and subsegmental pedicles surrounded by the Glissonian sheath, bile ducts are found above and veins and arteries beneath.[18] Biliary segmentation is identical to portal vein segmentation. In contrast to portal vein branches, which may communicate, no communication is observed in biliary branches.[19]

RIGHT HEPATIC DUCT

The right hepatic duct has an average length of 0.9 cm and it is normally formed by the union of the anterior and posterior branches at the porta hepatis. Each branch is further bifurcated into superior and inferior branches to drain the intrahepatic biliary tract. Biliary segmentation is identical to portal vein segmentation. The right hepatic duct branches into four subsegments of the right lobe: V (right anterior inferior subsegment), VI (right anterior superior subsegment), VII (right posterior inferior subsegment) and VIII (right posterior superior subsegment). This is the usual pattern, present in 72% of specimens examined by Healey and Schroy.[11] In the remainder, the posterior branch or, rarely, the anterior branch crosses the segmental fissure to empty into the left hepatic duct or one of its tributaries. In these cases the right hepatic duct is absent.

An aberrant right hepatic duct, which occurs in 3.2 to 18.0% of patients, drains part of the right lobe of the liver directly into the extrahepatic biliary tree. Being close to the

cystohepatic angle (formed by the cystic duct and gallbladder below, the right lobe of the liver above, and the common hepatic duct medially), the aberrant duct may undergo accidental transection or ligation during cholecystectomy and therefore complications may ensue. These complications include formation of a biliary fistula, biloma, sepsis, pain and repetitive episodes of cholangitis. If the volume of parenchyma drained by the ligated duct is not small, biliary atrophy with resultant jaundice may occur.

LEFT HEPATIC DUCT

Medial and lateral branches converge to form the left hepatic duct, which has as average length of 1.7 cm. Each branch is formed by superior and inferior branches of the respective subsegments. The left hepatic duct drains the three segments of the left lobe: II (left lateral superior subsegment), III (left lateral inferior subsegment) and IV (left medial subsegment). Segment IV is drained by mediosuperior and medioinferior branches. This typical pattern was met in 67% of Healey and Schroy's specimens.[11] The medial and lateral branches unite in the left fissure (50%), to the right of the fissure (42%), or to the left of the fissure (8%).

Accessory hepatic ducts are observed in approximately 2% of patients and may originate from and run their course along both the left or right ductal system. They may present as a solitary finding or in conjunction with aberrant bile ducts and should be taken care of. Evaluation of the biliary anatomy is essential before hepatic lobectomy or segmentectomy. Inaccurate determination of existing biliary anatomic variations may potentiate ligature or section of these aberrant ducts, leading to major complications.

CONCLUSION

As is clear from the discussion a surgeon should always be fully aware of both the normal anatomy as well as the anomalies in the anatomy of not only the extrahepatic biliary region but the biliary region as well. Failure of recognition of the anomalies can have dangerous consequences for the patient. Accurate preoperative assessment of the hepatic vascular and biliary anatomy is essential to ensure safe and successful hepatic surgery. Such surgical procedures range from the more complex, like tumor resection and partial hepatectomy for living donor liver transplantation, to others performed more routinely, like laparoscopic cholecystectomy.

REFERENCES

1. Wilson JE, Dietrick JE. Agenesis of the gallbladder: case report and familial investigation. Surgery 1986 Jan;99(1):106-109.
2. Bennion RS, Thompson JE Jr, Tompkins RK. Agenesis of the gallbladder without extrahepatic biliary atresia. Arch Surg 1988 Oct;123(10):1257-1260.
3. Harlaftis N, Gray SW, Skandalakis JE. Multiple gallbladders. Surg Gynecol Obstet 1977 Dec;145(6):928-934.
4. Alonso-Lej F, Rever WB Jr, Pessagno DJ. Congenital choledochal cyst, with a report of 2, and an analysis of 94 cases. Int Abstr Surg 1959 Jan;108(1):1-30.
5. Caroli J, Soupalt R, Kossakowski J, Plocker L, Paradowska M. Congenital polycystic dilation of the intrahepatic bile ducts; attempt at classification. Sem Hop 1958 Feb; 34(8/2):488-495.
6. Todani T, Watanabe Y, Fujii T, Uemura S. Anomalous arrangement of the pancreatobiliary ductal system in patients with choledochal cyst. Am J Surg 1984 May;147(5):672-676.
7. Todani T, Watanabe Y, Narusue M, Tabuchi K, Okajima K. Congenital bile duct cysts: classification, operative procedures, and review of thirty-seven cases including cancer arising from choledochal cyst. Am J Surg 1977 Aug;134(2):263-269.
8. Okada A, Oguchi Y, Kamata S, Ikeda Y, Kawashima Y, Saito, R. Common channel syndrome—diagnosis with endoscopic retrograde cholangiopancreatography and surgical management. Surgery 1983 May;93(5):634-642.
9. O'Neill JA, Templeton JM Jr, Schnaufer L, Bishop HC, Ziegler MM, Ross AJ 3rd. Recent experience with choledochal cyst. Ann Surg 1987 May;205(5):533-540.
10. Nagorney DM, McIlrath DC, Adson MA. Choledochal cysts in adults: clinical management. Surgery 1984 Oct;96(4):656-963.
11. Healey JE Jr, Schroy PC. Anatomy of the biliary ducts within the human liver: analysis of the prevailing pattern of branchings and the major variations of the biliary ducts. AMA Arch Surg 1953 May;66(5):599-616.
12. Twelfth International Congress of Anatomists [London, 1985]. Nomina anatomica. 3rd ed. Edinburgh (UK): Churchill Livingstone; 1989. p. 56-89.
13. O'Rahilly, Rohan R.; Müller, Fabiola. Human embryology and teratology. 3rd ed. New York: Wiley-Liss; 1996. 266 p.
14. Le foie, Champetier J. In: Chevrel JP, editor. Anatomie clinique. Vol. 2, Le tronc. Paris: Springer-Verlag France; 1994. p. 389-406.
15. Michels NA. Newer anatomy of the liver and variant blood supply and collateral circulation. Am J Surg 1966 Sep;112(3):337-347.
16. Van Damme JPJ, Bonte J. The branches of the celiac trunk. Acta Anat (Basel) 1985;122(2):110-114.
17. Suzuki T, Nakayasu A, Kawabe K, Takeda H, Honjo I. Surgical significance of anatomic variations of the hepatic artery. Am J Surg 1971 Oct;122(4):505-512.
18. Les voies biliares CJ, Champetier J. In: Chevrel JP, editor. Anatomie clinique. Vol. 2, Le tronc. Paris: Springer-Verlag France; 1994. p. 407-420.
19. Anderhuber F, Lechner P. Occurrence of anastomoses of the intrahepatic bile ducts. Acta Anat 1986;125(1):42-49.

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