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ANATOMIC VARIATIONS

Rare anatomic variations of the right hepatic biliary system

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Abstract

Purpose To report rare and clinically significant anatomic variations in the biliary drainage of right hepatic lobe.

Methods Unique variations in the extra- and intrahepatic biliary drainage of right hepatic lobe were observed in 6 cadaveric livers during dissection on 100 formalin-fixed en bloc cadaveric livers.

Results There was presence of aberrant drainage of right segmental and sectorial ducts in four cases and of accessory right posterior sectorial duct in two cases.

Conclusions We encountered some extensively complicated biliary drainage of right hepatic lobe, unsuccessful recognition of which can lead to serious biliary complications during hepatobiliary surgeries and biliary interventions.

Keywords Hepatic ducts · Biliary anatomy · Liver anatomy · Hepatobiliary surgery

Introduction

Precise knowledge of biliary anatomy is a prerequisite for obtaining optimal results in ever-increasing complex hepatobiliary surgeries (e.g., extended hepatic resections, liver transplantation, and laparoscopic cholecystectomy). Biliary complication remains a major cause of morbidity and mortality, despite improvements in hepatic surgical techniques [1].

In the typical pattern of biliary system, the confluence of segments 2 and 3 hepatic ducts and one or more ducts from segment 4 forms the left hepatic duct (LHD). The ducts of segments 6 and 7 form right posterior sectorial duct (RPSD) and those of segments 5and 8 form right anterior sectorial duct (RASD). The RASD lies vertical to the left of right anterior portal vein. The direction of the RPSD is more horizontal; running dorsally and cranially to right anterior portal vein (Hjortsjo crook). The RASD and RPSD join to form the right hepatic duct (RHD), above the right portal vein (RPV), in an extrahepatic position. The common hepatic duct (CHD) is formed by the union of RHD and LHD at the hepatic hilum, anterior to the RPV (Fig. 1a). The deviation from this typical biliary anatomy is commonly found in clinical practice and has been appropriately classified in the previous studies [3, 15]. However, some new or extremely rare variations of clinical significance still can be encountered and should be documented. We herein report six unique cases of complex biliary anatomy that may pose as one of the important risk factors for bile duct injury during various hepatobiliary procedures.

Materials and methods

A complex biliary anatomy in the right hepatic lobe was observed in 6 male cadaveric livers (20–38 years of age) during dissection on 100 formalin-fixed en bloc cadaveric livers. The study was approved by the institute's ethics committee. In all the cases, there was no history of abdominal surgery or liver disease and cause of death was shock secondary to thermal burns in four cases and head injury in two cases. The extra- and intrahepatic biliary systems were dissected under a magnascope (magnification—×2.5). An aberrant RHD that ran dorsally and cranially to the RPV or right anterior PV and joined the distal bile duct (BD) at its cranial side was considered supraportal type and the one that ran ventrally and caudally to the RPV or right anterior PV and joined the distal BD at its caudal side was considered infraportal type (Fig. 1a, b).

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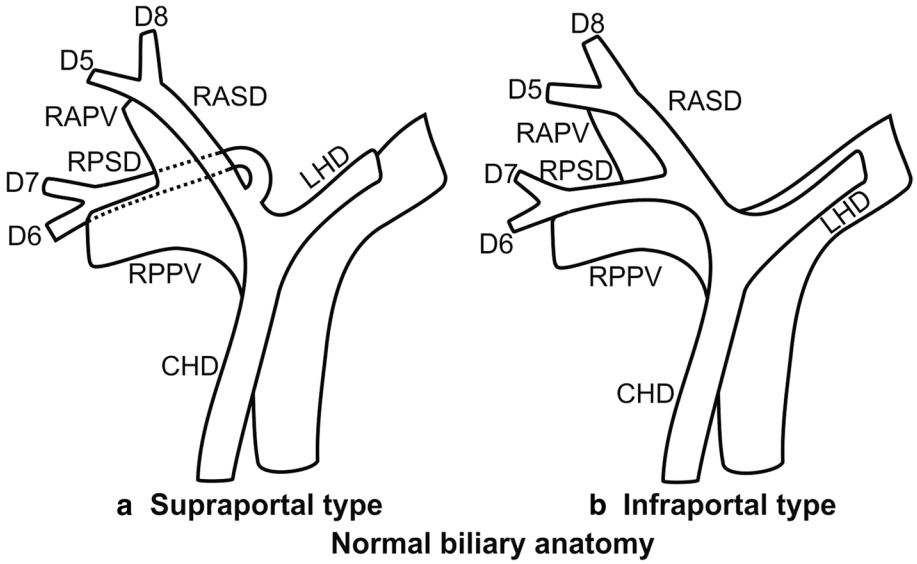

Fig. 1 Schematic representation of normal biliary anatomy. **a** Supraportal relation of right biliary ducts. **b** Infraportal relation of right biliary ducts. *CD* cystic duct, *CHD* common hepatic duct, *CBD* common bile duct, *D5* segment 5 duct, *D6* segment 6 duct, *D7* segment 7 duct, *D8* segment 8 duct, *GB* gallbladder, *LHD* left hepatic duct, *RAPV* right anterior portal vein, *RASD* right anterior sectorial duct, *RHD* right hepatic duct, *RPPV* right posterior portal vein, *RPSD* right posterior sectorial duct

Results

Case 1

Aberrant hepatic ducts draining segment 8 (D8) and segment 5 (D5) joined independently to the LHD at the hepatic hilum to form the CHD (triple confluence of D5, D8 and LHD). The RHD and RASD were absent. Aberrant RPSD draining segments 6 and 7 (D6 and D7) ran ventrally and caudally to the right posterior PV and joined the CHD (infraportal type). The cystic duct (CD) was long and coursed parallel to CHD and drained into it behind the first part of duodenum (lower drainage of CD) (Fig. 2a, b).

Case 2

Segments 6 and 7 hepatic ducts drained separately into the RHD and LHD, respectively. Segment 6 duct (D6) ran ventral and caudal to the RPV and joined the RASD on its caudal side (infraportal type) to form the RHD. An aberrant segment 7 duct (D7) ran dorsal and cranial to the RPV and crossed the hepatic hilum to join the LHD on its cranial side (supraportal type) (Fig. 2c, d).

Cases 3 and 4

An unusual biliary anatomy was observed in 2 liver specimens wherein the main RHD was formed by the union of segment 5 duct (D5) and RPSD draining segments 6 and 7. This aberrant RHD coursed ventrally and caudally to the RPV (infraportal type) and joined with LHD to form the CHD. In both the cases, segment 8 duct crossed the

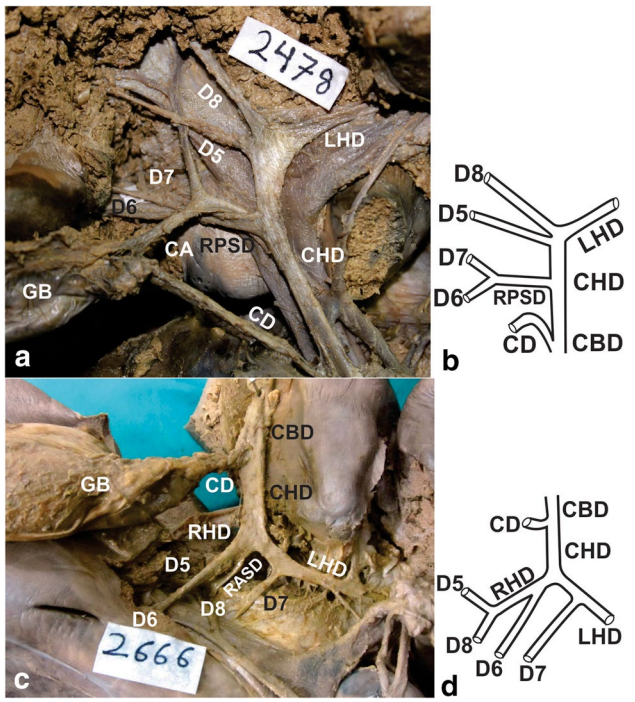

Fig. 2 **a** Anterior view of hepatic pedicle in case 1 showing the triple confluence of segment 5 duct, segment 8 duct and LHD to form the CHD with aberrant drainage of RPSD into CHD. Lower drainage of CD into CHD is also seen. **b** Schematic representation of case 1. **c** The aberrant drainage of segment 7 duct into the LHD in case 2. (CBD has been reflected up at the hepatic hilum). **d** Schematic representation of case 2. *CA* cystic artery, *CD* cystic duct, *CHD* common hepatic duct, *CBD* common bile duct, *D5* segment 5 duct, *D6* segment 6 duct, *D7* segment 7 duct, *D8* segment 8 duct, *GB* gallbladder, *LHD* left hepatic duct, *RASD* right anterior sectorial duct, *RHD* right hepatic duct, *RPSD* right posterior sectorial duct

Cantlie's line and hepatic hilum and drained into the LHD. In case 3, CD and a duct from gallbladder bed (duct of Luschka) drained at the level of confluence of RHD and LHD (Fig. 3a–d).

Cases 5 and 6

In two cases, there were double RPSD draining segments 6 and 7. In case 5, normal RPSD (supraportal type) draining segments 6 and 7 joined with the RASD to form a RHD which later joined with LHD at the hepatic hilum to form a CHD. Accessory RPSD draining segments 6 and 7 were present that opened at the CD/CHD junction (infraportal type) (Fig. 4a, b). In case 6, an aberrant RPSD (supraportal type) draining segments 6 and 7 joined with RASD and LHD at the hepatic hilum (triple confluence) to form a CHD and accessory RPSD draining segments 6 and 7 opened into the common bile duct(CBD) distal to CD/CHD junction (infraportal type) (Fig. 4c, d).

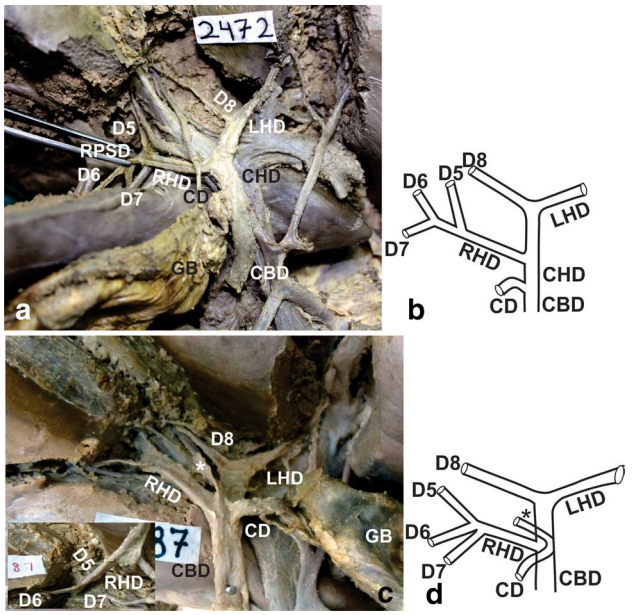

Fig. 3 **a** Anterior view of hepatic pedicle in case 3 showing an aberrant RHD draining segments 5, 6, and 7 and joining with LHD ventrally and caudally to the RPV to form the CHD. Segment 8 duct is draining directly into LHD. **b** Schematic representation of case 3. **c** Anterior view of hepatic pedicle in case 4 showing an aberrant RHD draining segments 5, 6, and 7 and joining with LHD ventrally and caudally to the RPV to form the CHD. Segment 8 duct is draining directly into LHD. CD and a duct from GB fossa (*) are draining at the level of confluence of RHD and LHD. Inset shows the confluence of RHD. (CHD has been reflected up at the hepatic hilum). **d** Schematic representation of case 4. *CD* cystic duct, *CHD* common hepatic duct, *CBD* common bile duct, *D5* segment 5 duct, *D6* segment 6 duct, *D7* segment 7 duct, *D8* segment 8 duct, *GB* gallbladder, *LHD* left hepatic duct, *RHD* right hepatic duct, *RPSD* right posterior sectorial duct, * duct from GB fossa

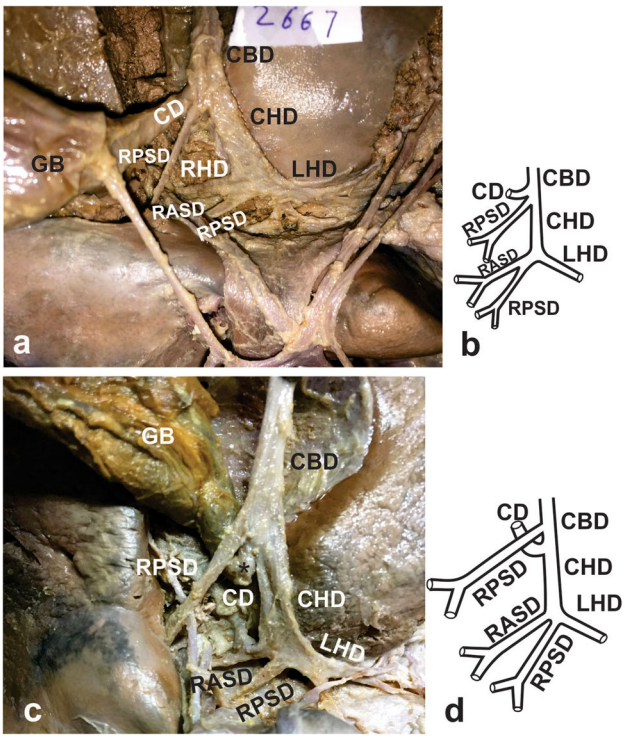

Fig. 4 **a** Double RPSD in case 5 (CBD has been reflected up at the hepatic hilum). A normal RPSD is joining with the RASD to form a RHD. An accessory RPSD is present and opening at the CD/CHD junction. **b** Schematic representation of case 5. **c** Double RPSD in case 6 (CBD has been reflected up at the hepatic hilum). An aberrant RPSD is joining with RASD and LHD at the hepatic hilum (triple confluence) to form a CHD. An accessory RPSD is present and opening into the CBD just distal to CD/CHD junction. **d** Schematic representation of case 6. **CD* cystic duct, *CHD* common hepatic duct, *CBD* common bile duct, *GB* gallbladder, *LHD* left hepatic duct, *RASD* right anterior sectorial duct, *RHD* right hepatic duct, *RPSD* right posterior sectorial duct

Discussion

With the advent of minimally invasive therapeutic biliary interventions and hepatic surgeries, accurate identification and widespread knowledge of intra- and extrahepatic bile duct anatomy has become crucial [3].

The anatomical variability of the biliary system is a common finding with a prevalence of 35–42% [3, 15]. The common biliary anomalies include an accessory hepatic duct, aberrant hepatic duct, a Luschka duct or a subvesical duct. Despite accurate studies on large groups of subjects, there are still some rare hepatic duct variations which are not found in standard classifications. We encountered some highly complicated right hepatic duct confluence, unsuccessful recognition of which can lead to serious biliary complications with increased morbidity and mortality rates during hepatobiliary surgery.

The confluence of aberrant right hepatic duct (ARHD) into extrahepatic bile duct, cystic duct or cystic body has been classified by Hisatsugu et al. [7] (Fig. 5) and followed in various studies. In these reports, the term aberrant and accessory bile ducts were used as synonyms and the drainage of aberrant duct was classified into five types. However, we have used the term aberrant for those hepatic ducts that present abnormal but the only route of drainage of hepatic segments and the term accessory for those hepatic ducts that are additional ducts draining the same area of the liver. We observed Hisatsugu's type 2 (aberrant HD merge at CHD/CD junction) in cases 3 and 5, type 3 (aberrant HD merge with CHD between the RHD/LHD confluence and CD drainage) in case 1, and type 4 (aberrant HD merge distal to CHD/CD junction) in case 6 but in conjunction with other hilar bile duct anomalies. Hisatsugu's types 2, 3 and 4 have been reported in 0.1–0.5%, 4.5–5.7% and 0.2%, ***respectively in the previous studies [7, 10, 13].

In the present study in three cases (cases 1, 3, and 4), D8 instead of draining into RHD crossed the Cantlie's line and the hepatic hilum to drain into LHD. In such cases, one may confuse D8 for segment 4 duct (D4) and thus it becomes important to distinguish D8 from D4. Normally, D4 as observed in cases 1, 3, and 4 drains into LHD near the umbilical fissure and does not reach the hepatic hilum.

The presence of an aberrant RPSD draining into CHD or into CD is one of the most common biliary anomalies with an overall incidence of 1–8% [3, 15]. Kurata et al. [13] and Ohkubo et al. [15] in their study on these aberrant RPSD draining into extrahepatic ducts observed that all these aberrant RPSD were of infraportal type. In another study using CT-cholangiography [11], aberrant RPSD were found in ten cases (5%),nine of which were typical infraportal type while in one case aberrant duct joined CHD on the left side after curving behind the portal vein, although it was unclear whether the aberrant duct of the latter case was infraportal or not. In the present study, aberrant/accessory right hepatic ducts draining below the confluence of RHD and LHD always had an infraportal course whereas those draining above the confluence of RHD and LHD were more commonly of supraportal type. These results suggest that it is very important and useful to preoperatively screen for the course of aberrant RHD in relation to the right branch of PV.

Segmental anatomy of the right hemiliver is more complex than that of left hemiliver and large number of anatomical variations is found in the right hemiliver. Early investigators have divided the right and left hemiliver into two subdivisions, leading to quadripartition of the liver. Hjortsjo in 1951 [8] proposed the right hemiliver to have three sectors. In Hjortsjo's segmental anatomy, the anterior segment of right hemiliver was divided into two areas with a vertical plane in which a hepatic venous branch of middle or right hepatic vein coursed. Recently, Kogure et al. [12] and Fasel and Schenk [5] supported this tripartition concept of Hjortsjo and reclassified the right hemiliver into three vertical segments namely, anterior, middle, and posterior each being supplied by ventral, dorsal, and posterior branches, respectively. The anterior and middle segments correspond to ventral and dorsal regions of Couinauds segments 8 and 5, respectively and posterior segment is equivalent to Couinauds segments 7 and 6. Cho et al. [2] studied the biliary drainage of right hemiliver according to the tripartition concept and observed high variability in the biliary drainage of ventral and dorsal biliary ducts. In their study, ventral and dorsal ducts instead of forming a confluence, drained separately in 25% of the cases. Similarly, in our study, segmental ducts of right anterior sector (D8 and D5) drained separately in cases 1, 3 and 4. Thus, according to the biliary anatomy in these cases, they can be considered as independent segments.

The anatomic variations of the biliary duct are often associated with variations in the portal venous system and the hepatic arterial system. More specifically, portal venous anomalies have been found to be significantly related to the anomalous biliary drainage, especially in the right lobe. In the present study, portal venous anatomy was normal in all cases and there was presence of replaced common hepatic artery from superior mesenteric artery in case 1 and replaced left hepatic artery from left gastric artery in case 6. However,

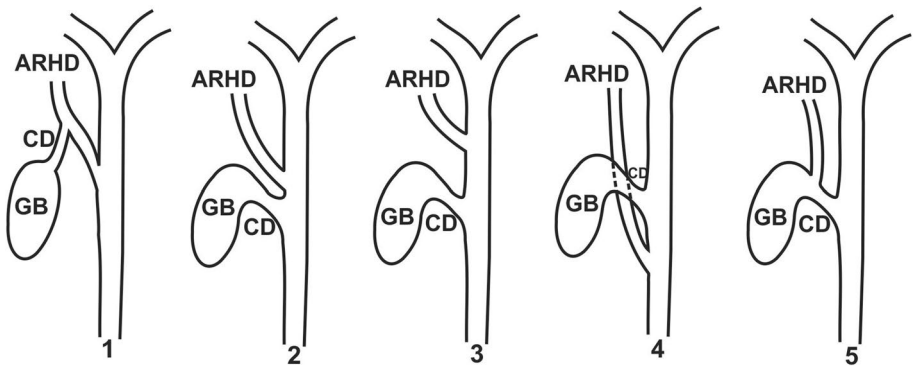

Fig. 5 Schematic representation of Hisatsugu's classification. *ARHD* aberrant right hepatic duct, *CD* cystic duct, *GB* gallbladder

the branching pattern of RHA and LHA in these cases did not display any variation.

Embryologically, the development of distal portion of right and left hepatic ducts takes place by endodermal proliferation of the common hepatic duct which develops from the cranial end of hepatic diverticulum. The common hepatic duct and the distal parts of both hepatic ducts are known to connect to several converging ductules in the hilar mesenchyme, which in turn are in direct communication with the ductal plate. Persistence or variations in the remodeling of these channels explain, in part, the existence of the several normal variants in the configuration of the right and left hepatic ducts with the ''normal'' Y-shaped junction of right and left hepatic ducts with the common hepatic duct being present in only 57% of adults [19]. However, more than one theory exists for the development of the intrahepatic bile ducts. One theory states that the intrahepatic biliary tree is derived from ingrowth of the epithelium of the extrahepatic ducts [6]. The other postulates that the entire intrahepatic biliary system develops from hepatocyte precursor cells which are in contact with the mesenchyme of the portal vein (PV) and form the ductal plates. The ductal plates develop into intrahepatic ducts and proceed from hilum of the liver towards its periphery along the branches of developing portal vein [4]. Thus, PV is thought to behave as a frame for the progressive development of the intrahepatic biliary ducts of the liver. This explains the significant association between the anomalous bile ducts and portal vein variations that has been found previously. However, there is a third theory which states that ingrowth of hepatic diverticulum and formation of ductal plate, both participate in the final formation of biliary anatomy [16]. Extent of contribution by hepatic diverticulum and ductal plate may vary. This can be a possible explanation that BD variation may not always be associated with PV variation.

Biliary complications are an important cause of major morbidity in hepatic tumor resection, with a prevalence of 3.6–8.1% and high associated risks for liver failure and surgical mortality [1]. The complexity of the bile duct confluence and the aberrant right hepatic ducts observed in the present cases can account for the higher prevalence of biliary complications during right-sided hepatectomy and various transplantation procedures. These aberrant right hepatic ducts may undergo accidental transection or ligation resulting in complications including formation of a biliary fistula, biloma, sepsis, pain, and repetitive episodes of cholangitis.

Bile duct injury is one of the most severe complications of laparoscopic cholecystectomy (LC) and its incidence has been reported to be 0.4–0.7% [14]. Anatomical anomaly of the bile duct is one of the common causes of bile duct injury and previous reports revealed that the frequency of bile duct injury in cases with anatomical anomaly of bile duct was 3.2–8.4 times higher than that in cases without it [9]. To eliminate the risk of BD injuries, routine performance of intra-operative cholangiography during cholecystectomy has been proposed by many surgeons. However, others believe that careful dissection of Calot's triangle and exact identification of biliary tree anatomy are sufficient measures to avoid BD injuries. In the present study, the aberrant right hepatic ducts were present close to the cystohepatic angle in cases 3, 4, and 5 and there was anomalous site of insertion of CD in cases 1 and 4. Such anomalies need to be carefully recognized intraoperatively to avoid the BD injury.

The ducts of Luschka are small bile ducts that originate in the gallbladder fossa and drain in the majority of cases in ducts located at the right hepatic lobe. Luschka described them as "slender bile ducts running along the gallbladder fossa, draining into the right hepatic duct or common duct" [18]. The ducts of Luschka are one of the most common causes of bile leakage after cholecystectomies. The prevalence of these ducts is about 4% as reported in a systematic review by Schnelldorfer et al. [17]. In the present study, duct of Luschka draining GB bed into CHD/CD junction was present in 1% cases.

In summary, we present rare and clinically significant anatomic variations of the bile duct. Advancements in hepatobiliary surgeries and liver transplantation procedures require an aggressive pre-operative evaluation of biliary anatomy. Although several methods, like CT or MR cholangiograms, have become the modality of choice for noninvasive evaluation of abnormalities of the biliary tract, they are not routinely used in pre-operative imaging evaluation of patients undergoing common procedures such as laparoscopic cholecystectomy. Thus, a more widespread understanding of biliary anatomy and potential variations is needed for successful, complication-free hepatobiliary surgeries.

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Compliance with ethical standards

Conflict of interest None.

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