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REVIEW

Bile duct confluence: anatomic variations and its classification

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Abstract Accurate knowledge of the anatomy of the bile ducts is critical for successfully hepato-biliary surgery. We describe the anatomical variations of the confluence of the bile ducts, their branches patterns, frequency and classification. From 1996 to 2011, we have collected data of the bile duct confluence. 2,032 and 1,014 anatomical variations of right and left bile ducts, respectively, were reviewed and classified according to the branching pattern. The frequencies of each type of the right hepatic duct (RHD) were as follows: Type A1—1,247 (61.3 %); Type A2—296 (14.5 %); Type A3—272 (13.3 %); Type A4—124 (6.1 %); Type A5—21 (1 %) and others—72 (3.5 %) and, for the left hepatic duct (LHD) was as follows: Type B1—773 (76.2 %); Type B2—153 (15 %); Type B3—38 (3.7 %); Type B4—9 (0.8 %); Type B5—29 (2.8 %) and others—12 (1.1 %). Atypical branching patterns of both the right and left hepatic ducts were found in 14 and 8 %, respectively. The two most common variations of the RHD were right anterior and posterior hepatic ducts join together to form the RHD and trifurcation where the RHD is absent and right anterior and posterior hepatic ducts join directly to the confluence with the LHD to form the common hepatic duct. The two most common variations in the LHD were segment IV drainage to the left and right hepatic ducts.

Keywords Hepatic bile duct · Anatomy · Classification

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Introduction

According to Couinaud [5], the hepatic biliary tract is made up of hepatic ducts that follow a modal disposition identical to that of the portal vein. The common hepatic duct (CHD) is formed from the reunion, at the level of the hepatic vein, of the left hepatic duct supplying segments I to IV and the right hepatic duct supplying segments V to VIII.

On the left side, the segmental duct for segment III receives the duct for segment II, and farther along the duct for segment IV. It then becomes the left hepatic duct (LHD) and receives, at its terminal part, the duct of segment I (sometimes partially empty into terminal part of the right hepatic duct).

The LHD drains segments II, III and IV of the left hemiliver. The so-called normal confluence comprises a duct formed from ducts of segments II and III and one or more ducts from segment IV.

The segment III duct follows the left horn of the Rex *recessus* and joins the segment II duct above the segment II portal branch. For the LHD, this normal anatomy is reported in 82 %. In 4 % of patients, a right sectoral duct can join the LHD (3 % posterior and 1 % anterior) [3].

The right hepatic duct (RHD) is formed from the reunion of the lateral hepatic duct supplying segments VI and VII and the paramedian hepatic duct supplying segments V and VIII. But this modal disposition is only found in 57 % of cases [5]. There are, therefore, many anatomic variants of the convergence of biliary ducts.

The RHD may join the main hepatic duct below the normal confluence in 25 % of the cases (9 % anterior and 16 % posterior). A complete anterior duct was present in 35 % and a complete posterior duct in 61 % [3].

This study describes the anatomic variations of both right and left bile ducts confluence in terms of branching, drainage patterns, frequency and its classification.

Materials and methods

Patient selection

From 1996 to 2011, we have collected data of both right and left bile ducts confluence anatomy and its variations in the literature. 2,032 and 1,014, respectively, right and left anatomy variations were reviewed. We have used anatomical terminology according to Matusz [10].

Anatomic classification

Classification of the RHD anatomy according to Huang et al. [8], Nakamura et al. [11] and Varotti et al. [18] was studied by ERC, IOC, computerized tomography and Doppler ultrasonography, and surgical findings. The biliary tree in the right lobe was classified into six types based on right posterior hepatic duct (RPHD) and right anterior hepatic duct (RAHD) insertion: Type A1—RAHD and RPHD join together to form the right hepatic duct (RHD); Type A2—The RHD is absent and RAHD and RPHD join directly to the confluence with the LHD to form the CHD; Type A3—The RAHD (type 3a) or the RPHD (type 3b) opens directly into the LHD; Type A4—RAHD (type 4a) or the RPHD (type 4b) opens directly into CHD; Type A5—RPHD opens to cystic duct or its periphery aberrantly and others (for instance accessory duct to CHD and to RHD).

The LHD anatomy was classified only, by ERC, according to Huang et al. [8], into six types based on the segment IV insertion: Type B1—segment IV duct opens to left hepatic duct (LHD); Type B2—segment IV opens to CHD separately of the segment II and III duct; Type B3—segment IV opens to RAHP; Type B4—segment IV opens to CHD; Type B5—segment IV opens to segment II duct and others (for instance segments II and III drain individually into the RHD or CHD).

Imaging analysis

The RHD anatomy and their variations were assessed by: endoscopic retrograde cholangiography (ERC)—1,211 (59.5 %); intraoperative cholangiography (IOC)—418 (20.5 %); abdominal ultrasonography with Doppler and/or multi-sliced computed tomography and/or magnetic resonance imaging and/or IOC—124 (6.1 %); IO + operative report—77 (3.7 %). The LHD anatomy and their variations were assessed by: ERC—959 (94.5 %); IOC + 3D reconstruction—55 (5.4 %).

Results

The branches patterns of RHD were classified as one of the six types for both right and left hepatic ducts.

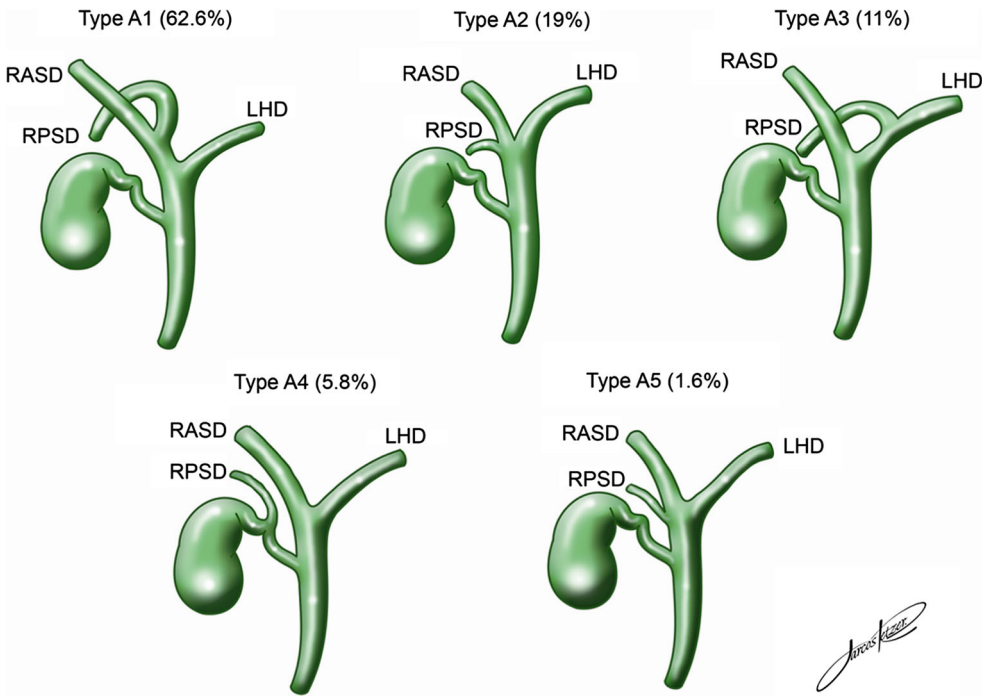

Fig. 1 Huang et al. [8] classification. Right hepatic duct divided into five types according to sectoral bile drainage and its respective frequencies

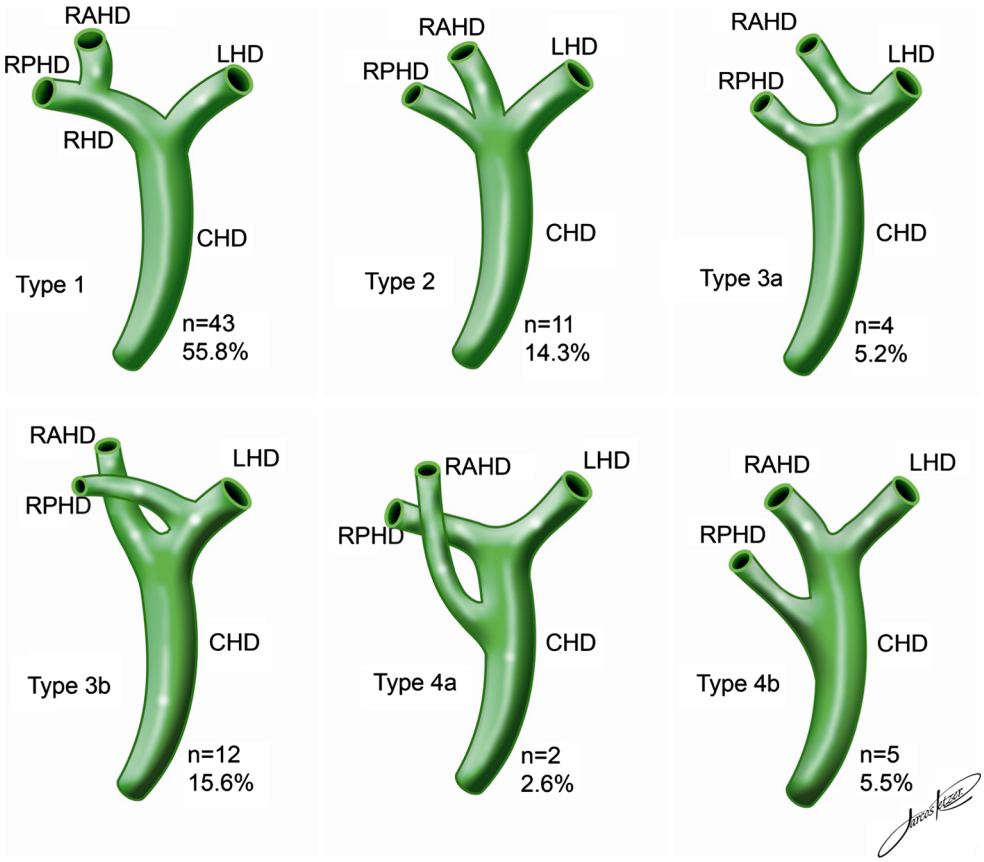

Fig. 2 Classification and respective frequencies of biliary tree anatomy variation according to Nakamura et al. [11] and Varotti et al. [18]. *CHD* common hepatic duct, *LHD* left hepatic duct, *RAHD* right anterior hepatic duct, *RPHD* right posterior hepatic duct

Right bile duct

The frequencies of each type of the 2,032 RHD variations were as follows: Type A1—1,247 (61.3 %); Type A2—296 (14.5 %); Type A3—272 (13.3 %); Type A4—124 (6.1 %); Type A5—21 (1 %) and others—72 (3.5 %), (Figs. 1, 2; Table 1).

Left bile duct

The frequencies of each type of the 1,014 LHD variations were as follows: Type B1—773 (76.2 %); Type B2—153 (15 %); Type B3—38 (3.7 %); Type B4—9 (0.8 %); Type B5—29 (2.8 %) and others—12 (1.1 %), (Fig. 3; Table 2).

Table 1 Right hepatic bile duct anatomic variations classification according to sectoral bile drainage

Right intra-hepatic bile duct anatomic variation	Huang [8] $N = 958$	Nakamura [11] $N = 118$	Choi [4] $N = 293$	Varotti [18] $N = 77$	Ohkubo [12] $N = 110$	Karakas [9] $N = 112$	Sharma [15] $N = 241$	Bageacu [1] $N = 124$	Total $N = 2{,}032$ (%)
Type A1	600	78	188	43	80	61	134	63	1,247 (61.3)
Type A2	182	11	29	11	06	16	29	12	296 (14.5)
Type A3	105	19	34	12	13	24	46	19	272 (13.3)
Type A4	56	10	19	05	05	11	18		124 (6.1)
Type A5	15		06						21 (1.0)
Others			17	06	06		13	30	72 (3.5)

Type A1 RAHD and RPHD join together to form the right hepatic duct (RHD); *Type A2* the RHD (right hepatic duct) is absent and RAHD and RPHD join directly to the confluence with the LHD (left hepatic duct) to form the CHD (common hepatic duct); *Type A3* the RAHD or the RPHD opens directly into the LHD; *Type A4* RAHD or the RPHD opens directly into CHD (common hepatic duct); *Type A5* RPHD opens to cystic duct or its periphery aberrantly

Table 2 Left hepatic bile duct anatomic variations classification according to sectoral bile drainage

Left intra-hepatic bile duct anatomic variations	Huang [8] $N = 959$	Ohkubo [12] $N = 55$	Total $N = 1{,}014$ (%)
Type B1	730	43	773 (76.2)
Type B2	153		153 (15.0)
Type B3	38		38 (3.7)
Type B4	9		9 (0.88)
Type B5	29		29 (2.85)
Others		12	12 (1.18)

Type B1 segment IV duct opens to left hepatic duct; *Type B2* segment IV opens to common hepatic duct separately of the segment II and III duct; *Type B3* segment IV opens to right anterior hepatic duct; *Type B4* segment IV opens to common hepatic duct; *Type B5* segment IV opens to segment II duct

Discussion

Knowledge of bile duct anatomical variations is crucial for surgical procedures such as liver resection, partial liver transplantation and also for minimizing postoperative complications. Many anatomical studies have been conducted to determine the specific hepatic bile duct anatomical variations [2, 9].

Postmortem anatomic studies of the biliary tract, after injection and corrosion, provide precise and reliable information on the anatomy of the biliary tract and its variants, as was clearly shown by Couinaud [5]. However, this method has its limitations. It is difficult to implement and sometimes fragments of biliary tree molds break, making detailed interpretation of biliary tract delicate.

Several preoperative examinations have been proposed to visualize biliary anatomy including ERC, percutaneous trans-hepatic cholangiography, ultrasonography with Doppler, multisliced computer tomography and magnetic resonance imaging [1, 4, 8, 9, 11, 12, 15, 18]. ERC is an invasive investigation requiring a short general anesthesia. Mortality risks are 1 % and morbidity reaches 7 % [14]. It yields high-quality 2D images of biliary tract. Percutaneous trans-hepatic cholangiography is another invasive technique with a high anatomic and diagnostic value despite the fact that flow of contrast medium is not very well seen because of the spatial structure of the biliary tree [19]. Nuclear magnetic resonance cholangiography and intravenous CT cholangiography are non-invasive procedures requiring injection in the biliary tract. It is highly feasible and has very few contraindications and the only limitation is cost [17]. Yeh et al. [20] who compared of all these techniques except oral contrast agent-enhanced CT cholangiography have shown that intravenous CT cholangiography enabled significantly better visualization than the other methods. Our study has shown that 2,170 (71.2 %) right and left anatomy and their variations were assessed by ERC and 495 (16.2 %) by IOC.

Although numerous biliary tract variations have been reported, we have found that they can be classified into five major categories, type A1 to A5, and type B1 to B5, respectively, for right and left bile ducts (Tables 1, 2).

The normal biliary anatomy has been reported to be present in 52.9–58 % of the population [11]. Anomalous drainage of the RPHD into the LHD is described as the most common atypical anatomy with rates from 11 to 15.6 %. The triple confluence and direct drainage of the

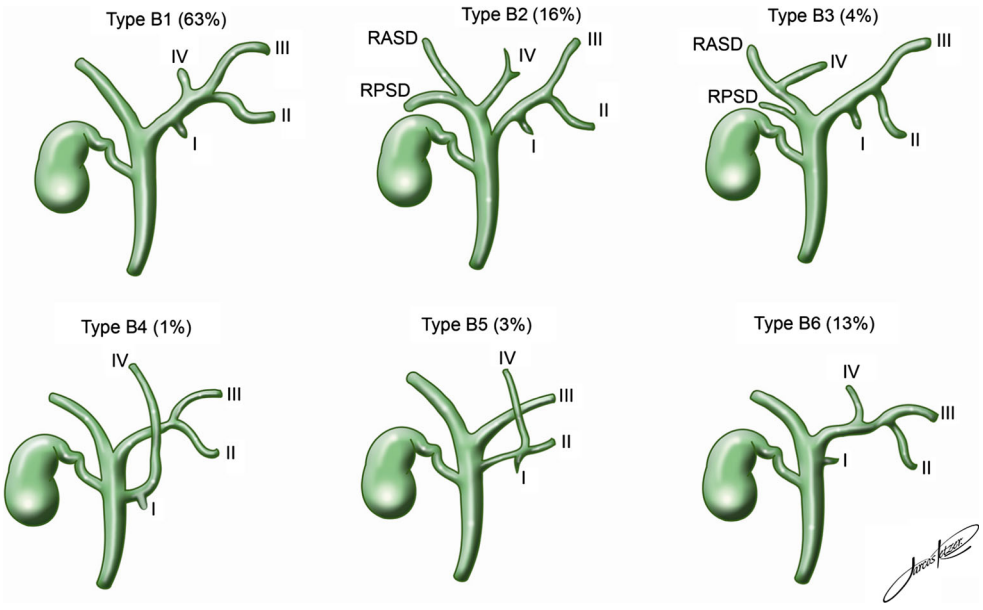

Fig. 3 Huang et al. [8] classification. Left hepatic duct divided into six types according to segmental bile drainage and its respective frequencies

RPHD into CHD have frequencies of 14–19 and 5.5 %, respectively (Figs. 1, 2).

In our findings, almost 90 % of the RHD variations were: Type A1—RAHD and RPHD join together to form the RHD; Type A2—the RHD is absent and RAHD and RPHD join directly to the confluence with the LHD to form the CHD and Type A3—the RAHD or the RPHD opens directly into the LHD. Drainage of the RPHD into LHD before its confluence with RAHD was found to occur in 13–19 % of the population [6]. Huang et al. [8] has found a variant form in 5,8 % in which the RPHD drained into the cystic duct. It has been reported that the incidence of this anatomic variation, known as "cystohepatic ducts", is 1–2 % [3, 16]; in addition, Hamlin [7] reported that in his experience, an anomalous RHD emptying into CHD or cystic duct was the most common biliary anomaly. Reid et al. [13] reported that three of 267 cholangiograms depicted anomalous RHD which emptied into the cystic duct.

Less than 11 % corresponding to type A4, A5 and others such as: RAHD or the RPHD opens directly into CHD and RPHD opens to cystic duct or its periphery aberrantly. In addition, 95 % of the LHD variations were: Type B1—segment IV duct opens to LHD; Type B2—segment IV opens to CHD separately of the segment II and III duct and Type B3—segment IV opens to RAHD.

Less than 5 % corresponding to type B4, B5 and others such as: segment IV opens to CHD and segment IV opens to segment II duct. Anomalous drainage of segment IV into RAHD and in segment II has rates of 4 and 3 %, respectively. The drainage could be much less frequent in the CHD with rates of 1 %. Also segment IV drained independently into RHD and RAHD in 16 and 4 %, respectively [8].

Choi et al. [4] reported that the first branch of the LHD was absent in 1 % of 293 IOC, in whom bile from segment II and III drained independently into RHD and CHD, respectively. Huang et al. [8] reported bile from segment II and segment IV drained independently into CHD in 3 and 1 %, respectively.

Conclusion

Atypical branching patterns of both the right and left hepatic ducts were found in 14 and 8 %, respectively. The two most common variations of the RHD were right anterior and posterior hepatic ducts which join together to form the RHD and trifurcation where the RHD is absent and right anterior and posterior hepatic ducts join directly to the confluence with the LHD to form the common hepatic duct. The two most common variations in the LHD were segment IV drainage to the left and right hepatic ducts.

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