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Review Article

Radiology Section

Magnetic Resonance Cholangiopancreatography in Identifying both Typical and Unusual Variations of Intrahepatic Bile Ducts: A Pictorial Review

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ABSTRACT

Understanding the internal and external liver anatomy is crucial for planning procedures such as liver transplantation, resection, laparoscopic surgeries, complex biliary reconstruction and radiological interventions in the biliary tree. This pictorial review aims to provide a comprehensive visual portrayal of both common and uncommon patterns of biliary tree anatomy in Magnetic Resonance Cholangiopancreatography (MRCP), along with a review of the literature describing the prevalence. The most typical pattern of Right Hepatic Duct (RHD) branching was found in approximately 50-70% of cases, whereas the most common variant involved the Right Posterior Sectoral Duct (RPSD) opening into the Left Hepatic Duct (LHD), followed by a trifurcation pattern. On the left side, in approximately three quarters of cases, the common trunk of the segment II and III ducts joined the segment IV duct, representing the most frequent LHD branching pattern. Cystic duct variations were observed, with the right lateral insertion being the most common in this review. Many complex cases of aberrant and accessory bile ducts were also noted. MRCP serves as a non invasive imaging method to visualise biliary duct morphology, reducing the risk of iatrogenic injuries during hepatobiliary procedures and surgery.

Keywords: Accessory bile ducts, Common trunk, Hepatobiliary procedures, Left hepatic duct

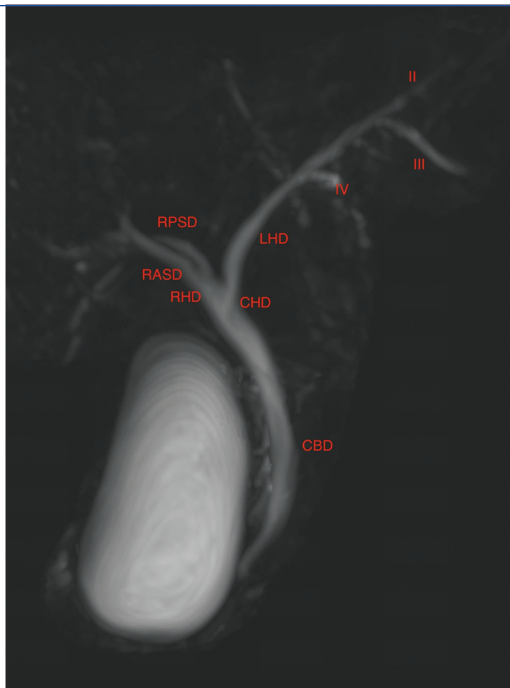
INTRODUCTION

The MRCP has emerged as a highly promising non invasive technique over the past two decades. It plays a crucial role in ensuring the success of various hepatobiliary radiologic interventions and surgical procedures while minimising postoperative complications. A precise understanding of intrahepatic bile duct and pancreatic duct anatomy and variations is essential in this context [1]. MRCP utilises heavily T2-weighted sequences, including modified FS sequences like RARE, HASTE, and FRFSE, using both breath-hold (employing a single-shot approach) and non breath-hold techniques (with respiratory triggering) [2]. Images can be acquired in 2D or 3D, allowing postprocessing manipulation with Multiplanar Reformation (MPR), Maximum Intensity Projection (MIP) and Volume Rendering (VR). Functional assessment of biliary excretion is now possible with hepatobiliary contrast agents like gadobenate dimeglumine and gadoxetic acid [3].

Hepatobiliary surgeries, such as liver transplants, tumour resections, and laparoscopic biliary surgeries, face challenges due to anatomical variations [4]. Normal biliary anatomy involves intrahepatic bile ducts paralleling the portal venous system, with the RHD comprising anterior sectoral (segments 5 and 8) and posterior sectoral ducts (segments 6 and 7), while the LHD formed by segmental tributaries. This typical anatomy is observed in about 57% of the population. These ducts unite to form the Common Hepatic Duct (CHD) [Table/Fig-1] [1].

The purpose of this review was to provide an overview describing the MRCP protocol [Table/Fig-2], while exploring variations in intrahepatic duct branching patterns through a pictorial approach.

Huang TL et al., classified the right intrahepatic ducts into five types [Table/Fig-3] [5]. Karakas HM et al., further included the distance of RPSD insertion from the confluence of the Right Anterior Sectoral Duct (RASD) and LHD [6]. The LHD confluence was classified into three types according to Cho A et al., [Table/Fig-4] [7]. Cystic duct variations are classified according to the direction and site of the cystic duct joining the CHD [Table/Fig-5] [5,7].

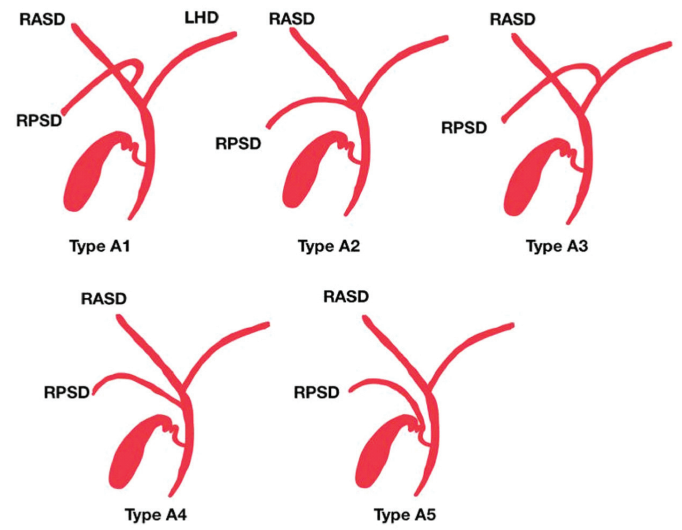


[Table/Fig-1]: Coronal 3D MRCP image showing the normal biliary anatomy. Right anterior and right posterior ducts fuse to form the Right Hepatic Duct (RHD). Primary confluence is formed by the fusion of the RHD and LHDs.
RASD: Right anterior sectoral duct; RPSD: Right posterior sectoral duct; RHD: Right hepatic duct; LHD: Left hepatic duct; CHD: Common hepatic duct; CBD: Common bile duct

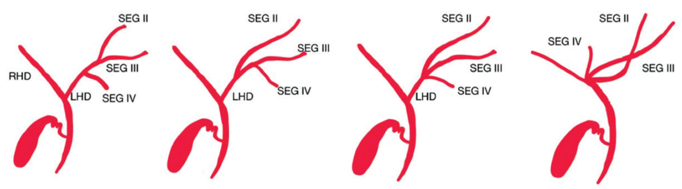
Parameters	T2-weighted breath-hold HASTE (liver down to ampulla)	3D T2-weighted FSE with respiratory triggering	T2 weighted breath-hold HASTE fat-saturated thick slab
TR/TE (ms)	2000/92	2400/702	4,500/735
Number of averages	1	1.5	1
Flip angle	156	105	169
Field of view (mm)	380×309	430×430	269×384
Matrix size	384×384	352×352	384×384

Slice thickness (mm)	5	1.45	40
Slice gap (mm)	1	0	N/A
Number of slices	42	80	1
Acquisition plane	Axial	Coronal oblique	Coronal/radial
Half-Fourier factor	5/8	Phase-encoding: off	Phase encoding: 7/8
		Slice-encoding: 6/8	
Parallel imaging acceleration factor	2	3	2
Receiver bandwidth (Hz/pixel)	68	355	352

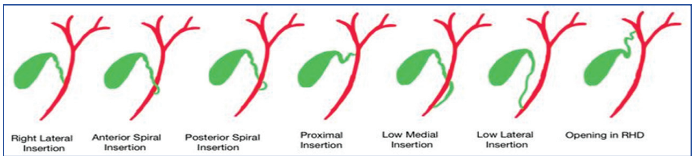
[Table/Fig-2]: Summary of MRCP imaging parameters.
HASTE half: Fourier acquisition single shot turbo spin echo; FSE: Fast spin echo



[Table/Fig-3]: Illustration representing the classification of the Right Hepatic Duct (RHD) according to Huang TL et al., [5].



[Table/Fig-4]: Pictorial diagram showing the variations in the left biliary ductal system according to Cho A et al., [7].



[Table/Fig-5]: Illustration representing the variations of cystic duct insertion.

The typical right hepatic biliary anatomy is encountered in approximately 53-63% of the population [8,9]. Several uncommon variations have been documented; hence, it is crucial to understand the patterns of intrahepatic duct branching and their variants before undertaking procedures such as right or left liver harvesting for living donor liver transplantation, segmental or lobar resection, or biliary interventions. These variations can make surgery more technically challenging and increase the risk of postoperative complications [10].

Similarly, in the widely accepted technique of laparoscopic cholecystectomy, there is a potential for undesirable complications, such as injuries to the Common Bile Duct (CBD) or hepatic bile ducts. These complications can arise when ducts other than the cystic duct are mistakenly clipped or transected, which can be burdensome for patients [10].

Authors have also analysed previous principal studies and summarised the results in [Table/Fig-6,7] [5,6,8-14]. The most common biliary duct branching variation was type III RHD variation [Table/Fig-6,8] [6-12]. In the remaining studies, as mentioned in [Table/Fig-7], type II RHD variation (trifurcation) was more common than type III [Table/Fig-9] [5,13,14]. Trifurcation was observed in approximately 10.3% of patients. These variations have no surgical significance except in left hepatectomy, where ligation of the RPSD may cause biliary cirrhosis of the posterior segments, specifically segment VI and segment VII.

Karakas HM et al., conducted a study on the distance of RPSD insertion in the RHD or LHD from the confluence [6]. It is also important to consistently report the lengths of the RHD and LHD, as well as the distances of the secondary biliary confluences of RASD and RPSD, or the RPSD opening in the LHD or CHD [Table/Fig-10]. This preoperative knowledge plays a crucial role in enabling surgeons to adjust their procedures and assist in biliary anastomosis. It often requires a more intricate microsurgical technique in these cases.

Aberrant or accessory posterior sectoral or segmental ducts from the right lobe to the CHD are occasionally described [Table/Fig-11-13]. During laparoscopic cholecystectomy, accidental dissection or ligation of these ducts can lead to complications such as bile leakage and segmental atrophy.

Regarding LHD variations, the most common LHD confluence was of type I, where the common channel of segments II and III joins with the segment IV duct to form the LHD, accounting for almost 70-80%. These findings align with previous studies [Table/Fig-6,7]. Comprehensive anatomical knowledge of these ducts is crucial before performing segmentectomy for hilar malignancy or left lobar wasting in living donor liver transplants [15].

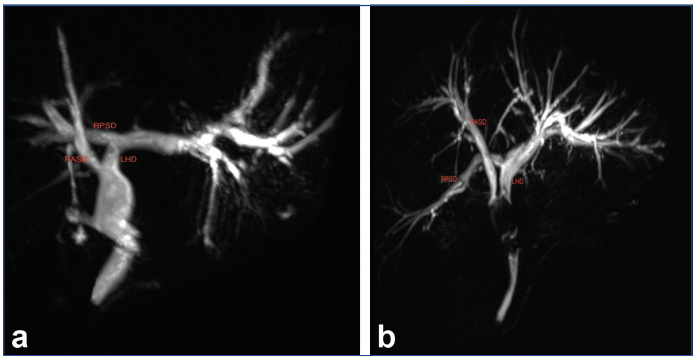
Rarer LHD variations with complex patterns were also encountered, as shown in [Table/Fig-14,15]. The medial insertion of the cystic duct was found to be the most common anatomy in present review. Many other rarer variations that hold special clinical importance in laparoscopic cholecystectomy are also enumerated, including

Previous studies (Authors, References, Years, Total number of cases, Races)		Choi JW et al., [8], 2003 (300 cases of intraoperative cholangiogram)	Ohkubo M et al., [9], 2004 (165 cases of intraoperative findings)	Sharma V et al., [10], 2008, (253 cases of ERCP)	Song GW et al., [11] 2007 (111 cases of MRCP)	Karakas HM et al., [6], 2008 (112 cases of MRI)	Sarawagi et al., [12], 2016, (224 cases)
		Koreans	Japanese	Indian	Korean	Turkish	Indian
Right hepatic biliary anatomy (Huang classification) [5]	Type-I	63	65	52.9	60.4	55	55.3
	Type-II	10	5	11.5	8.1	16	9.3
	Type-III	11	12	18.2	19.8	21	27.6
	Type-IV	6	5	7.1	7.2	10	4
	Type-V	2	-	0	1.8	-	0.8
Left hepatic biliary anatomy (Cho classification) [7]	Type-1	-	78	-	-	-	67.8
	Type-2	-	16	-	-	-	23.2
	Type-3	-	4	-	-	-	3.4

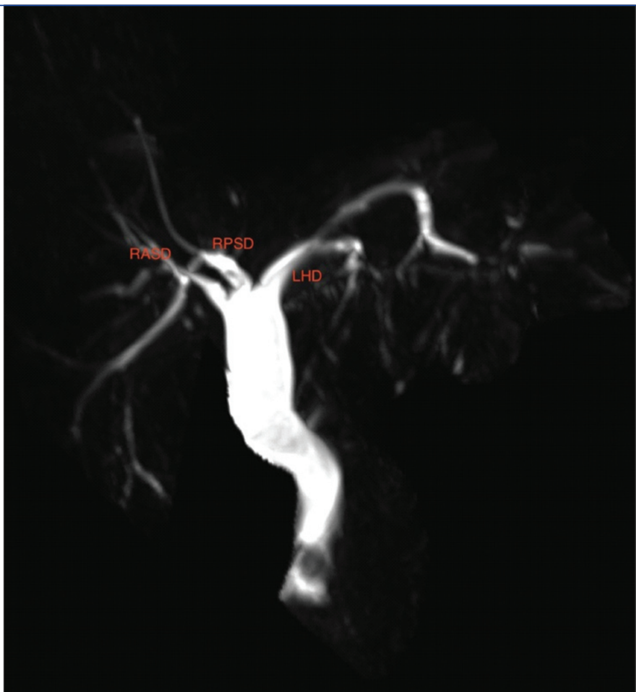
[Table/Fig-6]: The incidence of biliary channels variations as described in previous literature [6,8-12].
Values are presented as percentage. MRCP: Magnetic resonance cholangiopancreatography; MRI: Magnetic resonance imaging; ERCP: Endoscopic retrograde cholangiopancreatography

Previous studies (Authors, References, Years, Total number of cases, Races)		Huang TL et al., [5] 1996	Sureka B et al., [13] 2016	Swain et al., [14] 2020, 1, 038 cases of MRCP Indian population
		Chinese	Indian	Asian Race
Right biliary duct anatomy	Type-I	63	64	72.7
	Type-II	19	5	11.3
	Type-III	11	17 (Type III, IV and V)	9.7
	Type-IV	6	-	5.6
	Type-V	2	-	0.4
Left biliary duct anatomy	Type-1	-	69	90.4
	Type-2	-	20	1.9
	Type-3	-	6	7.7

[Table/Fig-7]: The incidence of biliary channels variations as described in previous literature [5,13,14].



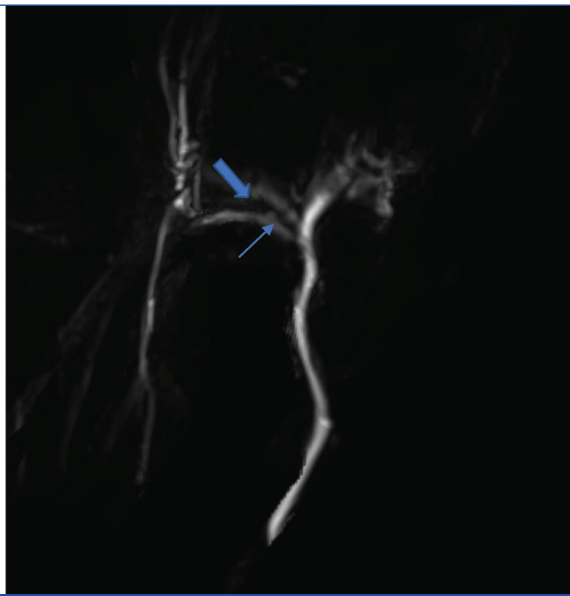
[Table/Fig-8]: a) Coronal 3D MRCP images showing RPSD opening in LHD (type A3) with lower CBD stricture causing mild upstream biliary dilatation; b) Coronal 3D post processed images showing Right Posterior Sectoral Duct (RPSD) opening into Left Hepatic Duct (LHD) about 2 mm proximal to the confluence of RASD and LHD.



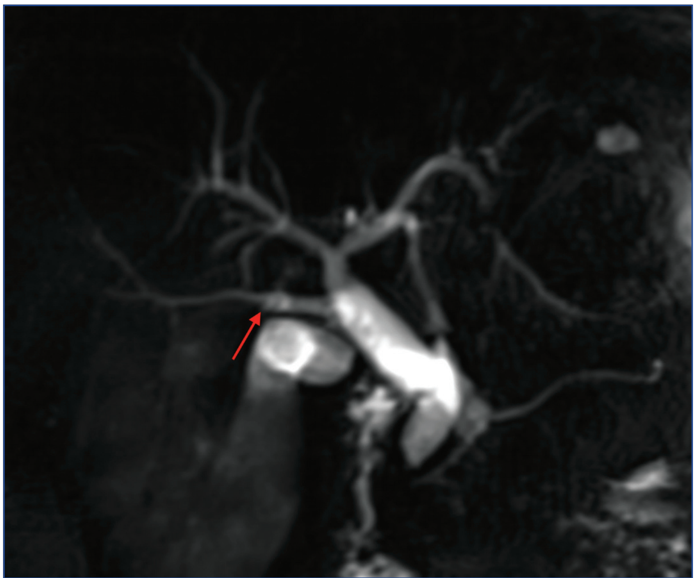
[Table/Fig-9]: A 3D Post processed coronal image showing the common confluence of Right Posterior Sectoral Duct (RPSD), Right Anterior Sectoral Duct (RASD) and Left Hepatic Duct (LHD), suggestive of the trifurcation pattern. Choledocholithiasis seen at distal end of CBD causing upstream biliary dilatation.

cystic duct openings with medial low insertion, at the ampulla, high insertion, or opening in the RHD [Table/Fig-16-19]. Authors also illustrate complex biliary anatomy comprising both RHD and LHD variations [Table/Fig-20].

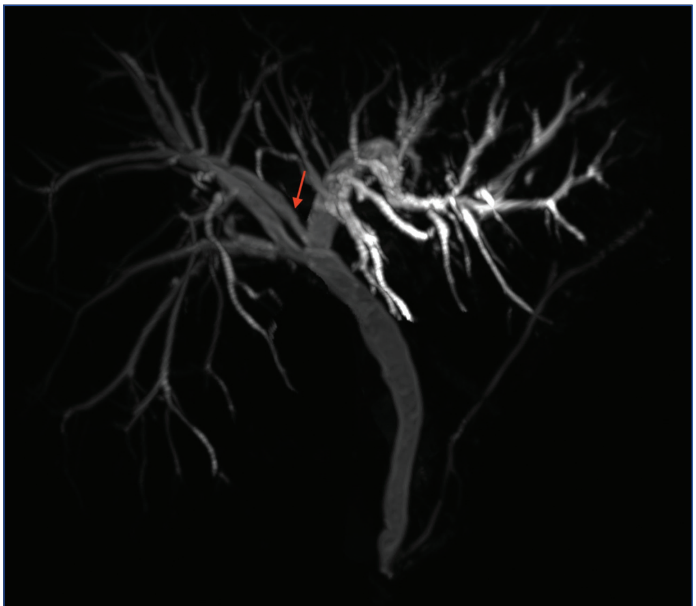
Hepatocyte-specific gadolinium-enhanced MRCP has been shown to provide more accurate delineation of bile duct anatomy. However, its limited availability, cost, longer acquisition time and potential risk of contrast-induced adverse reactions are notable drawbacks [12].



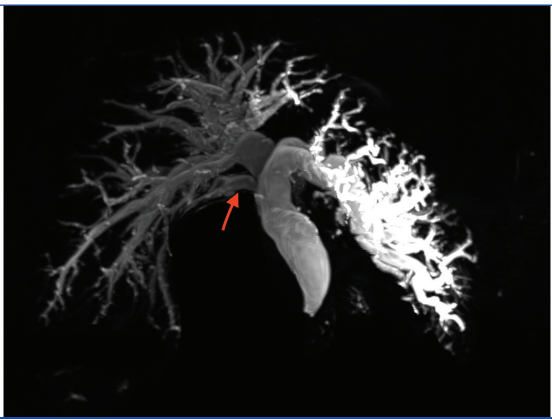
[Table/Fig-10]: Coronal 3D image showing RPSD (blue arrow) opening in CHD about 2.2 mm below the primary confluence formed by RASD (thick blue arrow) and LHD.



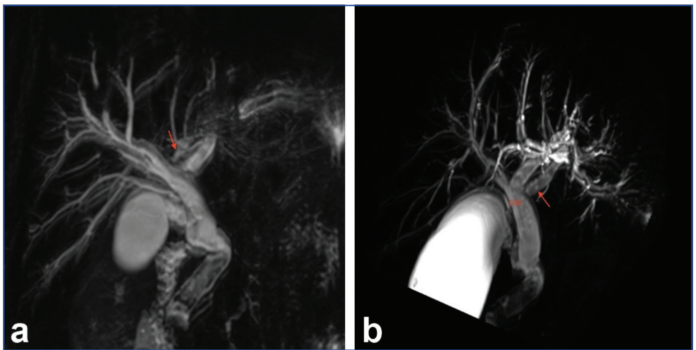
[Table/Fig-11]: A 3D post processed coronal images. This is a case of distal CBD inflammatory stricture with mildly prominent CBD and IHBR. An accessory duct (red arrow) arising from segment VII is seen opening in CHD at a distance of 12 mm from primary biliary confluence.



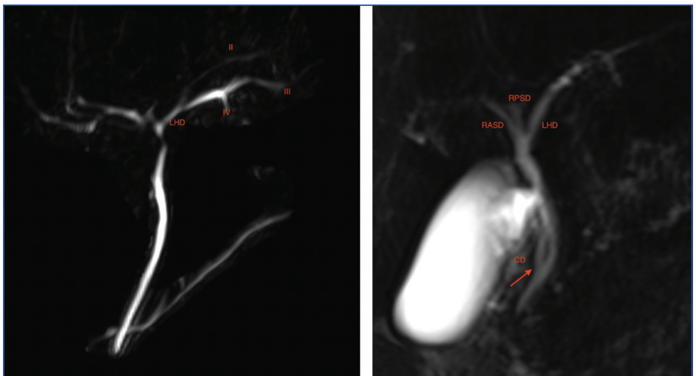
[Table/Fig-12]: A 3D post processed coronal images showing aberrant duct of segment VII (red arrow) opening into Left Hepatic Duct (LHD) just before the primary biliary confluence.



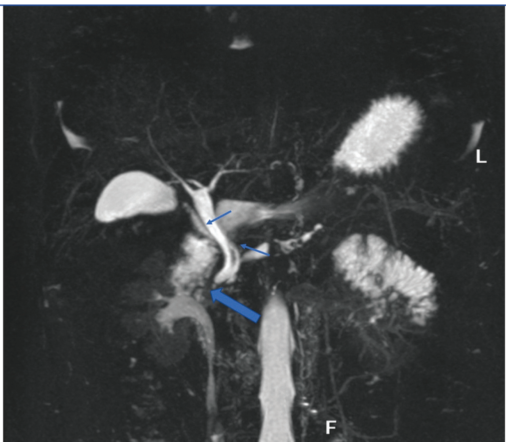
[Table/Fig-13]: A 3D post processed coronal images. This is a case of pancreatic head mass causing upstream biliary dilatation. There is an accessory duct arising from segment VI (red arrow) opening into the CHD about 6 mm below the primary confluence.



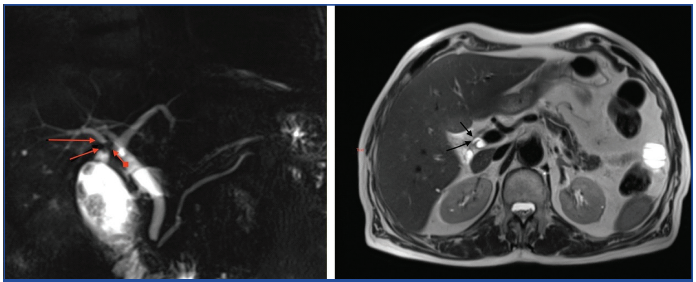
[Table/Fig-14]: a,b) A 3D post processed coronal images of the same patient with slight rotation showing Left Hepatic Duct (LHD) variations. In a case of choledocholithiasis, dilated intrahepatic biliary radicles are seen.
There is suspicious opening of the segment III duct (red arrow in both 14a and 14b) in RHD with primary biliary confluence formed by RHD and union of segment II/IV duct.



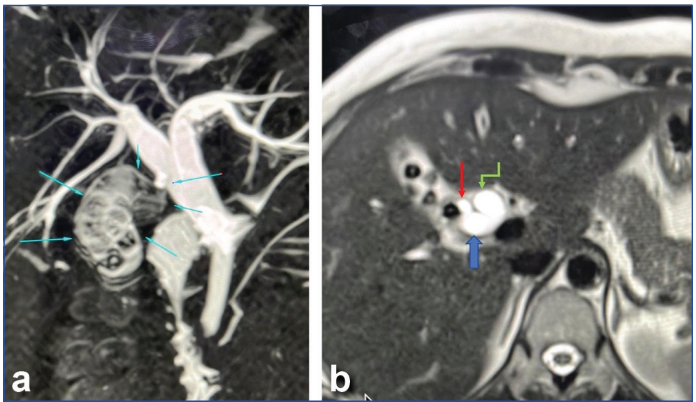
[Table/Fig-15]: A 3D post processed coronal images showing Left Hepatic Duct (LHD) variation. Segment III and IV forming a common duct with segment II draining in the common duct and forming LHD. **[Table/Fig-16]:** A 3D post-processed coronal images showing low confluence of CHD and cystic duct with cystic duct opening along the medial aspect of lower 1/3rd of common duct (red arrow). There is also a trifurcation pattern seen. (Images from left to right)



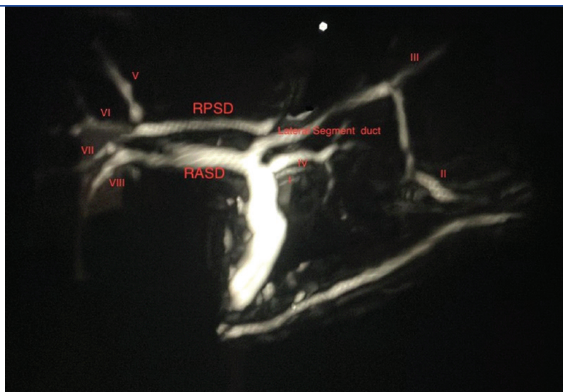
[Table/Fig-17]: A 3D post processed coronal images showing opening of cystic duct (thin blue arrow) at ampulla of vator (thick blue arrow).



[Table/Fig-18]: A 3D post processed coronal images and axial T2Wt images of the same patient posted for liver transplant showing high insertion of cystic duct in both the images (red and black arrows) in proximal CHD/at primary biliary confluence.



[Table/Fig-19]: A 3D post processed coronal: (a) Images showing choledocholithiasis (blue arrow) and (b) Axial T2 Wt images showing cystic duct insertion (red arrow) in Right Hepatic Duct (RHD) (thick blue arrow) just at the confluence (green arrow) in the same patient.



[Table/Fig-20]: A 3D post processed coronal images showing a complex biliary anatomical variant. Bile duct formed by fusion of segment II and III is opening into the Right Posterior Sectoral Duct (RPSD). Bile duct formed by the lateral segments duct and RPSD is confluencing with Right Anterior Sectoral Duct (RASD) to form the primary biliary confluence. Segment IV bile duct is opening into the proximal end of the CHD just below the primary biliary confluence.

CONCLUSION(S)

This review principally highlights the diverse anatomical variations in biliary passages through a comprehensive pictorial review, emphasising the importance of MRCP as a non invasive tool for evaluating biliary disease, providing preoperative imaging in complex hepatic surgeries, assessing liver donors and conducting biliary interventions. Awareness of these variations is essential to prevent iatrogenic injuries and reduce postoperative morbidity and mortality.

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