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Evaluation of intrahepatic and extrahepatic biliary tree anatomy and its variation by magnetic resonance cholangiopancreatography in Odisha population: a retrospective study

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Abstract: Intrahepatic and extrahepatic anatomical knowledge is essential for pre procedural planning of liver transplantation, liver resection, complex biliary reconstruction and radiological biliary tree intervention. Indian data of biliary anatomy and its variation is scant in literature. The aim of our study is to find out the prevalence of common and uncommon pattern of biliary tree anatomy in magnetic resonance cholangiopancreatography (MRCP) in our population. A total of 1,038 cases of MRCP of population of Odisha were obtained from Picture Archiving and Communication System of the department and were reviewed by two senior radiologists for anatomical pattern and variations. The typical and most common pattern of right hepatic duct (RHD) branching was seen in 72.8% cases. The most common variant of RHD was trifurcation pattern of insertion of right anterior sectoral duct (RASD), right posterior sectoral duct and left hepatic duct (LHD) forming common hepatic duct (CHD) in 11.3% of cases. The common trunk of segment (SEG) II and III ducts joining the SEG IV duct was the most common LHD branching pattern in 90.3% of cases. The most common pattern of cystic duct was posterior insertion to middle third of CHD (42.8%). MRCP is the non-invasive imaging modality for demonstration of biliary duct morphology to prevent iatrogenic injury during hepatobiliary intervention and surgery.

Key words: Magnetic resonance imaging, Anatomic variation, Bile ducts, Intraheaptic, Cholangiography

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Introduction

Knowledge of complex biliary anatomical variation is crucial before hepatobiliary intervention such as laparoscopic cholecystectomy, living donor liver transplantation, hepatic tumor resection and therapeutic biliary drainage [1, 2]. MRCP is the preferred non-invasive imaging modality for biliary anatomy evaluation as it is safe and is not associated with ionising radiation. High resolution cross-sectional, two dimensional and three dimensional (3D) projection imaging is possible for detailed anatomy which is comparable to endoscopic retrograde cholangiography (ERCP) and intraoperative cholangiograms [3, 4]. The individual biliary channels run parallel to portal veins. Liver is divided into eight functional independent segments (SEGs) (I to VIII SEG) based on Couinaud classification. SEGs VI and VII are drained by right posterior sectoral duct (RPSD) which is oriented horizontally and SEG V and VIII are drained by vertically oriented right anterior sectoral duct (RASD). The right hepatic duct (RHD) is formed by

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union of RPSD and RASD. The RPSD joins the RASD from left medial aspect. Sectoral ducts of SEGs II, III and IV fuse to form left hepatic duct (LHD). The bile duct from caudate lobe drains to origin of right or LHD. RHD and LHD join to form common hepatic duct (CHD). The cystic duct (CD) usually joins the middle third of CHD after the union of RHD and LHD. About 58% of population shows normal biliary anatomy [5].

We carried out the study to look for the normal and variation of biliary ducts anatomy with their prevalence in our state, Odisha which is located in eastern part of India with Asian race of population.

Materials and Methods

The present study was a retrospective analysis of 1,038 cases of MRCP done in our institution from January 2016 to July 2019, which included 532 males and 506 females with the age range of 2 to 96 years. The studies were done in 1.5T magnetic resonance imaging (MRI) machine (1.5T system, GE Signa; GE Healthcare, Fairfield, CT, USA) using body coil for the acquisition of the images. MRCP were done utilizing time of relaxation (TR)-8,000 ms; time of excitation (TE)-800 ms; flip angle 90 degrees; field of view (FOV) 250–300 mm; 40 mm thick oblique coronal slices at 0.4-mm interval on breath hold. Respiratory gated 3D images were obtained utilizing TR-1,204 ms; TE-650 ms; flip angle 90 degrees; FOV 280. The 3D MRCP, coronal and axial MRI images extracted from Picture Archiving and Communication System were analyzed by two senior radiologists. Our classification of RHD variations was similar to Huang et al. [6] (Table 1). However, we added another type-VI which included as unclassified type. The LHD variation was similar to Cho et al. [7]. We classified the CD variation according to direction and site of CD joining the CHD (Table 1) [6, 7]. The low insertion of CD indicates the joining of CD with distal third CHD and proximal insertion of CD indicates the joining of CD with proximal third CHD close to primary confluence. The data was analyzed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Co., Armonk, NY, USA). Values were expressed in percentages. The study was carried out after institutional research board and ethical committee approval.

Table 1. Classification of RHD variations (Huang et al. [6]), LHD variation (Cho et al. [7]) and CD variation and their incidence in our study along with its distribution in male and female cases

Patterns of right and left biliary duct and cystic duct		No. of cases	No. of male	No. of female
Type of right side biliary duct anomaly (Huang et al. [6] type)				
Type-I	RPSD drains into the RASD	756 (72.8)	400 (38.5)	356 (34.3)
Type-II	Trifurcation pattern of insertion of RPSD, RASD, and LHD	117 (11.3)	53 (5.1)	64 (6.2)
Type-III	RPSD drains into LHD	100 (9.6)	50 (4.8)	50 (4.8)
Type-IV	RPSD drains into the CHD	59 (5.7)	26 (2.5)	33 (3.2)
Type-V	RPSD drains into the CD	4 (0.4)	2 (0.2)	2 (0.2)
Type-VI	Unclassified, one case of CD and RASD joining the CHD, one case of RHD drains to CD	2 (0.2)	1 (0.1)	1 (0.1)
Type of left LHD variation (Cho et al. [7] type)				
Type-1	SEG II and III ducts join to form a single lateral segmental duct with one or two SEG IV ducts opening into this and forming LHD	937 (90.3)	476 (45.9)	461 (44.4)
Type-2	SEG II duct joins the common trunk of SEG III and IV to form the LDH	20 (1.9)	10 (1.0)	10 (1.0)
Type-3	SEG II, III, and IV ducts joins together to form LHD	80 (7.7)	45 (4.3)	35 (3.4)
Unclassified type	SEG II and common trunk of SEG III and IV joins separately to RHD	1 (0.1)	1 (0.1)	0 (0.0)
Type of CD variation (according to present study classification)				
Type-A	Anterior spiral insertion with middle third of CHD	140 (13.4)	76 (7.3)	64 (6.2)
Type-B	Medial spiral CD insertion with middle third of CHD	1 (0.1)	0 (0.0)	1 (0.1)
Type-C	Posterior spiral insertion with middle third CHD	444 (42.8)	204 (19.7)	240 (23.1)
Type-D	Right lateral insertion of CD with middle third of CHD	408 (39.3)	232 (22.4)	176 (17)
Type-E	Low medial insertion of CD with distal third of CHD	35 (3.3)	17 (1.6)	18 (1.7)
Type-F	Low lateral insertion of CD with distal CHD	1 (0.1)	0 (0.0)	1 (0.1)
Type-G	Proximal insertion of CBD into proximal third of CHD	7 (0.7)	2 (0.2)	5 (0.5)
Type-H	CD joins the RHD (CD-RHD)	1 (0.1)	0 (0.0)	1 (0.1)
Type-I	Unclassified pattern, CD drains to RASD (CD-RASD)	1 (0.1)	1 (0.1)	0 (0.0)

Values are presented as number (%). RHD, right hepatic duct; LHD, left hepatic duct; CD, cystic duct; RPSD, right posterior sectoral duct; RASD, right anterior sectoral duct; CHD, common hepatic duct; SEG, segment.

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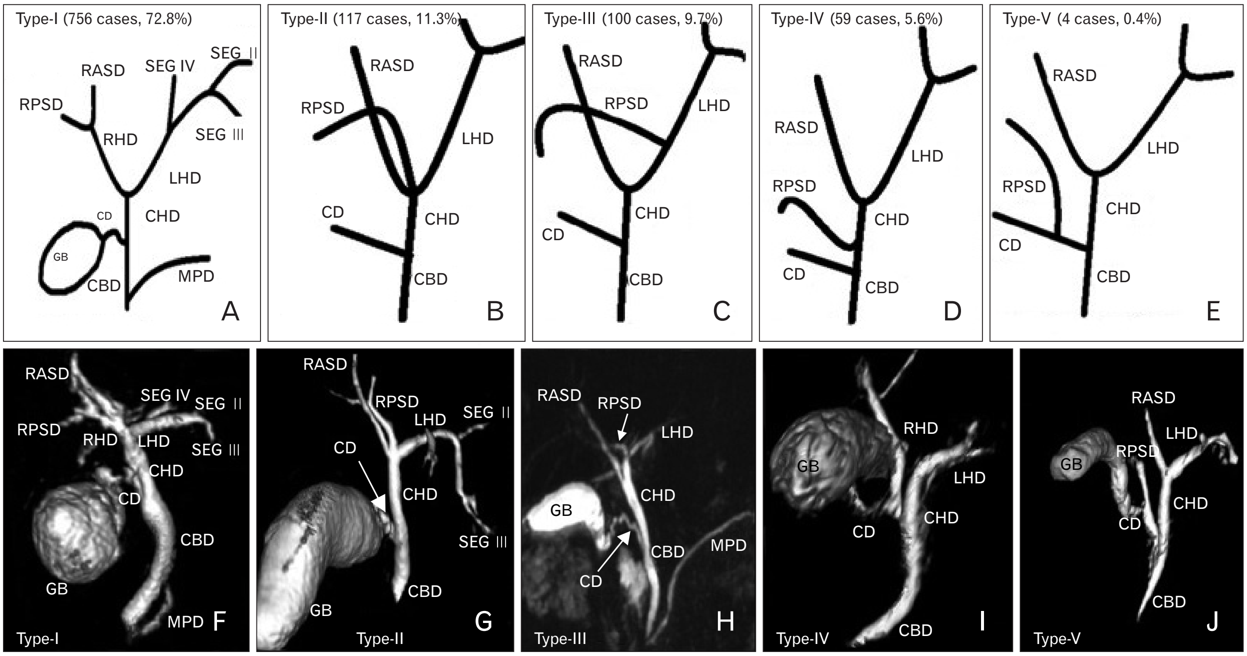

Fig. 1. Right hepatic biliary duct branching pattern (Huang et al. [6] type); Upper row images (A–E) of the figure show schematic picture of right biliary duct pattern from type-I to type-V with number of cases and frequency in each type. Lower row images (F–J) of the figure show corresponding MRCP images of type-I, II, III, IV, and V pattern of biliary duct branching. Typical branching pattern (A, F), trifurcation pattern (B, G), drainage of RPSD to LHD (C, H), drainage of RPSD to CHD (D, I) and drainage of RPSD to CD (E, J) are shown in images. RPSD, right posterior sectoral duct; RASD, right anterior sectoral duct; RHD, right hepatic duct; SEG, segment; LHD, left hepatic duct; CHD, common hepatic duct; CD, cystic duct; GB, gall bladder; CBD, common bile duct; MPD, main pancreatic duct.

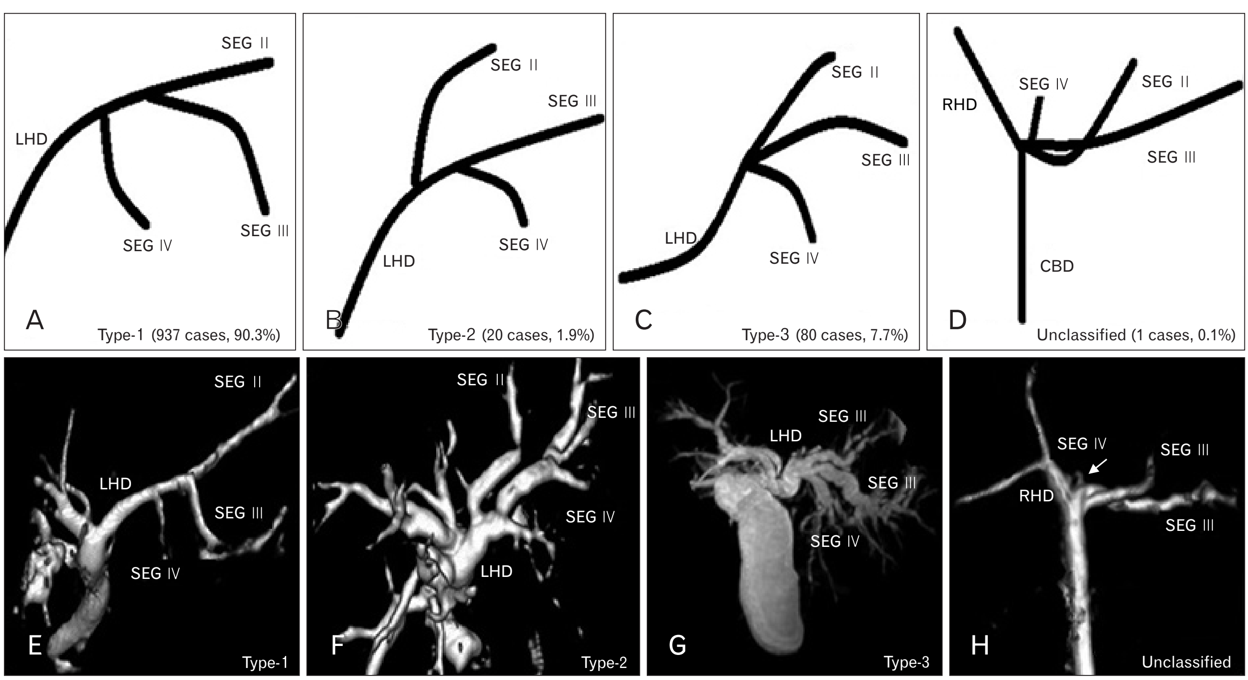

Fig. 2. Left hepatic biliary duct branching pattern (Cho et al. [7] type); A to D images show schematic picture of type-1, 2, 3, and unclassified pattern of LHD branching with number of cases and frequency of each type. Corresponding MRCP images are shown in image E to H respectively. Image H shows joining of SEG II and common trunk of III and IV to the right hepatic duct. LHD, left hepatic duct; SEG, segment; RHD, right hepatic duct; CBD, common bile duct.

Results

Total 1,038 MRCP were studied. The mean age of cases was 48.98±17.26 year. A 532 cases (51.3%) were males while 506 cases (48.7%) were females. In the group of right sided biliary duct variation (according to Huang classification), type-I (typical) branching pattern was noted in 756 cases (72.8%), type-II in 117 cases (11.3%), type-III in 100 cases (9.6%), type-IV in 59 cases (5.7%), and type-V in 4 cases (0.4%) (Fig. 1) [6]. Type-1, 2, and 3 LHD branching pattern (according to Cho et al. [7]) were noted in 937 cases (90.3%), 20 cases (1.9%), and 80 cases (7.7%) respectively (Fig. 2). One unclassified type was seen where the SEG II duct and common duct of SEG III and IV join the RHD separately (Fig. 2) [7]. We classified the types of CD variation as mentioned in the Table 1 [6, 7]. CD variations were seen with anterior spiral insertion in 140 cases (13.4%), medial insertion in one case (0.1%), posterior spiral insertion in 444 cases (42.7%), right lateral insertion in 408 cases (39.3%), low medial insertion in 35 cases (3.4%), low lateral parallel insertion in one case (0.1%), proximal insertion of CD in 7 cases (0.7%), drainage of CD into RHD in one case (0.1%) and to RASD in one case (0.1%). Right anterior accessory duct was seen draining into anterior aspect of CHD in one case (0.1%) (Figs. 3 and 4).

Discussion

The typical right hepatic biliary anatomy has been re-

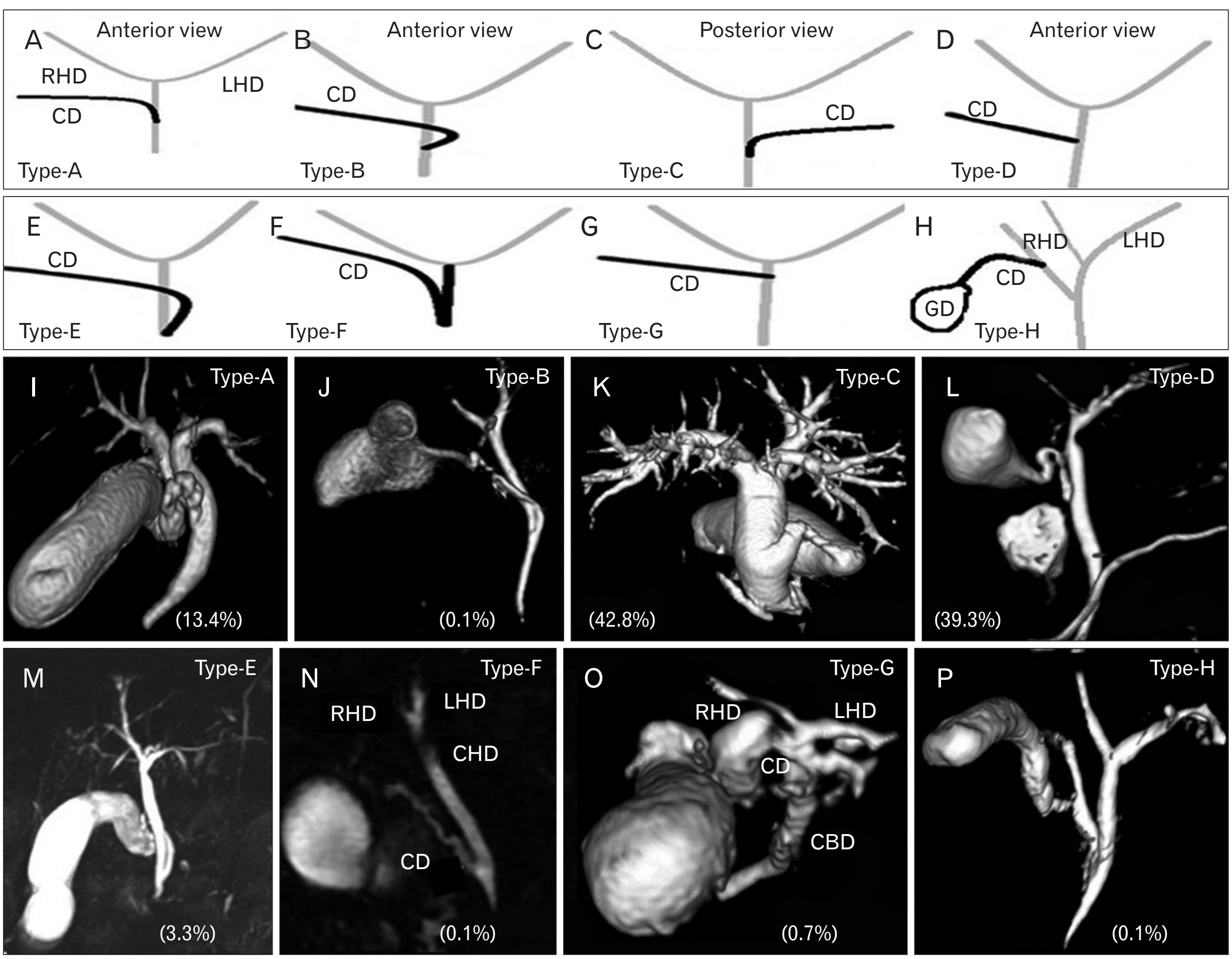

Fig. 3. Cystic ductal anatomical pattern: Images from A to H show schematic diagram of types of CD insertion (from type A to type H). Images from I to P show corresponding magnetic resonance cholangiopancreatography images of CD insertion pattern with frequency. Anterior spiral insertion (A, I), medial spiral insertion (B, J), posterior spiral insertion (C, K), right lateral insertion (D, L), low medial insertion (E, M), low lateral insertion (F, N), proximal insertion (G, O) of CD to CHD are shown in figures. One case of CD insertion to RHD is shown in image H and P. RHD, right hepatic duct; CD, cystic duct; LHD, left hepatic duct; GB, gall bladder; CHD, common hepatic duct.

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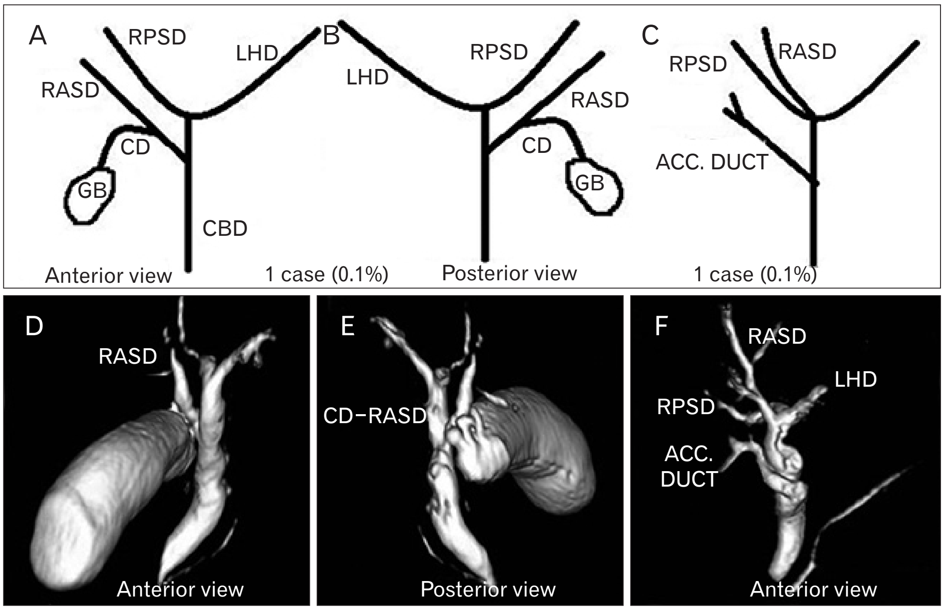

Fig. 4. Unclassified pattern of biliary anatomy: Schematic and magnetic resonance cholangiopancreatography images show type-I unclassified CD insertion pattern ie CD insertion to right anterior sectoral duct (anterior view in A and D, posterior view in B and E), drainage of right anterior accessory duct to anterior aspect of CHD (C, F). RASD, right anterior sectoral duct; RPSD, right posterior sectoral duct; LHD, left hepatic duct; CD, cystic duct; GB, gall bladder; CBD, common bile duct; ACC. DUCT, right anterior accessory duct; CD-RASD, cystic duct junction to the RASD.

Table 2. The incidence of biliary channels variations as described in previous literature

Previous studies (authors, references, years, total number of cases, races)	Right biliary duct anatomy					Left biliary duct anatomy		
	Type-I	Type-II	Type-III	Type-IV	Type-V	Type-1	Type-2	Type-3
Puente et al. [9], 1983 (3,845 cases of cholangiogram), Chileans	57.6	11.1	12.9	4.6	-	-	-	-
Huang et al. [6], 1996, unknown, Chinese	63	19	11	6	2	-	-	-
Couinaud et al. [10], 1975, not known	57	12	16	4	2	-	-	-
Yoshida et al. [11] 1996 (1,094 cases direct cholangiogram), Japanese	67.7	17.7	8	6	0.1	-	-	-
Choi et al. [15], 2003 (300 cases of intraoperative cholangiogram), Koreans	63	10	11	6	2	-	-	-
Ohkubo et al. [12], 2004 (165 cases intraoperative findings), Japanese	65	5	12	5	-	78	16	4
Song et al. [13], 2007 (111 cases of MRCP), Korean	60.4	8.1	19.8	7.2	1.8	-	-	-
Karakas et al. [14], 2008 (112 cases of MRI), Turkish	55	16	21	10	-	-	-	-
Cho et al. [7], 2003 (27 cases), Japanese	-	-	-	-	-	59	30	11
Sharma et al. [16] 2008 (253 cases ERCP), Indian	52.9	11.5	18.2	7.1	0	-	-	-
Sarawagi et al. [17], 2016 (224 cases), Indian	55.3	9.3	27.6	4	0.8	67.8	23.2	3.4
Surekha et al. [8], 2016, unknown, Indian	64	5	17 (type III, IV, and V)			69	20	6
Taghavi et al. [18], 2017 (362 cases ERCP evaluation), Iranian	45	21.5	13.3	3.6	0	-	-	-
(Present study) 1,038 cases of MRCP, Indian population, Asian race	72.7	11.3	9.7	5.6	0.4	90.4	1.9	7.7

Values are presented as percentage. MRCP, magnetic resonance cholangiopancreatography; MRI, magnetic resonance imaging; ERCP, endoscopic retrograde cholangiography.

ported to occur in 55% to 67% in larger population studies [9, 11]. We found about 72.8% of typical right biliary anatomy in our study. No complete classification of biliary anatomy is present. Different classifications of biliary anatomy have been proposed as there are many variation of biliary anatomy [6]. It is essential to know the complex SEGal hepatic biliary anatomy for staging and localization of intrahepatic liver neoplasms or bile duct tumors, hepatic lobectomy or segmentectomy, complex interventional biliary procedures and before cholecystectomy to prevent complications due to unwanted biliary duct injury [5]. The most common biliary duct branching variation was trifurcation pattern (Type-II, 11.2%) followed by union of RPSD to LHD (Type-III, 9.7%) in our study. This finding is comparable to few of the previous studies [6, 8, 11, 18]. In rest of the studies as mentioned in the Table 2, Type-III RHD variation was more common than type-II pattern [7, 9, 10, 12-17]. Above two variations have no surgical significance except in left hepatectomy, where ligation of RPSD may cause biliary cirrhosis of SEG VI and VII [9].

Type-1 (90.3%) was the most common type LHD confluence pattern in which the common channels of SEG II and III joins the SEG IV biliary duct of liver. Type-2 and 3 are seen in 1.9% and 7.7% of population respectively. Type-1 (one) pattern was seen in 59% to 78% population in previous studies [8, 12, 15, 17]. However, type-3 pattern of LHD was the second most common pattern in our study unlike previous studies.

The CD shows extreme variable course and levels of union with CHD. No standard classification of CD variation was described in literature. CD anatomy can be evaluated by ultrasonography, computed tomography, direct cholangiography, MRCP and cholescintigraphy. MRCP provides better imaging evaluation of CD noninvasively. Anatomic variants of the CD are common and are usually of no clinical significance [20]. However proper interpretation of CD anatomy and variation is required to understand the disease process, prevent the iatrogenic injury and for medicolegal purpose in case of post-operative complications [21]. In our study, we classified the CD variation into 9 types (type-A to I). The most common type of CD pattern was posterior insertion of CD over middle third of CHD (42.8%) followed by right lateral insertion (39.3%) in our study. Sarawagi et al. [17] found posterior CD insertion as the most common variant in 20.2% cases followed by medial spiral insertion of CD (16.1%). Surekha et al. [8] found medial insertion of CD variation as most common variation in 10% to 17% cases. Hussein et al. [19] found right lateral insertion in 75% of cases out of 238 cases. We did not find any case of double CDs, short CD or any fusiform dilation of CD in our study. No accessory duct from liver to gall bladder was seen.

In addition to normal biliary classification, many unclassified complex anatomy cases have been found in different studies. We found three unclassified pattern. In first case, CD is seen draining into RASD. Right anterior accessory duct is seen joining on anterior aspect of CHD in second case. Left SEG II duct and common duct of SEG III and IV were seen joining the RHD separately in third case (Figs. 2 and 4).

What this study adds to existing knowledge?

This study included larger number of cases and reported anatomical pattern and variation of right, left biliary ducts and CD in population of Odisha which has not been reported before. Most of the recent literatures included part of hepatic biliary anatomy with less number of cases. We found complex unclassified new anatomical variation of biliary channels which were reported rarely.

Limitation of our study was that there was no comparison of the MRCP finding with intraoperative cholangiogram. Thin collapsed segmental biliary duct without bile may not be seen in non-enhanced MRCP. Multicentre larger study is required to determine the prevalence of biliary tract anomaly more accurately in India.

In conclusion, in summary, atypical branching patterns of right hepatic biliary channels were found in 27.2% of MRCP belonging to population of Odisha. The two most common variations of right hepatic biliary anatomy were trifurcation pattern of insertion of the RASD, RPSD, and LHD followed by RPSD draining directly into the LHD. Common confluence of SEG II, III and IV ducts joins together to form LHD was the common LHD anatomical variation. Posterior spiral insertion of CD with middle third CHD was the most common pattern of CD union with CHD. Knowledge of intrahepatic and extrahepatic biliary variations is useful for planning of hepatobiliary surgery and radiological biliary intervention.

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Data analysis or interpretation: RKS, MKG, SSP, RD. Drafting of the manuscript: KKS, RKS. Critical revision of the manuscript: RKS, MKG. Approval of the final version of the manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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References

1. Hashimoto M, Itoh K, Takeda K, Shibata T, Okada T, Okuno Y, Hino M. Evaluation of biliary abnormalities with 64-channel multidetector CT. Radiographics 2008;28:119-34.
2. Güngör F, Sür Y, Gür EÖ, Dilek ON. A rare anatomical variation of the bile ducts: Cystic duct draining to the right hepatic duct. Turk J Gastroenterol 2019;30:375-6.
3. Hekimoglu K, Ustundag Y, Dusak A, Erdem Z, Karademir B, Aydemir S, Gundogdu S. MRCP vs. ERCP in the evaluation of biliary pathologies: review of current literature. J Dig Dis 2008; 9:162-9.
4. Xu YB, Bai YL, Min ZG, Qin SY. Magnetic resonance cholangiography in assessing biliary anatomy in living donors: a meta-analysis. World J Gastroenterol 2013;19:8427-34.
5. Mortelé KJ, Ros PR. Anatomic variants of the biliary tree: MR cholangiographic findings and clinical applications. AJR Am J Roentgenol 2001;177:389-94.
6. Huang TL, Cheng YF, Chen CL, Chen TY, Lee TY. Variants of the bile ducts: clinical application in the potential donor of living-related hepatic transplantation. Transplant Proc 1996;28: 1669-70.
7. Cho A, Okazumi S, Yoshinaga Y, Ishikawa Y, Ryu M, Ochiai T. Relationship between left biliary duct system and left portal vein: evaluation with three-dimensional portocholangiography. Radiology 2003;228:246-50.
8. Sureka B, Bansal K, Patidar Y, Arora A. Magnetic resonance cholangiographic evaluation of intrahepatic and extrahepatic bile duct variations. Indian J Radiol Imaging 2016;26:22-32.
9. Puente SG, Bannura GC. Radiological anatomy of the biliary tract: variations and congenital abnormalities. World J Surg 1983;7:271-6.
10. Couinaud C. Le foie; études anatomiques et chirurgicales. Paris: Masson, 1957.
11. Yoshida J, Chijiiwa K, Yamaguchi K, Yokohata K, Tanaka M. Practical classification of the branching types of the biliary tree: an analysis of 1,094 consecutive direct cholangiograms. J Am Coll Surg 1996;182:37-40.
12. Ohkubo M, Nagino M, Kamiya J, Yuasa N, Oda K, Arai T, Nishio H, Nimura Y. Surgical anatomy of the bile ducts at the hepatic hilum as applied to living donor liver transplantation. Ann Surg 2004;239:82-6.
13. Song GW, Lee SG, Hwang S, Sung GB, Park KM, Kim KH, Ahn CS, Moon DB, Ha TY, Kim BS, Moon KM, Jung DH. Preoperative evaluation of biliary anatomy of donor in living donor liver transplantation by conventional nonenhanced magnetic resonance cholangiography. Transpl Int 2007;20:167-73.
14. Karakas HM, Celik T, Alicioglu B. Bile duct anatomy of the Anatolian Caucasian population: Huang classification revisited. Surg Radiol Anat 2008;30:539-45.
15. Choi JW, Kim TK, Kim KW, Kim AY, Kim PN, Ha HK, Lee MG. Anatomic variation in intrahepatic bile ducts: an analysis of intraoperative cholangiograms in 300 consecutive donors for living donor liver transplantation. Korean J Radiol 2003;4:85-90.
16. Sharma V, Saraswat VA, Baijal SS, Choudhuri G. Anatomic variations in intrahepatic bile ducts in a north Indian population. J Gastroenterol Hepatol 2008;23(7 Pt 2):e58-62.
17. Sarawagi R, Sundar S, Raghuvanshi S, Gupta SK, Jayaraman G. Common and Uncommon Anatomical Variants of Intrahepatic Bile Ducts in Magnetic Resonance Cholangiopancreatography and its Clinical Implication. Pol J Radiol 2016;81:250-5.
18. Taghavi SA, Niknam R, Alavi SE, Ejtehadi F, Sivandzadeh GR, Eshraghian A. Anatomical variations of the biliary tree found with endoscopic retrograde cholagiopancreatography in a referral center in southern Iran. Middle East J Dig Dis 2017;9:201-5.
19. Hussein AM, Botros SM, Abdelhafez AH, Mahfouz M. Biliary tree variations as viewed by intra-operative cholangiography - comparing Egyptian versus international data. Egyptian Journal of Radiology and Nuclear Medicine 2016;47:1283-92.
20. Turner MA, Fulcher AS. The cystic duct: normal anatomy and disease processes. Radiographics 2001;21:3-22; questionnaire 288-94.
21. Sarawagi R, Sundar S, Gupta SK, Raghuwanshi S. Anatomical variations of cystic ducts in magnetic resonance cholangiopancreatography and clinical implications. Radiol Res Pract 2016; 2016:3021484.