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Intrahepatic bile duct variation: MR cholangiography and implication in hepatobiliary surgery

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Abstract

Background: The aim of this study was to assess the prevalence of biliary anatomical variants using 3-T MR cholangiography (MRC) with its impact in reduction of the complication of hepatobiliary surgical techniques.

Results: MRC was applied to 120 subjects (24 potential liver donors and 96 volunteers) and the right posterior hepatic duct insertion was documented, and accordingly, the biliary variants were classified based on Huang classification (Huang et al, Transplant Proc 28: 1669–1670, 1996).

Biliary anatomic variants were divided based on Huang classification: Huang A1, 65.83% ($n = 79$); Huang A2, 11.67% ($n = 14$); Huang A3, 13.3% ($n = 16$); Huang A4, 7.5% ($n = 9$); and Huang A5, 1.67% ($n = 2$). The total frequency for A2, A3, A4, and A5 was 34.17% ($n = 41$). The distance between RPHD insertion and the junction of right and left hepatic ducts (L) was measured, and Huang A1 cases were then subtyped into S1 subtype ($L > 1$ cm) and S2 subtype ($L \leq 1$ cm). We had 52 subjects with subtype S1 (43.33%) and 27 subjects with subtype S2 (22.5%).

Twenty-three subjects had bile duct exploration or intraoperative cholangiograms and showed Huang type A1 in 14 (60.87%), type A2 in 3 (13.05%), and type A3 in 6 (26.08%). Twenty-two (95.65%) had the same classification in MRC and intraoperative while only one case (4.35%) was considered as A2 at MRC but the intraoperative classification was Huang A3, which was attributed to the insertion of the RPHD insertion at the distal end of the left hepatic duct.

Conclusion: MRC is an accurate tool for biliary tract mapping before hepatobiliary surgery to provide excellent identification of biliary variants which can reduce the incidence of biliary complications.

Background

Detailed mapping of biliary anatomy is an essential pre-operative requirement for the proper choice of therapeutic approach as well as for reduction of iatrogenic biliary pathology which can negatively affect the hepatobiliary surgery outcome [1–4].

Despite the gross improvement in the surgical techniques of liver transplantation and the better survival rates, the biliary complications is still on the top of the complication in living donor liver transplantation, occurring in 7–10% of donors; also, biliary complication has a prevalence of 3.6–8.1% after hepatic tumor

resection [5–8]. Even in low complication rate procedure such as laparoscopic cholecystectomy (complications <1%), the pre-operative biliary mapping can avoid iatrogenic biliary injuries of non-recognized anatomical variants [9].

Biliary mapping using the diagnostic endoscopic retrograde cholangiography has major complication ranging from 1.4 to 3.2%, so having a non-invasive, simpler, and more safe technique would be of great value [10–12].

The start of using magnetic resonance cholangiopancreatography (MRCP) in early 1990s played a non-radiated, non-invasive safe modality [9, 10, 13] with more advancement, and using 3-T clinical MRI, MRC showed a highly promising tool for biliary tree

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assessment that can display a nearly motion artifact-free high-resolution images in short scan time [14].

There are many classifications of biliary anatomical variations, of which Huang classification method [15] is a widely used based on the variable insertion of right posterior hepatic bile duct (RPHD). It has five variants classification (Table 1). While Champetier classification [16] excluded the dominant Huang type A and dealt with other variants only, it has one more type (E); in that type, cystic duct receives the opening of both right anterior hepatic duct (RAHD) and RPHD.

The aim of the current study was the assessment of the prevalence of the anatomical intrahepatic biliary variants by using 3-T MR cholangiography (MRC) with its impact to lower hepatobiliary surgical techniques' complications.

Methods

Study subjects

The current study included 120 subjects: 24 potential liver donors and 96 volunteers (referred for MRI lumbar spine) and had no medical history of significant problems. They were 62 males and 58 females. The ages ranged from 18 to 63 years (mean 41 ± 16.3 years).

Approval from our institutional review board was obtained, and subjects' consent was taken.

MRC protocol

MRI was done for all subjects using 3.0-T magnetic resonance system (Intera Achieva; Philips—Netherlands). A six-element phased array coil was used.

The subjects were instructed to fast 6 h prior to MRI to distend the gallbladder and to have an empty stomach as well as to suppress the movement of intestines; however, no anti-peristaltic medicine or oral contrast media were applied.

- The protocol of MRI included routine transverse T1-WI breath-hold in- and opposed-phase gradient-echo MRI as well as T2-WI TSE MRI with fat saturation and MRC;
- Coronal and coronal oblique ($\pm 15^\circ$) breath-hold single-slice RARE (rapid acquisition with relaxation enhancement).

Table 1 Huang classification

Variant type	Site of opening of tight posterior hepatic duct (RPHD)
Huang A1	The right anterior hepatic duct (RAHD)
Huang A2	The hepatic confluence (trifurcation)
Huang A3	The left hepatic duct (LHD)
Huang A4	The main hepatic duct (MHD)
Huang A5	The cystic duct

- Then, respiratory-triggered 3D TSE (turbo spin-echo) was obtained. Abdominal respiratory belt was used.

Image data analysis was done using dedicated workstation depending on the raw images, and reconstruction was done to obtain cholangiographic images with a MIP (maximum intensity projection) and VR (volume rendering) sometimes (Table 2).

Image interpretation

The insertion of RPHD was documented in every subject; accordingly, the biliary variants were grouped according to Huang classification [15]. The distance between insertion of RPHD and the junction of right and left hepatic duct was measured, and then the mean for each variant was estimated.

Comparison of the results of cholangiograms done intra-operatively as well as explorations of bile duct results ($n = 22$ donor) were compared with the corresponding MRC results.

Statistical analysis

Statistical package SPSS version 17 was used for analysis of statistics. McNemar's test and t test were applied for statistical analyses (P value of < 0.05 was assigned to be a significant).

Results

The current study included 120 subjects (62 males and 58 females) with age ranged from 18 to 63 years (mean 41 ± 16.3 years).

According to RPHD insertion [15] (Fig. 1), biliary anatomic variants were divided based on Huang classification.

Accordingly, the prevalence of variants was as follows (Fig. 2 and Table 3):

Type A1 (Fig. 3), 65.83% ($n = 79$); type A2 (Fig. 4), 11.67% ($n = 14$); Huang A3 (Fig. 5), 13.3% ($n = 16$);

Table 2 MRI protocol

	RARE	3D-TSE
TR (repetition time)	9800 ms	2600 ms
TE (echo time)	920 ms	740 ms
Matrix	256×256	217×256
Slice thickness (mm)	50	1
Flip angle	90°	90°
Field of view	$30 \times 30 \text{ cm}^2$	$30 \times 30 \text{ cm}^2$
Echo train length	256	87
Signal averages number	1	1
Acquisition time	Each slice: 9.8 s	Depend on the respiratory frequency (2–5 min)

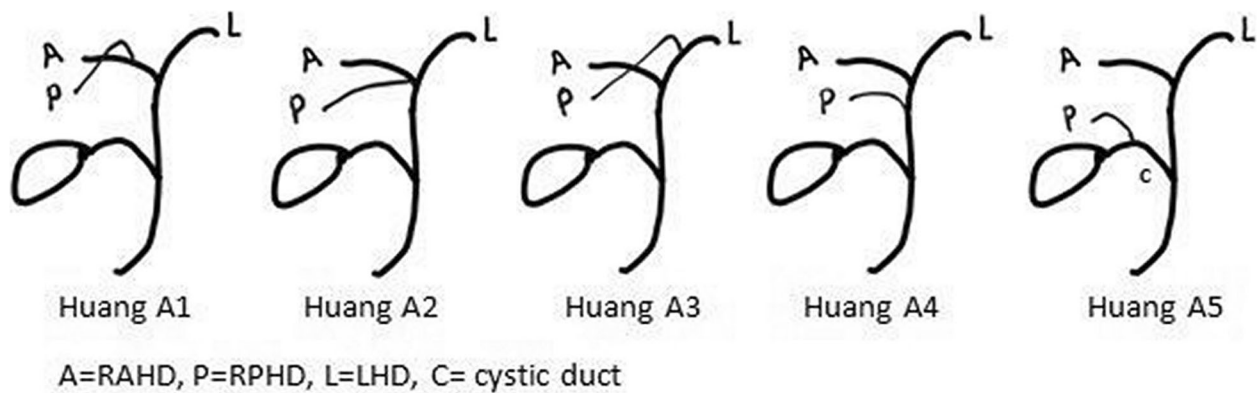


Fig. 1 Diagram illustrates Huang classification (RPHD, right posterior hepatic duct; RAHD, right anterior hepatic duct; LHD, Left hepatic duct)

Huang A4 (Fig. 6), 7.5% ($n = 9$); and type A5 (Fig. 7), 1.67% ($n = 2$).

The total frequency for A2, A3, A4, and A5 collectively was 34.17% ($n = 41$).

The distance between the insertion of RPHD and the right and left hepatic ducts' junction (L) has a surgical importance as if L is more than 1 cm, it may need modification of surgical techniques. So, we had to subtype Huang A1 cases into S1 subtype ($L > 1$ cm) and S2 subtype ($L \leq 1$ cm). Our subjects were 52 with S1 (43.33%) subtype and 27 with S2 (22.5%) subtype.

The mean distance between the RPHD and the right and left hepatic ducts' junction was 9.73 ± 5.02 mm (ranging from 4 to 24 mm) for Huang A1 and 9.35 ± 4.93 mm (range = 3.4–22.3 mm) for Huang A3, while it was 9.16 ± 4.67 (ranging from 4.2 to 22.9 mm) in Huang A4.

The comparison of these different Huang types was insignificant regarding the distances between the

insertion of RPHD insertion to the junction of the right and left hepatic ducts.

Twenty-three subjects had bile duct exploration or intraoperative cholangiograms and showed Huang A1 in 14 (60.87%), Huang A2 in 3 (13.05%), and Huang A3 in 6 (26.08%). Twenty-two (95.65%) had the same classification in MRC and intraoperative while only one case (4.35%) was considered as A2 at MRC but the intraoperative classification was Huang A3, which was attributed to the insertion of the RPHD insertion at the distal end of the left hepatic duct.

Discussion

The need for precise intrahepatic biliary anatomy is essential especially with the biliary intervention procedures as well as liver surgery including liver resection and transplantation to have a safe hepatectomy and reduce biliary complications [17–20].

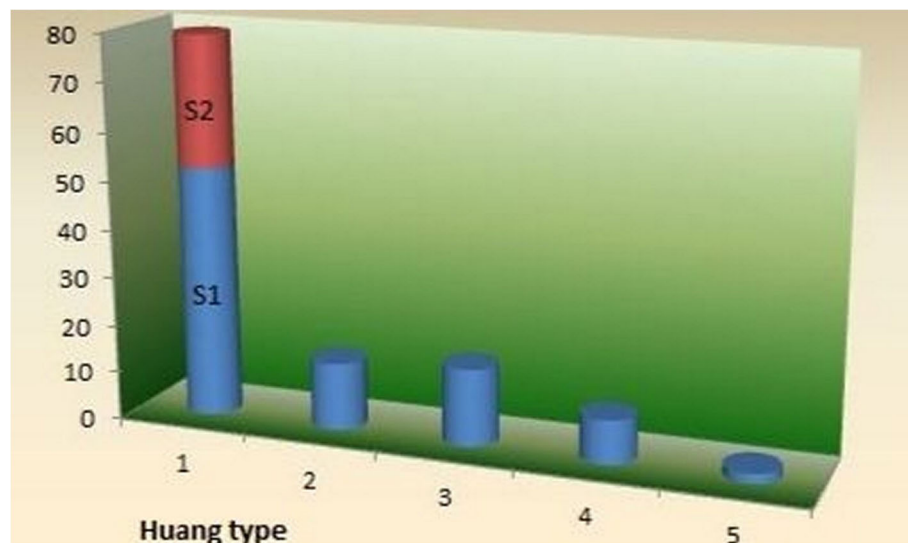


Fig. 2 Prevalence of biliary variants (Huang types) among study subjects

Table 3 Anatomical biliary variants prevalence

Type	Number	Percent
Huang A 1	79	65.83
Huang A 1 S1	52	43.33
Huang A 1 S2	27	22.5
Huang A 2	14	11.67
Huang A 3	16	13.33
Huang A 4	9	7.5
Huang A 5	2	1.67

While biliary anatomical variants are not a contra-indication for liver donation, however, detailed accurate pre-operative identification is essential to avoid iatrogenic ligation of the donor or recipient's major biliary tract, for example, ligation of aberrant RAHD or RPHD drainage into the left hepatic duct can cause cirrhosis [18, 19]. On the other hand, during right lobe transplantation, multiple biliary anastomoses in the recipient may be needed to prevent biliary obstruction [21].

MRCP is a noninvasive diagnostic technique with no radiation hazards and avoids the hazards of nephrotoxic contrast media and ERCP. It can show the high signal of the biliary and pancreatic secretions with dark background (sensitivity up to 90%) in normal biliary mapping [22, 23].

Breath-hold imaging can eliminate the artifacts caused by respiratory motion with the ability to

improve spatial resolution by using a longer time of acquisition. It shows the advantage of a relatively short time of acquisition; however, the quality of images is affected by a low signal-to-noise ratio as well as low spatial resolution. The respiratory-triggered technique is able to extend the time of acquisition thus having higher spatial resolution [24].

There is a high prevalence of biliary variants which was shown in a many previous studies [25–27].

In the current study, we used Huang classification to categorize intrahepatic ducts according to the RPHD insertion.

The current study showed that vast subject number had intrahepatic duct Huang type A1 (typical type) representing 65.83% ($n = 79$) of the examined subjects followed by Huang A2, 11.67% ($n = 14$); Huang A3, 13.3% ($n = 16$); type A4, 7.5% ($n = 9$); and Huang type A5, 1.67% ($n = 2$).

This coincides with many previous studies [3, 15, 24, 28–33] while lower incidence of A1 (56%) was encountered in the study of Wang et al. [34].

Huang type A is optimum for right hepatic lobe living transplantation as it is simple; however, the right hepatic duct (RHD) length has a crucial impact as with sufficient length, one biliary-enteric anastomosis may be done easily, while in the case of short RHD, it may need modification as double anastomoses to avoid injury risk of the bile duct in hepatic resection [15, 19, 20, 35]. In the current study, Huang A1 was the dominant type representing 65.83% ($n = 79$) of the subjects included in our study. Due to the surgical

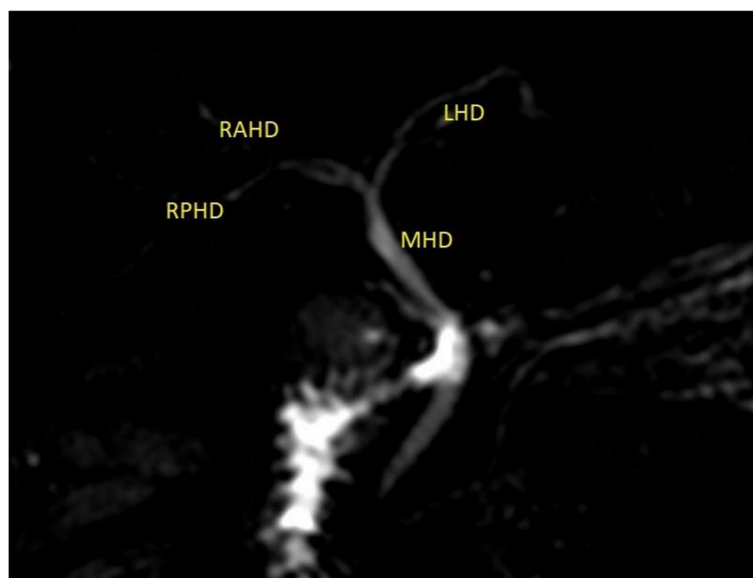


Fig. 3 MRC (RARE) Huang type A1: RPHD drain into the RAHD (RPHD, right posterior hepatic duct; RAHD, right anterior hepatic duct; LHD, left hepatic duct; and MHD, main hepatic duct)

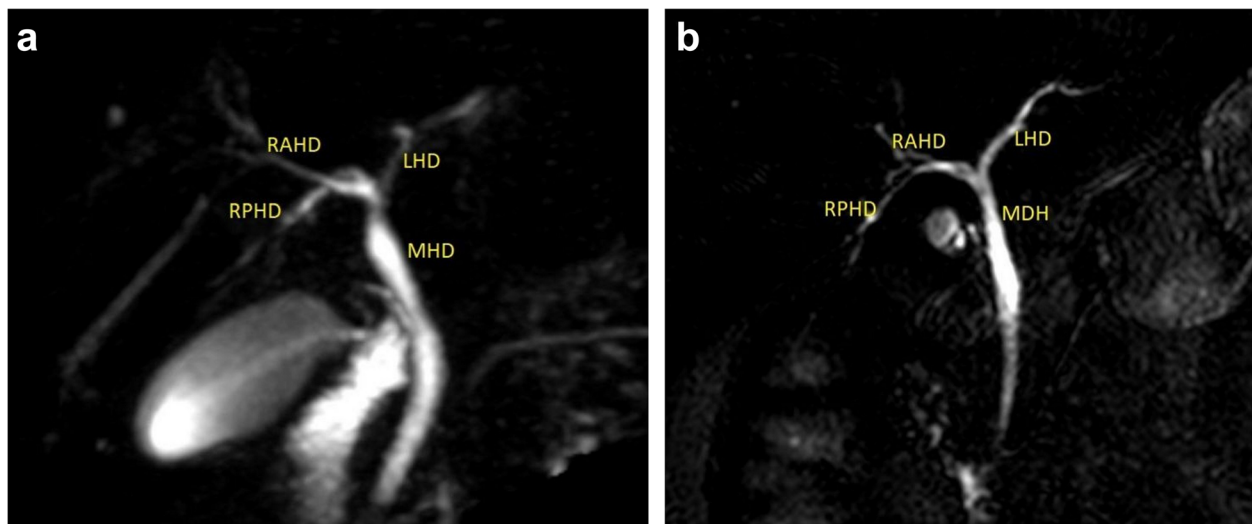


Fig. 4 MRC 3D TSE (a) and MRC (RARE) (b). Trifurcation (Huang A2): RPHD open into the hepatic common confluence (RPHD, right posterior hepatic duct; RAHD, right anterior hepatic duct; LHD, left hepatic duct; and MHD, main hepatic duct)

importance of the distance between RPHD insertion and the right and left hepatic duct junction which assume a trifurcation pattern (common RAHD, RHPD, and LHD junction) for distance of 1 cm or less [20, 28, 35, 36], we had to subtype our subjects of Huang A1 based on the distance (L) between the insertion of RPHD and the right and left hepatic duct junction into S1 ($L > 1$ cm) and S2 ($L = 1$ cm or less). Accordingly, we had Huang A1 subtypes: subtype S1 ($n = 52$, 43.33%) and subtype S2 ($n = 27$, 22.5%).

In current study, the second predominant type was Huang type A3 in which the RPHD ends into the LHD, and it was seen in 13.3% ($n = 16$) which coincides with many previous studies [3, 15, 20, 29, 31, 36]. Also, it is

close to the results of Basaran et al. [24] (Gawad 22) and Wang et al. [34] which was 20% and 18% respectively.

This variant may cause donor biliary injury and may necessitate double anastomoses to prevent postoperative biliary complication such as biliary leakage or segmental atrophy [9, 20, 36].

The third frequency was in the current study was for Huang A2 in which the RPHD open to the hepatic confluence (trifurcation) and represented 11.67% ($n = 14$) of our subjects which is near to the results of Wang et al. [34] which was 11% and higher than the frequency in the series of Basaran et al. [24] which was 5%. Some centers may avoid graft harvesting in biliary trifurcation to prevent a higher rate of postoperative complications.

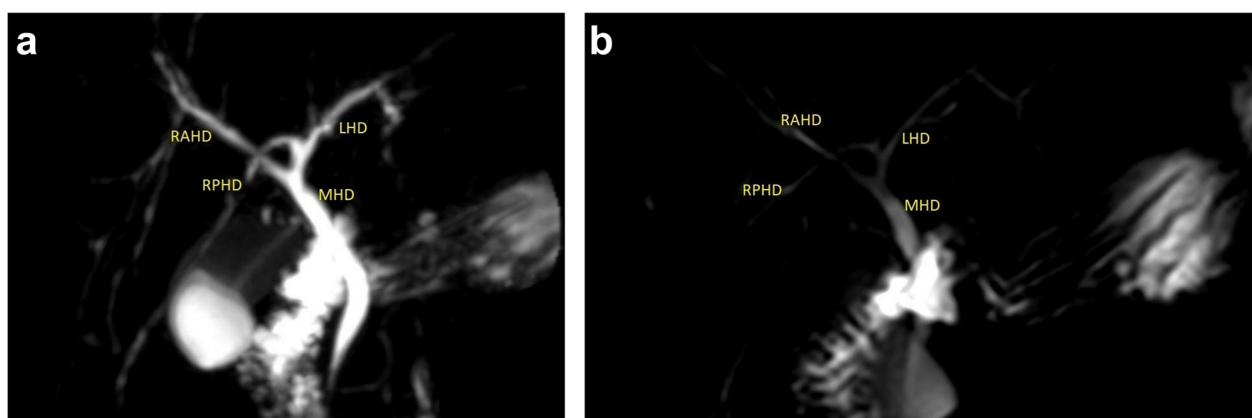


Fig. 5 MRC 3D TSE (a) and MRC (RARE) (b). Huang type A3: RPHD opens into LHD (RPHD, right posterior hepatic duct; RAHD, right anterior hepatic duct; LHD, left hepatic duct; and MHD, main hepatic duct)

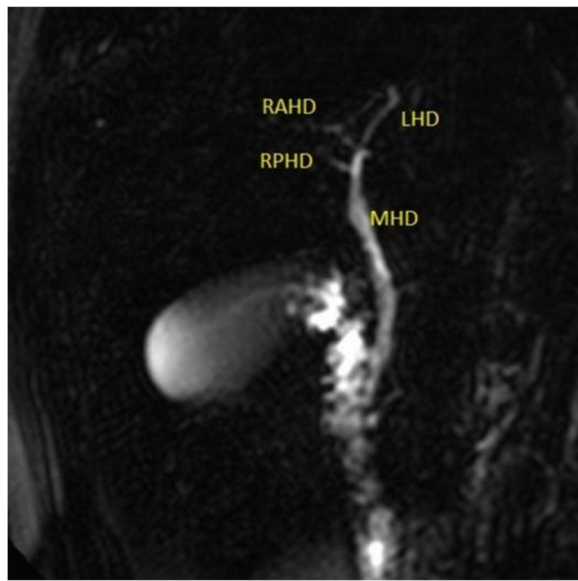


Fig. 6 MRC (RARE). Huang type A4: RPHD opens into main hepatic duct (MHD) (RPHD, right posterior hepatic duct; RAHD, right anterior hepatic duct; LHD, left hepatic duct; and MHD, main hepatic duct)

In Huang types A4 and A5, there is aberrant right posterior hepatic duct that drains to the CHD or cystic ducts respectively this can be inadvertently ligated or injured during biliary surgery [24].

Double anastomoses may be needed in Huang type A4 also to prevent possible postoperative biliary complications

in cases of liver transplantation [19, 20]. In current report, Huang A4 was seen in 7.5% of current subjects ($n = 9$) which is near to the results of Wang et al. [34] and higher than the results of Basaran et al. [24] who had donors having their RPHD drain into the main duct in 8% and 2.5% respectively.

We encountered Huang A5 in two subjects (1.67%) which is nearly of similar incidence reported in many previous studies [20, 37, 38].

Huang type 5 with RPHD draining into the cystic duct is of biliary surgical importance especially during laparoscopy as its damage may lead to biliary leakage and biloma [20, 37, 38].

In current study, 23 subjects had bile duct exploration or intraoperative cholangiograms, and 22 (95.65%) of them had the same MRC Huang type while only one case (4.35%) was reported as A2 at MRC but shown at intraoperative classification as Huang A3 due to RPHD insertion into the left hepatic duct's distal end.

We had some limitation in our study; first, it was a small cohort study, and secondly, only 23 of our subjects were confirmed by intraoperative procedure.

Conclusion

MRC is an accurate tool for biliary tract mapping before hepatobiliary surgery to provide excellent identification of biliary anatomical variants which can diminish the possibility of biliary complications.



Fig. 7 MRC 3D TSE. Huang type A5: RPHD drains into cystic duct (arrow) (RAHD, right anterior hepatic duct; LHD, left hepatic duct; MHD, main hepatic duct)

Abbreviations

ERCP: Endoscopic retrograde cholangiopancreatography; LHD: Left hepatic duct; MIP: Maximum intensity projection; MRC: Magnetic resonance cholangiography; MRCP: Magnetic resonance cholangiopancreatography; MRI: Magnetic resonance imaging; RAHD: Right anterior hepatic duct; RPHD: Right posterior hepatic duct; VR: Volume rendering

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Authors' contributions

EM conceived of the study, participated in its design and coordination, drafted the manuscript, and carried out the radiological results. RM helped in the drafting of the results and participated in the surgical assessment. Both authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Faculty of Medicine, Zagazig University (study protocol was approved in January 2017). The committee has no reference number, only the date. An informed written consent from each patient was taken before enrollment into the study.

Consent for publication

A written informed consent was obtained from all individuals relevant to this research.

Competing interests

The authors declare that they have no competing interests.

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