Hassan *et al. Egypt J Radiol Nucl Med (2024) 55:99*
https://doi.org/10.1186/s43055-024-01256-5

Egyptian Journal of Radiology
and Nuclear Medicine

RESEARCH

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Intrahepatic bile duct anatomical variation in liver transplant donors and its implication in liver transplantation

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Abstract

Background For patients with end-stage liver disease, liver transplantation is considered the chief curative option. Radiological imaging has a pivotal role in evaluating both donors and recipients before and after transplantation. So the purpose of our study is to assess anatomical variant of intra-hepatic bile duct variation among liver transplant donors by MRCP and its implication in liver transplantation. Retrospective study was carried out in Mansoura University Hospitals over period from January 2019 till June 2022. Study included 64 liver transplant donors aged from 21 to 46 years old. All subjects underwent MRCP. Analysis of data obtained from images as well as reconstruction was performed to get images of bile ducts with a maximum intensity projection and volume rendering.

Results Our study included 64 liver transplant donors. Donor mean age was 29.8 ± 2.57 years with range between 20 and 38 years. There were 40 males (62.5%) and 24 females (37.5%). Regarding right posterior hepatic duct drainage based on Huang classification, the type of bile duct variant was classified as follows: The most common variant was type A1 in 50% of the donors followed by type A4 in 20.3% then type A2 and type A3 in 14.1% each. The distance between RPHD insertion and junction between the right and left hepatic ducts (L) owns a surgical importance as it may need modification of surgical technique if L was more than 1 cm. So according to karakas classification, we had to subtype Huang A1 cases into K1 subtype ($L > 1$ cm) and K2a subtype ($L \leq 1$ cm). Our subjects were 20 with K1 subtype (31.25%) and 12 with K2a subtype (18.75%).

Conclusions Assessment of anatomical variation of right hepatic duct in liver transplant donor by non-invasive method as MRCP had a fundamental role to obtain successful surgical outcome and also to reduce hepatobiliary surgical complications.

Keywords Bile duct variant, MRCP, Liver transplantation

Background

Liver transplantation from a living donor is a possible treatment for those with advanced liver disease, instead of relying on organs from deceased donors. The use of imaging is vital for evaluating both the recipient and donor before and after the surgery, in order to identify any potential issues [1].

Despite significant advancements in surgical procedures for liver transplantation and improved survival rates, biliary complications remain a major concern for

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living donor liver transplantation. These complications occur in 7–10% of donors and have a prevalence ranging from 3.6 to 8.1% after hepatic tumor resection. [2].

Creating a thorough understanding of the structure and function of the bile ducts is crucial prior to any surgical procedure. It not only helps guide treatment decisions, but also helps prevent unintended harm to the bile ducts, which could have a detrimental impact on the success of hepatobiliary surgery. [3].

MRCP, magnetic resonance cholangiopancreatography, is a non-invasive way to take pictures of the biliary system and pancreatic duct. It has become very popular as the most dependable alternative to intraoperative cholangiography for clearly showing the biliary system. [4].

There are many classifications of biliary duct anatomical variation. According to Huang et al., the right intrahepatic bile duct is divided into 5 types based on the insertion site of the right posterior sectorial duct (RPSD). The classification was modified by Karakas HM et al., based on the insertion site of the RPSD and its distance from the confluence of the RASD and LHD. Furthermore, Cho A et al. classified left hepatic duct confluence into three types [5].

In our study, we were concerned about studying anatomical variation of right hepatic duct in liver transplant donor by using MRCP as one of main requirements for liver transplantation and also to reduce hepatobiliary surgical complications.

Methods

The study was performed at MRI Unit of Radiology Department at Mansoura University Hospitals. The study was retrospective conducted in the period from January 2019 till June 2022. It included 64 liver transplant donors aged from 21 to 46 years old. Approval from our institution's board of directors and subject consent were obtained.

MRCP was performed on all subjects using a 1.5-T magnetic resonance system (Intera Achieva; Philips—Netherlands). A six-element phased array coil is used. Subjects were asked to fast for 6 h before MRI to distend the gallbladder, fast, and inhibit intestinal motility. However, no anti-peristaltic drugs or oral contrast agents were used.

- MRI protocol included conventional transverse T1-WI in-phase and reverse-phase breath-hold gradient echo MRI and T2-WI-TSE MRI with fat saturation and MRC.
- Coronal and coronal tilt (±15°) single-slice breath-hold images (quick acquisition and enhanced relaxation).
- Abdominal respiratory belt was used to obtain respiratory-triggered 3D TSE (turbo spin-echo).

Table 1 MRCP protocol and sequences used for current study

	T2W SS-FSE	T2W SS-FSE	3D MRCP
Plane	Axial	Coronal	Coronal
Fat suppression	+ and −	−	+
Flip angle (°)	160	90	90
Slice thickness (mm)	4	4	1.4
FOV	40	40	36
Matrix (mm × mm)	320 × 320	320 × 320	512 × 224
TR/TE (ms)	4000/84	3500/100	3000/720
Scan time (ms)	59	59	176

Table 2 Huang classification

Type A1: Typical pattern with right posterior segmental duct joining right anterior segmental duct
Type A2: Trifurcation type: Simultaneous emptying of RPSD, RASD and left hepatic duct
Type A3: Anomalous drainage of RPSD into LHD
Type A4: Anomalous drainage of RPSD into CHD
Type A5: Anomalous drainage of RPSD into cystic duct

Image data analysis was performed using special workstations based on raw images and sometimes reconstruction using MIP (maximum intensity projection) and VR (volume rendering) to obtain cholangiogram images (Table 1).

Image interpretation

RPHD assessment was recorded for each subject; therefore, biliary variants were grouped according to the Huang classification [6] (Table 2) (Fig. 1). The distance between the RPHD insertion point and the junction of the left and right hepatic ducts was measured, and the mean value was estimated for each variant. The results of intraoperative cholangiography and bile duct studies were compared with the corresponding MRCP results.

Statistical analysis

Collected data were coded, processed, and analyzed using SPSS (Statistical Package for the Social Sciences) version 26 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Descriptive and analytical statistics were performed using the McNemar test (P values < 0.05 were considered significant).

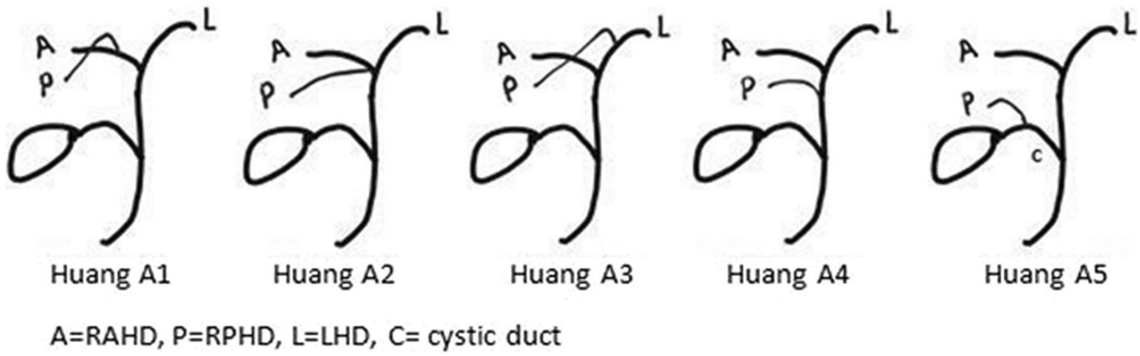

Fig. 1 Huang classification system of anatomical biliary variants

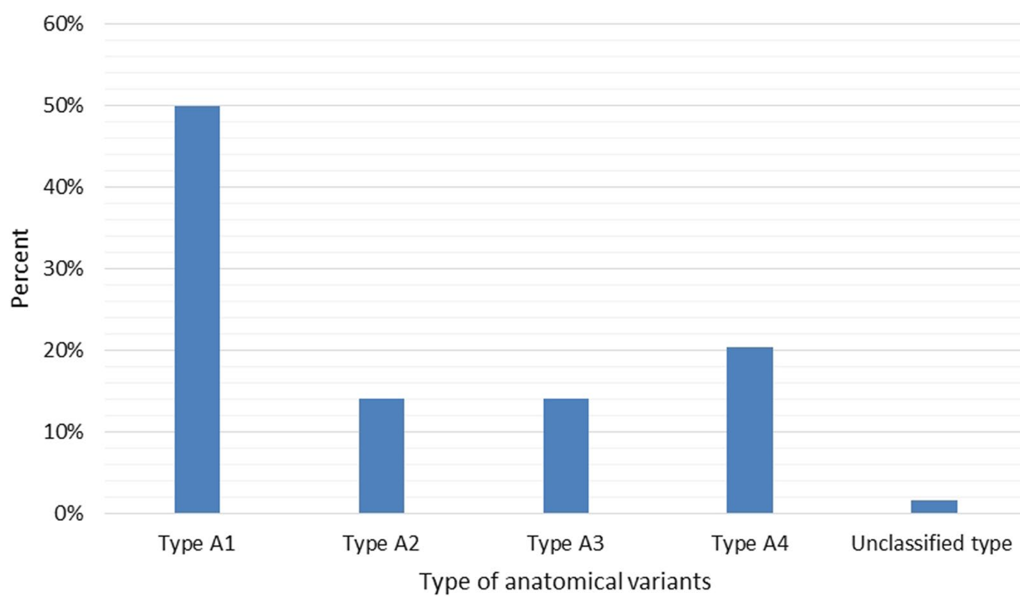

Fig. 2 Duct variants within the study

Results

The study included 64 liver transplant donors. Donor mean age was 29.8 ± 2.57 years with range between 20 and 38 years. There were 40 males (62.5%) and 24 females (37.5%).

Regarding right posterior hepatic duct drainage based on Huang classification [6], the type of bile duct variant was classified as follows: The most common variant was type A1 in 50% of the donors followed by type A4 in 20.3% then type A2 and type A3 in 14.1% each (Fig. 2).

The distance between the insertion of RPHD and the right and left hepatic ducts' junction (L) had a surgical importance as it may need modification of surgical technique if L was more than 1 cm. So, according to karakas classification, we had to subtype Huang A1 cases into K1 subtype ($L > 1$ cm) and K2a subtype ($L \leq 1$

Table 3 Type of duct variants in the cases of the study

Variables	Study cases *N* = 64	
	N	**%**
Type A1	32	50
Subtype K1	20	31.25
Subtype K2a	12	18.75
Type A2	9	14.1
Type A3	9	14.1
Type A4	13	20.3
Unclassified type	1	1.6

cm). Our subjects were 20 with K1 subtype (31.25%) and 12 with K2a subtype (18.75%) (Table 3).

On comparison between preoperative MRCP and intraoperative cholangiogram in donors, there was no difference in type of biliary anatomy.

Discussion

The most important treatment option for patients with end-stage liver disease is LDLT. The results have been reported to be very encouraging, with transplant and patient survival rates as high as 80% within one year. However, LDLT is a challenging surgical procedure and donor safety must be paramount. The main complication after LDLT is biliary complications, with an incidence rate as high as 30–50% [7].

Precise preoperative imaging is vital to survey the biliary anatomy of a living donor candidate. An exact comprehension of donor biliary anatomy is fundamental for safe donor hepatectomy and to lessen recipient biliary complications [8].

MRCP has the potential to be a non-biohazardous, non-invasive method for evaluating LDLT donors. Different MRCP methods have been accounted for in the literature. The MR strategy utilized in this study demonstrated adequate to give the ductal information required to optimize the transplant procedure of living-related liver donors. The MR methodology which replaces the CT for evaluation of the biliary conduit framework takes out the need to uncover the possible donor to ionizing radiation and nephrotoxic contrast agent, as well as ERCP, hence diminishing the expense and related agony and likely complications (Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11) [9].

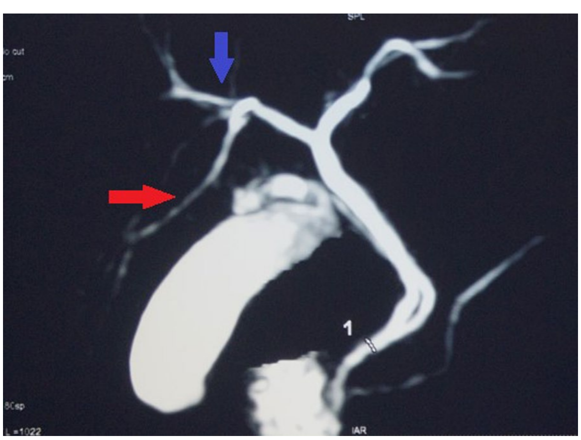

Fig. 3 MRCP 3D TSE. (Huang A1): right posterior sectorial duct-RPSD "red arrow" drains into the right anterior sectorial duct-RASD "blue arrow"

Fig. 4 MRCP 3D TSE. (Huang type A1): right posterior sectorial duct-RPSD "red arrow" drains into the right anterior sectorial duct-RASD "blue arrow"

Consequently, the purpose of the current study was to describe biliary system anatomical variations among donors of liver transplants.

The current study included 64 liver transplant donors who were recruited from Gastro-Enterology Centre, Mansoura University Hospitals, Mansoura, Egypt.

The mean age of the donors was 29.8 ± 2.57 years with range between 20 and 38 years. There were 40 males (62.5%) and 24 females (37.5%).

This was in concurrence with Ayoub et al. [10] who broke down the information of all recipients and donors

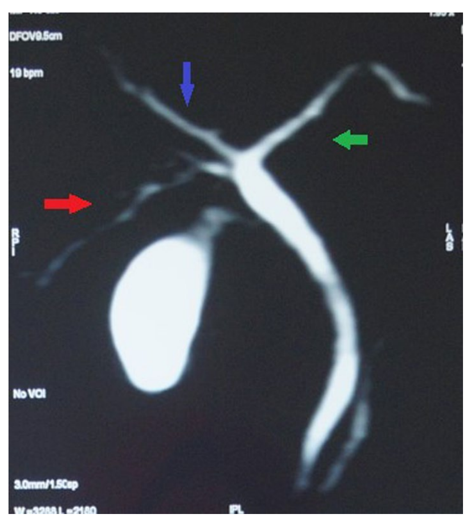

Fig. 5 MRCP 3D TSE (Huang type A2): trifurcation: Right posterior sectorial duct-RPSD 'red arrow", right anterior sectorial duct-RASD "blue arrow" and left hepatic duct-LHD "green arrow" open into the hepatic common confluence

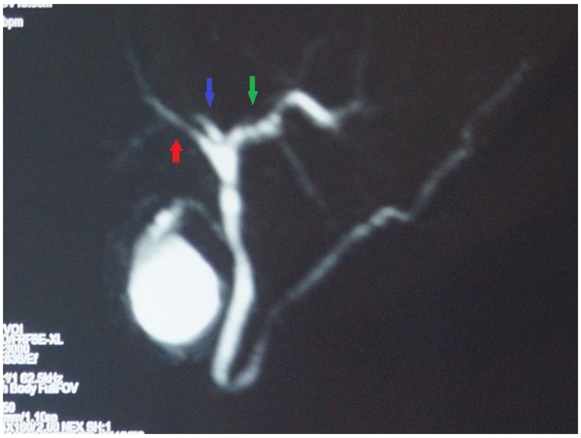

Fig. 6 MRCP 3D TSE (Huang type A2): Trifurcation: Right posterior sectorial duct-RPSD 'red arrow", Right anterior sectorial duct-RASD "blue arrow" and Left hepatic duct-LHD "green arrow" open into the hepatic common confluence

Fig. 7 MRCP 3D VR (Huang type A3): right posterior sectorial duct-RPSD 'red arrows" drains into left hepatic duct-LHD "green arrow"

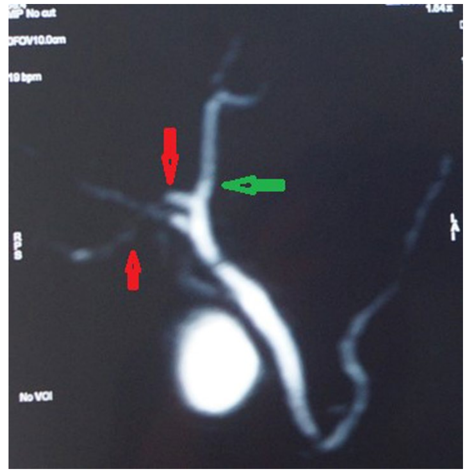

Fig. 8 MRCP 3D TSE (Huang type A3): right posterior sectorial duct-RPSD 'red arrows" drains into left hepatic duct-LHD "green arrow"

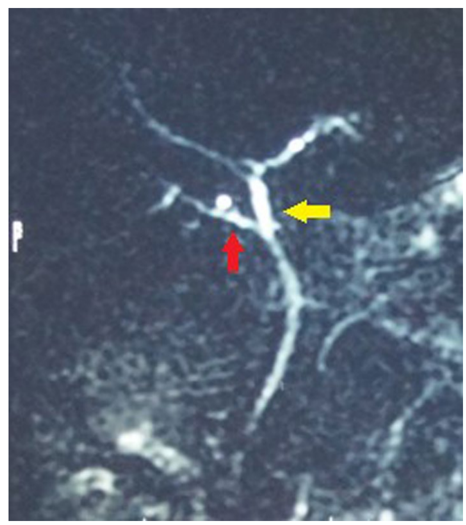

Fig. 9 MRCP RARE (Huang type A4): right posterior sectorial duct-RPSD 'red arrow" drains into common hepatic duct-CHD "yellow arrow"

of LDLT (June 2013–December 2017) in hepato-biliary pancreatic division and liver transfer. MRCP evaluated the biliary anatomy of 120 potential donors prior to surgery. The average age of the donors was 28.7 years, with 71 (66.4%) male and 36 (33.6%) female donors [10].

In the current study, regarding the type of duct anatomy, the most common type was type A1 (the typical pattern) in 50% while the types of duct variants included type A4 in 20.3% then type A2 (trifurcation type) and type A3 in 14.1% each and at last unclassified type in 1.6%.

Closely similar distribution was found in the study of El Hariri and Riad [2] that included 120 subjects. According to RPHD insertion, biliary anatomic variants were divided based on Huang classification into: type A1, 65.83% ($n=79$); type A2, 11.67% ($n=14$); Huang A3, 13.3% ($n=16$); Huang A4, 7.5% ($n=9$); and type A5, 1.67% ($n=2$).

The right hepatic duct is formed by the union of the right anterior and right posterior sectorial ducts in the normal biliary anatomy. The common hepatic duct is created when the left and right hepatic ducts combine. The common bile duct is created when the cystic duct and common hepatic duct combine.

In the current study, the standard pattern was the most common pattern of biliary anatomy in 50% of the cases. This was in accordance with the previous studies

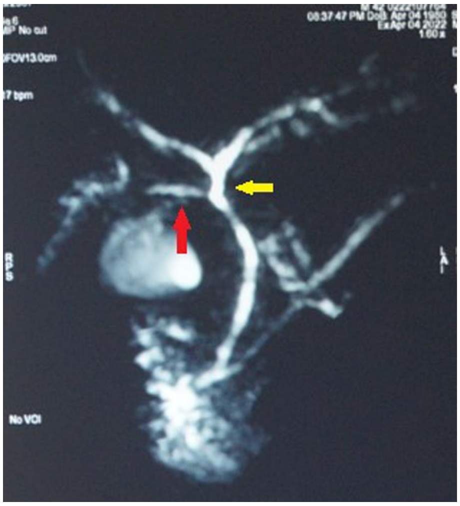

Fig. 10 MRCP 3D TSE (Huang type A4): right posterior sectorial duct-RPSD 'red arrow" drains into common hepatic duct-CHD "yellow arrow"

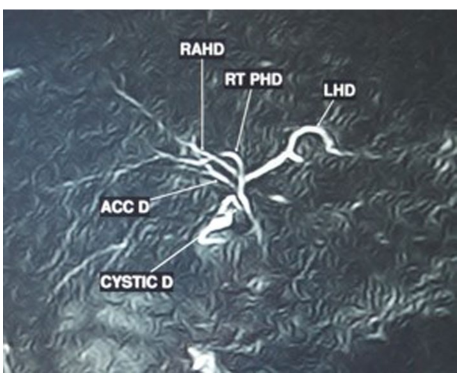

Fig. 11 MRCP RARE unclassified type: accessory right hepatic duct drains into CHD and trifurcation of CHD

of Jaganathan et al. [1] using magnetic resonance cholangiopancreatography (MRCP) that found standard biliary anatomical pattern in 56%, 55.3%, and 52.3% of liver donors, respectively.

With 3%–10% of donors experiencing biliary problems, this was the most frequent reason for morbidity in liver transplants with living donors. Bilomas brought on by bile leakage and bile duct strictures are among the problems. Rarely, bile leakage might happen along the liver parenchymal transection and at the biliary anastomosis. [7].

Surgeons can safely execute donor hepatectomy and preventing biliary problems by comprehensive preoperative examination and knowledge of biliary anatomic variances [8].

In the current study, the most common anatomical variant following the standard pattern was type A4 (Anomalous drainage of RPSD in CHD) in 20.3%. However, previous studies described lower prevalence of this type. Jaganathan et al. [1] reported this variant to be the second common variation observed in 6.2% of candidates. Naeem et al. [11] categorized this type as the fourth most common variant in their study, and it was observed in 22 patients (6.4%). Lower incidence was also seen in the studies of Wang et al. [12] about (8%).

In the current study, the second most common anatomical variants were both type A2 (trifurcation type) and type A3 (anomalous drainage of RPSD in LHD) in 14.1% for each of them. This agreed with Naeem et al. [12] who showed that the second most common variant was RPHD joining the LHD (Type 3) in 49 subjects (14.3%).

In disagreement with the current study, type A4 was the most common variation observed in the study by Jaganathan et al. [1] in 16 out of 65 candidates (24.6%). Sarawagi et al. [5] in their evaluation of 224 MRCP patients showed also that type III A was the most common variation (27.6%). Similar findings were observed in the studies of Basaran et al. [13] who reported type A3 in 20% of cases. Furthermore, El Hariri and Riad [2] showed that type A3 variant was the most common variant; however, they reported almost similar percentage (13.3%) as this study.

Due to the possibility of donor biliary damage, this variation may require additional anastomoses in order to prevent postoperative biliary complications including segmental atrophy or biliary leakage [14].

Regarding the type A2 (trifurcation type) variant (being the second most common variant in the current study), the current results agreed with Jaganathan et al. [1] who showed that the second common variation in their study was the trifurcation pattern, which was seen in six candidates, constituting 9.2%.

In Basaran et al. [13] and Wang et al. [12], this variance was observed in 5% of donors and 11% of their donors, respectively. To lower the risk of a higher rate of surgical complications, certain facilities might forego graft harvesting in biliary trifurcation.

In Huang type A4 patients, double anastomoses can also be required to guard against potential postoperative biliary problems in liver transplant instances [15]. In the current study, type A4 variant was shown in 13 cases (20.3%). Higher incidence was observed by El Hariri and Riad [2] as Huang A4 was seen in 7.5% of subjects ($n=9$).

In the current study, a different variation was observed, accessory right hepatic duct draining into the main hepatic duct with the main hepatic duct trifurcating. A few additional variations were also noted in the study by Naeem et al. [11], including RPHD draining in LHD with a segmental duct draining at the same location, trifurcation linked to a right segmental duct draining in LHD, a segmental duct from the left and right lobes forming a confluence that drains to the CHD, three segmental branches draining in LHD forming a trifurcation, and three segmental ducts forming a trifurcation on the right side.

There have also been a number of other anatomical variations documented in the literature; however, they were rare occurrences with few data that were clinically meaningful. Isolated segmental branches draining to the cystic or right hepatic ducts, isolated segmental ducts draining to the left or right hepatic duct, and complex biliary variations were a few examples [5]. Furthermore, it was crucial to evaluate variant biliary tree systems that are frequently associated with variations in the portal vein in order to lower the risk of iatrogenic insults [16].

As regards comparison between MRCP and intra-operative cholangiogram in the current study, there was no difference in type of biliary anatomy; however, decision of number of biliary anastomosis may vary after obtaining intraoperative cholangiogram depending on distance measured between right anterior and posterior sectorial ducts where there may be discrepancy between MRCP and intra-operative cholangiogram. If the distance between anterior and posterior sectorial ducts is too large, separate anastomosis is done.

In the current study, there was no statistically significant difference in the pattern of duct variants according to the gender of the donors. This agreed with Taghavi et al. [17] who showed that there was no statistically significant link between gender and variant anatomy. On the contrary, this disagreed with Naeem et al. [11] who showed that the types 1, 3, and 4 anatomic variants were recorded more frequently in females than in males, while type 2 was more prevalent in males as compared to females (18.7% v/s 4.9%; p value < 0.001).

Conclusions

Assessment of anatomical variation of intrahepatic duct in liver transplant donor by non-invasive method as MRCP had a fundamental role to obtain successful surgical outcome and also to reduce hepatobiliary surgical complications.

Abbreviations

MRCP	Magnetic resonance cholangiopancreatography
MIP	Maximum intensity projection
VR	Volume rendering
RPHD	Right posterior hepatic duct
RASD	Right anterior sectorial duct
LHD	Left hepatic duct
CHD	Common hepatic duct
LDLT	Living donor liver transplantation
RPSD	Right posterior sectorial duct
MRC	Magnetic resonance cholangiography
RARE	Rapid acquisition with relaxation enhancement
3D	Three-dimensional
TSE	Turbo spin echo
SPSS	Statistical Package for Social Sciences
MRI	Magnetic resonance imaging
CT	Computed tomography
ERCP	Endoscopic retrograde cholangiopancreatography

Acknowledgements

We are grateful to our patients who accepted to participate in our study.

Author contributions

All authors have read and approved the manuscript. The study concept and design were proposed by MMMH and MMAEGER; statistical analysis of data by MAERES and KGB; writing the original manuscript by MMMH and MMAEGER; revision of the manuscript for important intellectual content by MAERES, UAGS and KGB.

Funding

The authors state that this work has not received any funding.

Availability of data and materials

All the scientific data are available and presented in the manuscript. The source data are available on request.

Declarations

Ethics approval and consent to participate

Written informed consent was waived by the Institutional Review Board (IRB); Institutional Review Board (IRB) was obtained IRB approval: MS.22.01.1849.

Consent for publication

Al the patients were consented and informed of possible research publication. All authors hereby confirm all the copyrights if such work will be accepted in the Egyptian Journal of Radiology and Nuclear Medicine (EJRNM).

Competing interests

The authors declare that they have no competing interests.

Received: 2 December 2023 Accepted: 23 April 2024
Published online: 21 May 2024

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