BENHA MEDICAL JOURNAL bmj

Print ISSN 1110-208X

Online ISSN 2357-0016

Original article

Anatomical Evaluation of the Biliary System of Living Liver Donors using Pre-Operative Non-Enhanced MRCP in Comparison to Intra-Operative Cholangiogram

Tamer A. Kamal [a], Tarek S. El-Husseiny [b], Ahmed E. Shalaan [a], Waleed A. Hamed [c]

[a] Department of Diagnostic Radiology, Faculty of Medicine, Benha University, Egypt.

[b] Department of Gastrointestinal Surgery and Liver Transplant, Faculty of Medicine, Gastrointestinal Center, Mansoura University, Egypt.

[c] Department of Diagnostic Radiology, Higher Technological Institute of Applied Health Sciences, Egypt.

Corresponding to: Waleed A. Hamed**,** Department of Diagnostic Radiology – Higher Technological Institute of Applied Health Sciences

Email: waleed.ag@hotmail.com

Received: 28 August 2024

Accepted: 11 October 2024

Abstract

Background: Accurate preoperative evaluation of biliary anatomy is crucial for the safety and success of living donor liver transplantation (LDLT). MRCP, a non-invasive imaging technique, is widely used to identify biliary variations and anomalies in potential donors. **This study aims to** evaluate the effectiveness of non-enhanced MRCP in detecting biliary tree variations in living liver donors compared to intra-operative cholangiography (IOC). **Methods:** This prospective study was conducted on 50 potential liver donors (28 males, 22 females, aged 18-45 years) at Mansoura University, Gastro-Intestinal Center, Liver Transplantation Unit from August 2022 to August 2024. All donors underwent preoperative MRCP followed by IOC during surgery. MRCP findings were compared with IOC, the gold standard, to determine sensitivity, specificity, and accuracy. **Results:** MRCP correctly identified variant biliary anatomy in 46 of 50 donors. The most common variant was RPSD draining into the right hepatic duct (44%). MRCP showed a sensitivity of 91.3%, specificity of 100%, and overall accuracy of 95.7% compared to IOC, which provided additional details in 5 cases missed by MRCP. **Conclusion:** MRCP is a highly sensitive and specific non-invasive technique for preoperative biliary anatomy assessment in LDLT donors. It enables safer surgeries and reduces postoperative complications by accurately identifying biliary variants, though IOC may still reveal additional crucial details.

Keywords: MRCP, IOC, common hepatic duct, living liver donors, Liver transplantation.

Introduction

The emergence of liver transplantation has become the ultimate cure for end-stage liver failure and several other oncologically related therapeutic successful hepatic surgeries, including, partial hepatic resection, a comprehensive analysis of intrahepatic biliary anatomical details is an essential proceeding for surgery (1).

Living donor liver transplantation (LDLT) is the only alternative to cadaveric donor liver transplantation in regions that do not have enough cadaveric donors to meet the needs of their waiting lists. Although both have similar outcomes, donor safety is still the most important discussion. (2)**.**

LDLT has evolved since its introduction in 1989 in the University of Chicago into a widely accepted, and an equally efficacious therapeutic option compared with DDLT for end-stage liver disease. Surgical protocols at various centers converge on donor safety regarding biliary and vascular techniques. However, donor selection criteria remain considerably contrasting across centers (3).

In Egypt, LDLT is the only option for patients with end-stage liver disease and/or hepatic malignancy because cadaveric organ donation is not implemented. Predicting the graft weight and delineating the biliary anatomy of the potential donor can have a great impact on the choice of donor and estimation of the outcome of LDLT. The combination of abnormal biliary anatomy with a small graft size may potentially lead to a significant increase in postoperative complications (4).

In LDLT, the safety of the donor is the primary concern. The ultimate goal is to simultaneously consider the recipient's needs as well as the health of the donor. For a surgeon who performs the donor surgery, how to accurately divide the biliary tract is a key problem (5)**.**

It is very important that preoperative MRCP evaluation and intraoperative cholangiography (IOC) are compatible with each other and the biliary tract is cut in the right place, primarily for donor safety. At the same time, giving the graft with the bile ducts cut at the right place allows us to perform the most ideal bile drainage with the bile duct anastomosis made to the recipient (6)**.**

Anatomic biliary tree variations are reported to be found in approximately 30%–60%, and until now, numerous numbers of rare anatomic variations of the biliary tree have been reported. Therefore, precise preoperative evaluation of the biliary tree anatomy is extremely important to avoid intraoperative and postoperative complications associated with hepato-biliary surgery, including live liver donor surgery (7)**..**

Although LDLT is potentially lifesaving for the recipient, it exposes a healthy

individual to a major surgical procedure and associated risks without any therapeutic benefit. In previous studies, the prevalence of donor morbidity associated with LDLT was variable. The most common complications are bile leakage, biliary stricture, incisional hernia and wound infection. Untreated biliary complications can cause sepsis, multi-organ failure and even death (8).

Special considerations apply to LDLT compared with DDLT. Living donor assessment is performed in medical centers with a high level of expertise and resources. Experience in liver surgery has shown that there is considerable variability in liver anatomy. This issue has been the subject of discussion and has evolved as technology has improved. In terms of routinely utilized imaging techniques, it is imperative that the results allow complete understanding of all anatomic considerations. This is important to ensure donor safety as well as to manage expectations for recipient reconstructions (9).

This study aims to evaluate the role of non-enhanced MRCP in detecting biliary tree variations and anomalies as compared to intra-operative cholangiography of living liver donors.

Patients and methods

Patients:

This prospective study conducted at Mansoura University, Gastro-Intestinal Center, Liver Transplantation unit in the period from August 2022 to August 2024. It included fifty potential donors 28 males and 22 females with ages ranging from 18 to 45 years

An informed written consent was obtained from the patients. Every patient received an explanation of the purpose of the study and had a secret code number. The study was done after being approved by the Research Ethics Committee, Faculty of Medicine, Mansoura University.

Inclusion criteria were healthy potential donors of both sex with ages ranging from 18 to 45 years and BMI (< 28 kg/m2) who are 2nd to 3rd degree relatives to the recipient and there is donor-recipient compatibility those are determined at phase I of the study.

Exclusion criteria were donors with uncontrolled HTN, DM, diagnosed with IHD & rheumatic heart disease or having thrombocytopenia and/or elevated liver enzymes (hyperbilirubinemia or hypoalbuminemia). In addition, to donors who were HCV, HBV, CMV or EBV positive. Pregnant women were also excluded from the study. Those were excluded at phase I of study. Donors who were excluded during phase II were donors with hepatic focal lesions or Focal necrotic areas (like Bilharzial granuloma). Donors having moderate or severe fatty infiltration 15-20 % & reactive hepatitis changes (steato-hepatitis) or peri-portal fibrosis. Also, patients with hemosiderosis were excluded from the study

Methods:

All studied cases were subjected to the following: Detailed history taking, including [Personal history; name, age, gender and body mass index (BMI), Present history: course of the disease and duration, Past history of any medical condition or previous hospital admission and Family history of similar condition]. Full clinical examination: General examination including [General comment on patient conscious and mental state, Jaundice or pallor, Vital signs: pulse, blood pressure, capillary filling time, respiratory rate and temperature]. Routine laboratory investigations [complete blood count (Hb, WBCs, Platelets), random blood sugar, kidney function tests and liver function tests].

Preparation of the donors: Potential donors fasted for 10-12 hours to optimize imaging conditions. No contrast was used, and they wore loose clothing or gowns, removing any metal objects. They were briefed on the procedure, the importance of staying still, and provided written consent.

MRCP Technique: Potential donors underwent MRCP, involving image acquisition, processing, and analysis on a 1.5 Tesla MRI with specific protocols. A radiologist guided the examination to ensure accurate imaging of the bile ducts.

The MRCP protocol began with a multi-planner FFE localizer, followed by a series of respiratory-triggered sequences, including 2D axial T2 SSFSE, 3D coronal oblique Heavy T2 FATSAT FSE, 2D coronal T2 SSFSE, and 2D coronal thick slab MYELO sequences. These steps were designed to visualize the bile ducts with minimal motion artifacts, with a total exam time of 5 to 7 minutes.

Image processing: Image processing involved reviewing the imaging data on a workstation with 2D and 3D capabilities. A radiologist performed image reconstruction using MIP in the coronal plane, then manually edited the images to remove unnecessary details, creating clear coronal MIP images of the entire biliary system.

Three-dimensional models of the bile ducts were created using volume-rendering (VR) with artificial color enhancement. MIP and VR images were magnified and adjusted for optimal viewing, focusing on the right posterior sectorial duct. Native axial and coronal images were also reviewed for detailed evaluation of small bile ducts and accessory branches.

During image analysis, key points of focus included clear visualization of intrahepatic and extrahepatic bile duct anatomy, identification of biliary congenital anomalies, detection of biliary variants, and the presence of any accessory bile ducts. (SPSS Inc., Chicago, Illinois, USA)

Approval code: MD 13-8-2022

Statistical analysis and data interpretation:

All 50 potential donors had MRCP with adequate information of the central intrahepatic ducts branching pattern as determined by the radiologist at time of prospective reading, then the anatomical details were compared to the anatomical findings of intra-operative cholangiography. The diagnostic accuracy of MRCP for determining the branching pattern of the bile ducts at the hepatic hilum was correlated with the gold standard intra-operative cholangiography (IOC) to find the sensitivity, specificity, and accuracy of MRCP as a single preoperative method for assessment of biliary anatomy of living liver donors & mapping for operation.

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Validity indices were calculated as following using cross tabulation

1-Sensitivity (Sn)=detection rate=TPR (TPF): ability of test to detect variants in those who have it. SN= TP/ TP + FN

2-Specificity (Sp)=TNR (TNF): ability of test to exclude variants in those who do not have it. SP= TN/ TN + FP

3-Positive predictive rate (PPR): proportion of people with +ve test who have variants

PPV= TP/TP+FP

4-Negative predictive rate (NPR): proportion of people with -ve test who don't have variants

NPV= TN/TN+FN

5-Accuracy: TP+TN/TN+FN+TP+FP

Results

This study included 50 potential liver donors (28 male & 22 female). Their ages ranged from 18 to 45 years old (mean age 28 year), at the time of diagnosis. The commonest age group combined was (18-24 years, 44 %), followed by (25-31 years, 32 %), then (32-38 years, 18 %), finally (39-45 year, 6 %). 46 of the doner were right liver lobe donators while 4 were left liver lobe donators. **Table 1**

The typical and most preferred variant is the RPSD inserting into the proximal right hepatic duct more than 1 cm from the hepatic confluence, requiring a single bile duct anastomosis. Other variants, classified according to Huang, include RPSD draining into the right hepatic duct (44%), the confluence of hepatic ducts (10%), the left hepatic duct (34%), the common hepatic duct (8%), and other less common patterns. These variants influence the number of anastomoses needed during surgery, with fewer anastomoses associated with lower postoperative biliary complications. **Table 2**

In this study, MRCP findings in 50 donors revealed normal anatomy of the left hepatic duct, common bile duct, and

pancreatic duct, with no intra-ductal stones or abnormal gallbladder masses, and normal liver appearance on axial T2 images. Only two cases had gallbladder stones. MRCP correctly predicted variant biliary anatomy in 46 out of 50 donors. However, intra-operative cholangiography (IOC) provided additional details in five cases, identifying small intrahepatic bile ducts (IHB) draining into various parts of the hepatic and common bile ducts that MRCP missed. **Table 3**

The four cases that gave an inaccurate interpretation were Two cases of RPSD insertion into LHD (confirmed by IOC) which were reported as a normal bifurcation with insertion of RPSD into RHD and one case of biliary trifurcation (confirmed by IOC) which was reported as RPSD insertion into distal RHD with short carina. That last case had RPSD insertion into CHD (confirmed by IOC) which was reported as RPSD insertion into the distal RHD. In comparison of MRCP anatomical findings in our study with the reference standard intra-operative cholangiography, the sensitivity, specificity & accuracy was calculated and presented in **Table 4.**

Table 1: Age groups of the potential liver donors

Age group / Sex	18 – 24	25 – 31	32 – 38	39 – 45
Males	12 (24%)	9 (18 %)	5 (10 %)	2 (4 %)
Females	10 (20 %)	7 (14 %)	4 (8 %)	1 (2 %)

Table 2: Summary of the variation of RPSD insertion in the study

Type	Number	Description
A1	22	**The RPSD drains into the RHD (distance from the hepatic confluence to be measured; more than 1 cm is considered the normal anatomy & favored for single duct anastomosis).**
A2	5	**The RPSD drains into the confluence between both hepatic ducts**
A3	17	**The RPSD drains into the left hepatic duct.**
A4	4	**The RPSD drains into the common hepatic duct**
A5	1	**The RPSD drains into the cystic duct.**
A2 & A4	**1**	**The RPSD drains into the confluence between both hepatic ducts and another accessory right posterior duct drains into the common hepatic duct.**

Table 3: Insertion of RPSD in MRCP & IOC

Insertion of RPSD	MRCP	IOC
RPSD into RHD	22	19
RPSD into confluence of both hepatic ducts	5	6
RPSD into LHD	17	18
RPSD into CHD	4	5
RPSD into cystic duct	1	1
RPSD into confluence of both hepatic ducts and another accessory branch into the CHD	1	1

Table 4: IOC & MRCP sensitivity, specificity & accuracy

	Sensitivity (95%CI)	**Specificity (95%CI)**	**Accuracy (95%CI)**	**PPV (95%CI)**	**NPV (95%CI)**
MRCP	91.3 % (84.1-94.3)	100 % (92.8 – 100)	95.7 % (88.5–95.7)	100 % (92.1- 100)	**92.0 % (85.4–92.0)**
IOC	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**

- Female donor aged 18 years old:

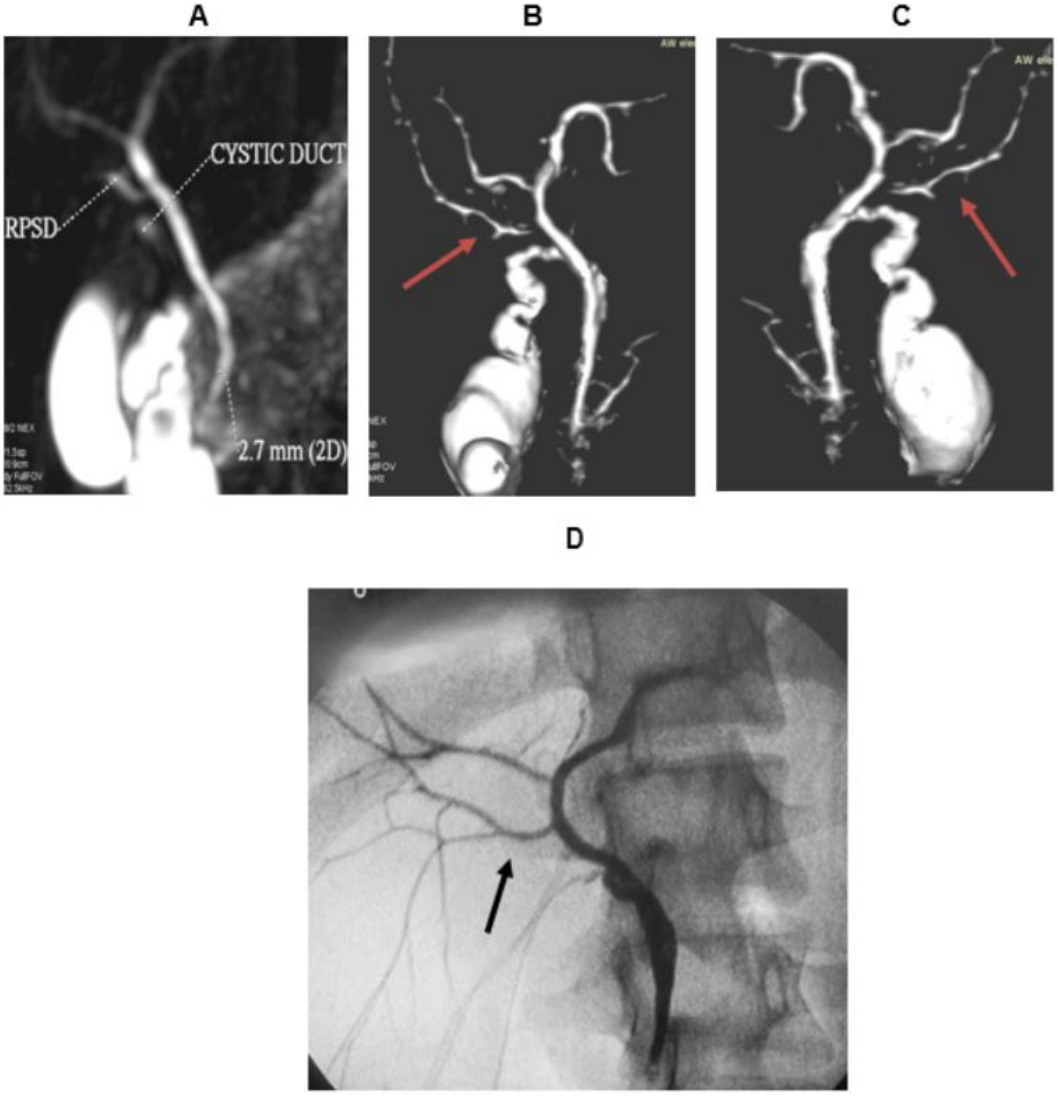

Figure 1

A) 2D coronal oblique thin slap Heavy T2 FAT SAT FSE **MRCP** image.

B) & C) Anterior & posterior views of post-processed 3D VR coronal **MRCP** image. They show the insertion of the RPSD (red arrows) into the middle part of the CHD above the cystic duct.

D) IOC image (AP view) confirmed the MRCP finding showing the insertion of theRPSD (black arrow) into the middle part of the common hepatic duct.

- Male donor aged 35 years old:

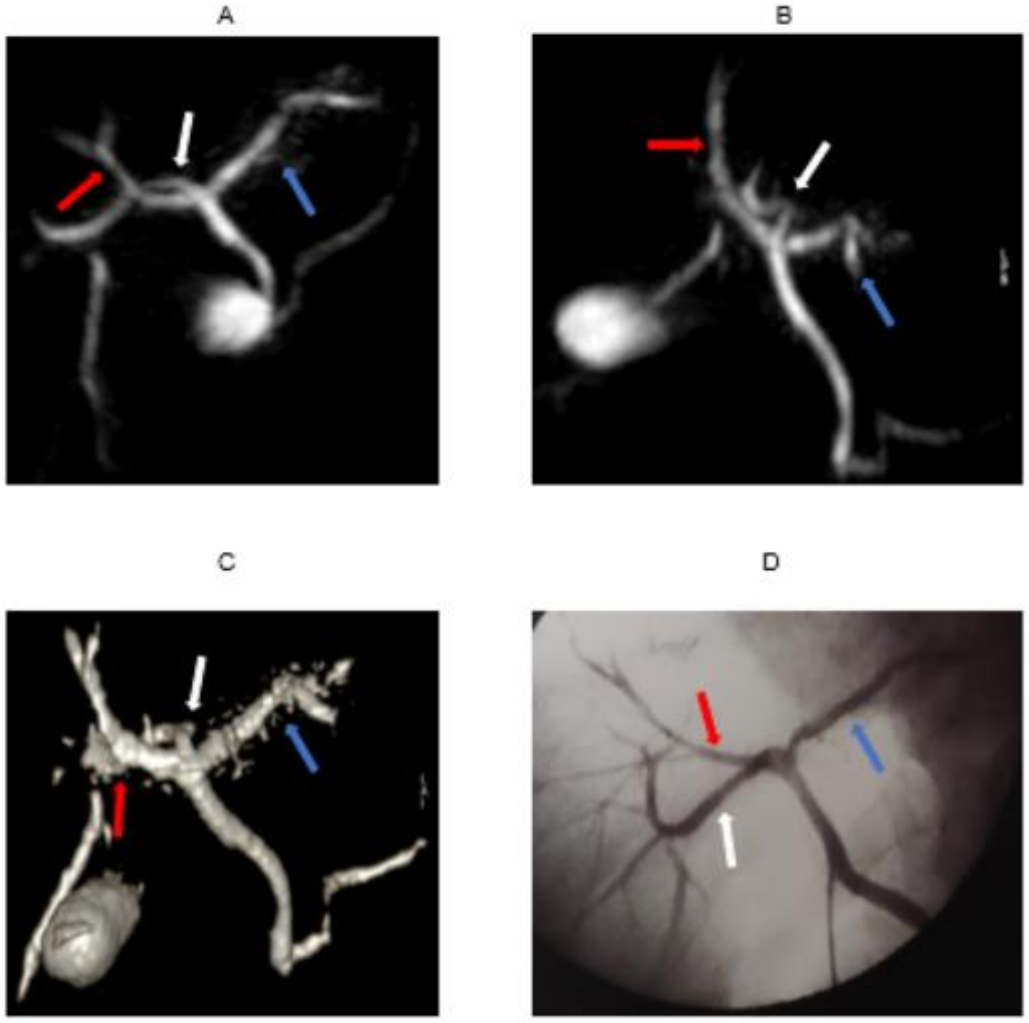

Figure 2

(A) & (B) 2D coronal oblique thin slap Heavy T2 FAT SAT FSE **MRCP** image.
(C) Coronal oblique of post-processed **3D VR coronal MRCP** image.

- They show the RASD (Red arrows), RPSD (White arrow) and the left hepatic duct (Blue arrow) draining into confluence of hepatic ducts (trifurcation pattern) to form the common hepatic duct.

(D) **IOC** image (AP view) confirmed these findings.

- Male donor aged 38 years old:

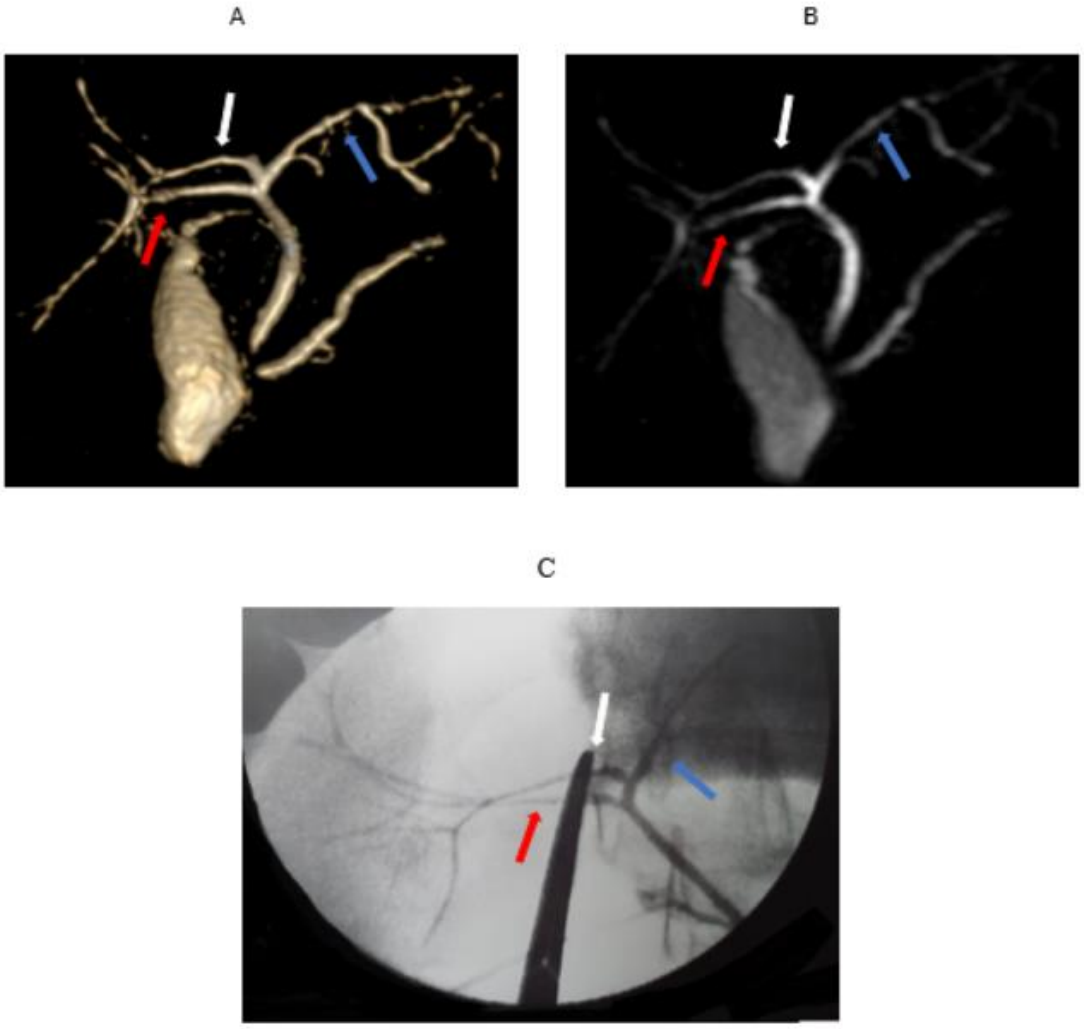

Figure 3

(A) Coronal oblique of post-processed **3D VR coronal MRCP** image.
(B) 2D coronal oblique thin slap Heavy T2 FAT SAT FSE **MRCP** image.
- ❖ They show the RPSD (White arrow) draining into the left hepatic duct (Blue arrow).
- ❖ The RASD is denoted by (Red arrow).

(C) **IOC** image (AP view) confirmed this finding where the RPSD is seen draining into the left hepatic duct.

Discussion

The objective of this study is to evaluate the role of non-enhanced MRCP in detecting biliary tree variations and anomalies as compared to intraoperative cholangiography of living liver donors. The study found that the most common variation of right posterior sectorial duct insertion was type A1 (44 %). About 10% were type A2, 34 % were type A3, 8 % were type A4, 2 % were type A5 and 2% were type A2 & A4.

In contrast to our findings, Jaganathan et al., found that the most common biliary tree variation was the drainage of the right posterior sectoral duct into the left hepatic duct, which was observed in 16 candidates (24.6%). A trifurcation biliary pattern was seen in six candidates (9.2%). The right posterior sectoral duct joined the common hepatic duct in four candidates (6.2%) (10).

On the other hand, Basaran et al., showed 67.5% of donors presented with a type A1 classic branching pattern, 5% with a type A2 trifurcation pattern, 20% with type A3, and 2.5% with type A4. In addition, showed that 56% of the donors had a type A1 classic branching pattern, 11% had a type A2 trifurcation pattern, 18% had a type A3 branching pattern, and 8% had a type A4 branching pattern (11) (12).

In agreement, Mazroua et al., found that MRCP could not correctly diagnose type 7 (Combination of type A1 and A4), so it was interpreted as type A2. Additionally, MRCP falsely diagnosed one of the standard classical types as a pattern. While the IOC precisely delineated the intrahepatic biliary radicles in all subjects, the 3D MRCP accurately delineated 33 subjects of 35, with a diagnostic accuracy of 97.1% (13).

In comparison of MRCP, anatomical findings in the current study with the reference standard intra-operative cholangiography, the sensitivity, specificity & accuracy of MRCP were (91.3 %, 100 % and 95.7 %, respectively) versus the sensitivity, specificity & accuracy of IOC were (100 %, 100 % and 100 %). On the other hand, Jaganathan et al., study showed a sensitivity of 100% and a specificity of 94.5% for identifying biliary variant anatomy on MRCP in comparison with the gold standard intraoperative cholangiogram. The accuracy of the MRCP in detecting the variant biliary anatomy in their study was 96.9% (10).

Limanond et al., used standard MRCP using a T2 SSFSE sequence in preoperatively mapping the biliary tracts of 26 LDLT donors. In that study, MRCP was 84.6% accurate in preoperative biliary mapping, although the study enrolled a small number of subjects (14). Also, Kim et al., used conventional MRCP in anatomical evaluation of liver donors that when compared with the actual biliary anatomy on IOC, MRCP was accurate in 90% of patients. Specifically, MRCP correct delineated normal anatomy in 15 of 17 patients and aberrant anatomy in 12 of 13 patients (15).

In Ragab et al., study, three-dimensional MRCP accurately determined the correct anatomy in 18 of 20 cases (15 normal and 3 abnormal) i.e., the overall sensitivity was 90%. Negative predictive value was also 90%. Specificity and positive predictive value were 100%. On the other hand, 3D MRCP was able to diagnose only 3 of 5 biliary anomalies with sensitivity for detecting biliary anomalies of 67%. The negative

predictive value was 88.2%, specificity and positive predictive value were both 100% (16).

MRCP data collection has been significantly improved in terms of spatial and temporal resolution, allowing MRCP to remain the gold standard for evaluating hepatobiliary disease. Furthermore, MRCP continues to play a crucial role in the non-invasive evaluation of several pancreaticobiliary disorders (17). The most common biliary variants are the ones mentioned and classified in Huang classification. However, other possibilities of biliary variants are theoretically endless (18).

This study has some limitations, including small sample size that may affect the generalizability of the findings; Further studies with larger sample sizes are recommended.

Conclusion

MRCP is a non-invasive technique with high sensitivity for detecting intrahepatic biliary variants in LDLT donors, crucial for preoperative planning. Identifying these variants enables safer and more effective surgeries, reducing postoperative complications.

References

1. Masood L, Sayeed S, Aslam S, Faiz B. Relationship between Variant Biliary and Vascular Anatomy in Living Liver Donors in Pakistani Population. Journal of the Dow University of Health Sciences (JDUHS). 2022;16:34-40.
2. Yankol Y, Mecit N, Kanmaz T, Kalayoğlu M, Acarlı K. Complications and outcomes of 890 living liver donor hepatectomies at a single center: risks of saving loved one's life. Turkish Journal of Surgery. 2020;36:192.
3. Soin AS, Chaudhary RJ, Pahari H, Pomfret EA. A worldwide survey of live liver donor selection policies at 24 centers with a combined experience of 19 009 adult living donor liver transplants. Transplantation. 2019;103:e39-e47.
4. Seleem MI, Salaam MA, Abd El Hamid NM, editors. Comparison between pre-operative radiologic findings and the actual operative findings of the graft in adult living donor liver transplantation2020: Elsevier.
5. Wei L, Zhang Z-t, Zhu Z-j, Sun L-y, Zeng Z-g, Qu W, et al. A new approach to accomplish intraoperative cholangiography in left lateral segmentectomy of living liver donation. Annals of Transplantation. 2019;24:155.
6. Donmez R, Gormez A. Evaluation of the Compatibility of Preoperative MRCP and Intraoperative Cholangiography in Imaging of the Bile Ducts in Living Donor Liver Transplantation. Indian Journal of Surgery. 2022;84:418-23.
7. Shizuku M, Kurata N, Jobara K, Yoshizawa A, Ogura Y. A novel anatomic variation of the intrahepatic biliary tree in live liver donor surgery: A case report. International Journal of Surgery Case Reports. 2021;79:231-3.
8. Karatoprak S, Kutlu R, Karatoprak NB, Dağ N, Yılmaz S. Percutaneous radiological biliary interventions after failed endoscopic treatment in living liver donors: experience of a high-volume transplantation center. Transplant International. 2021;34:2846-55.
9. Testa G, Nadalin S, Klair T, Florman S, Balci D, Frola C, et al. Optimal surgical workup to ensure safe recovery of the donor after living liver donation–A systematic review of the literature and expert panel recommendations. Clinical Transplantation. 2022;36:e14641.

10. Jaganathan S, Ray B, Velaga J. Our experience in tracking the tract: normal biliary anatomy and variants on magnetic resonance cholangiopancreatography in living donor liver transplantation. Cureus. 2023;15.
11. Basaran C, Agildere AM, Donmez FY, Sevmis S, Budakoglu I, Karakayali H, et al. MR cholangiopancreatography with T2-weighted prospective acquisition correction turbo spin-echo sequence of the biliary anatomy of potential living liver transplant donors. American Journal of Roentgenology. 2008;190:1527-33.
12. Wang, Y., Jodoin, P. M., Porikli, F., Konrad, J., Benezeth, Y., & Ishwar, P. (2014). CDnet 2014: An expanded change detection benchmark dataset. In Proceedings of the IEEE conference on computer vision and pattern recognition workshops (pp. 387-394).
13. Mazroua JA, Almalki YE, Alaa M, Alduraibi SK, Aboualkheir M, Aldhilan AS, et al. Precision mapping of intrahepatic biliary anatomy and its anatomical variants having a normal liver using 2D and 3D MRCP. Diagnostics. 2023;13:726.
14. Limanond P, Raman SS, Ghobrial RM, Busuttil RW, Lu DSK. The utility of MRCP in preoperative mapping of biliary anatomy in adult-to-adult living related liver transplant donors. Journal of Magnetic Resonance Imaging: An Official Journal of the International Society for Magnetic Resonance in Medicine. 2004;19:209-15.
15. Kim RD, Sakamoto S, Haider MA, Molinari M, Gallinger S, McGilvray ID, et al. Role of magnetic resonance cholangiography in assessing biliary anatomy in right lobe living donors. Transplantation. 2005;79:1417-21.
16. Ragab A, Lopez-Soler RI, Oto A, Testa G. Correlation between 3D-MRCP and intra-operative findings in right liver donors. Hepatobiliary surgery and nutrition. 2013;2:7.
17. Serinsöz S, Aktürk R. The Value of MRCP in the Evaluation of the Level and Degree of Biliary Obstruction in Obstructive Jaundice. Comprehensive Medicine. 2023;15:199-204.
18. Barsoum NR, Samie AA, Adel L, Asaad RE. Role of MRCP in assessment of biliary variants in living donor liver transplantation. The Egyptian Journal of Radiology and Nuclear Medicine. 2013;44:131-6.

To cite this article: Tamer A. Kamal, Tarek S. El-Husseiny, Ahmed E. Shalaan, Waleed A. Hamed. Anatomical Evaluation of the Biliary System of Living Liver Donors using Pre-Operative Non-Enhanced MRCP in Comparison to Intra-Operative Cholangiogram. BMFJ 2025;42(1):309-320.