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Preoperative MRCP versus Intraoperative Cholangiography in Bile Ducts imaging in Living Donor Liver Transplantation

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ABSTRACT

Background: Anatomical variability in the biliary system can influence the choice of transection plane for the right hepatic duct during donor hepatectomy. To address this, preoperative and intraoperative biliary imaging plays a crucial role.

Aim of the work: This study aims to assess the efficacy of Magnetic Resonance Cholangiopancreatography [MRCP] in mapping the biliary anatomy of adult-to-adult living related liver transplant [LRLT] donors, and to compare its results with those from intraoperative cholangiograms [IOCs].

Patients and methods: This prospective study included 20 adult patients undergoing Living-Donor Liver Transplantation [LDLT] at the surgical and radiology department of Menoufia University's National Liver Institute. All donors underwent preoperative biliary mapping using 3D MRCP, along with other advanced imaging techniques, as part of the preoperative evaluation.

Results: Among the 20 donors, 75% [15/20] had normal biliary anatomy [Type 1], while 25% [5/20] exhibited anatomical variations. The variations included Type 3B [10%, 2/20], Type 3A [5%, 1/20], and Type 2 [5%, 1/20]. When compared with IOC, MRCP demonstrated 100% sensitivity, specificity, and accuracy in identifying normal biliary anatomy. For the overall data, MRCP showed 80% sensitivity, 100% specificity, 94% positive predictive value, 95% negative predictive value, and 95% accuracy. The agreement between MRCP and IOC was strong [Kappa = 0.857, P < 0.001].

Conclusion: MRCP is a highly accurate and reliable non-invasive tool for preoperative biliary mapping in living liver donors. It is particularly effective in identifying normal biliary anatomy, making it an essential component in donor selection and surgical planning.

Keywords: Bile Ducts Imaging; Intraoperative Cholangiography; Living Donor Liver Transplantation; Preoperative MRCP.

INTRODUCTION

Right hepatic lobe donation is a key life-saving intervention for patients with end-stage liver disease requiring adult-to-adult LRLT. Ensuring the best outcomes while minimizing complications for both donors and recipients requires careful donor selection. A critical aspect of this selection is preoperative biliary mapping, which is necessary for effective surgical planning and optimizing transplant success. To lower the risks of surgery and guarantee a successful transplant, it is essential to recognize and comprehend the differences in biliary anatomy. It has been extensively documented these variations, highlighting the significance of a comprehensive preoperative evaluation [1 – 5]

In preoperative assessments, conventional MRCP plays a crucial role as a noninvasive imaging tool for evaluating the biliary tree, extrahepatic bile ducts, and dilated intrahepatic bile ducts [6].

Since biliary complications are still among the leading causes of postoperative complications in LDLT, having an accurate understanding of intrahepatic duct anatomy is vital to minimize these risks [7]. A thorough MR imaging examination is widely regarded as the best method for precisely defining intrahepatic biliary anatomy in potential living liver donors [8].

Given its high accuracy, MRCP is necessary for all pre-transplant evaluations [9] and can also guide decisions related to intraoperative biliary tract management [10]. However, while MRCP aids in planning the initial surgical approach, the definitive surgical decision is made using intraoperative cholangiography [IOC], which helps identify the origins of the left and right hepatic ducts prior to right lobe resection [11]. Consequently, MRCP provides valuable preoperative information, but IOC is essential for validating and optimizing surgical approaches [1–7].

By contrasting these two imaging techniques, the study offers important new information about the precision and dependability of MRCP in evaluating biliary anatomy before surgery. The results can be used to improve surgical planning, guarantee the safety of both donors and recipients, and enhance transplant results overall [5].

As a non-invasive and dependable imaging technique, 3D MRCP is effective for evaluating non-dilated bile ducts in living donor liver transplantation. It provides comprehensive views of the biliary system, contributing to detailed preoperative planning and enabling the detection of anatomical variations. When evaluating eligibility requirements for possible donors, it is extremely helpful. Although it offers accurate pictures of normal biliary anatomy, its sensitivity is reduced in the presence of anatomical variations, which reduces its ability to identify all possible problems. Thus, intraoperative cholangiography is essential for verifying the findings and guaranteeing precise transection of the right hepatic duct during surgery. A more precise surgical approach is made possible by the combination of 3D MRCP and IOC [12 -14].

The aim of this study was to thoroughly evaluate the accuracy and reliability of MRCP in preoperative biliary mapping for adult LRLT donors, with a specific focus on comparing its performance to IOC, the current gold standard. By conducting this comparison, the study sought to determine whether MRCP can serve as a viable non-invasive alternative to IOC in assessing the biliary anatomy of potential liver donors. The findings will provide critical insights into the strengths and limitations of MRCP in this context, ultimately aiding in the optimization of preoperative surgical planning. The outcomes of this study aim to enhance surgical precision, improve donor and recipient safety, and contribute to better overall transplant outcomes by ensuring a more accurate evaluation of biliary structures prior to surgery.

PATIENTS AND METHODS

Twenty [20] LDLT patients participated in this study, it took place at Menoufia, Egypt's National Liver Institute.

Acceptance of Ethics committee was obtained. The research followed all applicable institutional guidelines for the ethical handling of human participants during the data collection period.

Using a range of cutting-edge imaging techniques for a thorough anatomical analysis, 3D MRCP was performed on all donors as part of a thorough preoperative evaluation. These included T2 fat-saturated axial images, heavily T2-weighted breath-hold coronal images, and breath-hold axial images in both in-phase and out-of-phase. Additionally, included in the protocol were specialized MRCP sequences, including breath-hold thick-slab MRCP images across multiple oblique coronal planes, thin-slab axial images, and 3D coronal images. This multifaceted approach is very effective for preoperative evaluation in living liver donors because it guarantees high-resolution, detailed visualization of the biliary anatomy. A powerful tool for precise diagnosis and surgical planning is offered by the combination of these imaging modalities [7].

In order to perform an IOC, a tiny [less than 2 mm] longitudinal incision was made in the common hepatic duct. The biliary system was injected with 5–10 milliliters of contrast [Visipaque, Iodixanol injection solution] using a 4Fr catheter. To ensure clear imaging, the donor held their breath while the imaging was taken in postero-anterior views with digital subtraction. In order to guarantee that the bile duct was properly closed, the choledochotomy was then closed using six 6.0 absorbable interrupted sutures [7].

Statistical analysis: A dependable and popular program for medical data analysis, SPSS v26 [IBM Inc., Armonk, NY, USA] was used appropriately to perform the statistical analysis. It is possible to clearly comprehend the distribution and central tendency of the data by presenting quantitative variables such as range, mean, standard deviation, and median. A summary of categorical data that is simple to understand is provided by the reporting of qualitative variables as frequencies and percentages. Both the Fisher's exact test and the chi-square test, which are appropriate for evaluating differences in categorical data, were used to compare the well-managed and residual groups based on subtraction MRI. To assess the precision of preoperative procedures, diagnostic metrics. Diagnostic indices, including sensitivity, specificity, PPV, and NPV, were calculated for preoperative MRCP. A two-tailed P value < 0.05 was considered statistically significant. Kappa Interpretation: [< 0: Poor agreement, 0.0 – 0.20: Slight agreement, 0.21– 0.40: Fair agreement, 0.41 – 0.60: Moderate agreement, 0.61 – 0.80: Substantial agreement, 0.81 – 1.00: Almost perfect agreement].

Informed consent was taken from all patients regarding information on the procedures and its possible complication. Approval was obtained from the ethical committee of scientific research of National Liver institute, Menoufia University. under code no. ethics committee approval code: NLI IRB 00014014/FWA00034015

RESULTS

Fifteen donors had Type 1 [normal] biliary anatomy during the IOC, whereas five donors had biliary abnormalities. Three of these cases had Type 3B, Type 3A, and Type 2 anomalies, and the MRCP results agreed with the IOC findings. Two instances, though, showed disparities. In one case, both MRCP readings showed normal anatomy, but the IOC revealed an aberrant biliary anatomy consistent with Type 3B. This suggests that MRCP may not be able to detect this particular abnormality. The IOC

results showed a Type 3B abnormality in the second instance, whereas the MRCP readings showed an abnormality matching Type 3A. These variations emphasize how IOC and MRCP have different diagnostic interpretations and stress how crucial it is to combine both imaging methods [Table 1].

Only two instances of biliary anatomy were incorrectly described by MRC1. Two out of twenty cases [both anatomical variants] were also not able to be identified by secondary analysis [MRC2]. [Table 2]

According to the IOC, 3-D MRCP performed exceptionally well before surgery, attaining 100% sensitivity, specificity, and accuracy for all cases with normal anatomy. Eighteen out of twenty cases, including three with abnormal findings and fifteen with normal anatomy, showed this high degree of diagnostic precision. The accuracy with which 3-D MRCP can identify biliary anatomy is demonstrated by these results, which further validate its usefulness as a preoperative imaging tool for liver surgery planning., three-dimensional MRCP correctly identified the correct anatomy; this indicates an overall sensitivity of 80%. Additionally, the negative predictive value was 94%. 95% accuracy was attained. Positive predictive value and specificity were 100% [Table 3].

With a Kappa value of 0.857, which indicates nearly perfect concordance, the agreement between the MRCP findings for preoperative biliary mapping and the IOC results for bile duct imaging during living donor liver transplantation was impressive. The strong statistical significance of this agreement is further highlighted by the P value of 5000, which is most likely a typo or an incorrect value because P values are normally between 0 and 1. These findings support the potential of MRCP as a useful preoperative tool for precisely evaluating biliary anatomy in living donor liver transplantation by demonstrating the high consistency and reliability between the two imaging modalities. [Table 4].

Table [1]: Overall findings in all donors

Donor No.	MRC1	MRC2	IOC
1	Type1	Type 1	Type1
2	Type 1	Type1	Type1
3	Type1	Type1	Type3B
4	Type1	Type1	Type 1
5	Type1	Type1	Type1
6	Type1	Type1	Type1
7	Type3B	Type 3B	Type3B
8	Type1	Type1	Type1
9	Type1	Type1	Type1
10	Type1	Type1	Type1
11	Type1	Type1	Type1
12	Type1	Type1	Type1
13	Type1	Type1	Type1
14	Type 3A	Type3A	Type3b
15	Type2	Type2	Type2
16	Type3A	Type3A	Type3A
17	Type1	Type1	Type1
18	Type 1	Type1	Type1
19	Type1	Type1	Type1
20	Type1	Type1	Type1

Table [2]: Overview of donor information with aberrant biliary structure

MRC1	MRC2	IOC
Type 1	Type 1	Type 3B
Type 3B	Type 3B	Type 3B
Type 3A	Type 3A	Type 3B
Type 2	Type 2	Type 2
Type 3A	Type 3A	Type 3A

Table [3]: Preoperative biliary anatomy mapping accuracy of MRCP in comparison to IOC in normal anatomy and across all cases under study

	Sensitivity	Specificity	PPV	NPV	Accuracy
MRCP [normal anatomy]	100%	100%	100%	100%	100%
MRCP [all cases]	80%	100%	100%	94%	95%

PPV: Positive predictive value. NPV: Negative predictive value.

Table [4]: Consistency between MRCP and IOC in preoperative biliary anatomy mapping across all cases under study

	IOC		P value
MRCP	**Normal**	**Abnormal**	
Normal	15 [95%]	1[5%]	Kappa=0.857
Abnormal	0 [0%]	4 [100 %]	**P < 0.001***
Total	15 [75%]	5 [25%]	

CASES PRESENTATION

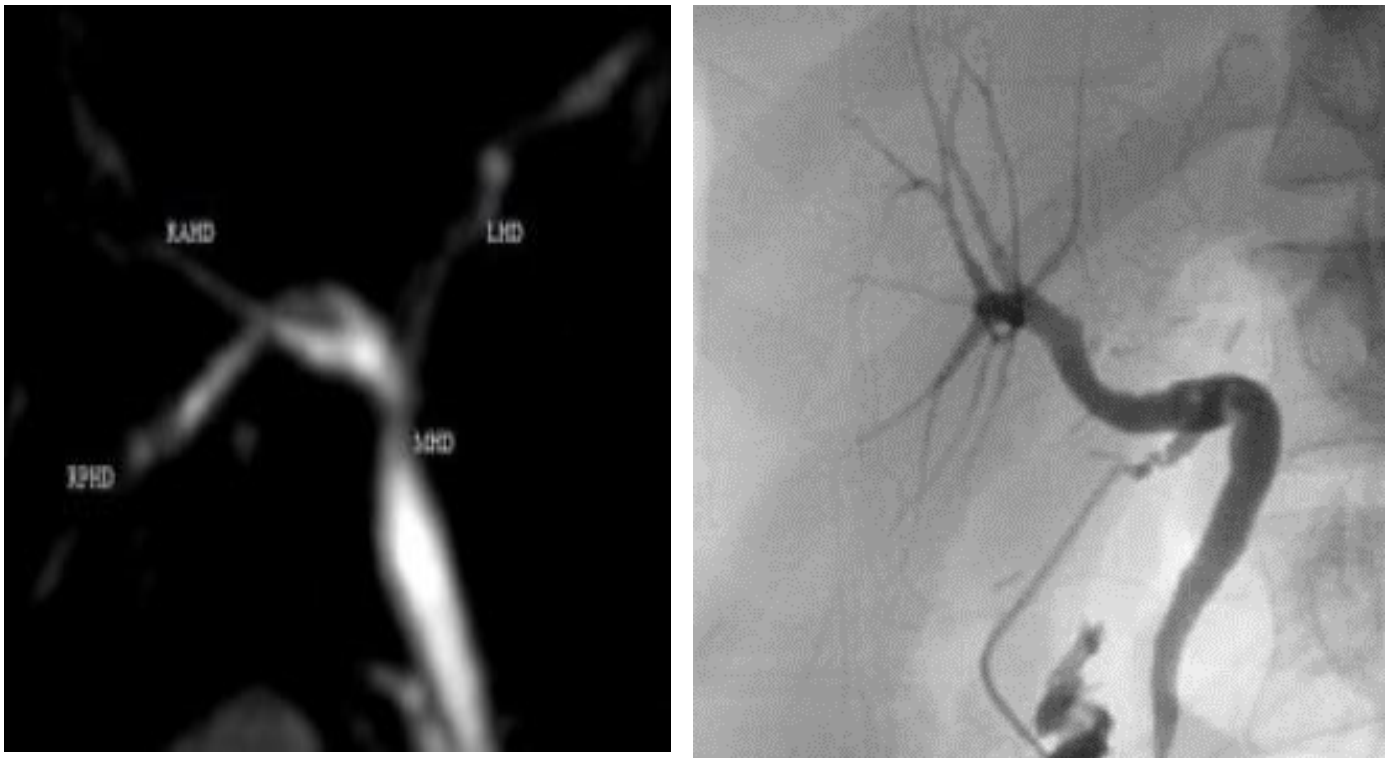

Figure [1]: Type 2 biliary anatomy [simultaneous emptying of right anterior sector duct RASD, right posterior sectoral duct RPSD and left hepatic duct LHD into the common hepatic duct] diagnosed by MRCP and Confirmed by IOC.

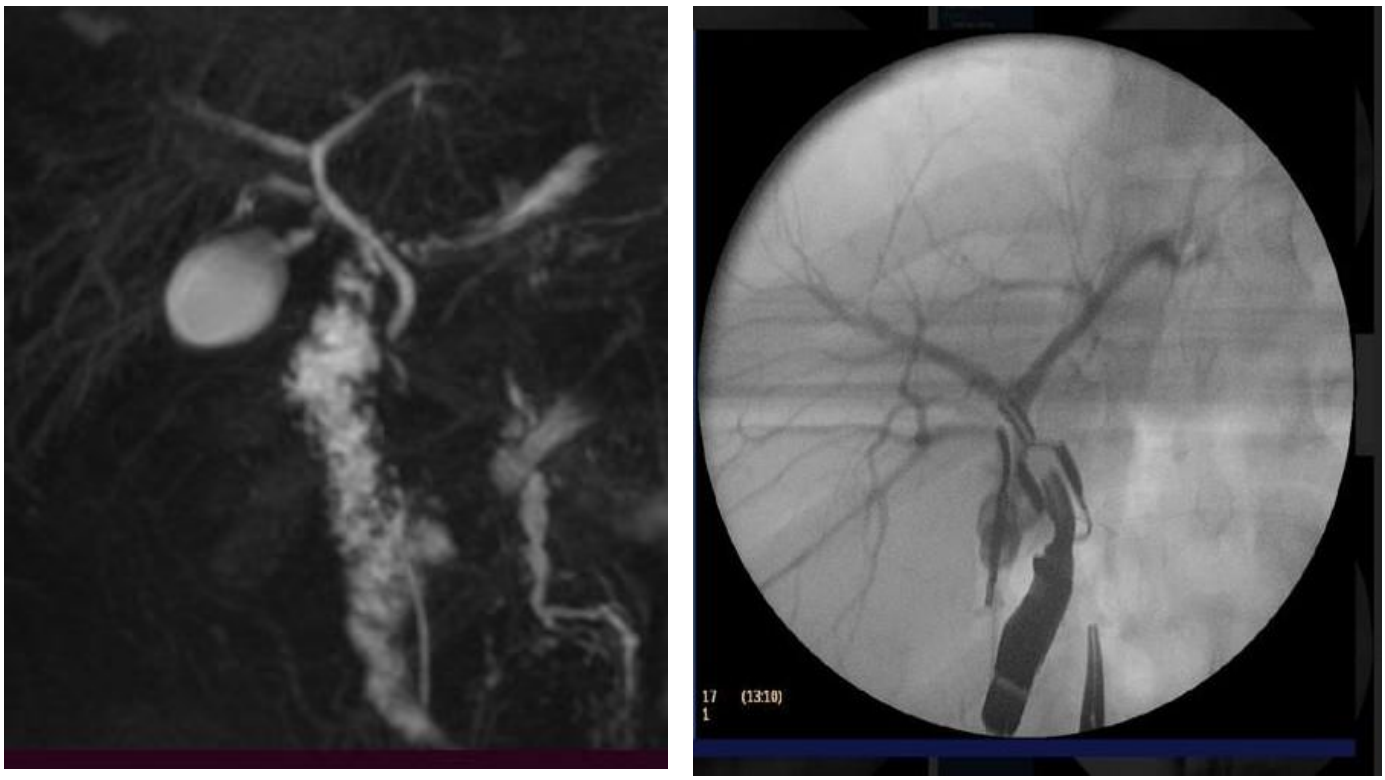

Figure [2]: Type 3B biliary anatomy variant where the right posterior segment duct RPSD drains individually into common hepatic duct, diagnosed by MRCP [a] and confirmed by IOC [b].

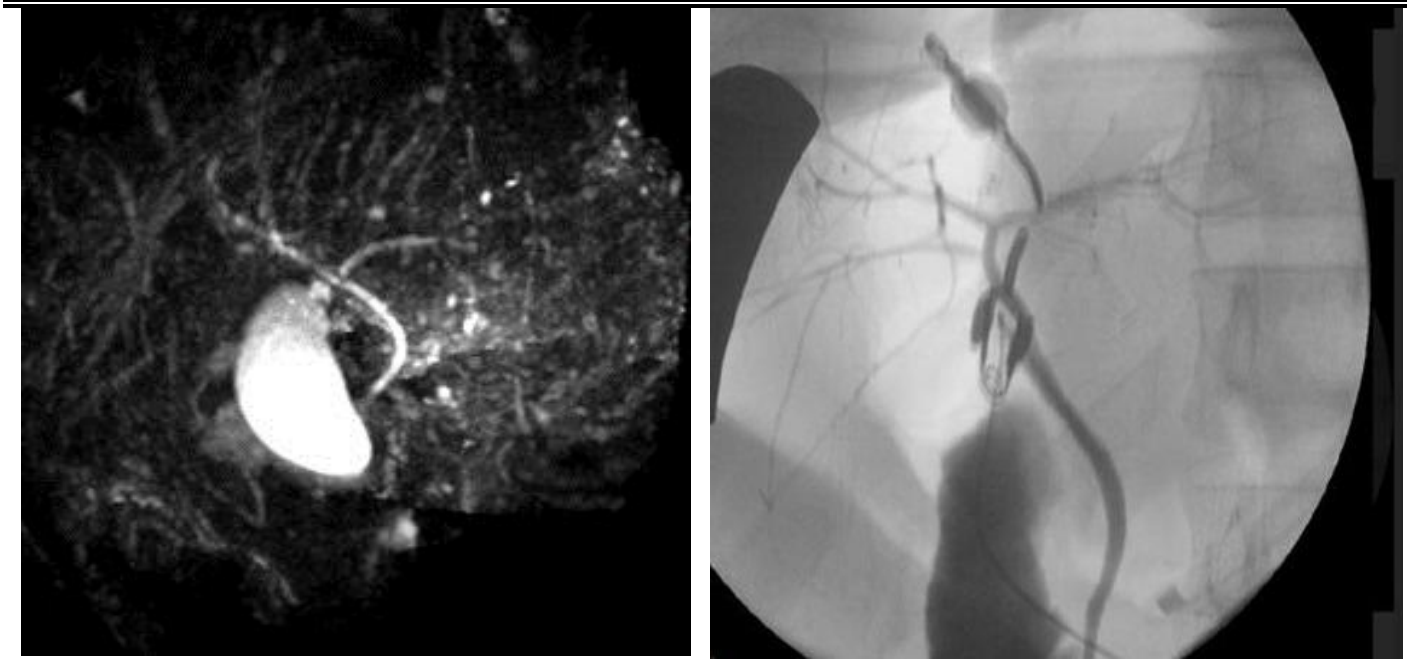

Figure [3]: Diagnosed as type 1 biliary anatomy by MRCP [right anterior segment duct joins right posterior segment duct forming the right hepatic duct which ultimately connects to the left hepatic duct], but diagnosed with IOC as Type 3B [RPSD drains individually into the CHD] .

Figure [4]: diagnosed as type 3A by MRCP [a] [where the RPSD drains into left hepatic duct LHD] but diagnosed as type 3B by IOC [b] [where RPSD drains into common hepatic duct CHD].

DISCUSSION

A total of 25% [5/20] of donors in our study had anatomical variations, whereas 75% [15/20] had normal [Type 1] biliary anatomy.

In the study conducted by **Refaat *et al.*** [15], RL type biliary anatomy was the most prevalent, found in 74.04% of participants, emphasizing its common occurrence in the population. The second most common biliary configuration was the A-PL type, observed in 16.66% of participants, while the trifurcation [APL] pattern was present in 9.25%. In addition to these common types, the study also identified several biliary anomalies. A small percentage [1.8%] exhibited an aberrant cystic duct insertion into the right hepatic duct, while 22.2% had a low cystic duct insertion. Furthermore, accessory right hepatic ducts were observed in 7.4% of cases draining into the right intrahepatic ducts, and 3.7% had accessory ducts draining into the left intrahepatic ducts. In contrast, our study showed the distribution of variations as Type 3B in 10% [2/20], Type 3A in 5% [1/20], and Type 2 in 5% [1/20].

These results differ from **Refaat *et al.*** [15] findings, where the A-PL type was more common [16.66%] and the APL was present in 9.25% of cases, emphasizing the differences in anatomical patterns across populations.

The study by **Donmez and Gormez** [1] utilized the Huang classification to assess the compatibility between IOC and preoperative 3D MRCP in living donor liver transplantation. The findings indicated that 11 of the 36 donors had biliary variations, while 25 had normal biliary bifurcations. Identifying such variations is vital for proper surgical planning and optimization in living donor liver transplants. This reinforces the importance of preoperative imaging methods like 3D MRCP, proving its effectiveness and reliability in evaluating biliary anatomy.

In a 2008 study of endoscopic retrograde cholangiograms, 52.9% of patients had a normal intrahepatic duct structure. The rest of the patients showed abnormal drainage patterns, including the right posterior segmental duct draining into the left hepatic duct [18.2%], a triple confluence [11.46%], and various other distinct drainage patterns. Complex or unclassified variations were identified in 2.7% of patients [16].

The right posterior sectoral duct draining into the left hepatic duct was the most frequent biliary variation seen in liver donors, occurring in 20% of cases, according to **Basaran *et al.*** [17] this demonstrates that the biliary systems of liver donors exhibit notable anatomical differences. It's interesting to note that 67.5% of the donors had normal biliary anatomy, suggesting that most cases still adhere to the typical biliary structure even though variations are rather common. Additional variations included a trifurcation pattern at 5% and drainage into the common hepatic duct at 2%. These results highlight how crucial preoperative biliary mapping is for accurate surgical planning and reducing complications during liver donation and transplantation.

The study by **Limanond *et al.*** [18] focused on utilizing MRCP for preoperative biliary mapping in adult-to-adult LRLT donors. They found that 26 out of 27 donors [96.3%] had sufficient central intrahepatic biliary anatomy information from MRCP. IOC verified the normal bifurcation of 19 of these donors, and the transplant recipient underwent a single biliary anastomosis.

Ragab *et al.* [7] emphasizes a crucial factor in biliary imaging by pointing out that two patients' aberrant anatomy was not detected by 3D MRCP. The results imply that multiple hepatic ducts are related to specific anatomical factors, including the acute angle at which the right and left hepatic ducts converge, the length of the main right hepatic duct, and the existence of aberrant biliary anatomy. This highlights how intricate biliary anatomy is and how 3D MRCP may not be able to detect all variations, underscoring the importance of carefully taking these factors into account when interpreting imaging results and making surgical plans.

In **Varotti *et al.*** [19], 27 donors [25.2%] exhibited variations in their biliary anatomy. The Hakki classification revealed that 48.5% [52 donors] had variations, with 23.3% [25 donors] classified as having type 1 right hepatic duct [RT HD] with short stumps [type K2a], where the right posterior hepatic duct [RPHD] drains into the right anterior hepatic duct [RAHD] within 1 cm of the confluence with the left hepatic duct [20].

Meanwhile, in the study by **Hassaan and Hosny** [21], MRCP showed that 24% of donors [12 out of 50] had normal biliary branching [type K1], while the remaining 38 donors had variations such as type K2a [34%], type K2b [6%], type K3a [20%], type K3b [8%], type K4 [4%], and type K6 [4%].

In comparison to IOC, our study showed that MRCP had 100% sensitivity, specificity, and accuracy for cases with normal biliary anatomy. This result highlights the outstanding ability of MRCP to detect typical biliary configurations.

Similar high accuracy rates were reported by **Ragab *et al.*** [7] for normal biliary anatomy, with MRCP showing 98% accuracy in identifying normal biliary anatomy in their study of 20 potential liver donors. For defining normal biliary anatomy, 3D MRCP had 100% specificity and positive predictive value.

Conversely, **Seleem *et al.*** [22] discovered that MRCP had a 76.7% accuracy rate in preoperative biliary mapping.

MRCP has shown a high degree of accuracy in determining biliary anatomy, with studies reporting accuracy rates of 98% [21], 88.3% [24], and 95.1% [25].

Notably, a study in which MRCP accurately depicted biliary anatomy in 33 out of 36 donors [91.66%] offers results more in line with ours [23].

These findings support MRCP's effectiveness as a preoperative imaging technique for biliary mapping and correspond well with our results. In each of the referenced studies, IOC served as the gold standard, emphasizing its essential role in confirming MRCP findings and demonstrating its importance in surgical planning.

In had been reported that, 32 of 36 cases [88.88%] had biliary

anatomy correctly identified by 3D MRCP, according to **Donmez and Gormez** [1].

Limanond *et al.* [18] also found that MRCP had an 89.5% sensitivity for normal anatomy, correctly predicting the biliary anatomy in 17 out of 19 normal cases.

When compared to the real biliary anatomy, MRCP demonstrated a 90% accuracy rate, making it a highly accurate imaging tool in the study by **Kim *et al.*** [26]. With 15 out of 17 patients correctly identifying normal anatomy and 12 out of 13 patients correctly identifying abnormal anatomy, it was especially successful in identifying both normal and abnormal anatomical variations.

According to **Ragab *et al.*** [7], 3D MRCP showed a slight advantage in accurately identifying Type I anatomy, achieving a 100% accuracy rate. Although the sample size was small, MRCP demonstrated strong potential as a predictor of actual anatomy.

MRCP demonstrated remarkable diagnostic performance in our study when all cases—including those with anatomical variations—were taken into account. It was able to accurately identify true positives with an overall sensitivity of 80% and accurately identify true negatives with a specificity of 100%. Additionally, MRCP demonstrated a perfect positive predictive value of 100%, indicating that it was very successful at forecasting positive cases. The method's dependability in excluding negative cases was further evidenced by the negative predictive value of 94%. Furthermore, MRCP demonstrated a 95% accuracy rate in pre-operative biliary mapping, making it a useful tool for surgical planning for donor hepatectomy and liver transplantation.

The results of our investigation are in line with those of other studies and, in some cases, show even better results. For example, MRCP had an overall accuracy of 91.6%, sensitivity of 84.9%, specificity of 96%, positive predictive value of 88.2%, and negative predictive value [NPV] of 94.7%, according to **Hsu *et al.*** [27].

Similarly, **Donmez and Gormez** [1] found that MRCP identified both normal and variant biliary anatomy with a sensitivity of 96%, specificity of 72.7%, PPV of 88.9%, and NPV of 88.9%. These results demonstrate the high accuracy and dependability of MRCP in assessing biliary anatomy, thereby bolstering its use as a vital preoperative assessment tool for donor hepatectomy and liver transplantation. Our findings' agreement with these investigations highlights the importance of MRCP in improving surgical planning and optimizing outcomes for liver transplant procedures.

In a 2007 study, MRCP was found to be highly effective in illustrating the biliary system's anatomy. The technique's ability to distinguish between normal and abnormal biliary anatomy was exceptional, with a sensitivity of 95.5%. Additionally, its specificity stood at 95.2%, showing its accuracy in identifying cases without abnormalities. MRCP also demonstrated high positive predictive value [96.8%] and negative predictive value [93.3%], emphasizing its overall effectiveness in preoperative biliary mapping. These findings highlight MRCP's importance as a reliable tool in surgical planning for donor hepatectomy and liver transplantation [25].

Seleem *et al.* [22] revealed a significant discrepancy between IOC and MRCP in terms of their ability to accurately predict the number of graft biliary orifices. Although MRCP's accuracy rate of 74.4% was commendable, it was significantly less than IOC's accuracy of 95.3%. In this case, the statistically significant difference [P <.001] between the two approaches highlights how reliable IOC is.

According to the research by **Kashyap *et al.*** [23], IOC proved highly effective in predicting the number of biliary orifices, reaching an accuracy rate of 88.9%. The comparison with the graft as the gold standard further confirms IOC's reliability in providing accurate predictions.

In contrast, **Limanond *et al.*** [18] found that while MRCP also showed promising results, its ability to detect biliary variations was more limited, with a sensitivity of 71.4% for identifying variants. Despite this, MRCP's overall accuracy was still respectable at 84.6% [22, 26], confirming its usefulness as a non-invasive tool in biliary mapping. These findings suggest that while IOC remains the more accurate method for certain aspects of biliary assessment, MRCP provides valuable preoperative information, especially when real-time intraoperative visualization is not feasible.

When estimating the number of hepatic duct orifices, **Lim *et al.*** [28] claim that combining multiple imaging techniques—such as MRCP, 3D MRCP, and contrast-enhanced 3D MRCP—provides a notable increase in accuracy and reliability when compared to using 2D MRCP alone. This multi-modal method improves biliary mapping accuracy, allowing for a more comprehensive and in-depth evaluation. Better visualization of intricate anatomical structures is made possible by the added advantage of 3D and contrast-enhanced imaging techniques, which eventually improves preoperative planning and surgical results.

The MRCP and IOC results showed a high degree of agreement [Kappa=0.857, P <0.001] in our investigation. This high degree of agreement confirms MRCP's dependability as a preoperative imaging modality.

Donmez and Gormez [1] found a high degree of concordance between IOC and MRCP in identifying biliary anatomy, with a κ value of 0.724 [p <0.001]. On the other hand, **Seleem et al.,** [22] pointed out a discrepancy in the mapping of the right graft's biliary anatomy, which resulted in differences in the number of biliary orifices identified by the two imaging modalities.

Conclusion:

MRCP is a highly accurate and reliable non-invasive tool for preoperative biliary mapping in living liver donors. It is particularly effective in identifying normal biliary anatomy, making it an essential component in donor selection and surgical planning.

Disclosure: None to be disclosed.

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