Role of MR Cholangiography in Evaluation of Hepatic Biliary Morphology in Living Liver Donors

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Abstract

Purpose: To assess the utility of magnetic resonance cholangiopancreatography (MRCP) in preoperative mapping of biliary anatomy in adult-to-adult living donor liver transplantation LDLT).

Materials and Methods: Fifty LDLT donors (39 males and 11 females) their age 20-37 years (mean age 20.8 years) referred from liver transplantation surgeons to radiology Departments at Dar Al Fouad Hospital for doing preoperative MRCP during the period from April 2009 to March 2011. Intraoperative cholangiography (IOC) was used as the reference standard. The MRCP was performed on 1.5 Testa MR magnets using respiratory triggering techniques T2-weighted sequences in axial/coronal thin sections, and variable-thickness rotating slabs. The accuracy of preoperative MRCP for biliary mapping in potential LDLT donors was analyzed compared to the IOC findings.

Results: Of the 50 donors, MRCP showed only 12 (24%) had type K1 anatomy (classical branching patterns of the biliary system). The remaining 38 subjects had anatomical variants: 17 (34%) had type K2a, 3 (6%) had type K2b, 10 (20%) had type K3a, 4 (8%) had type K3b, 2 (4%) had type K4 and 2 (4%) had unclassified pattern (type K6). Compared with IOC findings as the reference standard in our study, MRCP correlated with IOC in 48 (98%) of 50 subjects.

Conclusion: Preoperative MRCP accurately depicts the biliary anatomy and variants in LDLT donors and should be used in the preoperative workup of all donors, to allow exclusion of unsuitable donors, thus ensuring donor safety and optimal recipient outcome.

Key Words: MRCP — Living liver donors — Intra-operative cholangiography

Introduction

DURING donor graft hepatectomy proper identification the bile ducts at the portahepatis is a critical step to avoid post-surgical bile leakage and atrophy of the residual liver and/or the graft [ii].

Biliary complications, occurring in approximately 7%-10% of donors, represent the most common cause of morbidity in living donor liver transplantation; they include bile leakage and bile duct stricture pi.

Preoperative knowledge of hepatic biliary anatomic variants is mandatory for surgical planning and to help reduce postoperative complications [31].

MRCP is a noninvasive diagnostic imaging technique that replaced endoscopic cholangiography for evaluation of the hepatic biliary anatomy [4].

It has been demonstrated that detailed preoperative evaluation of biliary anatomic variants with MR Cholangiopancreatography is useful for preventing biliary surgery complication, helping the surgeons safely perform hepatectomy in the living donor liver transplantation and biliary reconstruction in the recipient [5,6].

MR imaging, with the added value of image post-processing, allows accurate identification of the biliary tree which helps to determine the best hepatectomy plane and helps to identify patients in whom additional surgical steps will be required [5,7].

Some variants can lead to inadvertent biliary tract injury in the donor or may complicate transplantation surgery. In some centers, biliary trifurcation may preclude graft harvesting because of the increase in the postoperative complication rate [8].

The aim of this work is to demonstrate the role of MR cholangiopancreatography (MRCP) in the

Abbreviations:
MRC : MR cholangiography.
IOC : Intra-operative cholangiography.
LDLT : Living donor liver transplantation.
evaluation of anatomical biliary variants in potential living donors for liver transplantation helping the surgeons to plan their approach before beginning the procedure and preventing biliary tract injuries resulting in a low post-operative biliary complications.

Patients and Methods

Fifty LDLT donors were referred from liver transplantation surgery unit to the radiology department Dar Elfouad hospital for doing preoperative MRCP during the period from April 2009 to March 2011. IOC was used as the reference standard. The study group was composed of 50 donors (39 men, 11 women; age range, 20-37 years; mean age, 27.08 years). Informed consent was taken from all the patients.

Technique of examination:

- Patients were asked to fast for at least 4 hours before the MR examination to promote gall bladder filling and gastric emptying.
- 5ml intravenous MR contrast agent (Gadopentetate dimeglumine) diluted in 250ml pineapple juice was ingested 15min before examination.

MRCP Technique:

- Imaging was performed with a 1.5-T MR magnet (Magnetom Symphony, Siemens Medical Solutions) using a 4-channel body phased-array surface coil as a radiofrequency receiver. A localizer was taken (TR/TE: 15/5ms, Slice Thickness: 10mm).
- T2-Trufi in coronal & axial cuts (TR/TE: 5/3ms, Slice thickness: 7mm)
- Parallel acquisition technique T2-HASTE-respiratory trigger-Thick Slice thickness-Coronal (TR/TE: 4500/752ms, Slice Thiclmess 40mm, FOV: 350mm, Gap: 0, Flip angle: 180°, Matrix: 307 x 384).
- T2-TSE 3D (turbo spin echo three dimensions) - coronal-respiratory trigger (TR/TE: 1800/678ms, Slice Thickness 1.5mm, FOV: 350mm, Gap: 0, Flip angle: 170°, Matrix: 384 x 384, Slice resolution: 84).
- We processed MRCP data sets with MIP and SSD algorithms.
- The source images were obtained in two planes, providing better anatomic orientation.
- For the image analysis, a series of 19 projections rotated by 10° intervals from —90° to 90° was created for each rendering algorithm. The reconstructions were obtained in the coronal plane.

The images of MRCP were classified according to Hakki classification for the biliary tree, which depends on the site of insertion of the right posterior hepatic duct (RPHD), as well as, its distance from the confluence of the right anterior hepatic duct (RAHD) and the left hepatic duct (LHD):

The details of our classification system were:

- Type K1; the RPHD opens into the RAHD in a distance more than lcm from the confluence between the RAHD and the LHD (classical branching pattern).
- Type K2 a; the RPHD opens into the RAHD in a distance 1 cm or less from the confluence of the RAHD and the LHD.
- Type K2 b; trifurcation pattern of insertion of the RPHD, RAHD and LHD.
- Type K3 a; the RPHD opens into the LHD in a distance lcm or less from the confluence of the RAHD and the LHD.
- Type K3 b; the RPHD opens into the LHD in a distance more than lcm from the confluence of the RAHD and the LHD.
- Type K4; the RPHD opens into the CHD.
- Type K5; the RPHD opens into the cystic duct.
- Type K6; furthermore accessory bile ducts and bizarre unclassified patterns of biliary tree variants.
- Then all MRCP images were compared with intra-operative cholangiography (IOC) findings.

Intraoperative cholangiography:

Intraoperative cholangiography was performed at Dar Al Fouad hospital by surgeons before hepatectomy in all 50 patients. After cholecystectomy, the cystic duct remnant was cannulated, and 10-20mL of iohexol (Omni paque, GE Healthcare) was hand injected to opacify the intrahepatic biliary system under fluoroscopic guidance. Anteroposterior and oblique views were obtained using a fluoroscopic C-arm system (OEC 9800. GE health care). Although the preliminary surgical plan was based on MRCP, the final decision was based on intraoperative cholangiography as the reference standard.

Statistical analysis:

MRCP and IOC final data were evaluated using descriptive statistical analysis including the usual frequencies, histograms, central tendency measures, measures of dispersions and the coefficient of sensitivity and specificity.
Results

The study group was composed of 50 donors (39 men, 11 women; age range, 20-37 years; mean age, 27.08 years). The images of MRCP and IOC were classified according to Hakki classification for the biliary tree and compared to each other (Tables 1-3).

In our study we consider the bizarre classified patterns of biliary tree variants as K6 (Figs. 1-5).

Of the 50 donors, MRCP shows only 12 (24%) had type K1 (classical branching patterns of the biliary system). The remaining 38 subjects had anatomical variants: 17 (34%) had type K2a, 3 (6%) had type K2b, 10 (20%) had type K3a, 4 (8%) had type K3b, 2 (4%) had type K4 and 2 (4%) had classified pattern (type K6). Compared with IOC findings as the reference standard in our study, MRCP correlated with IOC in 48 (98%) of 50 subjects.

In one subject MRCP results showed biliary variant classified as type K3a, as the RPHD was seen opened into the LHD in a distance lcm from the confluence of the RAHD and the LHD, whereas IOC revealed that the distance was more than 1 cm and was classified as type K3b.

The other one the MRCP findings revealed biliary variant classified as type K2a (as the RPHD was drained into RAHD at about 0.3cm away from the confluence between RAHD & LHD), whereas IOC revealed trifurcation pattern and classified as type K2b.

The overall sensitivity of MRCP in differentiating normal and variant biliary anatomy in our study was 100%, specificity was 85%, and accuracy was 98%.

![Fig. (1 A,B): 29 years old male living liver donor a.3D MIP reconstructive image shows RPHD drains into RAHD to a distance less than lcm Type 2a Haldci classifications. b IOC confirms the MRC.](image1)

![Fig. (2 A,B,C): 27 years old male living liver donor. (A&B) show 3D MIP reconstructive images showing RPHD inserted into the LHD (K3a type) C, IOC image confirm the MRC images.](image2)
Fig. (3 A,B,C): 31 years old male living liver donor (A&B) 3D MIP reconstructive images show unclassified anatomical map absent left main bile duct, the left hepatic lobe is seen drained by two superior (short block arrow) and inferior (long block arrow) biliary radicals. The superior left biliary radical joins the RPHD (arrow) forming a common trunk (0.46cm) RAHD joins the common trunk forming CHD. The inferior left biliary radical drains into the CHD. Ioc confirms the MRC images (Type K6 Hakki Classification).

Fig. (4): (A&B) Pre and (C&D) 15 min post pineapple juice (PJ) magnetic resonance cholangiopancreatography (MRCP) images. (E) 3D MIP reconstructive image shows RPHD drains into RAHD.
Fig. (5 A,B,C): 28 years old male living liver donor (A&B) show 3D MIP reconstructive images showing RPHD inserted into the CHD and accessory RPHD inserted into LHD (K4 type) C. IOC confirms MRImages.

Table (1): Types of biliary anatomy on MR Cholangiography images.

<table>
<thead>
<tr>
<th>Biliary Anatomy</th>
<th>Frequency (Number of donors)</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>12</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>K2 a</td>
<td>17</td>
<td>34.0</td>
<td>34.0</td>
<td>58.0</td>
</tr>
<tr>
<td>K2 b</td>
<td>3</td>
<td>6.0</td>
<td>6.0</td>
<td>64.0</td>
</tr>
<tr>
<td>K3 a</td>
<td>10</td>
<td>20.0</td>
<td>20.0</td>
<td>84.0</td>
</tr>
<tr>
<td>K3 b</td>
<td>4</td>
<td>8.0</td>
<td>8.0</td>
<td>92.0</td>
</tr>
<tr>
<td>K4</td>
<td>2</td>
<td>4.0</td>
<td>4.0</td>
<td>96.0</td>
</tr>
<tr>
<td>K6</td>
<td>2</td>
<td>4.0</td>
<td>4.0</td>
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<tr>
<td>Total</td>
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Table (2): Types of biliary anatomy on IOC images.

<table>
<thead>
<tr>
<th>Type of biliary anatomy</th>
<th>Frequency (Number of donors)</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
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<tbody>
<tr>
<td>K1</td>
<td>12</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>K2 a</td>
<td>15</td>
<td>30.0</td>
<td>30.0</td>
<td>54.0</td>
</tr>
<tr>
<td>K2 b</td>
<td>5</td>
<td>10.0</td>
<td>10.0</td>
<td>64.0</td>
</tr>
<tr>
<td>K3 a</td>
<td>10</td>
<td>20.0</td>
<td>20.0</td>
<td>84.0</td>
</tr>
<tr>
<td>K3 b</td>
<td>4</td>
<td>8.0</td>
<td>8.0</td>
<td>92.0</td>
</tr>
<tr>
<td>K4</td>
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<td>4.0</td>
<td>4.0</td>
<td>96.0</td>
</tr>
<tr>
<td>K6</td>
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<td>4.0</td>
<td>4.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
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Table (3): Comparison of MRCP and IOC.

<table>
<thead>
<tr>
<th>Type</th>
<th>MRCP %</th>
<th>IOC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>K2 a</td>
<td>34.0</td>
<td>30.0</td>
</tr>
<tr>
<td>K2 b</td>
<td>6.0</td>
<td>10.0</td>
</tr>
<tr>
<td>K3 a</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>K3 b</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>K4</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>K6 (unclassified)</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Total</td>
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<td>100.0</td>
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</table>

Discussion

Liver transplantation is the definitive treatment for patients with end stage liver disease. Owing to the shortage of deceased-donor livers for transplantation, physicians are increasingly using living liver donors [9,10].

This procedure is complex and poses risks to both the recipient and the donor. One of the most important challenges is that of managing the biliary ducts during liver lobe resection and re-implantation. Like the hepatic arterial anatomy, the biliary anatomy is quite variable [7,11,12].

Living donor liver transplantation (LDLT) demands careful pre-operative evaluation of the anatomy of the hepatic vessels and biliary tree to minimize morbidity to the healthy donor and recipient of the transplant [9,13].

Pre-operative assessment of the branching pattern of the bile duct at the hepatic hilum is important for surgeons to select appropriate donors and plan the surgical approach. There are a variety of anomalous branching patterns which can affect the surgical approach and biliary anastomotic technique and may even preclude liver donation [14].

Recently magnetic resonance cholangiopancreatography (MRCP) is most commonly used for preoperative assessment of biliary anatomy. MRCP is able to visualize important anomalous bile duct branching patterns in the majority of the cases [11,14].

In our study we used a 1.5-T MR magnet using a 4-channel body phased-array surface coil as a radiofrequency receiver in correspondence with Benjamin et al. [15] & Kim et al. [12].
Lim et al. [16] stated that the patient must fast at least 6 hrs before the examination which was applied in this study.

Coppens et al. [17] stated that administration of 250ml negative oral contrast material (pineapple juice) 15-30 min before performing the examination improves image quality and provide good visualization of the biliary ducts without superimposed high signal from the GIT and we agree.

Laurent et al. [18] also reported that diluted intravenous MR contrast agents (such as Gadopentetate dimeglumine or gadolinium DTPA) as oral contrast are effective and safe in eliminating signal intensity of the gastrointestinal tract, thus improving the depiction of the biliary system in MRCP which we also agree with.

In our study group, the examined population was composed of 50 living hepatic donors. we used 5ml intravenous MR contrast agent (Gadopentetate dimeglumine) diluted in 250ml pineapple juice administrated 15min before examination and we founded that the quality of images were improved with much better elimination of the high signal from the bowel.

Lee et al. [19] & Laurent et al. 2007 [18] in his study used (Mangafodipirtrisodium) hepatobiliary MR imaging contrast agent excreted primarily by the biliary system and can be used as a T1-weighted MR imaging to improve delineation of the biliary anatomy.

Morita et al. [20] & Mo et al. [21] used in their studies morphine sulfate injected intravenously to dilate the biliary trees.

These fore-mentioned substances couldn't be applied in our study due to the availability of hepatobiliary contrast agents & the feasibility of morphine injection in Egypt.

We used a phased-array coil as a radiofrequency receiver to improve the signal reception with maximum gradient strength 45mT/m and maximum slew rates 200 T/m/sec as stated by McSweeney et al. 2012 [22].

A localizer was taken (TR/TE: 15/5ms, Slice Thickness: 10mm) & T2-Trufl in coronal & axial cuts (TR/TE: 5/3ms, Slice thickness: 7mm) as stated by Riordan et al. [23].

Routine transverse breath-hold T 1-weighted in- and opposed-phase gradient-echo and T2-weighted fast SE images were taken to localize the biliary ducts in correspondence with Sirvanci et al. [24].

For respiratory triggering, a navigator technique is used to detect the diaphragm position at 1.5-T MR imaging in agreement with Lim et al. 2008 [16] & Kim et al. [12].

Then we did a respiratory trigger T2- HASTE- axial images as stated by Sirvanci et al. 2007 [24] & Lim et al. [16].

Parallel acquisition technique T2- HASTE-respiratory trigger-Thick Slice thickness-Coronal and T2-TSE 3D (turbo spin echo three dimensions)-coronal- respiratory trigger sequences were applied, then we processed MRCP data sets with MIP and SSD algorithms as reported by Kim and colleagues [12].

Riordan et al. [23] applied single plane source images in their study, yet Lim et al. 2008 [16], Kim et al. [12] & McSweeney and colleagues [22] applied source images obtained in two different planes for providing better anatomic orientation and we followed them in our study.

For image analysis, a series of 19 projections rotated by 10° intervals from —90° to 90° was created. The reconstructions were obtained in the coronal plane as stated by Sirvanci et al. [24].

In our study all MRC images were interpreted, using classification system of the biliary tract similar to Hakki (modified Huang) classification for the biliary tree, which depends on the site of insertion of the RPHD, as well as, its distance from the confluence of the RAHD and theLHD as stated by Karakas et al. [6] & Artioli et al. [ii].

Comparing our series to Sirvanci et al. [24] study on 67 donors, our incidence of type K1 anatomy was 24% compared to 26.8%, our incidence of type K2a anatomy was 34% compared to 19.4%, our incidence of type K2b anatomy was 6% compared to 20.8%, our incidence of type K3a anatomy was 20% compared to 14.9%, our incidence of type K3b anatomy was 8% compared to 14.9%, our incidence of type K4 anatomy was 4% compared to 0%, and our incidence of type K6 anatomy was 4% compared to 4% also.

Compared with IOC findings as the reference standard in our study, MRCP revealed the accurate and detailed anatomy of the biliary system in 48 (98%) of 50 subjects.
The overall sensitivity of MRCP in differentiating normal and variant biliary anatomy in our study was 100%, specificity was 85%, and accuracy was 98%, compared to sensitivity 95.5%, specificity 95.2% & accuracy 88.3% as reported by Song et al. [25] in a study on 47 donors, and a sensitivity 84%, specificity 100% & accuracy 95.1% as stated by Sirvanci et al. 2007 [24] in a study on 67 donors.

We assumed that the higher sensitivity level in our study may be attributed to the pre-procedure administration of 5ml intravenous MR contrast agent (Gadopentetatedimeglumine) diluted in 250ml pineapple juice causing better elimination of the high signal intensity of the gastrointestinal tract, thus improving the depiction of the biliary system in MRCP images.

**Conclusion:** Preoperative MRCP accurately depicts the biliary anatomy and variants in LDLT donors and should be used in the preoperative workup of all donors, to allow exclusion of unsuitable donors, thus ensuring donor safety and optimal recipient outcome.

**References**


