Despite improvements in hepatic surgical techniques, biliary complication remains a major cause of morbidity and mortality, and accurate diagnosis is crucial for treatment planning. Thus, a detailed knowledge of the hepatic anatomy is a prerequisite for successful, complication-free liver surgeries [1-4]. Presurgical planning with detailed anatomy is a key component of liver surgeries, including transplantation, tumor resection, and laparoscopic hepatobiliary surgeries [2]. Magnetic resonance imaging is an accurate and noninvasive technique for evaluating the hepatic vascular and biliary anatomy, is devoid of ionizing radiation and is safe for patients who are allergic to iodinated contrast agents [5]. The purposes of this study were to use Magnetic resonance cholangiography (MRC) to investigate the anatomical variants of biliary tracts in Taiwanese population, to demonstrate imaging features of these common and rare biliary variants and to stress its implications for liver surgery.

**MATERIAL AND METHOD**

**Patient**

This was a retrospective single-institution study that was approved by our institutional review board. In our hospital, a total of 476 living related liver transplantation donors received conventional T2 MRC examination for pre-operative evaluation over a 45-month period (from April 2006 to December 2009). Due to suboptimal imaging quality, 14 patients (3%) were excluded from this study. A total of 462 patients were enrolled for evaluation (age range, 17-58 years, mean 31.4; 233 male, 229 female).

**MRC protocol**

All MRC were obtained with a 1.5T scanner (GE, Signa Excite). Morphine (0.04 mg/kg body weight) was given intravenously prior to the examination to improve imaging quality of the biliary tree. Our protocol includes one set of
2D coronal thick slice fast spin echo (FSE) MRC (relaxation time/echo time = 4000 ms/901.1 ms) and a second set of 3D oblique coronal thin slice fast spin echo T2-weighted image MRC (relaxation time/echo time = 5454.6 ms/551.4 ms, spatial resolution = 0.66 mm × 0.66 mm × 2.8 mm). Post-processing of the image data was performed to reconstruct maximum intensity projection (MIP) images and multiplanar reformatted images (MPR).

Normal biliary tract anatomy

The normal biliary drainage system is parallel to the portal venous supply. The right posterior segmental duct (RPSD) draining the posterior segments (VI and VII) join the right anterior segmental duct (RASD) draining the anterior segments (V and VIII) to form the right hepatic duct (RHD). The right posterior segmental duct is almost horizontal, but the right anterior segmental duct tends to be more vertical. The right posterior segmental duct usually runs posterior to the right anterior segmental duct and fuses to form the right hepatic duct. The left hepatic duct (LHD) is formed by segmental tributaries the drain segments II–IV. The common hepatic duct is formed by fusion of the right hepatic duct and left hepatic duct. The bile duct draining the caudate lobe usually joins the origin of the left or right hepatic duct.

Biliary tract variation

Common variations of the biliary tract were divided into 7 types according to Yoshida classification [6]: Type 1 (Fig. 1), union of the right anterior segmental duct (RASD) and the right posterior segmental duct (RPSD) to form a right intrahepatic duct.

**Figure 1.** MRCP and drawing illustration show type 1 biliary tract variation: union of the right anterior segmental duct (RASD) and the right posterior segmental duct (RPSD) to form a right intrahepatic duct.

**Figure 2.** MRCP and drawing illustration show type 2 biliary tract variation: union of the right anterior segmental duct (RASD), right posterior segmental duct (RPSD), and left intrahepatic duct (LHD) to form a trifurcation.
and the right posterior segmental duct (RPSD) to form a right hepatic duct (RHD); Type 2 (Fig. 2), union of the rRASD, RPSD, and left hepatic duct (LHD) to form a triple confluence; Type 3 (Fig. 3), the RPSD draining directly into the LHD; Type 4 (Fig. 4), the RPSD draining into common hepatic duct (CHD); Type 5 (Fig. 5), union of the RPSD, left superior segmental duct (LSSD) and left inferior segmental duct (LISD) to form a trifurcation; Type 6 (Fig. 6), union of the RASD, RPSD and LSSD as a triple confluence and the LISD draining into the CHD; Type 7 (Fig. 7), the LISD draining into the CHD. There are several rare variants with accessory ducts which were not included in the Yoshida classification were grouped into type 8 (Fig. 8-13).

**RESULTS**

All of the 462 patients with visualization of the third order branches of the intrahepatic ducts on MRC were selected for analysis. In this study, normal biliary duct anatomy was present in 65.8% of patients. Drainage of the right posterior segment into the left hepatic duct before its confluence with the right anterior segmental duct was the most common anatomic variant of the biliary system (type 3, 13.0%). Another common variant of main hepatic biliary branching was the so-called triple confluence (type 2, 9.1%), which is characterized by simultaneous emptying of the right posterior segmental duct, right anterior segmental duct, and left hepatic duct into the common hepatic duct. These variants at the level of the confluence become important in...
Figure 5. MRCP and drawing illustration show type 5 biliary tract variation: union of the right posterior segmental duct (RPSD), left superior segmental duct (LSSD) and left inferior segmental duct (LISD) to form a trifurcation.

Figure 6. MRCP and drawing illustration show type 6 biliary tract variation: a union of the right anterior segmental duct (RASD), right posterior segmental duct (RPSD) and left superior segmental duct (LSSD) as a trifurcation and the left inferior segmental duct (LISD) draining into the common hepatic duct.

Figure 7. MRCP and drawing illustration show type 7 biliary tract variation: the left inferior segmental duct (LISD) draining into the common hepatic duct.
Biliary tract variation in Taiwanese

Table 1. Incidence of common and rare biliary variation

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<tbody>
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</tr>
<tr>
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<tr>
<td>Others (%)</td>
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<td>10</td>
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DISCUSSION

According to a literature review, the incidence of the typical pattern of biliary system has been reported to be 57%-72% [7-19]. With the increasing complexity and prevalence of hepatobiliary surgeries (e.g., transplantation surgery and hepatic resection), a detailed preoperative evaluation of the hepatic vascular and biliary anatomy is mandatory to minimize postoperative morbidity [4].

Determination of biliary anatomy can be performed preoperatively by endoscopic retrograde cholangiography (ERC), intraoperative cholangiography (IOC), conventional T2 MRC, contrast enhanced T1 MRC and multi-detector row computed tomography cholangiography (CTC). ERC is able to provide precise evaluation of the biliary tract with the best imaging quality. ERC, however, is associated with certain risks, including post-ERC pancreatitis, biliary tract injury and duodenal perforation [19]. Intraoperative cholangiography (IOC) can be challenging, time consuming and injurious. IOC is rarely performed in our institution, which stress the importance and necessity of accurate and safe methods for preoperative evaluation of the biliary tree anatomy.

MRC has potential as a noninvasive, non-biohazardous diagnostic modality for pre-operation evaluation [5]. The basic concept is that heavily T2-weighted images demonstrate high signal intensity from structures containing static fluid. The limitation of this conventional MRC technique has been inadequate depiction of the biliary tract, especially in nondilated ducts [4]. In our study, Morphine was used for increasing the frequency and amplitude of basal contractions of the sphincter of Oddi. Reduced outflow of bile and pancreatic juice and distension of biliary tract was also noted as an effect of Morphine.

Figure 8. MRCP and drawing illustration show one rare biliary tract variation: the right posterior segmental duct (RPSD) draining into the left intrahepatic duct (LHD) inferiorly.
**Figure 9.** MRCP and drawing illustration show one rare biliary tract variation: bilateral IHDs form a trifurcation respectively.

**Figure 10.** MRCP and drawing illustration show one rare biliary tract variation: one accessory hepatic duct draining into CHD.

**Figure 11.** MRCP and drawing illustration show one rare biliary tract variation: LISD draining into RASD and the RPSD draining into CHD.
However, we must note the adverse effects of Morphine, such as miosis, dizziness, nausea, vomiting, bowel ileus and respiratory depression. During this study, two patients were sent to emergency room due to hypotension and another 14 patients complained minor side effects (e.g., nausea, dizziness and skin rash). Poor visualization of biliary tree on T2 MRC was encountered in 3% of our patients even with the help of Morphine. Other imaging modalities are needed for these patients with poor distention of bile ducts.

The usefulness of CTC using intravenous injection of contrast medium has been shown to provide much better spatial resolution than other indirect cholangiography. Previous studies have reported that CTC enables significantly better biliary tract visualization than conventional T2-weighted or contrast enhanced T1-weighted MRC either alone or in combination [20]. CTC is minimally invasive and simple to perform. The image data enable visualization of the biliary tract anatomy, as well as the relationship between biliary tract and hepatic vasculature, and the data are easily reformatted into 3D displays [21]. However, the contrast medium is currently not available in Taiwan.

The hepatocyte-specific contrast agents, gadolinium benzylxoypropionictetraacetate (Gd-BOPTA) and gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid (Gd-EOB-DTPA) were developed to improve the detection and characterization of focal liver lesions at MR imaging. The injected contrast medium is taken up into the functional hepatocyte and is excreted via the biliary system. Because of this property, hepatocyte-specific contrast agent has the potential to be a biliary contrast agent. When combined with T2-weighted MR cholangiography, both Gd-EOB-DTPA and Gd-BOPTA enhanced MR imaging could be effective in evaluation of biliary anatomy. In patient with suboptimal imaging quality T2-WI MRC, hepatocyte-specific contrast

**Figure 12.** MRCP and drawing illustration show one rare biliary tract variation: accessory segmental left IHD draining into CHD.

**Figure 13.** MRCP and drawing illustration show one rare biliary tract variation: S4 segmental IHD draining into CHD directly.
agent enhanced T1-WI MRC should be considered as an alternative. However, hepatospecific contrast medium enhanced MRC itself has several limitations, including: high cost, limited availability, the potential risk of contrast-induced adverse reactions, and long examination times [10].

Sufficient knowledge and detailed anatomic demonstration before hepatobiliary surgery are mandatory to avoid formidable complications, which might lead to biliary cripple and/or mortality, if not adequate corrected. For example, for those with Yoshida classification 3 who undergo left hepatectomy, his or her right posterior segmental branch might be erroneously ligated without proper biliary reconstruction, if this biliary anomaly is not well recognized preoperatively. Further, for those with Yoshida classification 4 who undergo laparoscopic cholecystectomy, the right posterior segmental branch might be mistaken as cystic duct and erroneously divided. Of note, the type 3 and type 4 occurred in 13% and 8.9%, respectively, of our patients surveyed by MRCP, which therefore represent an important issue for hepatobiliary surgeons. Furthermore, there are several rare biliary tract variations, such as aberrant (Fig. 13) and accessory hepatic ducts (Fig. 10, 12). An aberrant hepatic duct is the only hepatic duct draining a particular hepatic segment, whereas an accessory duct is an additional hepatic duct draining the same area of the liver. An aberrant right hepatic duct, which occurs in 3.2%–18.0% of patients, drains part of the right lobe of the liver directly into the extrahepatic hepatic tract [4]. The aberrant duct may undergo accidental transection or ligation during cholecystectomy, and complications may therefore occur. These complications include formation of a biliary fistula, biloma, sepsis, pain, and repetitive episodes of cholangitis. Increasing demand for liver transplantation with a concomitant shortage of cadaveric livers had increased the prevalence of living donor liver transplantation (LDLT) [21]. Right-lobe LDLT is expected to provide advantages over left-lobe LDLT in terms of graft size. In order to obtain full benefits of a larger graft volume of the right-lobe LDLT, it is therefore essential to avoid the surgical complications associated with increased anatomical variations [22-25]. The surgical complications are classified into early and late complications. Early complications include periductal bile leakage with resultant edema, fibrosis or secondary stricture, and ischemia. Bile duct strictures are the most common late complications and may develop a few months or many years after surgery [26].

CONCLUSION

The incidence of biliary tract variation in our study has been measured to be similar as previous studies. Preoperative imaging of the biliary branching pattern remains the only method to diagnose and treat problems posed by variations in biliary anatomy [27]. MRC offers a reliable and non-invasive visualization of the biliary tract, enabling the surgical approach to be planned and adapted to prevent an injury of a variant of the hepatic duct confluence.

REFERENCE

Biliary tract variation in Taiwanese


