Background and Purpose: Magnetic resonance cholangiopancreatography (MRCP) is a non-invasive technique for examination of the biliopancreatic tract. Respiratory-triggered 3-dimensional turbo spin echo (3DTSE RT) and breath-hold thick slab single-shot turbo spin echo (ssTSE BH) are both useful MRCP techniques. The purpose of this study was to compare these 2 sequences with endoscopic retrograde cholangiopancreatography (ERCP) in patients with biliary tract disease.

Methods: Forty four patients with suspected biliary obstruction were recruited to receive MRCP within 3 days before ERCP. MRCP was performed using both 3DTSE RT with maximum intensity projection images and ssTSE BH. ERCP was performed and assessed by 2 endoscopists.

Results: MRCP was successfully performed in all patients, whereas ERCP failed in 6 patients (13.6%). MRCP was effective in detecting the presence of choledocholithiasis in 13 of 14 patients, ERCP in 12 of 12, and 2 failed ERCP. MRCP was effective in detecting benign biliary obstruction in 18 of 19 patients, and ERCP in 15 of 15, but 4 patients failed ERCP and choledocholithiasis was misdiagnosed by MRCP in 1 patient. Both MRCP and ERCP correctly diagnosed malignant bile duct obstruction in 10 of 11 patients, and both misdiagnosed that condition as benign obstruction in 1 patient. There was no significant difference between MRCP and successful ERCP in detecting lesions. MRCP was significantly better than ERCP when both successful and failed ERCP were encountered (p = 0.0498). Both 3DTSE RT and ssTSE BH produced the same results in depicting the biliary ducts and lesions in 37 patients (84.1%). Four patients (9.1%) showed better images on 3DTSE RT, whereas 3 patients (6.8%) showed better images on ssTSE BH.

Conclusions: 3DTSE RT and the ssTSE BH were complementary to each other in MRCP studies. Using these 2 techniques, MRCP has a high successful rate and diagnostic accuracy when compared with ERCP in detecting bile duct disease.

Key words: Magnetic resonance imaging; Cholangiopancreatography, endoscopic retrograde; Bile duct obstruction, extrahepatic; Common bile duct calculi

during a single breath-hold and has lead to its widespread use.\textsuperscript{12,13}

To our knowledge, there have been no studies comparing MRCP and ERCP reported in Taiwan. This study prospectively compared the diagnostic value of MRCP and ERCP in patients with biliary obstructions.

**Methods**

**Patients**

From April 2000 to December 2000, 48 patients with suspected biliary tract obstruction who were scheduled to receive ERCP were included in this prospective study. They agreed to receive MRCP 2 to 3 days before ERCP and any subsequent treatment procedures or follow-up studies. Four of these patients were excluded due to loss of follow-up or refusal to undergo pathologic evaluation. Finally, a total of 44 patients were included in the study.

The study group comprised 14 patients with choledocholithiasis, 19 patients with benign biliary obstruction, and 11 patients with malignant bile duct obstruction including icteric hepatocellular carcinoma, hilar cholangiocarcinoma, pancreatic cancer, ampulla of Vater cancer, and gall bladder (GB) cancer. All cases of malignant obstructions were demonstrated by pathology. All cases of choledocholithiasis were demonstrated either by ERCP with lithotripsy (11 cases) or by operation (3 cases). All patients with benign strictures received regular ultrasonography follow-up every 3 months, and MRCP or computed tomography scan 6 months later.

**MRCP**

MRCP images were obtained by a 1.5T MR machine (Philips Gyroscan ACS-NT, power tract 6000, The Netherlands) with 120 mT/m maximum gradient capability and a phase-array body coil. After localized imaging, T2-weighted pulse sequences were obtained in the coronal and transverse planes. A T2-weighted fat-suppressed pulse sequence was obtained on the axial plane to locate the biliary pancreatic system. The image parameters for the respiratory-triggered 3-dimensional turbo spin echo (3DTSE RT) sequence were as follows: TR, 2500 ms; effective TE, 750 ms; turbo factor, 102; flip angle, 90 degrees; slice thickness of raw data, 2 mm with no gap; field of view, 270 mm; matrix, 256 x 205; section, coronal planes; and acquisition time, 4 minutes and 10 seconds. Fat saturation was used. The source images were then processed to obtain maximum intensity projection (MIP) images of the pancreaticobiliary tree.

The image parameters of the breath-hold thick slab single-shot turbo spin echo (ssTSE BH) sequence were as follows: TR, 8000 ms; effective TE, 850 ms; turbo factor, 128; flip angle, 90 degrees; slice thickness 30 to 40 mm; field of view, 250 mm; matrix, 256 x 205; and acquisition time, 8 seconds. Each image covered the entire pancreaticobiliary tree. The sequences were repeated for 4 to 6 different projections of the pancreaticobiliary system.

All of the patients were required to fast for 8 hours and an antiperistaltic drug (hyoscine butylbromide) was given intravenously 5 minutes before examination. Two patients did not receive the injection due to underlying cardiovascular disease.

Two radiologists who were blinded to the subsequent findings of ERCP assessed the results prospectively and separately. All of the images, including T1, T2, 3DTSE RT (MIP with multiplanar reformat, and the raw data), and ssTSE BH were recorded on hard copies for evaluation. The 2 radiologists were asked to evaluate the dilatation of ducts, presence of intraluminal filling defects, strictures, or evidence of malignancy, and to decide whether 3DTSE RT or ssTSE BH better depicted the biliary ducts and lesions.

The diagnosis of biliary stone was based on the presence of round or faceted signal void lesions with clear margin, or the presence of meniscus sign in the distal common bile duct (CBD). Stricture was diagnosed based on the presence of tapering or abrupt interruption of ducts.\textsuperscript{3} The findings associated with ductal abnormalities were also recorded. In equivocal cases, images were recalled and reviewed at the workstation for clarification. The final results were obtained by consensus.

**ERCP**

ERCP was performed by 1 of 2 endoscopists who were blinded to the MRCP results, using a side viewing duodenoscope (Olympus JF240, Japan) with video monitor display. A fluoroscopic unit (Pt Philips, Diagnost 94, The Netherlands) was used. Antiperistaltic treatment (hyoscine butylbromide) was given to all the patients except 2 patients with cardiovascular disease. Ten to 20 mL contrast medium (Iopamiro 370, Bracco, Milano; 1:1 dilution) was injected through the scope until the biliary system and main pancreatic duct was opacified. Sphincterectomy and duct exploration with basket probe were used if equivocal stones were noted during contrast injection.

If biliary stones were noted in ERCP examination, endoscopic sphincterectomy with mechanical lithotripsy was performed, and if malignancy in the ampulla of Vater was suspected, biopsy and pathologic evaluation was done. The 2 endoscopists evaluated the dictated results and images separately and the final results were obtained by consensus.
Statistical analysis
The sensitivity, specificity, negative predictive value, positive predictive value, and accuracy of data were evaluated. Stata (version 7.0, Texas, USA) for Windows was used for statistical evaluation. McNemar’s test was used to determine significant differences.

Results
MRCP was successfully performed on all 44 patients, whereas ERCP failed in 6 patients. The failure rate in ERCP was 13.6%. Three of the failures were due to a large diverticulum in the second portion of the duodenum near the papilla of Vater. One of the failures was due to previous Billroth II subtotal gastrectomy. The remaining 2 were due to insertion failure. Among the successful ERCPs, 2 patients with benign strictures received sphincterectomy before contrast injection because of difficulty in insertion of the catheter. One patient received sphincterectomy and duct exploration because subtle stone was suspected during the contrast injection.

Both MRCP and ERCP were effective in detecting the presence of choledocholithiasis (Fig. 1). Thirteen of 14 cases were correctly diagnosed by MRCP. ERCP failed in 2 of the 14 patients. The remaining 12 cases of choledocholithiasis were correctly diagnosed by ERCP. The stones were removed during the ERCP in 11 cases. The remaining 3 patients underwent surgery. One case of choledocholithiasis was not diagnosed by MRCP because pneumobilia obliterated the true

**Fig. 1.** Choledocholithiasis in a 57-year-old man. A) Respiratory-triggered three-dimensional turbo spin echo showing a stone in the distal CBD (arrow) in raw data and B) in the maximum intensity projection image (arrow). C) Breath-hold single-shot turbo spin echo shows the CBD stone (arrow). D) Endoscopic retrograde cholangiopancreatography shows the CBD stone (arrow). Both magnetic resonance cholangiopancreatography (MRCP) and endoscopic retrograde cholangiopancreatography (ERCP) are effective in detecting the choledocholithiasis.
stone. The presence of pneumobilia also demonstrated well on ultrasonography. This case was false negative for CBD stone in MRCP study. ERCP failed in this case.

In benign biliary obstruction, 18 of 19 cases were correctly diagnosed by MRCP (Fig. 2). One case was misdiagnosed as a 0.5 mm stone in the distal end of the CBD by MRCP. The low signal stone-like lesion was noted in both raw data of 3DTSE RT and ssTSE BH. ERCP failed due to previous Billroth II subtotal gastrectomy. This patient underwent operation 10 days later and only sludge and thick bile was noted in CBD besides GB stones. ERCP failed in 4 of the 19 patients. ERCP correctly diagnosed benign stricture in the remaining 15 patients.

Both MRCP and ERCP had the same results in diagnosing malignant biliary obstruction (10 of 11 cases). GB stones and cancer invading the CBD was misdiagnosed as GB stones with acute cholecystitis and Mirrizi syndrome by both studies in 1 patient. The correct diagnosis was made during surgery.

MRCP correctly diagnosed bile duct calculi in 13 of the 14 patients (93%) with choledocholithiasis, and absence of CBD calculi in 29 of 30 patients (97%) [including benign and malignant strictures]. The overall sensitivity of MRCP in detecting choledocholithiasis was 93%. The specificity of MRCP was 97%, positive predictive value was 93%, negative predictive value was 97%, and the accuracy was 95%. ERCP correctly identified all of the CBD stones and no false negative stone was noted. The sensitivity, specificity and accuracy of the successful ERCP in detecting choledocholithiasis was 100% (Table).

**Fig. 2.** Benign stricture in a 76-year-old woman. A) Respiratory-triggered 3-dimensional turbo spin echo raw data and B) maximum intensity projection image shows common bile duct (CBD) and intrahepatic bile ducts (IHD) dilatation without any stone in distal CBD (arrow). C) Endoscopic retrograde cholangiopancreatography (ERCP) showing no CBD stone (arrow). D) An endoscopic retrograde biliary drainage tube (arrow) was inserted during the ERCP. Both magnetic resonance cholangiopancreatography (MRCP) and ERCP demonstrated the benign stricture in this case with successful ERCP.
Overall, there was no significant difference between MRCP and successful ERCP in detecting lesions, but MRCP was significantly better than ERCP when all successful and failed cases in ERCP were encountered ($p = 0.0498$). No complications resulting from MRCP were noted. Two patients with choledocholithiasis felt abdominal pain and showed some motion artifact on the 3DTSE RT because of long acquisition time, but all of the images were of good quality on ssTSE BH. By contrast, ERCP induced pancreatitis in 2 patients (2/38 successful ERCP cases, 5.3%), both of whom were well after conservative treatment.

In this series, MRCP was performed with both 3DTSE RT and ssTSE BH. Thirty seven out of the 44 patients (84.1%) had similar results in the depiction of biliary ducts and lesions in both of these sequences, 4 out of the 44 patients (9.1%) showed better images on 3DTSE RT, whereas 3 patients (6.8%) showed better images on ssTSE BH.

**Discussion**

ERCP has been used as a standard of reference for visualizing biliary obstruction and its etiology.\(^6\) The development of MRCP techniques provided greater imaging detail in diagnosing pancreaticobiliary disease.\(^{10,11}\) For the differential diagnosis of biliary obstruction, the presence of signal void lesions in MRCP is a reliable sign of the choledocholithiasis. In benign stricture, MRCP clearly demonstrates smooth tapering of the high T2 signal ducts. For diagnosis of malignant obstruction, besides the irregular abrupt interruption, the presence of the extraductal malignant lesions in MR images is very helpful.\(^3\) Use of these techniques for differential diagnosis in this study clearly demonstrated the applicability of MRCP.

In this study, the overall diagnostic accuracy of choledocholithiasis was 95% by MRCP, and 100% by successful ERCP. Differences in diagnostic findings for these techniques occurred in 2 patients. One case of choledocholithiasis was missed by MRCP because of pneumobilia in CBD and intrahepatic bile ducts. ERCP failed in this case. Both stones and air might appear as signal void in T2 images. Pneumobilia is lighter than stone, and might appear in the upper portion of biliary duct on axial images, whereas stone would be located in the lower portion of the ducts.\(^{14}\) However, the amount of pneumobilia in this case was large; it occupied the whole lumen and made diagnosing stones in the same lumen difficult. The limitations of MRCP in diagnosing biliary stones in the presence of pneumobilia were also discussed in previous literature.\(^{14}\) Diagnostic assessment using MRCP should be done very carefully in these patients.

One benign stricture was misdiagnosed as choledocholithiasis on MRCP. The stone-like lesion was noted in both raw data of 3D TSE and ssTSE. ERCP failed in this patient, who received surgery 10 days after MRCP and ERCP. No stone was detected during the operation. In this case, the possibility of stone passage from the distal CBD before or during surgery could not be ruled out. Considering the 2 cases with failed ERCP studies, the diagnostic accuracy of the choledocholithiasis by ERCP was no better than MRCP in this study.

Our magnetic resonance imaging machine allowed us to perform breath-hold single-shot turbo spin echo MRCP and the respiratory-triggered 3D turbo spine echo with MIP reconstructed MRCP. The stones could be identified clearly both in the raw data of 3DTSE and the thick slab ssTSE images. The thickness of the raw data of 3D MRCP is 2 mm, but the acquisition time is long. Four of our patients who could not hold their breath well but had good respiratory trigger showed excellent images in this sequence. The thickness of ssTSE is 30 to 40 mm, but ssTSE could be done within 8 seconds during one breath hold. Three of our patients who could hold their breath well but had poor respiratory trigger or motion during the MRCP examination showed better images in this sequence. A previous study reported that in a 1.0T MR machine, the 2 sequences provided complementary information in the depiction of biliary ducts in signal-to-noise ratio and contrast-to-noise ratio.\(^{15}\) In this study, we demonstrated that the 2 sequences were also complementary to each other in depicting lesions with a 1.5T MR machine.

**Table.** Diagnosis value of magnetic resonance cholangiopancreatography (MRCP) versus endoscopic retrograde cholangiopancreatography (ERCP).

<table>
<thead>
<tr>
<th>Final diagnosis</th>
<th>MRCP Success/total</th>
<th>MRCP Sensitivity*</th>
<th>ERCP Success/total</th>
<th>ERCP Sensitivity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choledocholithiasis(^1)</td>
<td>14/14</td>
<td>13/14 (93%)</td>
<td>12/14</td>
<td>12/14 (100%)</td>
</tr>
<tr>
<td>Benign obstruction</td>
<td>19/19</td>
<td>18/19 (95%)</td>
<td>15/19</td>
<td>15/15 (100%)</td>
</tr>
<tr>
<td>Malignant obstruction(^2)</td>
<td>11/11</td>
<td>10/11 (91%)</td>
<td>11/11</td>
<td>10/11 (91%)</td>
</tr>
</tbody>
</table>

* Sensitivity is based on successful cases.
\(^1\) The overall accuracy in diagnosing choledocholithiasis including all of the 3 groups was 95% by MRCP, and 100% by successful ERCP.
\(^2\) The overall accuracy in malignant obstruction was 91% for both MRCP and ERCP.
All of the ERCP in this study was performed by 1 of 2 expert endoscopists. Sphincterotomy and duct exploration with a basket probe was used in patients when a subtle stone was suspected to exist during contrast injection. This might explain why our ERCP achieved 100% sensitivity and specificity in those cases where it was successfully performed.

The diagnostic accuracy of malignant obstruction was the same in both MRCP and ERCP in this study. MRCP may have the additional advantages of showing the extension of malignant tumors as well as the ductal presentation, and in demonstrating ducts proximal to stenosis. But ERCP is superior to MRCP in demonstrating the view of the ampulla of Vater and in the biopsy of suspected ampullary carcinoma.

The failure rate for ERCP was 13.3% in this study. The success rate of ERCP depends on the experience of the operator. Our success rate was similar to that found in previous studies (70 to 97%).\(^{10}\) Two cases (5.3%) developed acute pancreatitis after undergoing ERCP study. The morbidity rate in this study was also similar to previous reports.\(^{8,16,17}\) No mortality occurred in this study. No failure or morbidity occurred in our MRCP studies. The association of ERCP with high failure rate, morbidity and even mortality is well known and has resulted in a shift in its use from diagnosis to treatment.\(^{18}\)

There was no significant difference between MRCP and successful ERCP in detecting lesions in this study. MRCP was significantly better than ERCP when successful and failed ERCP were encountered \((p = 0.0498)\), but this result was only of borderline significance.

In conclusion, good quality MRCP images were obtained in this study using both 3DTSE respiratory trigger and sSTSE thick slab breath-hold image. In view of the high failure rate of ERCP, MRCP provides a useful non-invasive and highly accurate diagnostic alternative. However, the benefit of ERCP in lithotripsy and pathologic evaluation of the ampulla of Vater cannot be achieved by MRCP.

References