

## Clinical Applications of MR Cholangiopancreatography

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### Abstract

**Introduction:** We review the clinical applications of magnetic resonance cholangiopancreatography (MRCP) and illustrate them with clinical examples. **Methods:** A literature search was performed in MedLine using the keywords “MR cholangiopancreatography” and “MRCP”. The relevant articles were reviewed. The radiology information system was searched for MRCP examinations performed from July 1999 to December 2002. A surgical database of resected cases was also referenced. Illustrative cases were chosen in consultation with surgical authors to show the clinical applications of MRCP. **Results:** MRCP is useful for assessment of choledocholithiasis, choledochal cysts, pancreas divisum, primary sclerosing cholangitis, pancreatitis and anatomical variation of the biliary ducts. When complemented with dynamic gadolinium-enhanced studies, MRCP is useful for assessment of ductal cholangiocarcinoma, pancreatic and gall bladder neoplasms. Illustrative cases are provided. **Conclusion:** MRCP is an important modality for the clinical assessment of biliary and pancreatic disorders.

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**Key words:** Cholangiocarcinoma, Calculi, Gall bladder carcinoma, MR imaging, Pancreatic carcinoma

### Introduction

Magnetic resonance cholangiopancreatography (MRCP) has attracted a lot of interest from clinicians because it is a non-invasive method of obtaining a cholangiographic image without the morbidity that is associated with endoscopic retrograde cholangiopancreatography (ERCP).

Clinicians and radiologists must understand that the true power of MRCP lies not in providing a cholangiographic image. The individual slices, or source images, that make up the cholangiographic image often provide more information as it allows cross-sectional imaging of the ductal lumen and ductal wall. This is especially so if dynamic gadolinium-enhanced scans are added to the examination as enhancing tumours would be detected. The reader is referred to a recent comprehensive review by Fulcher and Turner.<sup>1</sup> This article aims to illustrate the salient clinical applications of MRCP.

### Technique

Many techniques and scan protocols are available for MRCP examination. Table I is a routine employed by the first author with a General Electric (GE) Signa 1.5T LX magnetic resonance (MR) scanner (General Electric, Milwaukee, Wisconsin, USA) and a torso phased-array coil. Ideally, the examination should be monitored by the radiologist and additional sequences prescribed to solve problems.

### The “Cholangiogram”

There are 2 ways to obtain a cholangiographic image. A maximum intensity projection (MIP) image can be formed from thin (4 mm) source images at various projections (Fig. 1). A single thick section (4 cm) can be obtained with a long echo time (TE). The cholangiographic image provides a good overall orientation of the biliary system to the surgeon.

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TABLE I: MRCP SCAN PROTOCOL FOR GE SIGNA 1.5T LX MAGNETIC RESONANCE SCANNER WITH TORSO PHASED-ARRAY COIL

| Plane/sequence                                 | Ax SSFSE                            | Cor SSFSE                         | Cor Thick slab | Ax 3D SPGR*                | Ax FMPSPGR (in/out)           | Ax FRFSE T2                                                                                                        | Cor oblique SSFSE        |
|------------------------------------------------|-------------------------------------|-----------------------------------|----------------|----------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------|
| Coverage                                       | Liver/pancreas                      | Liver/pancreas                    | Liver/pancreas | Liver/pancreas             | Liver/pancreas                | Liver                                                                                                              | Biliary/pancreatic ducts |
| TR/TE (msec)                                   | 1534/87.6                           | 2105/87.6                         | Min/Min        | 5.1/1.1 TI 20              | 200/1.8 (out)<br>200/4.2 (in) | 2400/100<br>Echo train 20                                                                                          | 1609/241                 |
| FOV (cm)                                       | 32 x 32                             | 32 x 32                           | 35 x 35        | 32 x 25                    | 32 x 24                       | 32 x 24                                                                                                            | 32 x 32                  |
| Thickness/<br>spacing (mm)                     | 6/0                                 | 4/0                               | 40/0           | 5<br>(interpolated, 2.5)   | 6/1                           | 6/0                                                                                                                | 3/0                      |
| Matrix                                         | 256 x 256                           | 256 x 256                         | 256 x 192      | 256 x 128                  | 256 x 128                     | 256 x 192                                                                                                          | 256 x 160                |
| NEX                                            | 0.54                                | 0.53                              | 0.53           | 1                          | 1                             | 1                                                                                                                  | 0.55                     |
| Bandwidth (kHz)                                | 31.2                                | 31.2                              | 62.5           | 31.2                       | 62.5                          | 41.7                                                                                                               | 20.8                     |
| Approximate<br>scan time                       | 0:19<br>(2-3 breath-holds required) | 0:29<br>(2 breath-holds required) | 0:0.76         | 0:22                       | 0:21                          | 0:24<br>(2 breath-holds required)                                                                                  | 0:25                     |
| Scan options<br>(specific to<br>Signa 1.5T LX) | VB, ED                              | VB, ED                            | -              | ZIP 512, Z2,<br>VB, ED, FS | VB, ED                        | Flow compensation,<br>slice direction,<br>FS, VB, ED,<br>superior and<br>inferior saturation<br>bands, tailored RF | VB, ED                   |

\* Performed with spectral and inversion suppression of lipids. Pre-gadolinium scans were obtained. After intravenous gadolinium, 3 consecutive scans were obtained beginning with the arterial phase (approximately 13 seconds after start of injection). A delayed scan was performed after a 15-minute delay.

Ax: axial; Cor: coronal; ED: extended dynamic range; FOV: field of view; FMPSPGR: fast multi-planar spoiled gradient echo; FRFSE: fast recovery fast spin echo; FS: fat saturation; Min: minimum; MRCP: magnetic resonance cholangiopancreatography; NEX: number of excitation; RF: radiofrequency; SSFSE: single shot fast spin echo; TR: repetition time; TE: echo time; TI: inversion time; VB: variable bandwidth, Z2: slice zero-fill interpolation processing to interpolate two slices for every slice scanned; ZIP 512: zero-fill interpolation processing to transform a matrix of 256 x 256 to a matrix of 512 x 512; 3D SPGR: three-dimensional spoiled gradient echo

However, it is important to stress that stones can be obscured on these images and the diagnosis must always be based on the source images.

### To “Gad” or Not to “Gad”

Dynamic gadolinium-enhanced gradient-echo T1-weighted scans are an extremely important sequence that should complement MRCP examinations. Although they add to cost, clinicians and radiologists must understand that they are vital in demonstrating the enhancement in tumour masses, which may be overlooked or mistaken for stones. Unless the clinician feels that the possibility of cholangiocarcinoma is extremely remote, it is always wise to include a dynamic gadolinium-enhanced sequence to the MRCP examination (Fig. 2).

### TE

A moderately long TE demonstrates adjacent anatomy better than a very long TE sequence. This is useful in detecting masses associated with strictures and in showing

the adjacent anatomy.<sup>2</sup> The drawback of a moderately long TE sequence is that the resultant MIP cholangiogram is of poor quality due to the residual signal from non-fluid tissue. For a very long TE examination, there is hardly any signal from non-fluid tissue and fluid from the bile and pancreatic ducts is well shown (Figs. 1a & 1b).

## Clinical Applications

### Ductal Calculi

ERCP has a sensitivity of 90% and a specificity of 98% when validated with intraoperative cholangiography.<sup>3</sup> Recent studies on MRCP have reported sensitivities of 90% to 100% and specificities of 92% to 100%, which are comparable to and, in most cases, exceed that of ERCP.<sup>1</sup> The positive predictive value ranges from 96% to 100%. More importantly, the negative predictive value of a MRCP examination ranges from 96% to 100%. This high negative predictive value for common duct stones enables one to avoid performance of diagnostic ERCP in most cases.

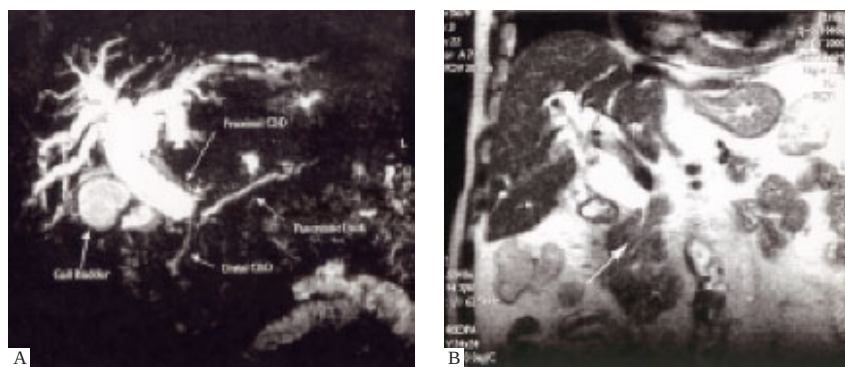


Fig. 1. Cholangiocarcinoma of the distal common bile duct (CBD). (A) Maximum intensity projection (MIP) image. Note the stricture at the lower end of the CBD. With the smooth stricture all the way to the ampulla, it is difficult to demonstrate “shouldering”. Hence, it is difficult to make a definitive diagnosis of cholangiocarcinoma. (B) Coronal single-shot fast spin echo (SSFSE) image with an echo time (TE) of 94.7 msec. Note that on a moderate TE SSFSE image, the fluid is bright but the background does not lose so much signal that it is completely obscured. Although such an image is not ideal for reconstructing the MIP image seen in (A), the tumour mass is well seen (arrow) and this allows a more definitive diagnosis of cholangiocarcinoma. The MIP image, however, provides good overall orientation to the surgeon.

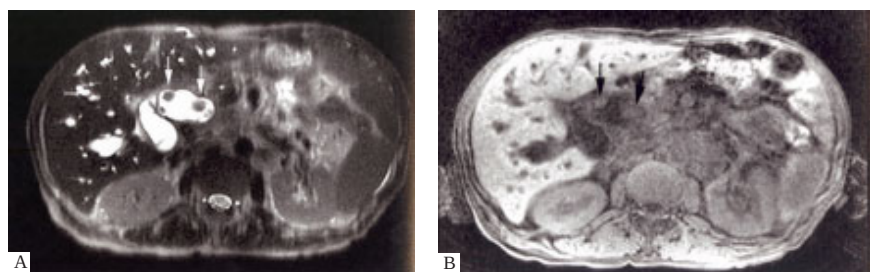


Fig. 2. Multifocal intraductal cholangiocarcinoma. (A) Axial HASTE (TE, 95 msec) image. Two filling defects are seen within the anterior aspect of the common bile duct (arrows). Note that it is unusual for calculi to “float”. (B) Pre-gadolinium axial gradient-echo fat-suppressed T1-W image. Note that the lesions are of a lower signal compared to skeletal muscle (arrows). Pre-gadolinium images are essential to assess subtle enhancement. (C) Portal venous phase axial gradient-echo T1-W image. The lesions (arrows) show enhancement and are now hyperintense to muscle and are compatible with intraductal cholangiocarcinomas. Such subtle enhancement is better appreciated on MR imaging compared to CT (Reproduced with permission from SGH Proceedings 2001; 9:190). HASTE: half-fourier turbo spin echo; TE: echo time; MR: magnetic resonance; CT: computed tomography.

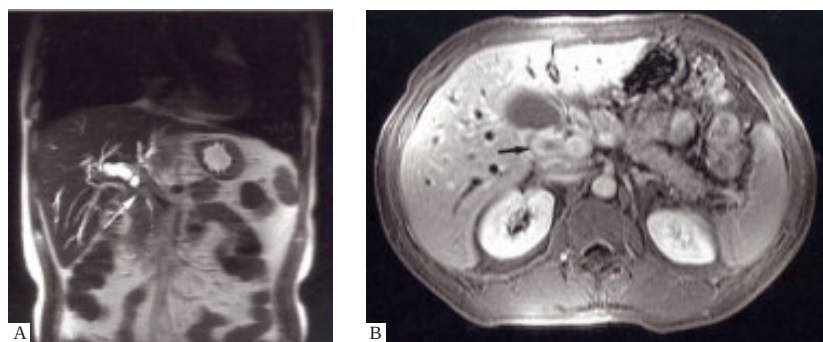


Fig. 4. Ductal cholangiocarcinoma. (A) Coronal SSFSE image. Dilated intrahepatic ducts are obstructed by a mass at the mid common bile duct (arrow). (B) Post-gadolinium portal venous phase axial gradient-echo fat-suppressed T1-W image. The mass is irregular and demonstrates enhancement (arrow). SSFSE: single-shot fast spin echo.

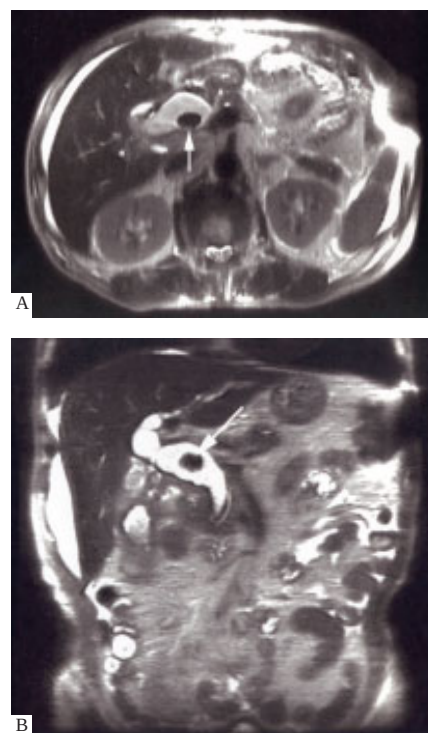


Fig. 3. Common bile duct calculus. (A) Axial SSFSE (TE, 87.6 msec) and (B) coronal SSFSE (TE, 87.6 msec) images. Note the intraductal filling defect within the common bile duct representing intraductal calculus. Ascites are also seen. SSFSE: single-shot fast spin echo; TE: echo time.

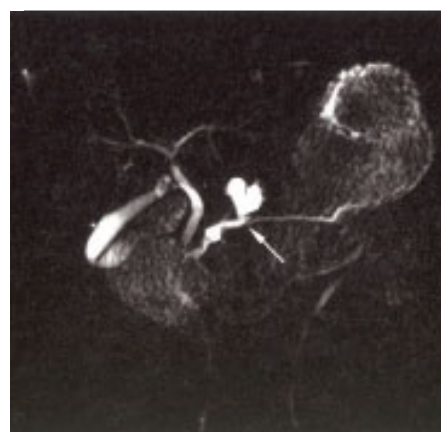


Fig. 5. Thick slab SSFSE image of benign intraductal cystic neoplasm of pancreas with dysplasia. Note a cystic lesion communicating with duct of Wirsung. Histology showed benign intraductal cystic neoplasm of the pancreas with presence of dysplasia.

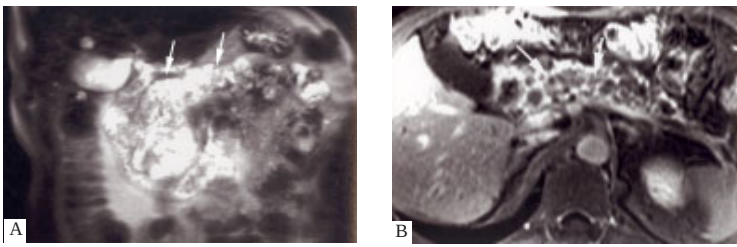


Fig. 6. Malignant intraductal cystic neoplasm of the pancreas. (A) Thick slab SSFSE image. Note that the pancreatic duct is dilated and filling defects are seen within (arrow). Incidental note is made of hepatic cysts. (B) Post-gadolinium portal venous phase axial gradient-echo T1-W image. The intraductal soft tissue demonstrates enhancement. No extrapancreatic extension was found during surgery. Total pancreatectomy was performed and histology showed malignant intraductal cystic neoplasm of the pancreas.

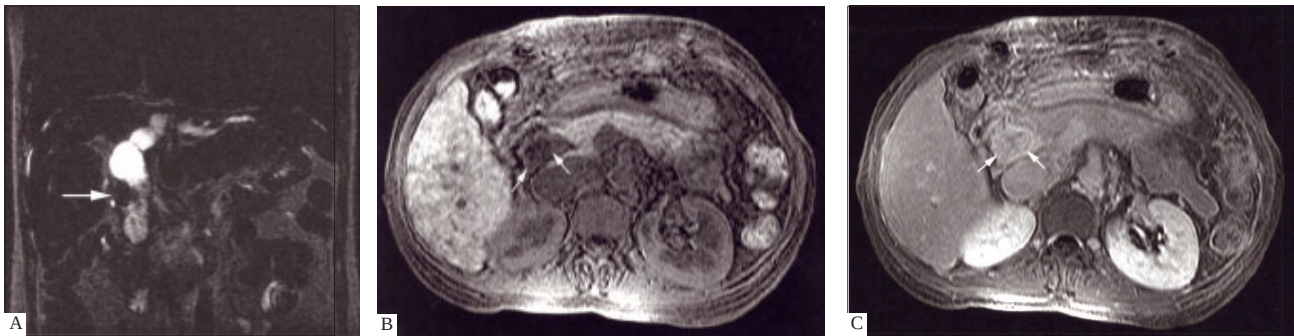


Fig. 7. Choledochal cyst complicated by cholangiocarcinoma. (A) Coronal SSFSE image with long TE. An eccentric mass is noted in the mid-CBD. (B) Pre-gadolinium axial gradient-echo fat-suppressed T1-W image. The intraductal soft tissue is hypointense relative to skeletal muscle. (C) Post-gadolinium portal venous phase axial gradient-echo fat-suppressed image. There is enhancement of the intraductal soft tissue (arrow), which is now hyperintense relative to skeletal muscle. The findings are compatible with cholangiocarcinoma. The diagnosis of cholangiocarcinoma in the distal CBD is difficult to make based on MRCP source images alone. CBD: common bile duct; MRCP: magnetic resonance cholangiopancreatography; SSFSE: single-shot fast spin echo; TE: echo time.

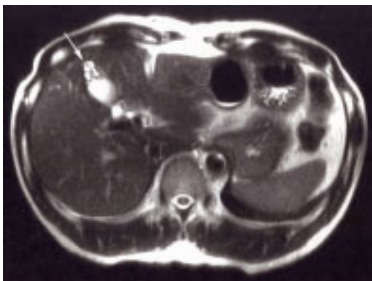


Fig. 8. Axial SSFSE image of adenomyomatosis gall bladder fundus. Note the fluid in the prominent Rokitsky-Aschoff sinuses (arrow). Adenomyomatosis was confirmed histologically.



Fig. 9. Gall bladder adenoma and intra-pancreatic pseudocyst. (A) Pre-gadolinium axial gradient-echo T1-W image. Note a soft tissue mass in the gall bladder hypointense to skeletal muscle (arrow). The pancreatic duct is destroyed with the resultant formation of an intra-pancreatic pseudocyst in the region of the duct in this patient with post-ERCP pancreatitis. (B) Post-gadolinium portal venous phase axial gradient-echo fat-suppressed T1-W image. Note that the gall bladder mass enhances (arrow) and becomes hyperintense relative to skeletal muscle. The pancreatic pseudocyst does not enhance. Histology of the gall bladder mass showed adenoma (Reproduced with permission from SGH Proceedings 2001; 9:190). ERCP: endoscopic retrograde cholangiopancreatography.

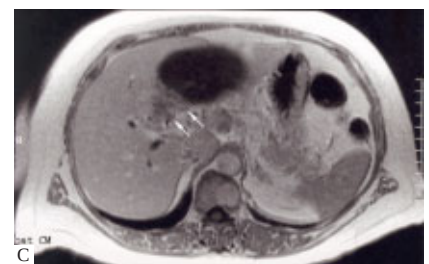
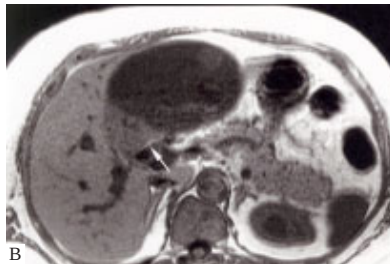
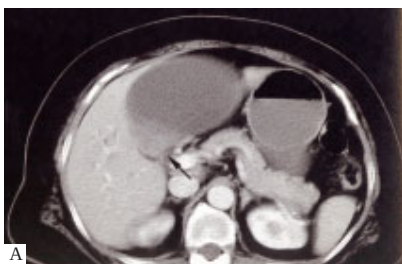


Fig. 10. Gall bladder carcinoma. (A) Portal venous phase contrast-enhanced spiral CT scan. Note the soft tissue material in the neck of the gall bladder (arrow). It is difficult to determine if this is related to sludge or tumour. (B) Pre-gadolinium axial gradient-echo T1-W image. (C) Post-gadolinium portal venous phase axial gradient-echo T1-W image. There is heterogeneous enhancement of the gall bladder mass (arrow). Histology showed gall bladder carcinoma.

However, one should be aware of pneumobilia, compression of duct by adjacent vessel and *en face* visualisation of the cystic duct. These conditions can mimic calculi. The diagnosis of ductal calculi should only be made after visualising the intraluminal filling defect in both the axial and coronal planes (Fig. 3).

#### *Cholangiocarcinoma*

MRCP source images are able to demonstrate the presence and level of stricture. However, the morphology of the stricture is often inconclusive. Low<sup>4</sup> analysed the morphology of strictures on ERCP and found that it was a poor predictor of malignancy. Ductal cholangiocarcinomas can be visualised as enhancing nodular masses associated with bile ducts (Fig. 4). Yeh et al<sup>5</sup> demonstrated 84.6% of cholangio-carcinomas by the presence of an enhancing lesion on MR imaging. However, in the absence of an enhancing mass, it is difficult to precisely characterise a stricture.

#### *Pancreatic Tumour*

MRCP images demonstrate the dilatation of the biliary and pancreatic ducts well (double duct sign) in pancreatic carcinoma of the head of the pancreas. However, this sign may occur in chronic pancreatitis. MRCP complemented by dynamic gadolinium scans may demonstrate pancreatic masses not seen on computed tomography.<sup>6</sup> MRCP can determine if cystic pancreatic masses communicate with the pancreatic duct, as in the case of intraductal cystic neoplasm of the pancreas (Figs. 5 and 6).<sup>7</sup>

#### *Choledochal Cysts and Congenital Anomalies*

MRCP is equivalent to ERCP in the assessment of choledochal cysts and in detecting an anomalous union of the pancreatic and biliary ducts.<sup>8</sup> Associated calculi are also readily detected. Dynamic gadolinium-enhanced scans may also demonstrate cholangiocarcinoma complicating choledochal cysts (Fig. 7).

#### *Anatomic Variants of Bile Ducts*

The ability to image fluid makes MRCP an ideal modality to detect anatomic variants of the bile ducts prior to surgery. Examples of these variants include accessory right and left hepatic ducts that insert caudal into the confluence or into the gall bladder, low insertion/anomalous cystic duct insertion, trifurcation anomalies and crossover anomalies (such as segment 6 duct inserting into the left hepatic duct). These variants may occur in up to 37% of individuals.<sup>9</sup> Detection of these variants may avoid inadvertent ligation of the common bile duct and biliary leaks.

#### *Pancreas Divisum*

Pancreas divisum occurs in 5.5% to 7.5% of individuals

and may be predisposed to acute pancreatitis.<sup>10</sup> In a series of 108 patients with ERCP correlation, pancreas divisum was correctly identified with no false positive or false negative diagnoses.<sup>11</sup>

#### *Primary Sclerosing Cholangitis*

MRCP can depict the mural irregularities, strictures and out-pouching associated with primary sclerosing cholangitis. A small case-control study showed that MRCP has a sensitivity of 88% and a specificity of 97% for the diagnosis of primary sclerosing cholangitis.<sup>12</sup> ERCP is useful early in the disease when the ductal abnormalities are subtle, and late in the disease when the ducts are distorted by cirrhosis.

#### *Gall Bladder*

Adenomyomatosis can be imaged as fluid-filled Rokitsky-Aschoff sinuses can be seen (Fig. 8).<sup>13</sup> Dynamic gadolinium-enhanced scans can determine if gall bladder masses are enhancing. Enhancing gall bladder masses may be related to gall bladder adenoma or carcinoma (Figs. 9 and 10).

#### *MRCP or ERCP*

In many institutions, MRCP has replaced diagnostic ERCP due to the high negative predictive value of a negative MRCP examination. A recent consensus statement from the National Institutes of Health in the United States expressed that MRCP and ERCP have comparable sensitivity and specificity for the diagnosis of choledocholithiasis and recognised that, with newer diagnostic modalities such as MRCP, ERCP is evolving into a predominantly therapeutic procedure.<sup>14</sup> The consensus statement also expressed that ERCP should be avoided if there is a low likelihood of biliary stone or stricture, especially in women with recurrent pain, a normal bilirubin and no other objective sign of biliary disease.<sup>14</sup> MRCP is a good modality for this group of patients.<sup>1</sup> However, ERCP is still an important modality for drainage and interventional procedures of the biliary tract. It is also important in the assessment of post-surgical biliary leakages and is useful in clarifying complex anatomy or equivocal MRCP studies.<sup>1</sup>

#### **Conclusion**

MRCP, supplemented with dynamic gadolinium-enhanced scans, plays an important role in the evaluation of biliary and pancreatic disorders.

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