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MR cholangiopancreatography: prospective comparison of a breath-hold 2D projection technique with diagnostic ERCP

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Abstract. The aim of this study was to compare prospectively a breath-hold projection magnetic resonance cholangiopancreatography (MRCP) technique with diagnostic endoscopic retrograde cholangiopancreatography (ERCP). Seventy-six patients with suspected strictures or choledocholithiasis were referred for MRCP and subsequent ERCP examination, which were performed within 4 h of each other. The MRCP technique was performed using fat-suppressed rapid acquisition with relaxation enhancement (RARE) projection images obtained in standardised planes with additional targeted projections as required by the supervising radiologist. Two radiologists (in consensus) assessed the MRCP results prospectively and independently for the presence of bile duct calculi, strictures, non-specific biliary dilatation and pancreatic duct dilatation, and recorded a single primary diagnosis. The ERCP was assessed prospectively and independently by a single endoscopist and used as a gold standard for comparison with MRCP. Diagnostic agreement was assessed by the Kappa statistic. The MRCP technique failed in two patients and ERCP in five. In the remaining 69 referrals ERCP demonstrated normal findings in 23 cases, strictures in 19 cases, choledocholithiasis in 9 cases, non-specific biliary dilatation in 14 cases and chronic pancreatitis in 4 cases. The MRCP technique correctly demonstrated 22 of 23 normal cases, 19 strictures with one false positive (sensitivity 100 %, specificity 98 %), all 9 cases of choledocholithiasis with two false positives (sensitivity 100 %, specificity 97 %), 12 of 14 cases of non-specific biliary dilatation and only 1 of 4 cases of chronic pancreatitis. There was overall good agreement for diagnosis based on a kappa value of 0.88. Breath-hold projection MRCP can provide non-invasively comparable diagnostic information to diagnostic ERCP for suspected choledocholithiasis and biliary strictures and may allow more selective use of therapeutic ERCP.

Key words: MRI – MR cholangiopancreatography – ERCP – Bile ducts

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Introduction

Current non-invasive imaging techniques, such as ultrasound and computed tomography, have well-recognised limitations in the diagnosis of biliary and pancreatic duct pathology. As a result, many patients with suspected biliary and pancreatic disease undergo more invasive diagnostic procedures such as endoscopic retrograde cholangiopancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC). These procedures have a small but significant associated morbidity and mortality [1] in addition to being relatively time-consuming and costly. Magnetic resonance cholangiopancreatographic (MRCP) techniques can provide an alternative non-invasive method of imaging the biliary and pancreatic ducts. The techniques developed over the past 5 years now have a diagnostic performance comparable to diagnostic ERCP and are being utilised clinically in the management of biliary and pancreatic disease [2, 3].

Initial MRCP techniques utilised gradient-echo sequences [4] but are now predominantly based on heavily T2-weighted rapid acquisition with relaxation enhancement (RARE) sequences [5, 6]. The majority of published work has utilised 3D data sets either obtained as a stack of 2D slices or a true 3D acquisition obtained using quiet breathing, respiratory triggering, multiple or single breath-holds [7, 8, 9, 10, 11]. Relatively long effective echo times (150–300 ms) have been employed which help discriminate the long T2 value of biliary and pancreatic secretions but retain some signal from surrounding tissues. Interpretation involves review of the individual source images and typically maximum in-

tensity projection (MIP) post-processing of the volume data to allow a 3D visualisation of the biliary anatomy. This adds the requirement for a suitable workstation and additional processing time to the examination.

An alternative approach has been proposed which utilises a projection technique allowing rapid assessment of the biliary and pancreatic duct systems without the need for post-processing [12]. This RARE-based technique requires a particularly long effective echo time of 750–1000 ms resulting in image contrast based on fluid alone, so-called MR hydrography [5, 13]. The signal from other tissues, including many sources of artefact, decays away. This factor, combined with a variable-thickness 2D projection acquisition that can be positioned selectively to encompass all or part of the biliary and pancreatic duct systems, results in a projection image similar to that obtained at conventional ERCP [14, 15, 16, 17].

Evaluation studies comparing the 3D MRCP techniques with ERCP have given promising results; however, the accuracy of 2D projection techniques for demonstrating calculi and strictures has been less well studied, although early work has suggested that projection methods are less sensitive than 3D methods for demonstrating choledocholithiasis [17]. The purpose of this study was to evaluate a rapid breath-hold 2D projection approach in a prospective comparison with diagnostic ERCP.

Materials and methods

Patient population

Over an 18-month period 76 referrals for diagnostic ERCP with suspected biliary strictures or choledocholithiasis were studied. Choledocholithiasis was suspected in patients with either: sonographic evidence of calculi within the gallbladder combined with a dilated common bile duct (7-mm diameter or greater) with or without evidence of common duct calculi; a history of prior jaundice with known gall bladder calculi, frequently but not necessarily with a history of abdominal pain or a documented episode of pancreatitis; known gall bladder calculi and abnormal biochemical liver function tests in whom other causes had been excluded; recurrent pain, or a dilated common bile duct (greater than 10-mm diameter), or abnormal biochemical liver function tests following cholecystectomy. Strictures were suspected in patients with biliary tract dilatation demonstrated by any prior radiological examination with or without evidence of a mass lesion or abnormal biochemical liver function tests.

The only patients actively excluded were those in whom the diagnosis was known and therapeutic intervention (endoprosthesis, sphincterotomy) was planned, in addition to those patients with the usual contraindications for MRI.

The MRCP technique could not be performed in 2 of the 76 referrals: 1 patient was obese and would not fit into the magnet bore comfortably with the torso coil attached, and the other was unexpectedly claustrophobic. In both cases this was not anticipated prior to attempting the procedure. An additional 5 patients were excluded because ERCP could not be performed: 1 patient died shortly before ERCP from an incidental catastrophic rupture of an abdominal aortic aneurysm, 1 patient refused ERCP after sedation was administered, and in 3 patients the operator was unable to cannulate the common bile duct. The remaining 69 referrals comprised 66 patients of whom 33 were women and 33 men with an age range of 21–92 years. Three patients underwent second examinations because of presentation of new symptoms after prior removal of common duct calculi.

Imaging

The patients were fasted for 12 h prior to MRCP and ERCP which were undertaken within 4 h of each other in all cases. Informed patient consent was obtained and the study was approved by the local ethics committee. The clinical details and any prior imaging and diagnostic test results were available to the investigators undertaking the study examinations.

The MRCP examination was performed first in all cases using a GE 1.5-T whole-body MR system (General Electric Medical Systems, Milwaukee, Wis.) with a phased-array torso coil. Coronal images were obtained first using an end-expiration breath-hold fast spoiled gradient-echo sequence (TR/TE: 110/4.2 ms, 10 slices, 15-mm section thickness, no intersection gap, 32- to 36-cm square field of view, 256 × 128 matrix, one signal acquired, 16-s acquisition time. A set of axial T1-weighted conventional SE images through the liver and pancreas were also obtained for anatomical information and demonstration of the pancreas and liver hilum (TR/TE: 500–700/14–16 ms, section thickness 10 mm, intersection gap 5 mm, 32- to 36-cm square field of view, 256 × 256 matrix, one signal acquired).

Subsequent breath-hold MRCP images were obtained using one of two variations of a RARE projection technique. Both employed frequency-selective fat suppression, 256 × 256 matrix, section thickness 3–60 mm, 24- to 28-cm square field of view, and TE effective 750–770 ms. The first technique utilised a hybrid four-shot RARE (FSE) sequence with 64 echo train length, TR 4000 ms, 32-kHz received bandwidth, one signal acquired, permitting one to three sections or projections in a single 16-s breath-hold. The second technique, following a hardware upgrade during the study, used a single-shot half Fourier RARE sequence (SSFSE) with 128 echo train length, TR infinite, 62.5-kHz received bandwidth, half signal acquisition, permitting a single section to be acquired in approximately 1 s.

Initially, breath-hold axial MRCP images were obtained using three contiguous 40-mm-thick projections with the inferior projection centred over the pancreatic head. The biliary and pancreatic duct entry into the duodenum was identified on these axial images, and true coronal and 30° coronal oblique 40-mm-thick pro-

jection images (left anterior oblique, right anterior oblique) were obtained centred on this area. Additional projection images were obtained at the discretion of the supervising radiologist who could select any desired plane and slice thickness from 3 to 60 mm. Between 2 and 12 additional projections were obtained. At each location the images were repeated three times to allow for any variation in breath-hold position.

An experienced endoscopist (A. E. G.) undertook ERCP examination within 4 h of the MRCP in all cases. Patients were examined under intravenous sedation using a side-viewing endoscope (TJF-20, Olympus) and radiographs were made of relevant findings. Duct diameter was assessed from the radiographs using the diameter of the endoscope as a reference.

Analysis

The examinations were reported prospectively and independently. The MRCP examinations were assessed using a review workstation (General Electric Independent Console, General Electric Medical Systems, Milwaukee, Wis.) by consensus of two experienced MR radiologists (D. J. L. and P. W. P. B.). No attempt was made to evaluate the different projection images separately and the initial T1-weighted images were included as part of the whole examination. Assessment of ERCP was performed by one endoscopist (A. E. G.). All investigators were aware of the clinical presentation and any other prior imaging and laboratory studies that had been performed.

In each case the investigators independently evaluated technical adequacy, the diameter of the common duct, the presence or absence of obstruction, the level and suspected cause (benign or malignant) of any obstruction, the presence or absence of common duct calculi and the presence or absence of pancreatic duct dilatation. They were asked to make a single primary diagnosis of either normal, stricture, common duct calculus, chronic pancreatitis or non-specific dilatation. The endoscopist was also asked to record if the procedure was purely diagnostic, and the MRCP investigators were asked to record the length of the pancreatic duct demonstrated. The ERCP technique was taken as the reference standard for the study.

Common duct calculi were diagnosed on MRCP if a persistent (on two or more projections) focal signal void was demonstrated within the duct. Dilatation was diagnosed when the common bile duct diameter exceeded 6 mm, or 10 mm with prior cholecystectomy. Obstruction was diagnosed where dilatation was present with an identifiable obstructing lesion. The lesions were categorised as benign or malignant based on morphological criteria with abrupt change of calibre or "shouldering", spatial eccentricity and irregularity-considered malignant features in comparison with short length, gradual change of calibre and symmetry-considered benign features. Dilatation with no identifiable causative lesion was diagnosed as non-specific dilatation. Dilatation of the pancreatic duct was diagnosed if the duct diameter exceeded 3 mm and considered to be diagnostic of early chronic pancreatitis in the absence of any identifiable obstructing lesion. The results with regard to stricture and choledocholithiasis were analysed for specificity, sensitivity, negative predictive value (NPV) and positive predictive value (PPV), with relevant confidence intervals (CI). The agreement between ERCP and MRCP for primary diagnosis was assessed with the kappa statistic.

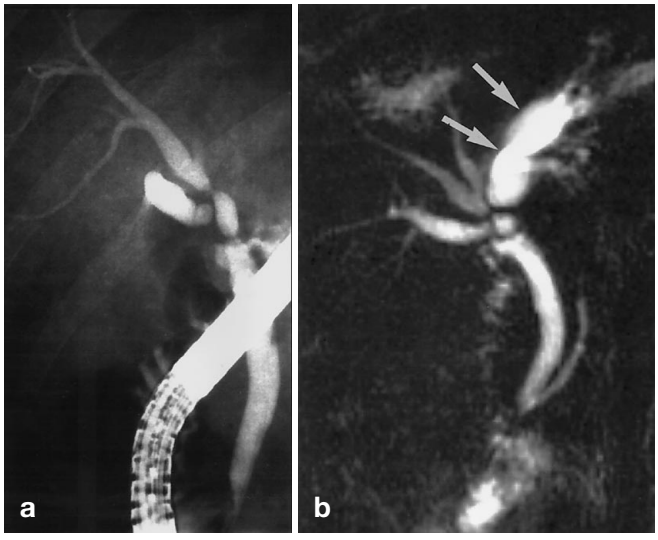


Fig. 1 a, b. Coronal images of a patient with benign hilar strictures following hepatic arterial occlusion. **a** Endoscopic retrograde cholangiopancreatography (ERCP) and **b** Magnetic resonance cholangiopancreatography (MRCP) projection images demonstrating the same strictures and the obstructed left main duct system *(arrows)* which could not be accessed and visualised at ERCP

Results

Technically adequate MRCP and ERCP images were obtained in all patients, and the final diagnoses made by each investigation are presented in Table 1. The MRCP technique correctly demonstrated strictures in 19 patients (Fig. 1) with one false positive and no false negatives giving a sensitivity of 100 %, specificity 98 % (CI 94–100 %), PPV 95 % (CI 85–100 %) and NPV 100 %. The false-positive stricture was demonstrated in a patient with established PBC who subsequently underwent liver transplantation. The MRCP images demonstrated a persistent asymmetrical extrinsic compression of the common duct but with no dilatation of the proximal ducts (Fig. 2 a, b), and this was interpreted as an early malignant obstructive lesion despite the lack of duct dilatation. The conventional T1-weighted images demonstrated enlarged hilar and para-aortic nodes up to 2 cm in diameter. At ERCP the common duct filled normally when contrast was injected, and although a minor deformity of the duct was visible (Fig. 2c], this was not considered significant. Subsequent CT-guided biopsy of the para-aortic nodes prior to transplant and histological examination of the explanted liver confirmed the

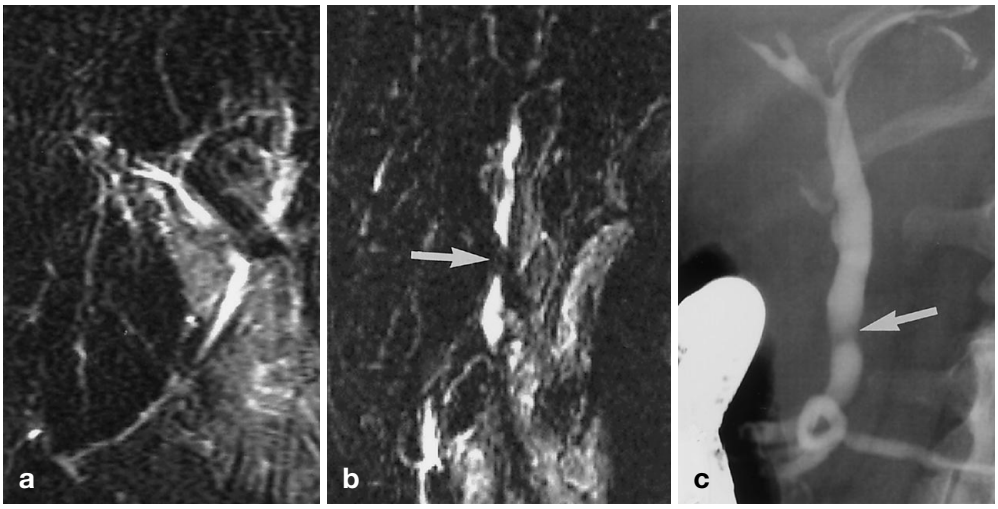


Fig. 2. A patient with primary biliary cirrhosis with a false-positive stricture at **a** MRCP which demonstrated extrinsic compression of the common bile duct. **b** Oblique coronal projection image. **c** Sagittal projection image. Endoscopic retrograde cholangiopancreatography did not confirm this lesion, although in retrospect it is visible "en face" *(arrow)*. Subsequent CT imaging, biopsy and liver transplantation confirmed the presence of multiple enlarged (2 cm) benign hilar lymph nodes

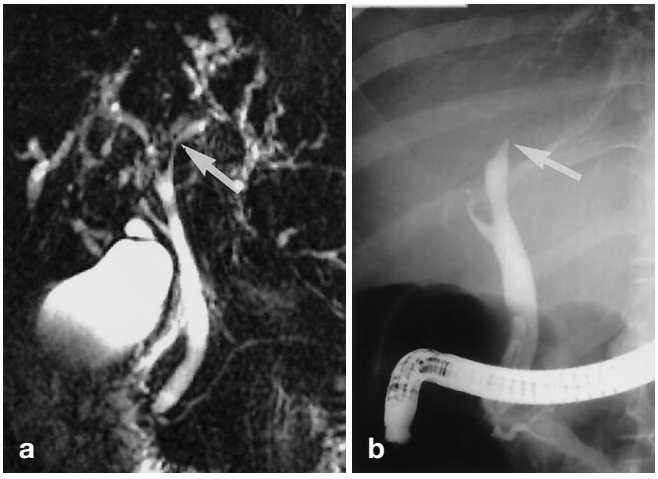


Fig. 3. Coronal projection images in a patient with established primary sclerosing cholangitis in whom **a** MRCP misdiagnosed a benign stricture *(arrow)* subsequently considered malignant. **b** At ERCP, where contrast could not be passed beyond a firm stricture and stenting was required, no histological confirmation was obtained

presence of enlarged reactive hilar nodes, but no evidence of malignancy.

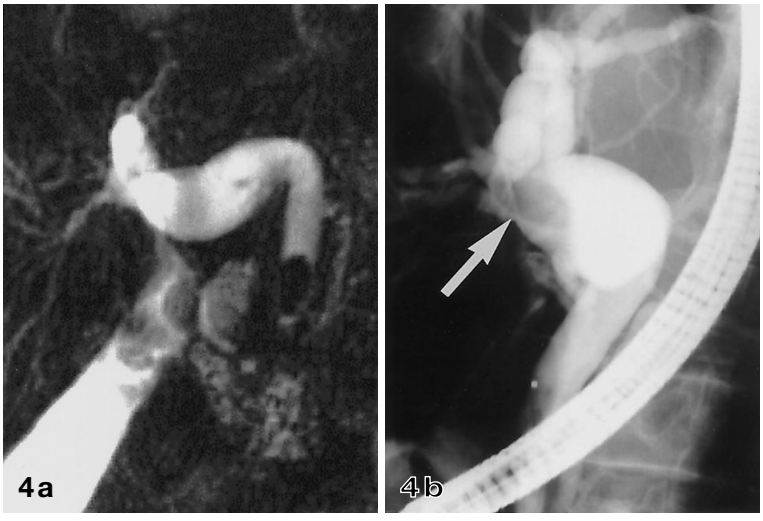
At ERCP 12 of the 19 strictures were considered malignant. There was complete concordance between techniques regarding the stricture level, and MRCP correctly identified 11 of 12 strictures as malignant but in 1 patient diagnosed a benign stricture which was considered malignant at ERCP. This occurred in a patient with severe established sclerosing cholangitis and complicated by a recent history of disseminated ovarian and breast carcinoma. The MRCP technique demonstrated multiple smooth intra-hepatic and hilar strictures considered benign (Fig. 3). At ERCP contrast medium would not pass beyond a firm hilar stricture which required guidewire manipulation to cross and was subsequently stented. This was interpreted as a malignant hilar stricture, although no histological confirmation had been obtained.

Overall, MRCP correctly demonstrated choledocholithiasis in 9 patients (Fig. 4). There were two false positives and no false negatives giving a sensitivity of 100%, specificity 97% (CI 93–100%), PPV 82% (CI 59–100%) and NPV 100%. Both false positives occurred in the distal common bile duct where persistent 2- to 3-mm intraluminal signal voids were demonstrated (Fig. 5). In the nine MRCP examinations with choledocholithiasis, the diameter of the smallest detected calculus was as follows: 5 mm or less in 4 cases, 10 mm or less but greater than 5 mm in 3 cases and greater than 10 mm in 2 cases.

In 18 patients alternative final diagnoses of non-specific biliary dilatation (14 cases, 12 of which were correctly diagnosed on MRCP) or mild chronic pancreatitis (4 cases, in 3 of which MRCP was reported normal) were made.

Table 1. The MR cholangiopancreatography (MRCP) and endoscopic retrograde cholangiopancreatography (ERCP) results

MRCP	ERCP					
	Normal	Stricture	Stones	Other	Chronic pancreatitis	Total
Normal	21	0	0	1	3	25
Stricture	0	19	0	1	0	20
Stone	2	0	9	0	0	11
Other	0	0	0	12	0	12
Chronic pancreatitis	0	0	0	0	1	1
Total	23	19	9	14	4	69



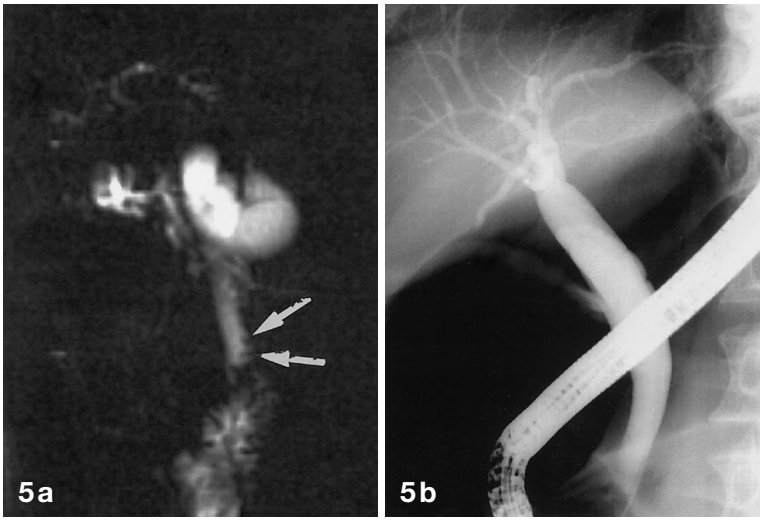


Fig. 4a, b. Coronal projection images of a patient with an elliptical calculus in the common bile duct. **a** Magnetic resonance cholangiopancreatography demonstrating in addition multiple small calculi in the gall bladder. **b** Endoscopic retrograde cholangiopancreatography confirms the presence of the calculus *(arrow)* which has been pushed more proximally into the duct

Fig. 5a, b. Coronal projection images in a patient with false-positive calculi at MRCP in whom there was an obstructive pattern of liver function tests and extrahepatic duct dilatation (8 mm) on prior sonography. **a** Magnetic resonance cholangiopancreatography demonstrated two persistent filling defects *(arrows)* at the distal end of an otherwise undilated common duct. **b** Endoscopic retrograde cholangiopancreatography demonstrated no evidence of calculi despite sphincterotomy and balloon dredging. The duct distended easily at ERCP and it is postulated that folds in the duct wall may have caused the appearance at MRCP

Overall, 25 examinations were reported normal by MRCP in 3 of which ERCP demonstrated mild chronic pancreatitis. The kappa value of 0.88 (CI 0.82–0.94) indicated good agreement between MRCP and ERCP regarding the primary diagnosis. In 38 of the 69 examinations (55 %) ERCP was considered a purely diagnostic procedure. The pancreatic duct was demonstrated in all but one MRCP examination in which the patient did not breath-hold and the average length of duct demonstrated in the remaining 68 MRCP examinations was 11.1 cm.

Discussion

Recent studies have demonstrated that MRCP can provide comparable results to diagnostic ERCP examinations. The majority of these have used 3D techniques, and relatively few studies have utilised a direct slab or projection technique [12, 15, 16, 17]. Projection techniques have several potential advantages; particularly for a given system and gradient performance they acquire data more rapidly than a 3D sequence, reducing respiratory and bowel-related artefacts. Acquiring data as a projection slab during a single breath-hold eliminates the chance of misregistration artefacts and permits ready visualisation of the whole biliary tree or a selected sub-volume. As the data does not require further post-processing, it can also be used immediately to direct further targeted image acquisition of the region of interest during the examination. The extended effective echo time required for the technique brings an additional advantage in allowing relatively small fields of view to be employed without significant wrap-around artefacts. There are potential disadvantages, particularly the concern that partial-volume effect and reduced contrast-to-noise ratio may obscure detail of both strictures and, more importantly, calculi [17].

In this study we compared a directed rapid breath-hold projection technique with diagnostic ERCP, which remains the gold standard diagnostic examination. The limitations of diagnostic ERCP with regard to both stone detection and the diagnosis of stricture type are acknowledged, but in our original study design it was considered appropriate to compare the MRCP projection technique initially with the established diagnostic examination, i. e. ERCP.

This study demonstrates firstly that a projection or slab MRCP technique can produce technically accept-

able results in the majority of patients. The ability to obtain images rapidly, within acceptable breath-holds, and in any plane eliminates the chance of many artefacts and allows rapid visualisation of the results and direction of the examination by the supervising radiologist. In this study the patients were fasted, and although small amounts of bowel fluid remained, related artefacts were not considered a problem. The presence of fluid in the stomach and duodenum were in practice often helpful for identifying the anatomy of the distal common bile duct and the relationships with the duodenal wall and ampulla. In our view this makes the use of negative oral contrast media not only unnecessary but potentially detrimental.

The sensitivity of MRCP projection techniques for detecting calculi has been questioned recently [18] and in one report shown to be inferior to a 3D breath-hold MRCP technique [17], although this occurred in a small patient group. In our study MRCP correctly diagnosed duct calculi (Fig. 4) in all cases (100%) with no false negatives when compared with diagnostic ERCP. However, in 1 patient both techniques overlooked a 5-mm calculus that was later found in a dilated common bile duct after a therapeutic sphincterotomy and balloon dredging was performed on the basis of a high clinical index of suspicion. This case emphasises the limitations of ERCP as the current gold standard examination. There were 2 false-positive cases at MRCP of small calculi in the distal common bile duct. In both cases the ducts were not dilated at the time of MRCP examination. In 1 case there had been a previous sphincterotomy, and it is possible that the calculus passed prior to ERCP, or that a gas bubble created the signal void. In the second case it is possible that ERCP overlooked small calculi, but the more likely explanation is that MRCP incorrectly diagnosed calculi and the observed filling defects were redundant folds in the distal duct wall (Fig. 5). This is supported by the common bile duct dilatation (8 mm) demonstrated on prior sonography and found at ERCP (9 mm), whereas the common bile duct diameter measured only 6 mm at MRCP. A sphincterotomy was performed and the duct dredged revealing no calculi. The final diagnosis was presumed prior passage of a duct calculus. We speculate that the use of cholecystokinin to stimulate filling of the common bile duct during the examination might prevent such a false positive if it were due to redundant folds of the biliary wall, although we have not had an opportunity to test this hypothesis.

The MRCP technique demonstrated all the strictures found at ERCP and in each case the information obtained regarding level and extent matched the findings at ERCP. In several cases MRCP provided more information, demonstrating obstructed intrahepatic segmental or lobar bile ducts not visualised at ERCP (Fig. 1). In 1 patient with established primary sclerosing cholangitis MRCP incorrectly diagnosed a benign stricture considered malignant at ERCP. The ERCP diagnosis was based on obstruction to the passage of contrast and the need for stenting; histological proof was not obtained. It is possible that the relatively thick projections used at MRCP obscured the detail of the relevant hilar stricture, although the images obtained were comparable (Fig. 3). The MRCP technique incorrectly diagnosed a malignant stricture in a patient with established primary biliary cirrhosis where a persistent extrinsic asymmetrical narrowing was demonstrated at MRCP (Fig. 2). In retrospect, it is likely that this represented early extrinsic compression from benign nodal enlargement (demonstrated at CT, and confirmed on explant liver examination and histology) that was overlooked at ERCP. We postulate that the injection of contrast at ERCP generated sufficient intra-ductal pressure to overcome the compression. The need to access obstructed bile ducts before they can be opacified (increasing the risk of subsequent infection) is widely considered a limitation of ERCP that is not shared by MRCP (Fig. 1).

Although not the primary objective of the study, the pancreatic duct was also assessed. In all but 1 case the duct (both normal and abnormal) was demonstrated, but the trend suggests that MRCP diagnostic sensitivity for chronic pancreatitis is relatively poor despite this good visualisation overall. This may relate either to interpretation relying on the distension of the duct achieved during contrast injection at ERCP or the relatively limited spatial resolution of MRCP at present. In a comparison study of 3D and projection MRCP the source images of the 3D technique better demonstrated side branches of the pancreatic duct than the projection technique [17]. Additional prospective studies need to be performed to fully evaluate MRCP techniques in pancreatic disorders. Initial work using secretin to improve visualisation of the duct system and to assess dynamic pancreatic changes to such a glandular stimulus have been promising and suggest that this may provide a new method of detecting early changes of chronic pancreatitis [19].

The MRCP technique has been identified as being of particular value in those patients in whom ERCP fails [20], a finding supported by this study in which MRCP was successful in 5 patients in whom ERCP failed. The MRCP technique could not be carried out in 2 patients, due to claustrophobia and obesity. It is particularly helpful clinically that the nature of the contraindications for both MRCP and ERCP do not typically preclude use of the alternative technique.

The results in this study for both stone and stricture detection compare well with 3D-RARE-based MRCP studies and indicate that a predominantly projection technique can provide results similar to diagnostic ERCP. In our study each MRCP examination was supervised by a radiologist who directed the acquisition of additional projection images, based on the initial standardised acquisitions. This allowed the area of interest to be targeted more closely and may be an important factor in the overall results. It is worth noting that 38 of the 69 (55%) ERCP examinations were considered purely diagnostic, because it is in this group that MRCP may prove of most clinical value.

In many studies, including this one, the exact nature of the MR technique has been to some extent dictated by the imager performance and sequence availability.

The gradient and sequence improvements that have been made over the duration of this study now make it possible to perform both breath-hold 3D and projection imaging during a single examination. Such a combined approach using both techniques could potentially maximise the available diagnostic information using MRCP techniques.

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