IMAGING THE PANCREATICO-BILIARY SYSTEM WITH MAGNETIC RESONANCE CHOLANGIOPANCREATOGRAPHY

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INTRODUCTION

Investigation of the biliary tree and pancreatic duct system has until recently relied upon the techniques of ultrasound and computerised tomography (CT), with endoscopic retrograde cholangiopancreatography (ERCP) being reserved for direct visualisation of ductal anatomy and, if required, therapeutic intervention. However, ERCP has a significant morbidity and mortality of 7% and 1%, respectively.[1,2] It is highly operator-dependent with failure to cannulate the common bile duct or pancreatic duct in up to 9% of examinations.[3] Ductal cannulation is difficult or impossible in patients with previous surgery, including Billroth Type 2 gastrectomy and hepatico-enterostomy.

Magnetic resonance cholangiopancreatography (MRCP) is a relatively new non-invasive technique for imaging the pancreatico-biliary system and avoids the limitations of ERCP. It provides images similar to those of ERCP without the use of contrast agents or sedation. It can be performed in all patients apart from those with specific internal ferro-magnetic foreign bodies or claustrophobia. Despite its slightly poorer spatial resolution, MRCP is comparable with ERCP in the assessment of choledocholithiasis, malignant obstruction of the biliary tree and pancreatic ducts, chronic pancreatitis and congenital biliary tree anomalies.[4–7] This article provides an overview of the technique and its application in a variety of clinical settings.

TECHNIQUE

The patient is fasted for approximately six hours prior to examination; IV contrast or antispasmodics are not used. The MRCP technique relies upon the use of heavily T2 weighted (T2W) imaging sequences, which display stationary fluid (i.e. bile and pancreatic secretions) as areas of high signal intensity. Solid tissue has a low signal intensity, whilst flowing blood has little or no signal. The exact imaging protocol employed varies. In our hospitals, the examinations are performed on 1·5 T Phillips Gyroscan machines. The imaging sequences include:

1. 6 mm axial T2W (UTSE) sections, with respiratory gating, of the biliary tree and pancreas;
2. three angled coronal heavily T2W sections (60 mm thick) with fat suppression (SPIR) to display the biliary tree and pancreatic duct; these images are obtained using a 'single shot' projectional technique within an eight second breath hold; and
3. a volume of thin (1 mm) heavily T2W coronal slices with SPIR through the biliary tree and pancreas with respiratory gating; this data set is also displayed as a three-dimensional maximum intensity projection (MIP) image.

The MIP image and thick angled coronal sections provide views of the pancreatico-biliary tree similar to conventional ERCP (Figures 1A and 1B). The thin coronal slices from the volume acquisition provide detailed information and are viewed on the workstation. The standard axial images provide an overview of the structures surrounding the fluid-filled ductal system, which is directly comparable to conventional CT images.

Each examination takes approximately 15–20 minutes. Patients tolerate the procedure well and fewer than 4% are unable to complete the examination due to claustrophobia.

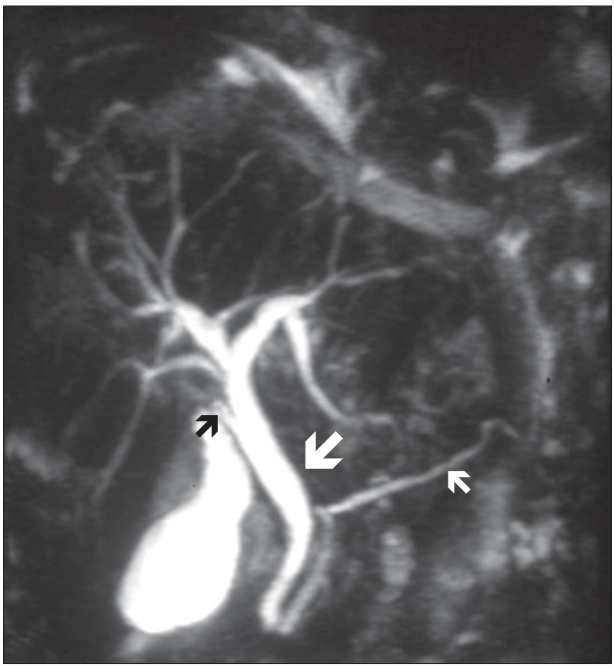

FIGURE 1A

Three-dimensional MIP reconstruction of multiple thin sections (1 mm). Normal cholangiopancreatographic findings. Gall bladder, cystic (small black arrow), common hepatic and bile ducts (large white arrow), main intrahepatic bile ducts and pancreatic duct (small white arrow) are all well demonstrated.

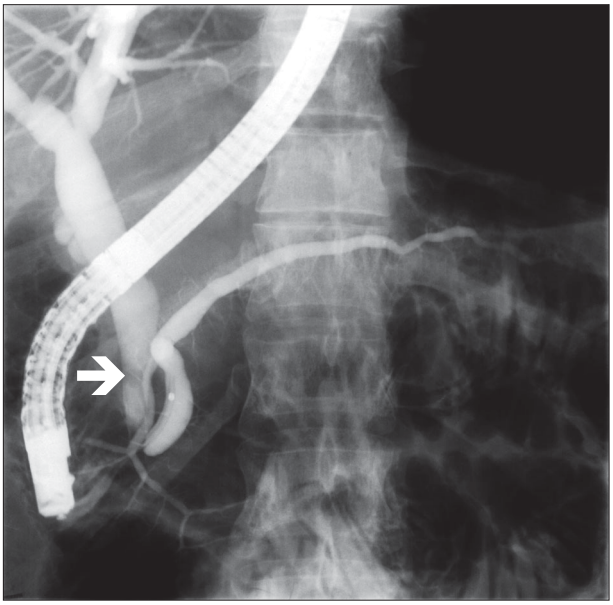

FIGURE 1B

Normal ERCP. Normal pancreatic duct appears of increased calibre as a result of direct distension with contrast. Small round filling defect at distal end of common bile duct (CBD) is due to an air bubble (arrow).

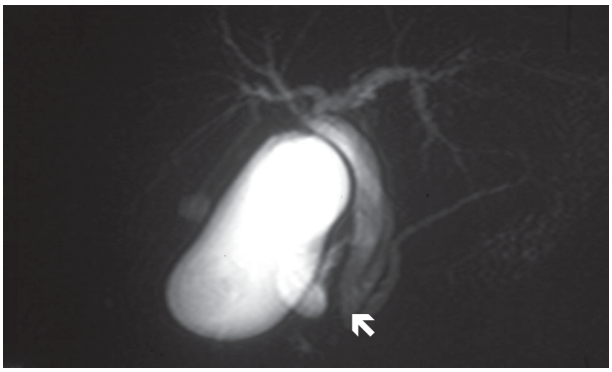

FIGURE 2

Thick section MRCP image (60 mm). Abnormal low insertion of cystic duct (arrow) into CHD.

NORMAL ANATOMY

The gall bladder and common bile duct are visualised in up to 98% of patients.[8] Failure of gall bladder visualisation may be secondary to previous cholecystectomy or a diseased gall bladder containing calculi and a negligible amount of bile. Distinction between these two situations can be made readily by studying the axial MR images. Visualisation of the intra-hepatic biliary tree is variable distal to the right and left hepatic ducts.[8] The pancreatic duct is visualised in the head and body of the gland in 97% of patients and in the tail in 83%.[4] Demonstration of pancreatic side branches varies from 19% in the head to 5% in the tail.[9] A dilated pancreatic duct can be visualised completely in up to 100% of cases.

CONGENITAL VARIANTS

Variants are well demonstrated by MRCP, including an aberrant insertion of the cystic duct into the common hepatic duct (CHD) (Figure 2).[6] Such patients are at higher risk of bile duct injury at cholecystectomy, and intraoperative cholangiography is used by some in an attempt to reduce this risk.[10] Routine use of operative cholangiography prior to cholecystectomy is controversial.[11] Magnetic resonance cholangiopancreatography cannot be used routinely in this role at present due to resource implications.

Other variants include *pancreas divisum*, which occurs in 9% of the population and which is the result of a failure of fusion of the dorsal and ventral pancreatic ducts. The larger dorsal duct drains the tail, body and superior part of the head of the pancreas and passes anterior to the distal common bile duct to end at the minor papilla. The smaller ventral duct drains the inferior head and uncinate process and joins with the common bile duct to exit via the major papilla. An increased incidence of acute pancreatitis is found in patients with this variant.[12] Magnetic resonance cholangiopancreatography has a sensitivity of up to 100% in its detection.[13] Annular pancreas, a less common congenital variant, is also demonstrable with MRCP.[14]

BENIGN BILE DUCT OBSTRUCTION

Ultrasound (US) and CT are traditionally used to determine the presence and extent of biliary obstruction, with ERCP serving both a diagnostic and a therapeutic role. Magnetic resonance cholangiopancreatography is comparable with ERCP and is superior to trans-abdominal ultrasound and CT in the detection of choledocholithiasis and benign common bile duct strictures.[15, 16] Endoscopic ultrasound (EUS) also has a high sensitivity and specificity in the detection of choledocholithiasis, a recent direct comparison with MRCP revealing similar results.[17] It is relatively invasive, highly operator-dependent and is as yet not widely available in this country.

The role of MRCP in the diagnosis of sclerosing cholangitis is less clear as a consequence of the inconsistent depiction of the intrahepatic biliary tree.[18] This in part reflects the fact that the ductal system is imaged in its normal or physiological undistended state in comparison to the biliary distension achieved during ERCP. As a result, early stenoses may be missed and short strictures may be overestimated because the downstream duct is collapsed. Nevertheless, good correlation between ERCP and MRCP images in sclerosing cholangitis has been demonstrated in a recent study.[19] Currently its role is normally confined to the follow-up of advanced cases and/or the development of complications.

The rare congenital disease of the intrahepatic biliary system, Caroli's disease, has also been well demonstrated on MRCP.[20]

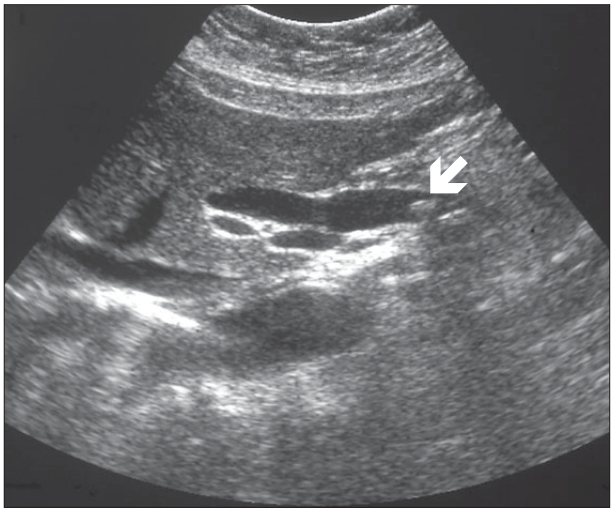

FIGURE 3A
Ultrasound image. Choledocholithiasis. Echogenic calculus demonstrated at distal end of dilated CBD (arrow).

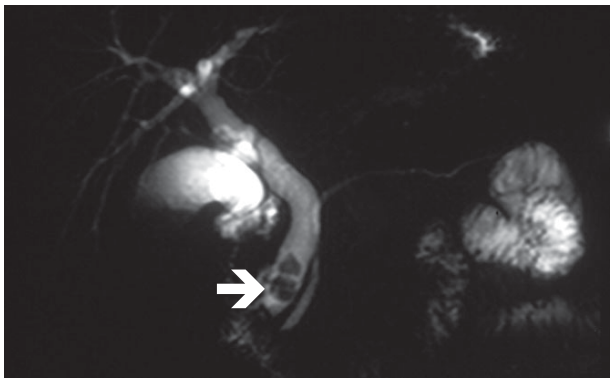

FIGURE 3B
Thick section MRCP image (60 mm). Choledocholithiasis. Two dark filling defects are demonstrated at the distal end of a dilated CBD (arrow). Normal pancreatic duct.

FIGURE 3C
T2 weighted axial MRI image (6 mm). Choledocholithiasis. Dark filling defect representing calculus (arrow) partially filling dilated CBD.

CHOLEDOCHOLITHIASIS

The sensitivity and specificity of MRCP in the detection of choledocholithiasis in a large number of series is 81–100%.[21] Calculi are identified as dark filling defects within the high signal bile, often in association with dilatation of the proximal biliary tree (Figures 3A–C). Small calculi not causing dilatation and impacted stones in the distal duct without surrounding high signal bile are more difficult to visualise. Careful review of both the axial images and thin slice volume sections are necessary for their identification. It has been suggested that MRCP be used in patients with a low clinical suspicion of choledocholithiasis, and that ERCP be utilised in those with a high clinical suspicion and in whom endoscopic sphincterotomy and stone retrieval is likely to be required.[22]

MALIGNANT BILE DUCT OBSTRUCTION

Malignant obstruction of the bile ducts is most commonly secondary to a carcinoma in the head of the pancreas or cholangiocarcinoma (Figures 4A–C), with portal lymphadenopathy and metastases being less common causes.

Differentiation between benign and malignant obstruction of the bile duct can be difficult. Early reports indicated accuracies of 30–62% for MRCP in this setting.[23–5] More recently, Fulcher *et al*. reported an accuracy of 98% in a series of 300 MRCP examinations, in which 32 were malignant obstructions.[4] Comparative studies of MRCP with ERCP have shown equal sensitivity in the detection of pancreatic carcinoma.[26, 27] Magnetic resonance cholangiopancreatography with axial T1 and T2 weighted scans have been shown to significantly improve diagnostic accuracy in differentiating benign from malignant obstruction.[28] Even with these developments, the accuracy of MRCP in diagnosing malignant obstruction is currently no greater than that of ERCP and CT.

The ability of MRCP to demonstrate the bile ducts proximal and distal to any obstructing lesion has been recognised to be useful in the diagnosis and staging of cholangiocarcinoma (Figure 4C). This has always been a problem for both ERCP and percutaneous transhepatic cholangiography (PTC). The use of gadolinium T1 weighted axial images has been shown to be of value in the assessment of the extent of cholangiocarcinoma.[29]

PANCREATITIS

In patients presenting with acute pancreatitis, the detection of gallstones and the state of the pancreaticobiliary tree are of major importance. Ultrasound and CT traditionally provide this information; the use of early ERCP remains controversial.[22] Magnetic resonance cholangiopancreatography affords the opportunity to acquire similar diagnostic information to ERCP in this setting without risk, and may be helpful in selecting those for endoscopic sphincterotomy. It has the additional benefit of simultaneously detecting and demonstrating

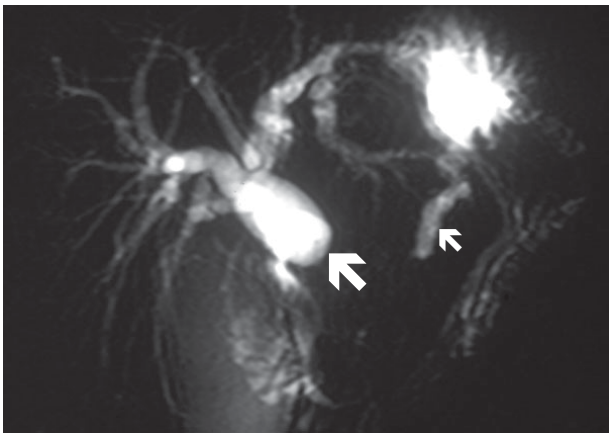

FIGURE 4A

Thick section MRCP image (6 cm). Pancreatic carcinoma. Markedly dilated extra- and intra-hepatic bile ducts (large arrow) with dilatation of gall bladder and distal pancreatic duct (small arrow).

FIGURE 4B

T2 weighted axial MRI image (6 mm). Pancreatic carcinoma. Large inhomogeneous high signal mass in pancreatic head (large white arrow) with encasement of superior mesenteric artery (black arrow) and vein (small white arrow) indicating irresectability. The diagnosis of malignant obstruction in this case is clear on these MR images alone. Frequently it is the combination of clinical features and other imaging findings (including US, CT and ERCP) that, together with the MRCP images, allows a diagnosis of malignant obstruction to be made.

the extent of fluid collections and pseudocysts (Figure 5A). It has a greater sensitivity than ERCP in the detection of pseudocysts, less than 50% of which fill up with contrast at ERCP.[30]

Endoscopic retrograde cholangiopancreatography can confirm the diagnosis of chronic pancreatitis, monitor its progress, aid surgical planning and provide therapeutic options. Magnetic resonance cholangiopancreatography has been found to correlate well with ERCP in this condition.[31] The spectrum of findings include ectasia of the side branches, irregular dilatation and stenoses of the main duct and side branches, pseudocysts and filling defects due to calculi or debris (Figure 5B).[8]

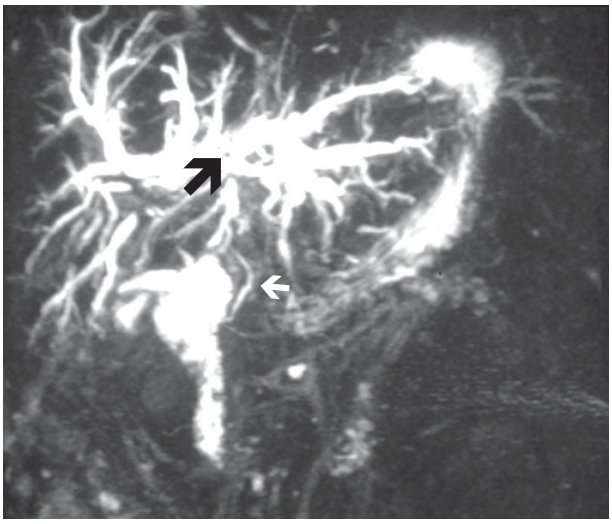

FIGURE 4C

Three-dimensional MIP reconstruction. Cholangiocarcinoma at junction of left and right hepatic ducts (large arrow). Marked intra-hepatic biliary dilatation. Non-dilated distal CBD can just be seen lateral to high signal of fluid within the second part of the duodenum (small arrow).

POST-SURGICAL ASSESSMENT

The pancreatico-biliary system can be difficult or impossible to image by ERCP in a number of post-surgical situations, including choledochojejunostomy, hepatico-jejunostomy and Billroth Type 2 gastrectomy. Magnetic resonance cholangiopancreatography is now the technique of choice in this situation, with a sensitivity of 100% in demonstrating the biliary-enteric anastomoses.[4] Demonstration of anastomotic strictures and calculi have been reported in 100% and 90% of cases, respectively, in a recent study.[32] We have also found MRCP to be of considerable value in the assessment of iatrogenic bile duct injury.

LIMITATIONS

The contraindications to MRCP are those of magnetic resonance imaging (MRI), i.e. the presence of specific ferro-magnetic objects within the body, such as pacemakers or aneurysm clips. Claustrophobia is the most common cause for an unsuccessful examination (with a frequency of <4%).

A number of technical and interpretative pitfalls are encountered with MRCP use.[33] Technical pitfalls include:

1. patients with significant respiratory problems may have difficulty breath-holding, which often results in sub-optimal images, particularly on T2W axial sections; however, it is rare that all sequences are so compromised that clinically useful information is not achieved;
2. the entire biliary and pancreatic ducts are seldom displayed on a single image; consequently, multiple images at different angles and projections have to be

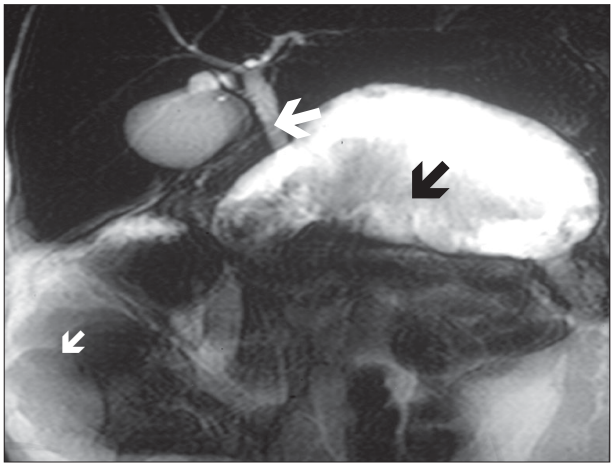

FIGURE 5A

Thick section MRCP image (60 mm). Acute pancreatitis. Large pseudocyst containing debris (large black arrow), normal calibre biliary tree (white arrow), free intraperitoneal fluid (small white arrow).

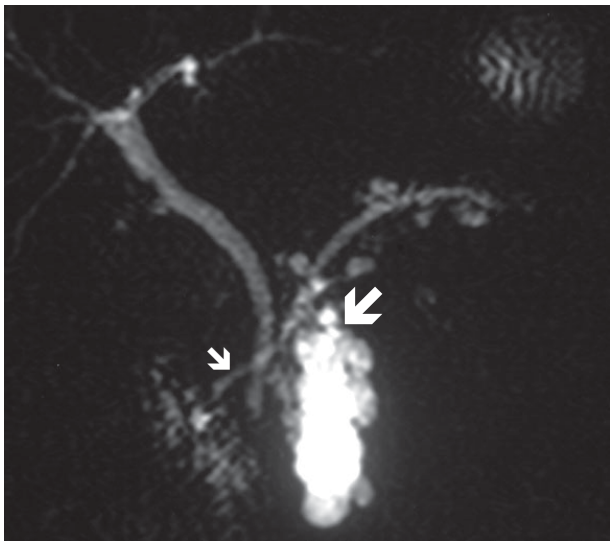

FIGURE 5B

Thick section MRCP image (60 mm). Chronic pancreatitis: *pancreas divisum*. Multiple small pseudocysts along pancreatic duct in body and tail of gland. Larger pseudocyst within pancreatic head (large arrow). The major (dorsal) pancreatic duct (small arrow) is seen to enter the duodenum separately from the CBD which enters the major papilla with the accessory (ventral) duct.

reviewed very carefully;

3. normal physiological changes within the ducts can suggest the presence of pathology on the static MRCP images; sphincter of Oddi contraction can, for example, simulate a stricture of the distal bile duct; repeating the scan, if necessary after IV glucagon, can demonstrate relaxation of the sphincter;[7]
4. adjacent metallic structures such as surgical clips cause susceptibility artefact, which may create the

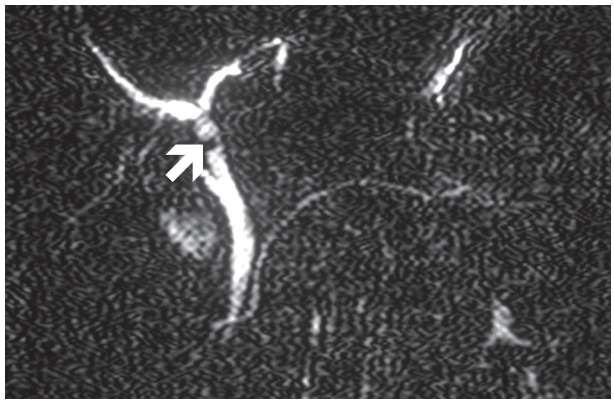

FIGURE 6A

Thick section MRCP image (60 mm). Dark filling defect (arrow) CHD with no proximal dilatation. Previous cholecystectomy.

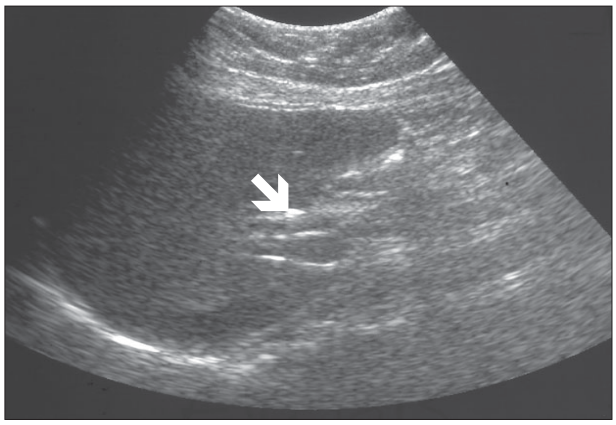

FIGURE 6B

Ultrasound image. Small linear echogenic structure (arrow) immediately anterior to CHD represents surgical clip on cystic duct stump.

appearance of ductal strictures or filling defects (Figures 6A and 6B); and

5. post-processing techniques, in particular the creation of MIP images, can cause errors, overestimate strictures and can obscure finer detail such as small calculi; the importance of a thorough review of the 'raw data' cannot be overestimated.

Interpretative pitfalls include:

1. the presence of pneumobilia, intrabiliary debris or haemorrhage can create 'calculi-like' filling defects; and
2. 'pseudo-dilatations' can be created by the overlapping of the cystic and bile ducts and the superimposition of non-ductal fluid filled structures such as bowel, renal or hepatic cysts; careful review of the axial images usually clarifies this.

The use of dilute MRI contrast agent (gadopentetate dimeglumine) to provide 'negative' contrast has been shown recently to be of use in eliminating signal from

the gastrointestinal tract and improving delineation of the pancreatico-biliary system.[34]

The reduced spatial resolution of MRCP in comparison with ERCP can result in problems in specific areas. Imaging of the intra-hepatic ductal system is of variable quality depending on the normal or physiological degree of biliary tree distension. This can cause difficulty in the detection of the early changes in sclerosing cholangitis, with a tendency to either overlook or, conversely, overestimate the length of short strictures. Similarly, in the assessment of pancreatitis, more subtle side branch changes are sometimes not resolved by MRCP in comparison with ERCP.

SUMMARY

Magnetic resonance cholangiopancreatography is an increasingly valuable and rapidly developing technique in the non-invasive assessment of the pancreatico-biliary tree. In many institutions it is replacing ERCP as a diagnostic procedure in the investigation of benign biliary obstruction and chronic pancreatitis. With further refinements MRCP, together with magnetic resonance angiography (MRA), could replace the other techniques currently employed in the diagnosing and staging of pancreatic tumours in a single examination. However, it should be remembered that, unlike ERCP, MRCP does not allow the opportunity to simultaneously perform therapeutic intervention.

REFERENCES

1 Baillie J. Complications of endoscopy. *Endoscopy* 1994; **26:**185–203.

2 Reinhold C, Bret PM. MR cholangiopancreatography. *Abdom Imaging* 1996; **21:**105–16.

3 Soto J, Yucel EK, Barish MA *et al.* MR Cholangiography after unsuccessful or incomplete ERCP. *Radiology* 1996; **199:**91–8.

4 Fulcher AS, Turner MA, Capps GW *et al.* Fourier RARE MR cholangiopancreatography: experience in 300 subjects. *Radiology* 1998; **207:**21–32.

5 Chan YL, Chan AC, Lam WW *et al.* Choledocholithiasis: Comparison of MR cholangiography and endoscopic retrograde cholangiography. *Radiology* 1996; **200:**85–9.

6 Taourel P, Bret PM, Reinhold C *et al.* Anatomic variants of the biliary tree: diagnosis with MR cholangio-pancreatography. *Radiology* 1996; **199:**521–7.

7 Matos C, Metens T, Deviere J *et al.* Pancreatic duct: morphologic and functional evaluation with dynamic MR pancreatography after secretin stimulation. *Radiology* 1997: **203:**435–41.

8 Vitellas KM, Keogan MT, Spritzer CE *et al.* MR cholangiography of bile and pancreatic duct abnormalities with emphasis on the single-shot fast spin-echo technique. *Radiolographics* 2000; **20:**939–57.

9 Ueno E, Takada Y, Yoshida I *et al.* Pancreatic diseases: evaluation with MR cholangiopancreatography. *Pancreas* 1998; **16:**418–26.

10 Phillips EH. Routine versus selective intraoperative cholangiography. *Am J Surg* 1993; **165:**505–07.

11 Wright KD, Wellwood JM. Bile duct injury during laparoscopic cholecystectomy without operative cholecystectomy. *Br J Surg* 1998; **85(7):**191–4.

12 Bernard JP, Saleh J, Giovanni M *et al.* *Pancreas divisum* is a probable cause of acute pancreatitis: a report of 137 cases. *Pancreas* 1990; **5:**248–54.

13 Bret PM, Reinhold C, Taorel P *et al.* *Pancreas divisum*: evaluation with MR cholangiopancreatography. *Radiology* 1996; **199:**99–103.

14 Reinhardt RD, Brown JJ, Foglia RP *et al.* MR imaging of annular pancreas. *Abdom Imaging* 1994; **19:**301–03.

15 Guibaud L, Bret PM, Reinhold C *et al.* Bile duct obstruction and choledocholithiasis. Diagnosis with MR cholangio-graphy. *Radiology* 1995; **197:**109–15.

16 Regan F, Fradin J, Khazan R *et al.* Choledocholithiasis: evaluation with MR cholangiography. *AJR Am J Roentgenol.* 1996; **167:**1441–5.

17 Ledinghen, V, Lecesne R, Raymond J-M *et al.* Diagnosis of choledocholithiasis: EUS or magnetic resonance cholangiography? A prospective controlled study. *Gastrointestinal Endoscopy* 1999; **49:**26–31.

18 Vitellas K, Keogan MT, Freed KS *et al.* Radiologic manifestations of sclerosing cholangitis with emphasis on MR cholangiopancreatography. *Radiographics* 2000; **20:**959–75.

19 Ernst O, Asselah T, Sergent G *et al.* MR cholangiography in primary sclerosing cholangitis. *AJR Am J Roentgenol* 1998; **171:**1027–30.

20 Asselah T, Ernst O, Sergent G *et al.* Caroli's disease: a magnetic resonance cholangiopancreatography diagnosis. *Am J Gastroenterol* 1998; **93(1):**109–10.

21 Fulcher AS, Turner MA, Capps GW *et al.* MR cholangiography: technical advances and clinical applications. *Radiographics* 1999; **19:**25–44.

22 Reinhold C, Bret PM. Current status in MR cholangiopancreatography. *AJR Am J Roentgenol* 1996; **166:**1285–95.

23 Wallner BK, Schumacher KA, Weidenmaier W *et al.* Dilated biliary tract: evaluation with MR cholangiography with a T2-weighted contrast enhanced fast sequence. *Radiology* 1991; **181:**805–08.

24 Ishizaki Y, Wakayama T, Okada Y *et al.* Magnetic resonance cholangiography for evaluation of obstructive jaundice. *Am J Gastroenterol* 1993; **88:**2072–7.

25 Hall-Craggs M, Allen CM, Theis BA *et al.* MR cholangiography: clinical evaluation in 40 cases. *Radiology* 1993; **189:**423–7.

26 Adamek HE, Albert J, Breer H *et al.* Pancreatic cancer detection with magnetic resonance cholangio-pancreatography and endoscopic retrograde cholangio-pancreatography: a prospective controlled study. *Lancet* 2000; **356:**190–3.

27 Georgopoulos SK, Schwartz LH, Jarnagin WR *et al.* Comparison of magnetic resonance and endoscopic retrograde cholangiopancreatography in malignant pancreatobiliary obstruction. *Arch Surg* 1999; **134:**1002–07.

28 Myeeong-Jin K, Mitchell DG, Katsuyohi I *et al.* Biliary dilatation: differentiation of benign from malignant causes – value of adding conventional MR imaging to MR cholangio-pancreatography. *Radiology* 2000; **214:**173–81.

29 Low RN, Sigeti JS, Francis IR *et al.* Evaluation of malignant biliary obstruction: efficacy of fast multiplanar spoiled gradient-recalled MR imaging vs spin-echo MR imaging, CT, and cholangiography. *AJR Am J Roentgenol* 1994;

162:315–23.
30 Nealon WH, Townsend CM Jr, Thompson JC. Preoperative endoscopic retrograde cholangiopancreatography (ERCP) in patients with pancreatic pseudocyst associated with resolving acute and chronic pancreatitis. *Ann Surg* 1989; **209:**532–8.
31 Sica GT, Braver J, Cooney MJ *et al*. Comparison of Endoscopic retrograde cholangiopancreatography with MR cholangiopancreatography in patients with pancreatitis. *Radiology* 1999; **210:**605–10.
32 Pavone P, Laghi A, Catalano C *et al*. MR cholangiography in the examination of patients with biliary-enteric anastomoses. *AJR Am J Roentgenol* 1997; **169:**807–11.
33 Fulcher AS, Turner MA. Pitfalls of MR cholangiopancreatography. *J Comput Assist Tomogr* 1998; **22(6):**845–50.
34 Chan JHM, Tsui EYK, Yuen MK *et al*. Gadopentetate dimeglumine as an oral negative gastrointestinal agent for MRCP. *Abdom Imaging* 2000; **25:**405–08.

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