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World J Gastroenterol 2007 May 14; 13(18): 2529-2534
World Journal of Gastroenterology ISSN 1007-9327

REVIEW

Magnetic resonance cholangiopancreatography: A useful tool in the evaluation of pancreatic and biliary disorders

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Received: 2007-02-16 Accepted: 2007-03-21

Abstract

Magnetic resonance cholangiopancreatography (MRCP) is being used with increasing frequency as a noninvasive alternative to diagnostic retrograde cholangiopancreatography (ERCP). The aim of this pictorial review is to demonstrate the usefulness of MRCP in the evaluation of pancreatic and biliary system disorders. Because the recently developed techniques allows improved spatial resolution and permits imaging of the entire pancreaticobiliary tract during a single breath hold, MRCP is of proven utility in a variety of pancreatic and biliary disorders. It uses MR imaging to visualize fluid in the biliary and pancreatic ducts as high signal intensity on T2 weighted sequences and is the newest modality for pancreatic and biliary duct imaging. Herein, we present the clinical applications of MRCP in a variety of pancreaticobiliary system disorders and conclude that it is an important diagnostic tool in terms of imaging of the pancreaticobiliary ductal system.

Key words: Bile ducts abnormalities; Bile ducts calculi; Bile ducts neoplasms; MR cholangiopancreatography; Pancreatic ducts; Pancreas; Neoplasms

Halefoglu AM. Magnetic resonance cholangiopancreatography: A useful tool in the evaluation of pancreatic and biliary disorders. *World J Gastroenterol* 2007; 13(18): 2529-2534

http://www.wjgnet.com/1007-9327/13/2529.asp

INTRODUCTION

Magnetic resonance cholangiopancreatography (MRCP) is a noninvasive imaging technique that accurately depicts the morphological features of the biliary and pancreatic ducts. By using heavily T2 weighted sequences, the signal of static or slow-moving fluid-filled structures such as the bile and pancreatic ducts is greatly increased, resulting in increased duct-to-background contrast. Recent studies have shown that MRCP is comparable with invasive retrograde cholangiopancreatography (ERCP) for diagnosis of extrahepatic bile duct and pancreatic duct abnormalities such as choledocholithiasis[1-3], malignant obstruction of the bile and pancreatic ducts[1,2], congenital anomalies[1,4], and chronic pancreatitis[5,6]. Common indications for MRCP usually include unsuccessful ERCP or a contraindication to ERCP and the presence of biliary-enteric anastomoses. (e.g. choledochojejunostomy, Billroth 2 anastomosis). In some institutions, MRCP is becoming the initial imaging tool for the biliary system, with ERCP reserved for only therapeutic indications. In this article we present clinical applications of MRCP in the pancreaticobiliary system pathologies including choledocholithiasis, biliary strictures, chronic pancreatitis, benign and malignant pancreatic neoplasms, pancreatic pseudocysts, congenital abnormalities and postsurgical biliary tract alterations.

TECHNICAL CONSIDERATIONS

During the MRCP examinations, respiratory motion induced blurring has limited demonstration of the biliary and pancreatic ductal system and different approaches have been considered to overcome this problem. As a result, the technical history of MRCP parallels the evolution of progressively faster T2 weighted imaging sequences, i.e., from gradient-echo, to fast spin echo (FSE), to single-shot fast spin-echo (SSFSE)[7]. SSFSE is a recently developed ultrafast T2 weighted sequence, which allows subsecond slice acquisition. This largely overcomes the problem of motion artifact in MRCP, because physiologic motion is "frozen", and imaging of the biliary and pancreatic ducts can be performed in a single breath-hold[8].

SSFSE is the current sequence of choice for MRCP, because it essentialy eliminates the problem of motion artifact, and because of greater contrast-to-noise ratio and increased spatial resolution when compared with FSE or gradient-echo-based T2 weighted sequences[9]. MRCP is usually performed by using SSFSE software and both a thick-collimation (single-section) and thin-collimation (multisection) technique with a torso phased-array coil. The coronal plane is used to provide a cholangiographic display, and the axial plane is used to evaluate the pancreatic duct and the distal common bile duct. In addition we perform three-dimensional reconstruction by using a maximum intensity projection (MIP) algorithm on the thin-collimation source images. Although the thick-collimation and MIP images

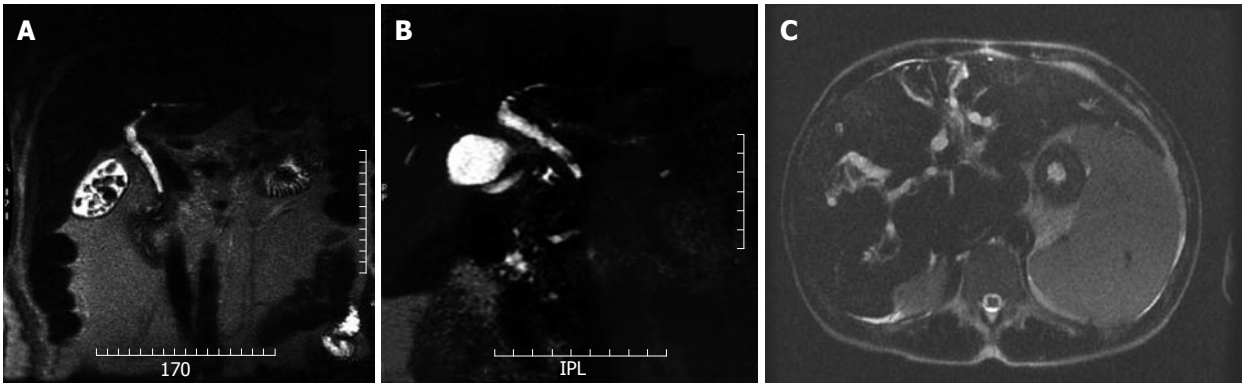

Figure 1 **A**: Coronal FSE thin section source image, numerous hypointense calculi are seen filling the gall -bladder. There is also a small hypointense calcule located at the distal CBD; **B**: Coronal FSE thin section source image, an approximately 3 cm long segment stricture along the distal CBD is seen in a patient with history of blunt abdominal trauma; **C**: Axial FSE thin section source image, multifocal strictures and dilatations of the intrahepatic biliary ducts causing a beaded appearance in a patient with sclerosing cholangitis.

more closely resemble conventional cholangiograms and are familiar to many clinicians, spatial resolution is degraded because of volume-averaging effects. Diagnostic decisions are usually made on the basis of the thin-collimation source images, however, MIP images often allow depiction of a greater length of duct on a single image than on any one thin-collimation source image. In addition, MIP images are useful in the three-dimensional depiction of ductal anatomy and in planning surgical procedures and radiation therapy. On the other hand, the source images, which provide greater spatial resolution, must be carefully scrutinized so as not to overlook small luminal filling defects and strictures, which may be obscured on the thicker-collimation images.

In a study of 108 patients with a variety of biliary and pancreatic diseases, bile duct stenoses, dilatation, and stones were all better seen on source thin slices than on either MIP reconstruction or single thick slice MRCP[10].

Another disadvantage of such techniques is that periductal structures are deliberately excluded from the final images, even though extraluminal detail may be of critical importance, as in the assessment of neoplastic duct obstruction.

PATIENT PREPARATION

Patients should be fasting for approximately 4-6 h prior to the exam to promote gallbladder filling and gastric emptying. Some authors have advocated the use of glugacon to suspend peristalsis, but use of rapid pulse sequences obviated this requirement. We do not need an exogenous contrast to demonstrate the pancreatic and biliary ducts. The long T2 of fluid compared with that of surrounding soft tissues and of calculi provides sufficient intrinsic contrast. Administration of a negative oral contrast helps reduce the signal intensity from overlapping fluid in the stomach and duedonum.

MRCP IN CHOLEDOCHOLITHIASIS

MRCP is comparable with ERCP in detection of choledocholithiasis and superior to CT and US[2,3]. Numerous studies have shown sensitivities of 81%-100% and specificities of 85%-100%[11].

Biliary stones, independently of calcium content, present almost always a low signal intensity on MR images. Therefore, the stone is identified as a round or oval-shaped "filling defect" within the common bile duct (CBD), surrounded by the high signal intensity bile (Figure 1A). Although spatial resolution of MRCP is lower than ERCP, the higher contrast resolution allows 2 to 3 mm stones to be easily detected[12].

It is crucial to scrutinize the thin, source images because the sensitivity for detection of small stones decreases with an increase in section thickness owing to volume averaging of high signal intensity bile surrounding the stone.

Nevertheless, different pitfalls can be observed which requires correct identification in order to avoid wrong diagnoses. They are represented by: a-artefacts on MIP reconstructed images, b-CBD completely filled with stones, c-pneumobilia, and, d-differential diagnoses between air bubles and small stones.

MRCP IN BENIGN BILIARY STRICTURES

Benign biliary strictures are the result of surgical injury in 90%-95% of cases (laparoscopic cholecystectomy, gastric and hepatic resection, biliary-enteric anastomoses, post liver transplantation), external penetrating or blunt trauma, inflammation associated with lithiasis, chronic pancreatitis, stricture of the papillary region, toxic or ischaemic lesion of the hepatic artery or primary infection such as in primary sclerosing cholangitis[13].

MRCP has been shown to be comparable with ERCP in demonstrating the location and extent of strictures of the extrahepatic bile duct (Figure 1B), with sensitivities of 91%-100%[14]. However, the accuracy in detections of strictures of the intrahepatic bile ducts is under investigation.

MRCP IN SCLEROSING CHOLANGITIS

Sclerosing cholangitis is a fibrosing, inflammatory process of the bile ducts that leads to sclerosis and stenosis of both intrahepatic and extrahepatic bile ducts.

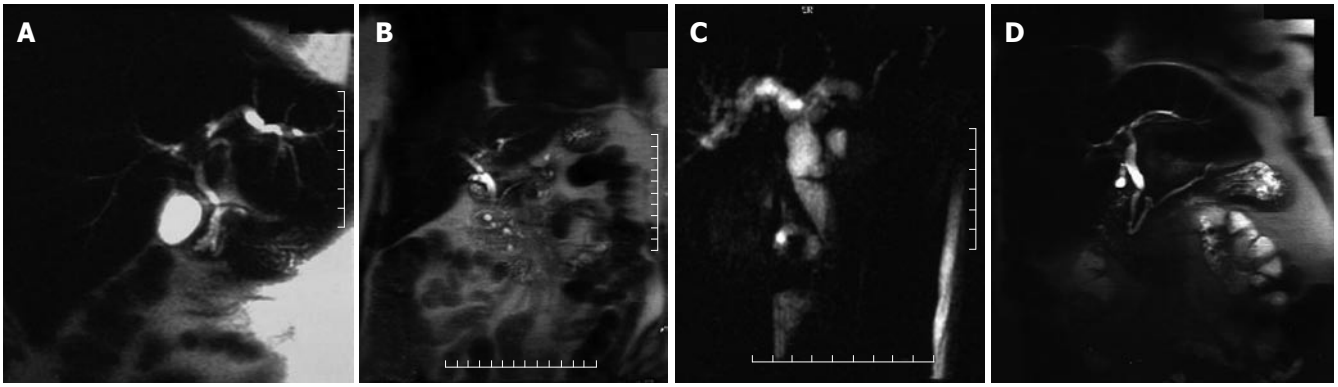

Figure 2 **A**: Coronal MIP image, a hypointense solid mass involving both the left and right main hepatic ducts representing Klatskin tumor is seen. There is also proximal dilatation of the bile ducts before the mass; **B**: Coronal MIP image, a dorsal pancreatic duct is seen coursing the CBD and draining into the minor papilla. A smaller ventral pancreatic duct is draining into the major papilla together with the CBD; **C**: Coronal MIP image, clearly depicts the "double duct sign"; **D**: Coronal MIP image, a small periampullary carcinoma leading to mild dilatation of both CBD and pancreatic duct.

Strictures are multifocal and alternate with slight dilatation or normal-caliber bile ducts, producing a beaded or "pruned tree" appearence (Figure 1C).

Because MRCP is not as sensitive as ERCP to the early peripheral ductal changes of sclerosing cholangitis, it should be reserved for diagnosis of complications or follow up of more advanced cases.

MRCP IN CHOLANGIOCARCINOMA

Cholangiocarcinoma may present as a stricture, involving the CBD (30%-36%), the common hepatic duct (15%-30%), the biliary bifurcation, with the typical aspect of Klatskin tumour (10%-26%), and the intrahepatic ducts (8%-13%) with no evidence of mass lesion or as a nodular process with intrahepatic solid mass. The MRCP features are a sudden biliary obstruction with dilatation of bile ducts above. In the case of Klatskin tumours, information regarding the involvement only of the right or left biliary system or both can be easily obtained, with important consequences on therapeutic approach (Figure 2A). Similiar to other neoplastic lesions, conventional MR images are needed for correct lesion identification and staging. In particular, for cholangiocarcinoma, T1 weighted images after contrast medium injection can be very helpful in correct identification of the lesion and of its relationship with surrounding organs, although in the case of stenosing lesion, no expansile process is usually identified.

MRCP IN BILIARY INJURIES

Initial studies suggest that iatrogenic biliary injuries are well demonstrated at MRCP[15]. Bile leaks result in accumulation of fluid, usually in the subhepatic space, which is readily detected at MRCP. But MRCP can not determine if a leak is active. Recently, there have been reports of use of selective hepato-biliary contrast agent, mangafodipir. This is metabolized by hepatocytes and excreted in bile. This agent may prove useful in noninvasive detection of active bile leaks[16], but prospective trials have not yet been published.

MRCP IN THE CONGENITAL ANOMALIES OF THE BILIARY AND PANCREATIC DUCTS

A number of congenital variants in biliary duct anatomy are of surgical significance, because they have been shown to increase the risk of bile duct injury during cholecystectomy. Such variants include a low cystic duct insertion, a medial cystic duct insertion, a long parallel course of the cystic and common hepatic ducts, a short cystic duct, and an abberant right posterior sectorial duct draining to the cystic duct or to the common hepatic duct[4].

Using conventional cholangiography as the standart of reference, MRCP had a sensitivity and specificity of 86% and 100% in the diagnosis of cystic duct variants, and 71% and 100% in the diagnosis of aberrant right hepatic duct, respectively[4].

In normal individuals, the main pancreatic duct (duct of Wirsung) drains through the major papilla; this duct is the major drainage route of the pancreas in 91% of individuals. The accessory pancreatic duct (duct of Santorini) drains through the minor papilla and is present in 44% of individuals. Pancreas divisum, the most common anatomic variant of the pancreas, results from failure of fusion of the dorsal and ventral pancreatic ducts and may be associated with an increase prevalance of acute pancreatitis[5]. The larger, dominant dorsal pancreatic duct, which drains the pancreatic tail, body, and superior head, courses anterior to the CBD and drains into the minor papilla separately from the CBD, superior to the major papilla. The smaller ventral duct, which drains the inferior pancreatic head and uncinate process, accompanies the CBD into the major papilla (Figures 2B and 3A). Bret *et al*[17] reported an accuracy of 100% for MRCP in the diagnosis of pancreas divisum.

MRCP IN CHRONIC PANCREATITIS

The MRCP diagnostic criteria for chronic pancreatitis include duct dilatation, narrowing, stricture, or irregularity[7]. Other possible imaging findings are irregularity of

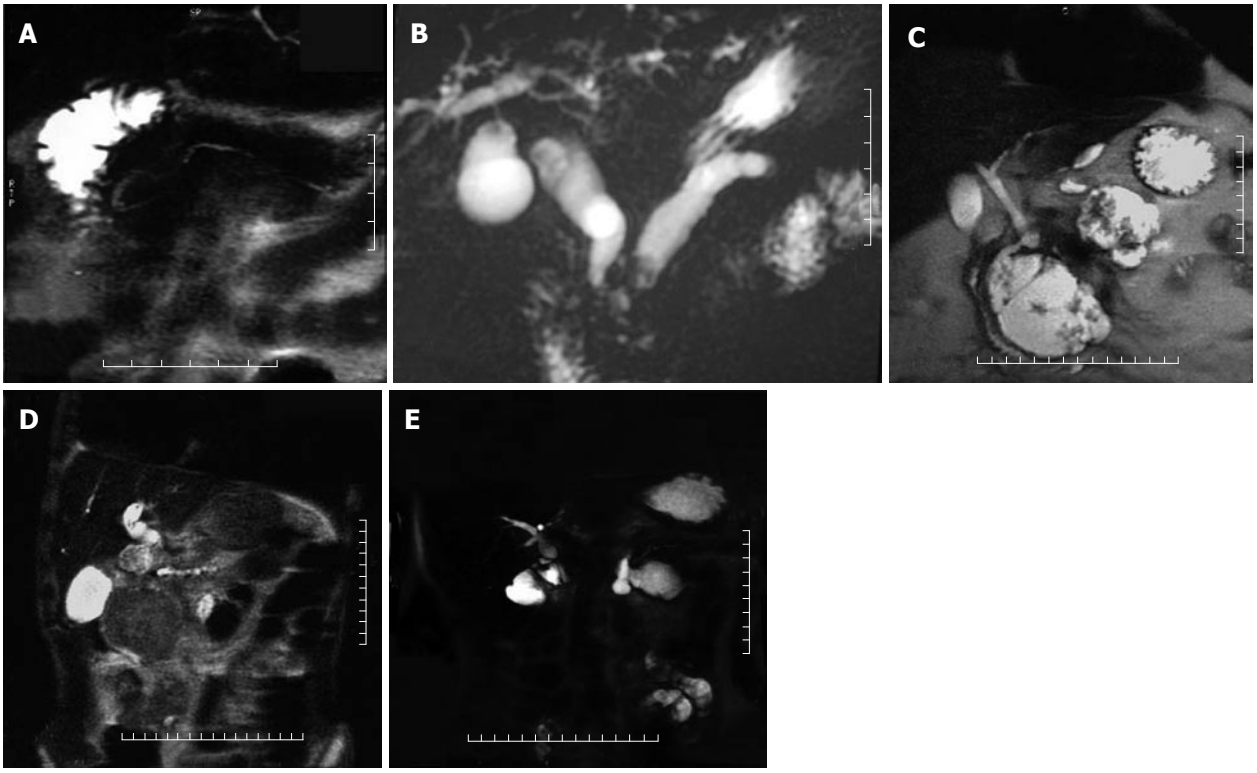

Figure 3 **A**: Coronal SSFSE thin section source image, the same duct abnormalities is clearly seen in a different patient with pancreas divisum; **B**: Coronal SSFSE thin section source image, CBD and pancreatic duct showing conspicuous dilatation in a chronic pancreatitis patient; **C**: Coronal FSE thin section source image, large pseudocyst formations are seen throughout the pancreas obscuring the CBD and pancreatic duct; **D**: Coronal FSE thin section source image, a large heterogeneous high signal intensity pancreatic head adenocarcinoma causing dilatation of both CBD and pancreatic duct is seen; **E**: Coronal MIP image, there is moderate dilatation and following abrupt but smooth tapering of CBD draining into the jejunum (choledochojejunostomy), also a small dilated cystic duct is seen. Remnant pancreatic duct in the tail draining into the afferent jejunal loop (pancreaticojejunostomy). The patient had a history of whipple operation for pancreatic head adenocarcinoma.

pancreatic contour, pseudocysts, and ductal filling defects due to stones, debris or mucinous plugs. In advanced chronic pancreatitis, the duct dilatation is more marked and can be accompanied by CBD dilatation producing "double duct sign" as in the case of pancreatic head carcinoma (Figure 3B).

In chronic pancreatitis intraductal calculi may be seen. These calculi are seen as low signal filling defects surrounded by high signal intensity pancreatic fluid (meniscus sign). In severe pancreatitis, side branches have a "chain of lake" appearance.

Soto *et al*[18] found the sensitivity of MRCP for dilatation as 87%-100%, for narrowing 75%, and for ductal calculi 100%. The authors conclude that MRCP can accurately demonstrate pancreatic duct abnormalities in chronic pancreatitis.

However, because MRCP is probably not sensitive to the early side-branch changes of chronic pancreatitis, MRCP should be reserved for diagnosis of complications or follow-up of more advanced cases. ERCP is more sensitive to early side-branch changes because of its increased spatial resolution.

PANCREATIC PSEUDOCYST

Pancreatic pseudocysts are encapsulated fluid collections that may occur in association with acute or chronic pancreatitis. (Figure 3C) MRCP is more sensitive than ERCP in detection of pseudocysts because less than 50% of pseudocysts fill with contrast material at ERCP[19]. However MRCP is less sensitive in demonstrating the site of communication with the pancreatic duct.

Although as many as 60% of pseudocysts may resolve spontaneously, others will become complicated by infection or hemorrhage. MRI and MRCP are useful in demonstrating pseudocysts and possibly their ductal communications as well as in establishing the presence of associated hemorrhage without the risk of infecting the pseudocyst as may occur at ERCP.

MRCP IN NEOPLASTIC BILIARY OR PANCREATIC DUCT OBSTRUCTION

Approximately 90% of malignant pancreatic neoplasms are ductal in origin with most being adenocarcinomas. Pancreatic carcinoma is seen as a focal mass in 95% of cases, whereas diffuse involvement of the gland occurs in the remaining 5%[20]. Of these focal carcinomas, 62% are located in the pancreatic head, with the remainder located in the body (26%) and tail (12%) of the pancreas[20].

The MRCP findings of pancreatic carcinoma include encasement and obstruction of the pancreatic duct or bile duct. Dilatation of both ducts constitutes the "double duct sign", which is highly suggestive of but no diagnostic for malignancy[14]. (Figure 2C and Figure 3D) In pancreatic head carcinoma, biliary and pancreatic duct dilatation occurs in 77% of cases, biliary duct dilatation in 9%, and pancreatic duct dilatation in 12%[20].

However, a normal-sized pancreatic duct should not cause this diagnosis to be excluded because the caliber will be normal in up to 20% of patients with pancreatic malignancy causing bile duct obstruction.

In a study of breath-hold SSFSE MRCP in 32 patients with pathologically confirmed neoplastic duct obstruction, the level of obstruction was correctly identified in 27 (84%) and 28 (88%) of the 32 cases by two independent observers, respectively, and the site of underlying tumor was correctly identified in 27 (84%) and 29 (91%) cases[21].

In cases of periampullary carcinoma, apart from the CBD obstruction, high grade obstruction with abrupt termination and mild dilatation of the pancreatic duct is usually present[22] (Figure 2D).

MRCP is also useful in the evaluation of intraductal papillary mucinous tumors. These tumors arise from the epithelium of the main pancreatic duct or side branches. They are slow-growing tumors characterized by production of large amounts of mucin. Side-branch ductal involvement is typically associated with benign adenomas and a localized cystic parenchymal lesion. Main pancreatic duct involvement alone presents as diffuse duct dilatation, gross mucin production, and micropapillary studding, and is typically associated with malignancy[23,24]. The diagnosis was traditionally made at ERCP. MRCP is now considered superior to ERCP because of its ability to demonstrate the full extent of ductal involvement, particularly when obstructing mucin prevents complete ductal opacification by ERCP[25]. In addition, MRCP can demonstrate main ductal and side branch stenosis and dilatation, associated cystic lesions, and communication between these lesions and the ductal system[26]. Filling defects caused by papillary projections may also be demonstrated.

PANCREATIC TRAUMA

Pancreatic injuries occur in 2%-12% of patients with blunt abdominal trauma[27]. Disruption of the pancreatic duct is a key prognostic indicator, and early diagnosis is important. Although CT is a sensitive method for detecting parenchymal injury, demonstration of duct injury often requires ERCP[28]. MRCP has recently been advocated as a noninvasive method for diagnosing pancreatic ductal injury[29]. In a series of seven trauma patients reported by Soto *et al*[30], MRCP accurately demonstrated the status of the duct and the site of duct transection in all patients. Though CT will likely remain the mainstay for diagnosis of pancreatic injury, MRCP shows promise in the planning of therapeutic surgical or endoscopic interventions in this setting[30].

MRCP IN POSTSURGICAL BILIARY TRACT ALTERATIONS

Biliary-enteric anostomoses such as choledocho-jejunostomy, hepaticojejunostomy, and Billroth 2 anostomosis make it difficult or impossible to access the major papilla at endoscopy. In patients with such anastomoses, MRCP is the imaging modality of choice for the work-up of suspected pancreaticobiliary disease.

It has been reported that MRCP is 100% sensitive in detection of anastomotic strictures and 90% sensitive in detection biliary tract stones proximal to the anastomosis[31]. MRCP is also 100% sensitive in demonstrating the choledochojejunal anastomosis after a whipple procedure[1] (Figure 3E).

Close scrutiny of the source images is mandatory because the biliary-enteric anastomosis and stones can be obscured on the thick-section and MIP images by the high signal intensity of the surrounding bile and bowel fluid.

Strictures may be overestimated on the MIP images[31].

ADVANTAGES AND LIMITATIONS

A clear advantage of this technique is the lack of invasiveness. In addition, MRCP is not limited in patients with altered anatomy (choledocho or pancreaticojejunostomy, Billroth 2 etc.) and it is not operator dependent.

The current shortcoming of MRCP is its relatively low spatial resolution which limits the visualization of non-dilated pancreatic duct side branches and characterization of strictures. This makes MRCP inable to assess small duct disease. Examples of small duct disease include subtle intrahepatic duct changes of sclerosing cholangitis, and side branch changes of mild chronic pancreatitis. This limitation is also partially related to the lack of duct distension at MRCP.

CONCLUSION

In summary, MRCP is a non-invasive important tool in the diagnosis of bilio-pancreatic diseases and has a comparable accuracy to ERCP. Despite relatively low spatial resolution when compared with ERCP the early assessments of diagnostic performance suggest that MRCP can; (1) reliably demonstrate normal and abnormal pancreatic and biliary ducts, (2) accurately diagnose the cause and site of obstruction, (3) be of diagnostic value when ERCP is unsuccessful.

ERCP cannot be performed after biliary-enteric anastomosis when the anastomosis is beyond the duedonum, as is frequently the case. Likewise, ERCP cannot be performed after gastro-enterostomy such as a Billroth 2. MRCP may be preferred to ERCP in patients with suspected solid extraductal masses, or cystic masses that do not communicate with the duct system[21]. Patient preference for non-invasive imaging may also be a consideration to perform MRCP rather than ERCP. It is likely that in the near future MRCP will replace diagnostic ERCP as the modality of choice for imaging the biliary and pancreatic ducts.

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S- Editor Liu Y **L- Editor** Alpini GD **E- Editor** Che YB