Article published online: 2021-07-31

Review: Advances in magnetic resonance cholangiopancreatography: From morphology to functional imaging

Kavita Gulati, Onofrio A Catalano, Dushyant V Sahani
Abdominal and Interventional Radiology, Massachusetts General Hospital, Boston, USA

Correspondence: Dr. Dushyant V Sahani, Abdominal and Interventional Radiology, Massachusetts General Hospital, Harvard Medical School, 55 Fruit Street, Boston, MA 02114, USA E-mail: dsahani@partners.org

Introduction

Magnetic resonance cholangiopancreatography (MRCP) is a medical imaging technique, which uses magnetic resonance to visualize the biliary tree and pancreatic ducts in a non-invasive way. Though several variations of this technique have been developed in the recent years, they all share the use of a heavily T2W pulse sequence, which selectively displays static or slow-moving fluid-filled structures as high intensity areas. The recent development of many three dimensional (3D) sequences has substantially enhanced the quality of the MRCP images. Likewise, the introduction of hepatobiliary contrast media and secretin, has enabled functional assessment of biliary excretion and the exocrine pancreas, respectively.

In this article, we present new MRCP techniques using 3D acquisition and the role of functional MRCP. In addition, we discuss commonly imaged biliary and pancreatic duct pathologies, including congenital anomalies, obstruction, trauma and tumors.

Techniques

Traditional Fluid-Based Techniques (2D MRCP)

The underlying principle of MRCP is imaging fluid in the biliary and pancreatic tree while suppressing background signals from non-fluid structures. Heavy T2W sequences are used to accomplish this purpose. Single-shot, fast spin-echo (SSFSE) sequences are considered ideal for this task. Two different and complementary approaches are generally used for 2D MRCP: a thick-slab, single-shot, turbo spin-echo (TSE) T2W sequence and a multisection, thin-slab, single-shot TSE T2W sequence. Limitations of SSFSE techniques include image blurring induced by long echo train lengths (ETL), flow artifacts within the biliary tree that can occasionally simulate stones or masses and problems with saturation of adjacent slices when sequential acquisitions are performed.[1] With this technique, it is often necessary to acquire images at different angles, through the appropriate structures and therefore the technique is dependent on the operator's familiarity with the anatomy and pathology.

3D MRCP

Advances in gradient strength and image processing software have significantly influenced the development of 3D MRCP sequences that can be acquired in suspended respiration or with respiratory gated techniques using fast recovery sequences (FSE) or steady state free precession (SSFP). The near isotropic volumetric data from a 3D MRCP sequence can then be processed using a maximum intensity projection (MIP) or volume rendered technique (VRT) for an esthetically pleasing display of the biliary tree and pancreatic duct [Figure 1]. Table 1 shows the routinely used parameters for 2D and 3D MRCP. Table 2 examines the advantages and disadvantages of the 3D

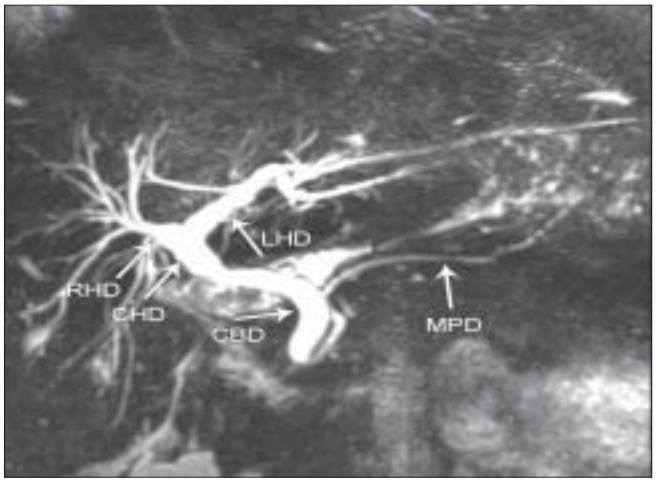

Figure 1: A 3D oblique coronal MRCP image displays normal biliary and pancreatic duct anatomy. RHD= Right Hepatic Duct, LHD = Left Hepatic Duct, CHD = Commom Hepatic Duct, CBD = Common Hepatic Duct, MPD = Main Pancreatic Duct

Table 1: One of the routinely used sets of parameters for 2D and 3D MRCP

Technique	TE (msec)	TR	Thickness (mm)
2D MRCP			
Oblique radial SSFSE T2 weighted (14 slices)	500	Minimum	40
Oblique right anterior SSFSE T2 weighted	160	Minimum	5
Oblique left anterior SSFSE T2 weighted	160	Minimum	5
3D MRCP			
3D MRCP fat saturated	500-600	4000	1.4

Table 2: Advantages and disadvantages of 3D MRCP

Advantages	Disadvantages
Volumetric acquisition	Motion artifacts from inadequate respiratory gating
High spatial resolution Excellent SNR (signal noise ratio)	Long breath hold acquisition time Banding artifacts near the diaphragm in SSFP

MRCP technique.

Functional / Contrast Enhanced MRCP

Although conventional, fluid-based T2W MRCP is excellent for demonstrating morphological details, there is still lack of functional information concerning bile production and excretion through the biliary tree. MR contrast agents with hepatobiliary excretion such as mangafodipir trisodium (Teslascan; GE Healthcare Technologies), gadobenate dimeglumine or Gd-BOPTA (Multihance; Bracco) and gadolinium-ethoxybenzyl-diethylene-triamine-pentaacetic acid or Gd-EOB-DTPA (Primovist, Schering-AG), are now being used for this purpose.

The optimum timing for biliary excretion of these contrast agents ranges from 10-60 minutes. The preferred acquisition sequence for T1W MRCP is a fat–saturated, spoiled gradient recall (SPGR) sequence. For image display, data can be processed with any of the preferred 3D rendering techniques [Figure 2].

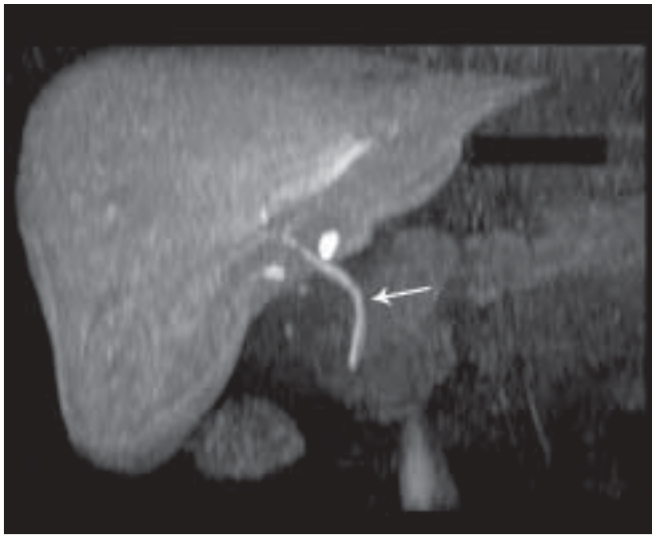

Figure 2: Contrast enhanced T1W MRCP using Gd-BOPTA. A coronal oblique 3D-GRE image, obtained at 1-hour post Gd-BOPTA injection, displays high signal intensity; contrast-enhanced, extra-hepatic bile ducts (arrow)

Indications and current clinical role of contrast-enhanced MRCP (CE-MRCP)

1) Defining biliary anatomy for pre-surgical planning prior to major hepatectomies and living donor liver transplantation.
2) Evaluating the integrity of the bile duct
3) Differentiating true obstruction from pseudo-obstruction

Functional / Secretin Stimulated MRCP

With the availability of the new pharmaceutical agent, secretin (SecreFlo, Repligen Corporation, Waltham, MA, USA), functional MRCP of the pancreas and pancreatic duct is now a reality. Secretin stimulates exocrine secretion of the pancreas and hence improves visualization of the pancreatic duct by increasing its caliber. After the intravenous administration of 1ml of secretin per 10 kg body weight, thick slab MRCP in the coronal plane is performed and repeated every 15-30 seconds for 10-15 minutes. The effect of secretin stimulation starts almost immediately after intravenous administration and peaks between 2-5 minutes. Around 10 minutes post-injection, the caliber of the main pancreatic duct returns to the baseline value, as the pancreatic juice flows out through the papilla and progressively fills the duodenum [Figure 3]. However, the high cost of secretin and the lack of a reimbursement mechanism for its use in MRI currently remain impediments for widespread use.

Indications and current clinical role of secretin-MRCP (S-MRCP)

1) Detection and characterization of pancreatic ductal anomalies.
2) Evaluating the integrity of the pancreatic duct.
3) Diagnosing and differentiating benign versus malignant strictures of the pancreatic duct.
4) Characterizing cyst communication and fistula.
5) Assessment of pancreatic function and (possibly) sphincter of Oddi dysfunction.

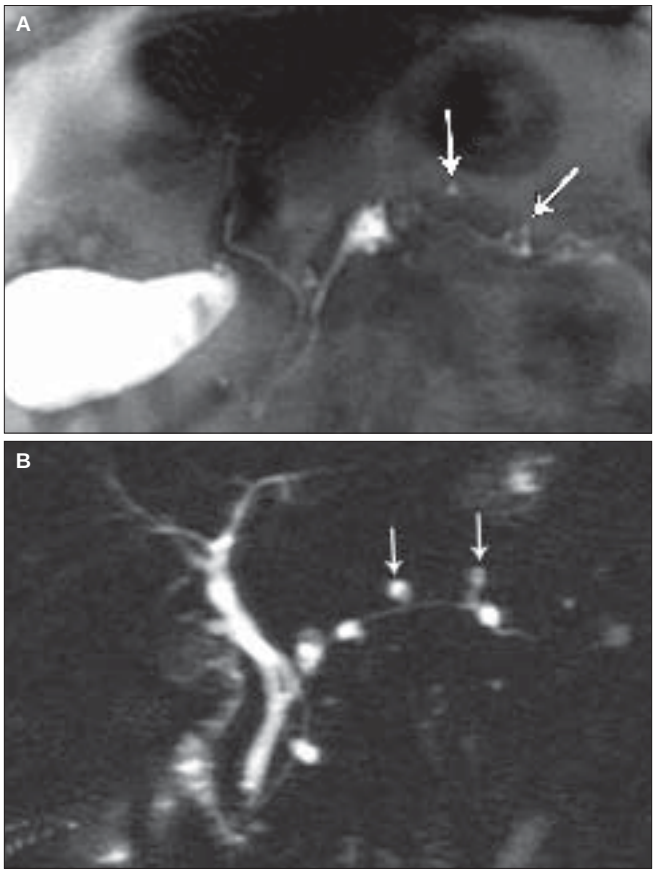

Figure 3 (A, B): Dynamic S-MRCP images obtained (A) before and (B) after secretin administration, in a middle-aged patient with side branch IPMNs (arrows). Improved visualization of IPMNs and their communication with the MPD is clearly demonstrated on secretin-enhanced images (B). IPMN - Intraductal Papillary Mucinous Neoplasm

MRCP Findings in Biliary Pathologies

A comparison of the common diagnostic modalities for the detection and characterization of biliary tract pathologies is given in the following table [Table 3]-

Congenital Anomalies

Anatomical variants (trifurcation and left dorsocaudal branch) and common congenital anomalies (left sided cystic duct, aberrant hepatic duct, choledochal cyst, parallel or high cystic duct, agenesis of gall bladder) can be evaluated confidently by MRCP. Currently, MRCP is considered the modality of choice for pre-operative evaluation of the biliary tree, for the diagnosis of congenital lesions and to define the anatomy [Figure 4].

Biliary Obstruction – Stone, Benign and Malignant Stricture

In the context of biliary obstruction, the role of MRCP is to detect obstruction, define its level and to identify a potential cause. This information can then be used to guide appropriate management.

Stone

MRCP is usually performed to confirm or exclude the diagnosis of CBD stones, suspected on other tests such as USG or CT scan, usually prior to an endoscopic procedure [Figure 5]. Studies conducted using 2D MRCP, for the detection of CBD stones, have reported a sensitivity, specificity and accuracy of 90%, 88% and 89% respectively, which after the exclusion of stones with diameters smaller than 6 mm, have improved to 100%, 99% and 99% respectively.[2] The detection accuracy of stones <6mm is likely to improve with the newer 3D sequences.

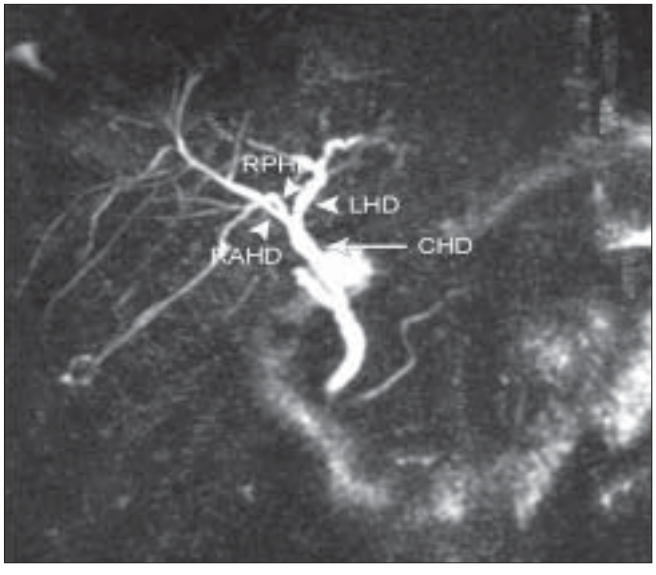

Figure 4: A 3D MRCP displaying a bile duct variant - biliary trifurcation. Note the simultaneous fusion of RAHD, RPHD and LHD (arrowheads) to form CHD (arrow). RAHD = Right anterior hepatic duct, RPHD = Right posterior hepatic duct, LHD = Left hepatic duct, CHD = Common hepatic duct

Table 3: Advantages and disadvantages of MRCP over direct cholangiography

MRCP	Direct cholangiography (ERCP and PTC)
Advantages	
Non Invasive	Invasive
No risk of complications	Risk of complications such as bleeding, perforation, sepsis, pancreatitis
Relatively operator independent	Highly operator dependent
No ionizing radiation	Ionizing radiation involved
Visualize both intraductal and extraductal anatomy	Visualize only ductal anatomy
Disadvantages	
No possibility of intervention	Biliary tree intervention possible, can be therapeutic

ERCP = Endoscopic Retrograde Cholangiopancreatography, PTC = Percutaneous Transhepatic Cholangiography

Benign Biliary Stricture

Benign biliary strictures are shorter, smoother and more symmetric; they can be post-inflammatory, congenital or idiopathic. Primary sclerosing cholangitis (PSC) is a commonly described cause of benign biliary strictures. Earlier studies have shown MRCP to be accurate in the detection, classification and staging of primary sclerosing cholangitis with a reported sensitivity and specificity greater than 85% [Figure 6].[3]

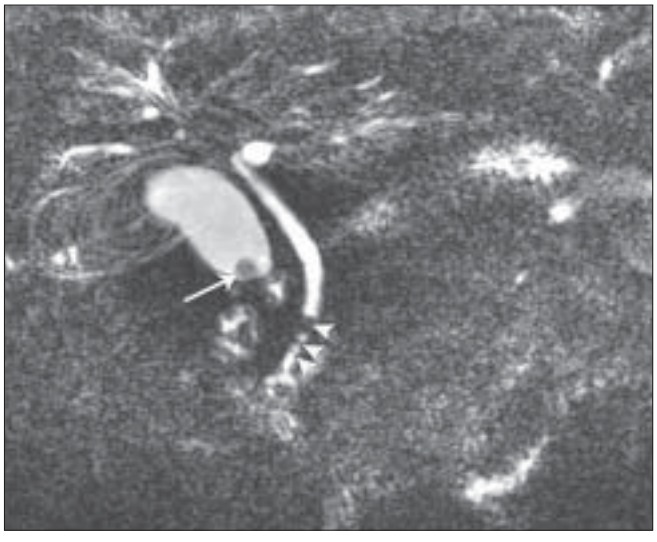

Figure 5: CBD stones in a 53-year old man, who presented with abdominal pain. A partition image from a 3D MRCP shows filling defects (arrowheads) from stones in the distal CBD. In addition, note the stone in the gall bladder (arrow)

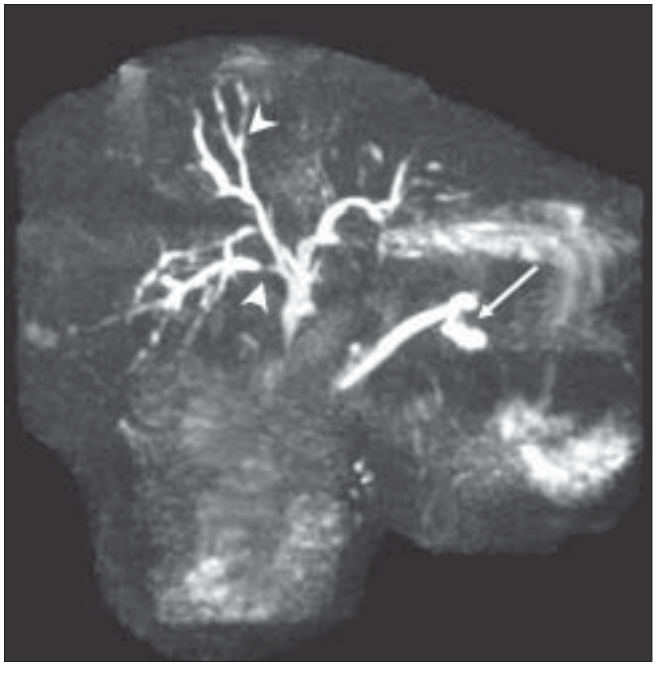

Figure 6: A 3D MRCP image from a patient with primary sclerosing cholangitis (PSC), reveals alternating narrowing and dilatation of the intrahepatic biliary ducts (arrowheads). Incidental note is made of a coexistent branch duct IPMN (arrow)

Malignant Biliary Stricture

MRCP helps to define the extent of biliary strictures and their relationship to critical structures in the vicinity, in patients with known or suspected cholangiocarcinoma affecting the common bile duct [Figure 7] or the bifurcation (Klatskin tumor) [Figure 8]. The routine use of gadolinium–based, extra-cellular contrast agents, in addition to the routine MRCP sequences, is encouraged, to allow a more comprehensive assessment of the associated mass, presence of vascular encasement, liver metastases and regional lymph nodes.[4]

MRCP in Pancreatic Pathology

Various imaging modalities are available for evaluating the pancreas and pancreatic duct. Table 4 shows a comparison of these modalities along with their strengths and limitations.

Congenital Anomaly of Pancreas (Pancreas Divisum)

Pancreas divisum, although present in 7-10% of the population, may be a cause of recurrent pancreatitis, in some patients. Although, the exact mechanism of pancreatitis in this subset of patients is still debated, the therapeutic

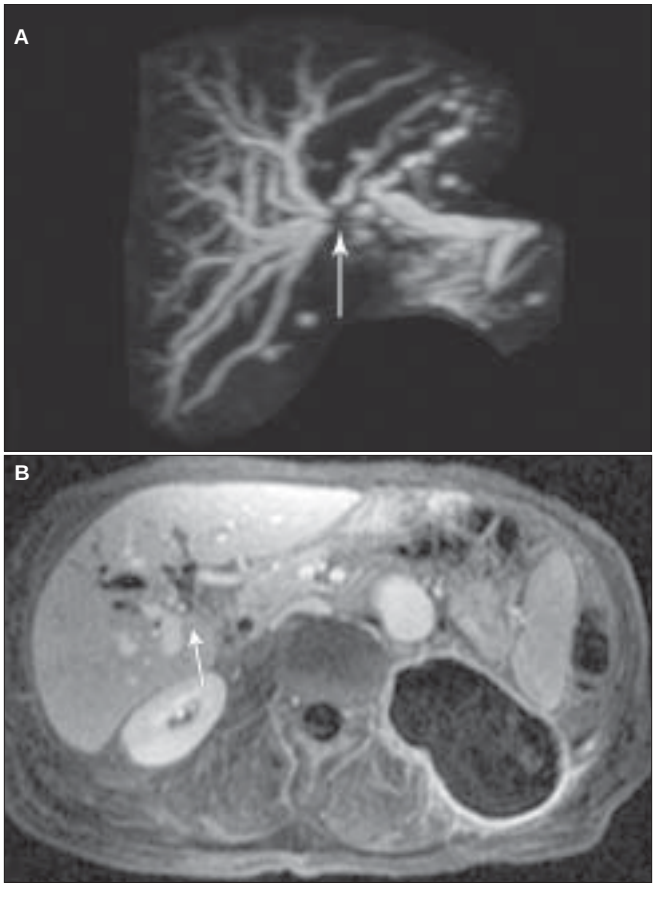

Figure 7 (A, B): RHD cholangiocarcinoma in an 80-year old woman presenting with jaundice. 3D MRCP MIP image (A) shows grossly dilated intrahepatic biliary radicals and an abrupt cut-off at the convergence of the RHD (arrow). Axial Gd-enhanced T1W fat-saturated image (B), shows a poorly enhanced, oval-shaped lesion in the porta hepatis, corresponding to the hilar cholangiocarcinoma (arrow)

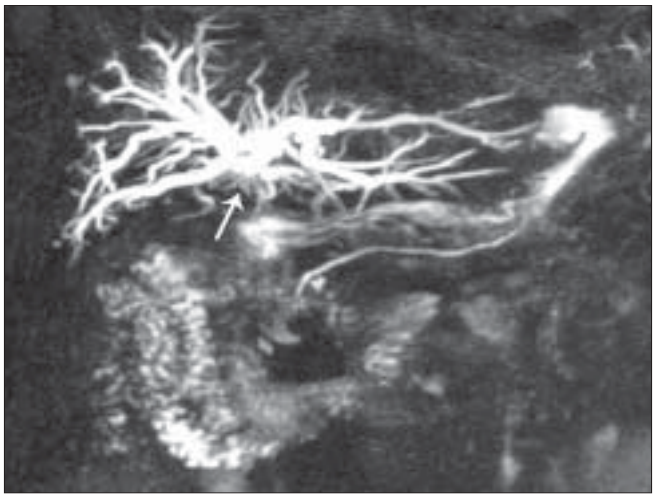

Figure 8: A 3D MRCP image from a 65-year old man presenting with jaundice. Gross intrahepatic biliary ductal dilatation is evident on the MIP image with obstruction at the bifurcation from a Klatskin's tumor (arrow). The entire MPD is clearly demonstrated

benefits of minor papillotomy have been established in this cohort. Therefore, identifying this subset of patients with pancreas divisum and pancreatitis who might benefit from therapeutic intervention is an important indication for MRCP, especially with the use of 3D acquisitions and S-MRCP. Investigators using S-MRCP in this clinical setting have reported an approximately 23% increase in the detection of pancreas divisum after secretin injection[5] [Figure 9].

Acute Pancreatitis

The role of MRCP is controversial in the setting of acute pancreatitis. Typically, CT is the most commonly used imaging modality in the setting of acute pancreatitis. In patients wherein CT cannot be performed due to iodinated contrast allergy or renal insufficiency, a combination of MRCP and gadolinium-enhanced MRI may help in the detection of pancreatitis and to stratify the patient's risk, based on the presence of necrosis, ductal integrity and

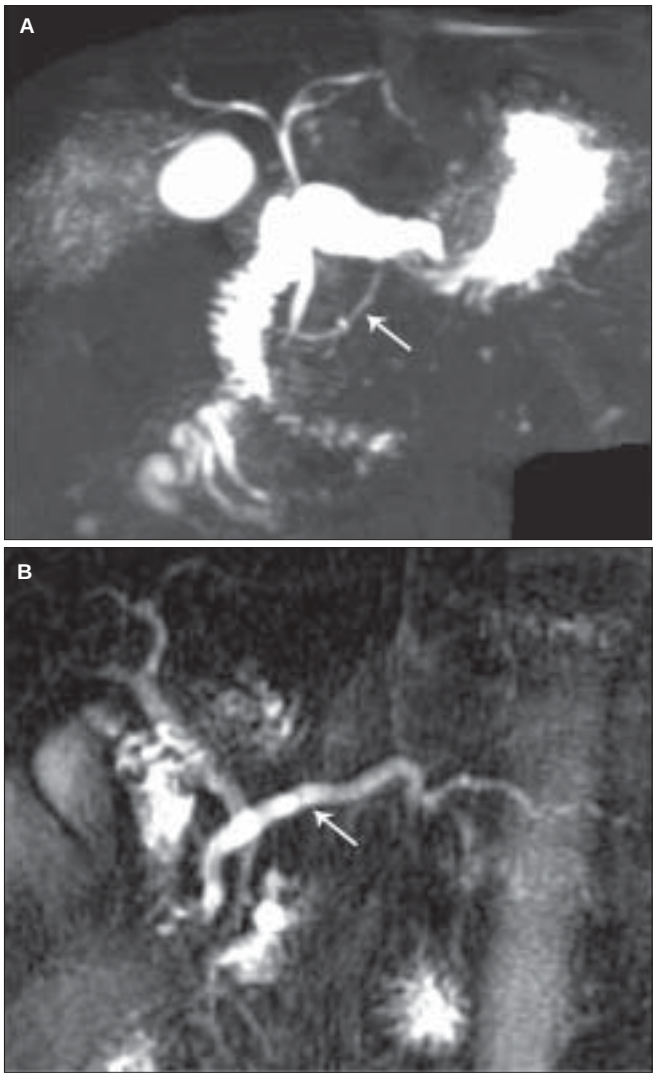

Figure 9 (A, B): MRCP images from two different patients with pancreas divisum are shown. 2D(A) and 3D (B) MRCP images are available. Note that the variant anatomy of the dorsal duct (arrow) is more confidently visualized on (B). Additionally, the entire pancreatic duct is displayed on a single 3D image (B), as compared to the the 2D image (A), where the anatomy is not that obvious

Table 4: Comparison of various diagnostic modalities for pancreatic evaluation

Modality	Role in duct evaluation	Advantage over other modalities	Limitations
Endoluminal Ultrasound	Ability to biopsy and aspirate	High sensitivity for intraluminal masses and parenchymal lesions	Invasive. Limited coverage of anatomy of interest
CT Pancreatography	Morphological Evaluation	Curved reformats of the pancreatic duct can allow evaluation of the entire extent of the duct on one image	Poor contrast resolution of small lesions. Requires mutidetector CT for good resolution
ERCP	Ability to biopsy and aspirate	Stones can be retrieved; balloon dilation/stent placement can be performed. Intraluminal masses not accessible by endoscopic ultrasound can also be biopsied	Invasive
MR/MRCP	Best contrast Resolution	Can also evaluate pancreatic parenchyma Only modality that can provide functional evaluation of exocrine pancreas and pancreatic duct.	Expensive Biopsy not possible

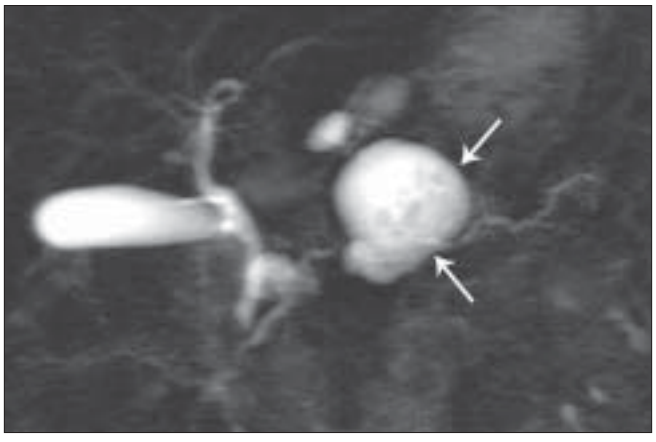

Figure 10: Pancreatic pseudocyst in a patient, 6 weeks following an attack of acute pancreatitis. A coronal oblique, 2D MRCP image displays a well-circumscribed cystic structure (arrows), close to the MPD. A connection with the MPD however was not shown by the MRCPstudy

hemorrhage. Due to the patients' fragile clinical status and other monitoring needs, obtaining optimal quality MRI images remains a formidable task. MRI is therefore, usually used very selectively, as a problem-solving modality. The use of secretin is not encouraged in the acute setting due to the potential of a flare-up of the inflammation [Figure 10].

Pancreatic Duct Integrity

The assessment of pancreatic duct disruption or leakage, in cases of trauma and inflammation, helps stratify patients for endoscopic, invasive radiological or surgical intervention. ERCP has long been the modality of choice for this indication; however, S-MRCP is now being considered as the preferred modality. Demonstration of disruption, communication of the pancreatic duct with a collection and increased volumes of extra-pancreatic collections after secretin administration are considered signs of pancreatic duct disruption. In addition, MRCP can also detect complete duct disconnection, by demonstrating the duct below and above the disruption, unlike ERCP where only the duct below the disruption is visualized. In addition, ERCP can potentially introduce infection from the bowel into the previously sterile pancreatic fluid collections.[6]

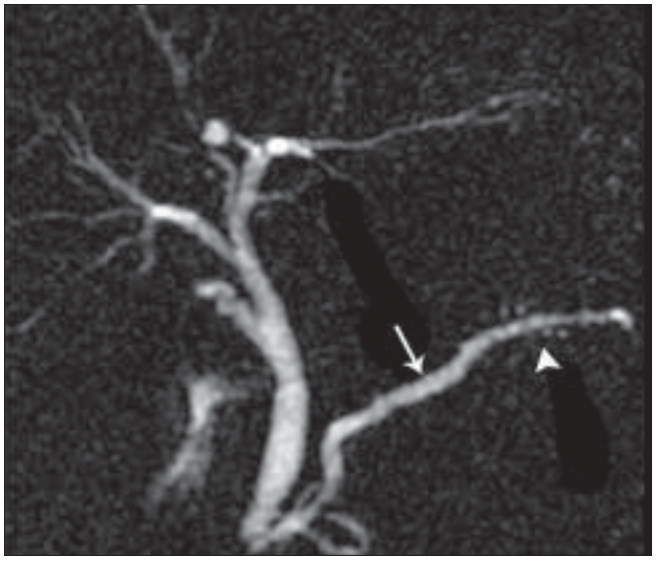

Figure 11: A 3D coronal oblique MRCP of a known case of chronic pancreatitis, shows dilated MPD (arrow) and side branches (arrowhead)[7]

Chronic Pancreatitis

The diagnosis of suspected chronic pancreatitis has been a challenge with conventional MRCP, because of its previous low accuracy, when compared to ERCP, which has traditionally been considered the gold standard for the evaluation of chronic pancreatitis [Figure 11]. Now, with the refinement of MRCP techniques and the availability of secretin, the diagnostic accuracy of MRCP has improved substantially. Duct irregularity, filling defects and strictures can now be more confidently studied, along with quantitative assessment of exocrine function. Furthermore, in patients considered for endoscopic management of

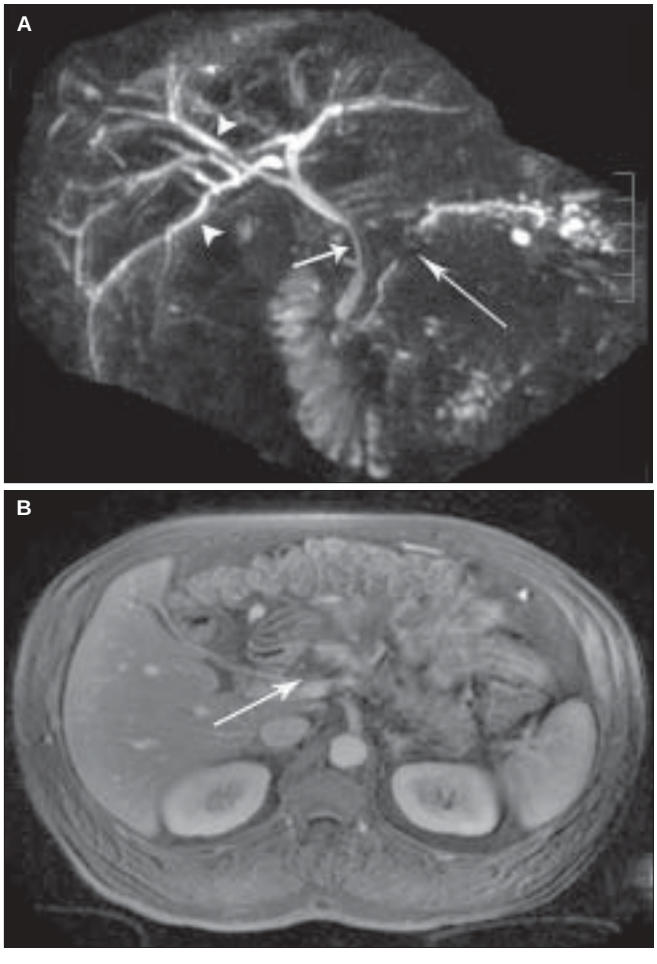

Figure 12 (A, B): 3D MRCP (A) display from a patient who presented with jaundice. A long, irregular stricture is noted in the CBD (arrow) with another stricture in the mid-pancreatic duct (long arrow) along with upstream dilatation of the bile ducts and MPD (arrowheads), respectively. CE-MR T1W fat-saturated image (B) shows a mass in the neck of pancreas encasing the CBD and MPD (long arrow). This was confirmed surgically to be adenocarcinoma of the pancreas

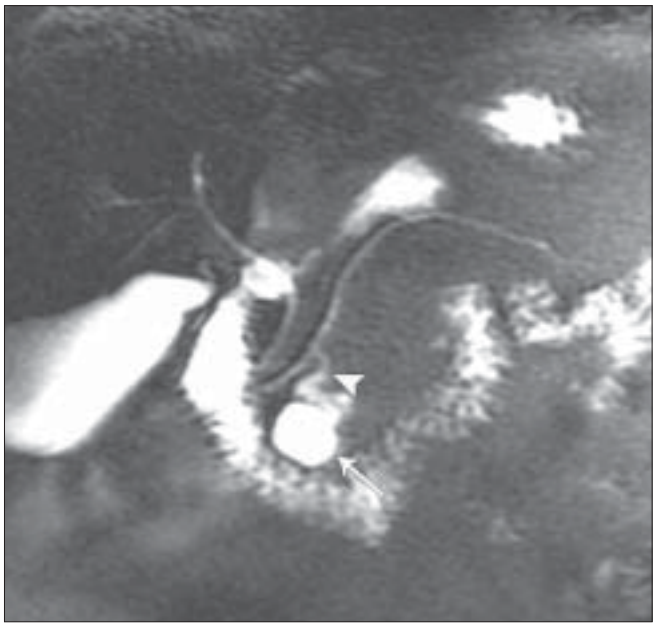

Figure 13: A 2D oblique coronal MRCP image shows a septated cystic structure in the uncinate process of the pancreas (arrow) diagnosed as IPMN, connected to the MPD (arrowhead)

pancreatic duct stones and strictures, there has been an increase in the use of MRCP to provide a roadmap. The role of S-MRCP is however limited in advanced cases of chronic pancreatitis where diminished exocrine function results in reduced pancreatic fluid production.

Malignant Pancreatic Duct Sticture and Intraductal Papillary Mucinous Neoplasm (IPMN)

Both malignant pancreatic duct stricture (Figure 12) and cystic lesions of the pancreas are well seen. MRCP is a reliable technique for the comprehensive evaluation of cystic lesions of the pancreas, allowing detection, categorization into a subtype (main duct versus side branch), definition of the extent of main duct involvement and of cyst communication with the duct in cases of side-branch IPMN [Figure 3, 13].[8] Also differentiation between benign and malignant IPMNs can be performed confidently in most cases, based on cyst morphology, mural nodules or dilatation of the MPD. Furthermore, MRCP is the modality of choice over MDCT for the detection and characterization of small pancreatic cysts.

Conclusion

The combination of conventional and functional MRCP offers a technique for the comprehensive evaluation of a wide range of biliary and pancreatic diseases and their effect on morphology and function. Understanding the clinical perspectives and then optimizing the imaging protocols are the key determinants that influence the development of a successful MRCP practice.

References

1. Glockner JF. Hepatobiliary MRI: Current concepts and controversies. J Magn Reson Imaging 2007;25:681-95.
2. Guarise A, Baltieri S, Mainardi P, Faccioli N. Diagnostic accuracy of MRCP in choledocholithiasis. Radiol Med (Torino) 2005;109:239-51.
3. Fulcher AS, Turner MA, Franklin KJ, Shiffman ML, Sterling RK, Luketic VA, *et al*. Primary sclerosing cholangitis: Evaluation with MR cholangiography: A case-control study. Radiology 2000;215:71-80.
4. Freeman ML, Sielaff TD. A modern approach to malignant hilar biliary obstruction. Rev Gastroenterol Disord 2003;3:187-201.
5. Matos C, Metens T, Delhaye M, Le Moine O, Cremer M. Pancreas divisum: Evaluation with secretin-enhanced magnetic resonance cholangiopancreatography. Gastrointest Endosc 2001;53:728-33.
6. Kinney TP, Punjabi G, Freeman M. Technology insight: Applications of MRI for the evaluation of benign disease of the pancreas. Nat Clin Pract Gastroenterol Hepatol 2007;4:148-59.
7. Larena JA, Astigarraga E, Saralegui I, Merino A, Capelastegui A, Calvo MM. Magnetic resonance cholangiopancreatography in the evaluation of pancreatic duct pathology. Br J Radiol 1998;71:1100-4.
8. Sugiyama M, Atomi Y, Hachiya J. Intraductal papillary tumors of the pancreas: Evaluation with magnetic resonance cholangiopancreatography. Am J Gastroenterol 1998;93:156-9.

Source of Support: Nil, **Conflict of Interest:** Research agreement GE healthcare speaker bureau, Bracco Diagnostics..