

MAGNETIC RESONANCE UPDATE

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LEARNING OBJECTIVES



*Upon completion of this activity,
participants should be able to:*

- Understand the key elements and the basic underlying principles of the procedure of magnetic resonance cholangiopancreatography (MRCP).
- Learn the role of MRCP in the evaluation of a variety of disorders of the pancreaticobiliary system.
- Review the key imaging features of common disease entities of the pancreaticobiliary system.
- Recognize the advantages and limitations of MRCP when compared to invasive methods.

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Drs. Adusumilli and Siegelman have indicated that they have no relationships to disclose relating to the subject matter of this article.

MRCP

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Magnetic resonance cholangiopancreatography (MRCP), an imaging technique for evaluating the pancreaticobiliary system, is a noninvasive alternative to endoscopic retrograde cholangiopancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC). ERCP was initially used as a diagnostic imaging modality for the pancreaticobiliary system, and later, as a therapeutic tool. The procedure has potential complications, such as pancreatitis, cholangitis, hemorrhage, and duodenal perforation, that compromise its benefits as a routine diagnostic test.¹

MRCP was introduced in 1991 as a noninvasive way to image the biliary tree.² The technique exploits the inherent differences in the T2-weighted contrast between fluid-filled structures and adjacent soft tissue. Intravenous contrast agents are not necessary to obtain MRCP images, which is ideal for patients with renal insufficiency or contrast allergy. MRI, in general, is a safe procedure that does not use ionizing radiation or require routine conscious sedation. The safety of MRCP makes it appropriate for pediatric and elderly populations, patients with comorbid illnesses, and individuals with a high risk of developing ERCP-related complications. Over the past decade, the quality and diagnostic accuracy of MRCP have improved, allowing this technique to evaluate a wide variety of disorders of the pancreaticobiliary system.

EVALUATION AND PREPARATION

MRCP has no contraindications except for the same safety considerations applied to routine MRI, including the presence of a pacemaker, aneurysm clip, or a metallic foreign body in the orbits.³ Patient preparation is minimal for MRCP. It is recommended that patients fast for three to four hours prior to the procedure in order to reduce fluid within the stomach, decrease duodenal peristalsis, and promote filling of the gallbladder.^{4,5} Negative oral contrast agents can improve depiction of the pancreaticobiliary tree by eliminating the bright signal intensity of fluid in the adjacent gastrointestinal tract.⁶ Such oral agents are not required because MRCP can be performed using thin-section tomographic images. Thus, adjacent fluid-filled bowel segments often do not obscure evaluation of the adjacent ductal structures.

IMAGING TECHNIQUE

The principle behind MRCP is that static or slow-moving fluids, such as bile and pancreatic secretions, appear as high signal intensity on heavily T2-weighted sequences while background soft tissues appear as very low signal intensity. Imaging is routinely performed in the axial and coronal plane with the oblique plane (35° to 45° to the coronal) reserved for evaluating anatomic variants suspected on other imaging planes.^{4,5,7} One technique of MRCP involves a respiratory-gated fast spin-echo sequence in which imaging is timed to

coincide with the patient's breathing. This technique is hindered by artifact from respiratory motion and bowel peristalsis.^{4,5,8} Other methods of performing MRCP involve the use of single-shot fast spin-echo (SSFSE) or half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequences. SSFSE and HASTE are heavily T2-weighted fast spin-echo sequences that can be performed in short breath-hold times, thereby reducing respiratory motion artifact.^{9,11} The latter techniques can acquire images in less than one second so that diagnostic MRCP exams may still be obtained in patients who cannot suspend respiration.

MRCP can be performed in two ways using the T2-weighted HASTE sequence. One method acquires a single thick slab of data in a two-second breath-hold and displays fluid-containing structures as high signal intensity.^{10,11} Postprocessing is not required because only a single image is obtained, which represents the average of the data contained in the entire imaging volume.¹² The second method acquires multiple thin slices that can be postprocessed on an imaging workstation. Postprocessing uses the maximum intensity projection (MIP) algorithm in which only the pixel with the highest signal intensity along a ray perpendicular to the plane of projection is displayed, thus highlighting bile and fluid-filled structures.^{10,12} The pancreaticobiliary tree is well depicted using either technique, but stones are easier to see on the source images of the multislice acquisition.¹¹

The interpretation of images follows the same principles as that of ERCP. The presence of strictures, duct dilation, filling defects representing stone or tumor, congenital anomalies, and fluid collections can be directly assessed on MRCP images. Evaluation of the thin slice tomographic slices is critical in MRCP in order to avoid missing filling defects and duct segments that may be obscured by hyperintense fluid on MIP reconstructions.^{13,14} ERCP does not have tomographic capabilities, so its images are similar to the single slice projection images as described above.

CLINICAL APPLICATIONS

•Pancreaticobiliary obstruction. MRCP has been documented as having a sensitivity of 96% and specificity of 99% for the diagnosis of biliary obstruction.¹⁵ MRCP can depict the level of obstruction and reveal associated masses to determine whether they arise from the ducts (cholangiocarcinoma) or involve the ducts by extension from tumors of the liver, gallbladder, pancreas, or adjacent lymph nodes.¹⁶ Most malignant lesions cause an abrupt narrowing of the bile duct with shouldered margins and mucosal irregularities as in cholangiocarcinoma. Benign lesions, such as ampullary stenosis, impacted stones, and dysfunction of Oddi's sphincter,¹² cause smooth and gradually tapered narrowing.

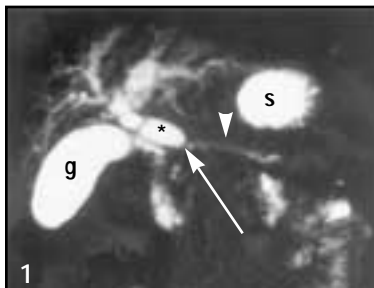


Figure 1. MRCP of a patient with new onset of jaundice and weight loss. Coronal MRCP image reveals dilation of intrahepatic and extrahepatic biliary ducts and main pancreatic duct (arrowhead), known as the double duct sign, to the level of the pancreatic head where there is an abrupt termination (white arrow, s = stomach, g = gallbladder, * = common bile duct). Contrast-enhanced images (not shown) revealed a 1-cm pancreatic head adenocarcinoma that was surgically confirmed. MRCP does not provide information concerning resectability of the tumor.

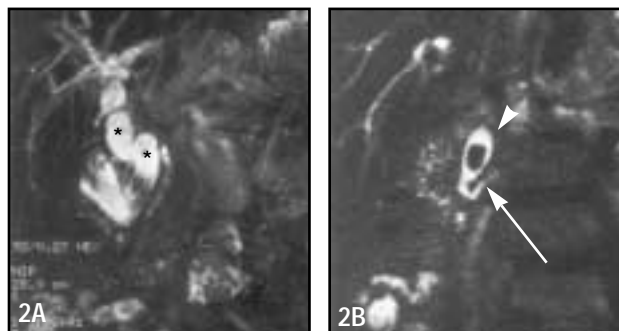


Figure 2. Thin section tomographic MRCP images of a patient with abdominal pain status postcholecystectomy. A: Coronal MIP reconstruction from a multislice MRCP reveals dilation of intrahepatic bile ducts and common bile duct (*) to the level of the pancreatic head. B: Single coronal source image from the multislice MRCP at same level reveals a 1.7-cm retained stone (arrowhead) in distal common bile duct that was obscured by hyperintense bile on the MIP image. A segment of the distal pancreatic duct is present (arrow).

although some degree of overlap exists between the two categories of lesions.¹⁷

Obstruction of the main pancreatic duct is the most common finding in pancreatic adenocarcinoma. The ducts downstream to the obstruction are usually normal. The ducts proximal to the malignant pancreatic duct obstruction often appear irregular, nodular, or eccentric, whereas inflammatory obstruction appears smooth or blunt.¹⁸ Contiguous obstruction of the pancreatic and common bile ducts is known as the double duct sign and is highly suggestive of malignancy

(Figure 1). A recent prospective trial revealed that MRCP is as sensitive as ERCP for pancreatic duct morphology.¹⁹ MRCP can show the level, length, and extent of obstruction with adequate depiction of the distal tract.¹⁸ Ampullary carcinoma classically causes diffuse and smooth dilation of the biliary and pancreatic ducts and is easily seen on MRCP when it is surrounded by fluid in the duodenum at the level of the ampulla of Vater.²⁰

•Cholecholithiasis. Calculi and tumors account for most cases of pancreaticobiliary obstruction. The accuracy of MRCP in the evaluation of common bile duct stones has been well documented with the sensitivity and specificity for stone detection reported to be 81% to 93% and 91% to 98%, respectively.^{21,24} The sensitivity of MRCP is greater than that of ultrasound²⁴ and CT.²⁵ Stones appear as filling defects within high-signal-intensity bile on MRCP irrespective of their calcification content (Figure 2). Detecting stones is more dependent on size. MRCP has been shown to underestimate the number of bile duct stones when compared to ERCP.²⁴ Small stones in the distal common bile duct can be difficult to detect with MRCP as they may be indistinguishable from stenosis.²¹

•Inflammatory conditions of the pancreaticobiliary tree. MRCP is useful in evaluating patients with clinical suspicion of chronic pancreatitis. Imaging features on MRCP include duct dilation, stenoses, strictures, intraductal calculi, and mucinous plugs.^{26,27} Stenoses in chronic pancreatitis are shorter, smoother, and more symmetrical than those associated with neoplasms.¹⁸ Decreased exocrine function and loss of duct distensibility can also be demonstrated on MRCP after stimulation with secretin.²⁸ MRCP can depict the number, shape, size, and location of the pseudocysts and confirm their continuity with the pancreatic duct, which is helpful in planning surgical or percutaneous intervention.^{17,18,27} Although ERCP can show similar findings, the injection of contrast media into a pseudocyst may cause superinfection.²⁹

Traditionally, ERCP has been the method of choice for evaluating the biliary tree in patients suspected of having primary sclerosing cholangitis, a chronic liver disease characterized by inflammation and fibrosis of the intrahepatic and extrahepatic biliary ducts.³⁰ The key cholangiographic findings include irregularly distributed strictures that can progress to the point of complete duct obliteration so that ducts at the periphery of the liver can no longer be depicted by ERCP (Figure 3).³¹ MRCP provides less spatial

resolution than ERCP, which limits its ability to detect early peripheral duct abnormalities. MRCP can demonstrate the ducts proximal to a high-grade or complete obstruction that may not be visualized on ERCP secondary to the inability to opacify these ducts in a retrograde manner.^{31,32} The MRCP finding of slightly dilated peripheral bile ducts unconnected to the central ducts in several hepatic segments is a characteristic sign of primary sclerosing cholangitis.³²

•Congenital anomalies of the pancreaticobiliary tree. Congenital variants of the biliary tree are important because they can increase the risk of bile duct injury during laparoscopic cholecystectomy.³³ MRCP is as accurate as contrast-enhanced cholangiography in diagnosing anatomic variants that could impact surgery.⁴ Two of these variants are a low inserting cystic duct that has a parallel course to the common hepatic duct and a cystic duct that inserts on the medial surface of the common bile duct.^{1,34} Another group of congenital anomalies includes choledochal cysts, which are cystic or fusiform dilations of the extrahepatic or intrahepatic biliary tree (Figure 4). Choledochal cysts are more commonly diagnosed in infancy or childhood and require surgical management because of their increased risk of infection and cholangiocarcinoma.³⁵ MRCP can offer diagnostic information about the anatomic characteristics of the cysts and whether associated complications such as choledocholithiasis exist.^{36,37} MRCP can accurately document the findings even among the subtypes of choledochal cysts that are more difficult to diagnose; for example, choledochoceles and Caroli's disease.^{38,39}

Pancreas divisum, the most common variant of pancreatic duct anatomy, represents failure of fusion between the dorsal and ventral parts of the pancreas.⁴⁰ There is an association with pancreatitis because of impaired pancreatic drainage as the main pancreatic duct drains through the minor papilla. On ERCP, evaluation of the pancreatic ducts is limited because only the ventral duct is opacified when only the major papilla is cannulated. MRCP can accurately diagnose pancreas divisum because it can noninvasively reveal both the ventral and dorsal pancreatic duct segments.^{27,40} A dominant pancreatic duct can be followed from the pancreatic tail to the head, passing anterior to the common bile duct to empty into the duodenum at the minor papilla (Figure 5).¹⁷ Administration of secretin can improve the detection of pancreas divisum by stimulating exocrine pancreatic secretions that increase duct size.⁴¹

•Mucinous cystic neoplasia. Mucin-producing pancreatic tumors can arise from the main

pancreatic duct (intraductal mucin-producing tumors) or from peripheral ducts (mucinous cystadenocarcinoma and cystadenoma). MRCP has been found to be equivalent to or better than ERCP in detecting cystic dilation of the branches and nodules or septa in the cystic lesions.⁴²⁻⁴⁵

LIMITATIONS

The chief limitations of MRCP are lack of accessibility to MR equipment and claustrophobia. Technical and interpretive pitfalls can also mask or simulate pathologic conditions of the pancreaticobiliary system. The entire biliary tree and pancreatic duct are often not depicted on a single MRCP image, and a ductal segment may not be imaged resulting in nonvisualization of a stone or stricture.¹³ Unlike ERCP and PTC, MRCP provides static images that may depict normal physiologic changes of the ducts that can simulate disease. For example, physiologic contraction of

the iodinated contrast may limit evaluation of the biliary tree.¹⁴

DISCUSSION

MRCP plays an important role when ERCP is unsuccessful because of duct obstruction that prohibits evaluation of the proximal ductal system, postoperative biliary-enteric surgery, or inability to cannulate the duct.⁴⁶ MRCP is also an ideal test for patients with a low suspicion for stone or biliary obstruction, with a high risk of complication from ERCP, or with a history of acute pancreatitis in which gallstones are to be excluded as a possible etiology. ERCP may prove to be better for determining whether a stricture is benign or malignant because of its ability to distend the stricture, obtain brushings, and perform intervention. In some severe strictures, ERCP may not show the proximal ducts because contrast material cannot pass beyond the obstructed segment. In this situation, MRCP can depict the length of the stricture and reveal the proximal ducts. The addition of conventional T1- and T2-weighted imaging can improve the diagnostic accuracy of distinguishing benign from malignant causes of biliary obstruction by better depicting extraductal soft tissue.⁴⁷

Occasionally, a precise map of the intrahepatic biliary system is required in cases where hepatic subsegmentectomy is considered for the treatment of hepatic tumors. MRCP is often disappointing in the delineation of nondilated intrahepatic bile ducts. In this setting, ERCP and PTC can effectively visualize the biliary tree with a 70% to 90% success rate regardless of the degree of dilation.¹⁷ MR contrast agents with biliary excretion can create a functional MR cholangiogram that can depict nondilated ducts and may be increasingly used in the future.^{48,49}

MRCP is considered the initial imaging modality in certain cases of congenital anomalies of the pancreaticobiliary tree. While MRCP may not be routinely required in every patient who is

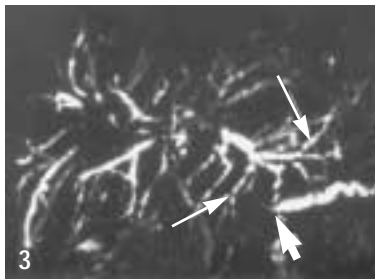


Figure 3. MRCP findings of primary sclerosing cholangitis in a 28-year-old man. Coronal MRCP image reveals diffuse segmental beading of multiple intrahepatic bile ducts (thin arrows) with irregularly distributed stenoses, typical findings of sclerosing cholangitis. Note focal stricture of the pancreatic duct at the junction of the pancreatic head and neck (arrow) with moderate dilation of the proximal pancreatic duct in body and tail, felt to represent sequelae of pancreatitis.

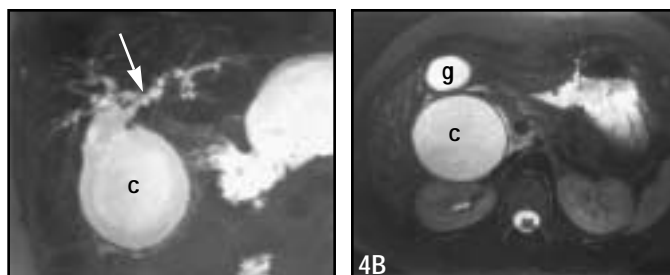


Figure 4. MRCP demonstrates a choledochal cyst in a 20-year-old woman. A: Coronal MIP reconstruction from MRCP reveals a 7-cm cyst in the porta hepatis arising from the common bile duct, representing an extrahepatic choledochal cyst (c) and multiple areas of focal intrahepatic biliary duct dilation (white arrow). B: Axial respiratory-triggered T2-weighted fast spin-echo image confirms that the gallbladder (g) is anterior to the choledochal cyst (c). The gallbladder was not depicted in A because it was not included in the coronal volume of the MIP reconstruction.

the distal common bile duct can mimic stenosis.¹³ Extraductal factors that can mimic obstruction of the extrahepatic bile duct include metallic surgical clips, gas in the gastrointestinal tract, and pulsatile compression by adjacent arteries.^{13,14} Intraductal material such as air, blood, and iodinated contrast decrease the signal intensity of bile on heavily T2-weighted imaging, which can mimic calculi and cause nonvisualization of the gallbladder or extrahepatic bile duct. MRCP should not be performed immediately after ERCP or PTC, unless these procedures end in technical failure, because

to undergo laparoscopic surgery, it is preferred over invasive methods if there is clinical concern for a congenital anomaly. MRCP is able to offer diagnostic information equal to that of ERCP for assessing choledochal cysts in adults and can be used as the imaging test of choice. However, MRCP may have difficulty in delineating the pancreaticobiliary junction in infants and young children. It may serve as the first test in the evaluation of these bile duct anomalies in children, but it is not ready to entirely replace ERCP as a preoperative tool.³⁷ MRCP can noninvasively evaluate the presence of pancreas divisum in cases of chronic idiopathic pancreatitis and identify a subset of patients who may benefit from sphincterotomy.

MRCP has evolved as a useful adjunct in evaluating both inflammatory and neoplastic conditions of the pancreas. In the setting of acute pancreatitis, MRCP can simultaneously reveal both the etiology of the inflammation and complications such as pancreatic pseudocysts. The goal of MRCP in evaluating chronic pancreatitis is to establish the diagnosis, plan treatment, detect biliary abnormalities, and monitor complications of disease. MRCP has limited application in the early stages of chronic pancreatitis because of its inability to detect subtle side-branch involvement and calcification.¹⁸ MRCP may also have difficulty

in distinguishing between malignant and benign pancreatic duct strictures in some instances.¹²

Obstruction of the main pancreatic duct can be reliably shown on MRCP in cases of pancreatic adenocarcinoma. The pattern of obstruction may help distinguish pancreatitis from cancer and also show the dilated upstream ducts. The diagnosis of small ampullary carcinomas can be challenging with MRCP, because the transmural portion of the pancreatic duct can be difficult to evaluate. It has been suggested that ERCP should still be performed after a negative MRCP in patients with a high suspicion of ampullary carcinoma because early detection allows for curative resection.⁵⁰ While MRCP can diagnose double duct sign, it does not provide information on vascular encasement, lymph nodes, and metastases, factors that determine whether a pancreatic adenocarcinoma is resectable. Thus, MRCP needs to be

supplemented with conventional MR sequences.^{19,47} MRCP has had an emerging role in evaluating mucinous cystic neoplasia in the case of duct ectatic mucinous tumors that can arise from the main pancreatic duct or side branches. ERCP was thought to be the only reliable modality to evaluate this type of tumor because it can prove the existence of communication between the neoplasm and pancreatic duct. Mucin can prevent the dilated side ducts

from filling with contrast, which is not a problem for MRCP as it can still show the communicating channels. MRCP does not always offer information as to whether a given lesion is malignant but is useful for follow-up of size. ERCP may be more valuable in making the diagnosis of malignancy because of its ability to obtain pancreatic fluid sampling and pancreatic duct biopsy.

The noninvasiveness of MRCP makes it suitable for patients with chronic disease who require follow-up cholangiography or pancreatography. Invasive methods with potential for complication may not be accepted by patients as a way to track diseases that require long-term surveillance, such as primary biliary cirrhosis and primary sclerosing cholangitis. Standard T1- and T2-weighted imaging with gadolinium can be performed simultaneously to increase the detection rate of early cancer; thus MRCP has an established role for this indication.

CONCLUSION

MRCP is well tolerated by patients and can be combined with conventional MRI for a comprehensive evaluation of the ductal system and parenchymal organs. At present, ERCP and PTC will continue to have the advantage of being both diagnostic and therapeutic modalities with higher spatial resolution. The lack of invasiveness and ionizing radiation of MRCP has brought this technique to the forefront of pancreaticobiliary imaging as a first line test that may replace ERCP and PTC as a diagnostic tool in certain clinical situations.



Figure 5. MRCP reveals pancreatic divisum. Dominant dorsal pancreatic duct (arrowheads) crosses common bile duct and drains into minor papilla, superior and separate from common bile duct (white arrow) that drains into ampulla of Vater (s = stomach).

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