

# MRCP

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## INTRODUCTION

Magnetic resonance (MR) cholangiopancreatography (MRCP) is a relatively new MR imaging technique that is used for noninvasive work-up of patients with pancreaticobiliary disease. 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 endoscopic retrograde cholangiopancreatography (ERCP) for diagnosis of extrahepatic bile duct and pancreatic duct abnormalities such as choledocholithiasis [1-4], malignant obstruction of the bile and pancreatic ducts [1,2,5], congenital anomalies [1,6,7], and chronic pancreatitis [8-10]. In some institutions, MRCP is becoming the initial imaging tool for the biliary system, with ERCP reserved for therapeutic indications.

Common indications for MRCP usually include unsuccessful ERCP or a contraindication to ERCP and the presence of biliary-enteric anastomoses (eg, choledochojejunostomy, Billroth II anastomosis). Although ERCP is still the standard of reference for imaging the pancreatico-biliary system, there are specific advantages of MRCP over ERCP. MRCP (a) is noninvasive; (b) is cheaper; (c) uses no radiation; (d) requires no anesthesia; (e) is less operator dependent; (f) allows better visualization of ducts proximal to an obstruction; and (g) when combined with conventional T1- and T2-weighted sequences, allows detection of extraductal disease. Disadvantages of MRCP include (a) decreased spatial resolution, making MRCP less sensitive to abnormalities of the peripheral intrahepatic ducts (eg, sclerosing cholangitis) and pancreatic ductal side branches (eg, chronic pancreatitis); and (b) imaging in the physiologic, nondistended state, which decreases the sensitivity to subtle ductal abnormalities. Furthermore, the main criticism of MRCP is that appropriate care is delayed in patients who need therapeutic endoscopic or percutaneous intervention of obstructing bile duct lesions. Thus, it is argued that in patients with high clinical suspicion for bile duct obstruction, ERCP should be the initial imaging modality to provide timely intervention (eg, sphincterotomy, dilatation, stent placement, stone removal) if necessary.

In this talk, we present the spectrum of bile and pancreatic duct abnormalities seen at MRCP with ERCP correlation, including biliary obstruction (choledocholithiasis, benign and malignant strictures); chronic pancreatitis; pancreatic pseudocyst; biliary cystadenoma and cystadenocarcinoma; postsurgical biliary tract alterations; and congenital anomalies. In addition, we present the technique of MRCP, the MRCP



**Fig. 1.** Normal MR cholangiographic findings. Thick section (40 mm) single shot FSE image (SSFSE) gives a pseudo-three dimensional appearance to the normal system depicted here.

appearance of the normal bile ducts and normal pancreatic duct, and pitfalls and artifacts of MRCP.

## MR TECHNIQUES

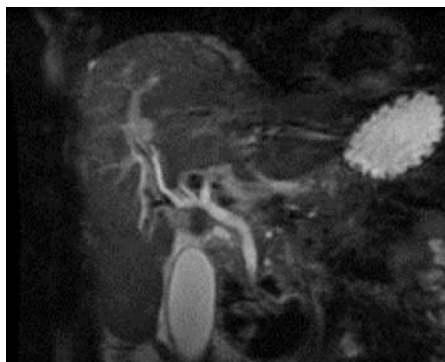
Because MRCP is a relatively new imaging technique and because of ongoing advances in software and coils, the technique is evolving and thus varies from institution to institution. MRCP is usually performed with heavily T2-weighted sequences by using fast spin-echo or single-shot fast spin-echo software 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 distal common bile duct. In addition, some institutions perform three-dimensional reconstruction by using a maximum-intensity projection (MIP) algorithm on the thin-collimation source images. Although the thick-collimation and three-dimensional MIP

images more closely resemble conventional cholangiograms and are familiar to many clinicians, spatial resolution is degraded because of volume-averaging effects. 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.

Fast spin-echo MRCP is performed by using respiratory gating; a long echo train (ie, 32); a long repetition time (three to five respiratory cycles, 8,000-10,000 msec); an echo time greater than 250 msec; fat saturation; thin collimation (3 mm with no gap); and three excitations. Imaging time is usually 4-6 minutes. Although the use of a long-echo-train sequence considerably reduces imaging time compared with that of conventional T2-weighted spin-echo sequences, artifacts from respiration and peristalsis are still problematic because the signal is averaged over multiple respiratory cycles. Single-shot fast spin-echo is a newer and more rapid MRCP sequence that can be performed in a single breath hold, thereby significantly reducing motion artifacts and increasing image quality [4,11-13]. As a result of less motion artifact (noise) with single-shot fast spin-echo MRCP, the signal-to-noise ratio increases compared with that of fast spin-echo MRCP. However, there is also a decrease in signal, albeit not as great as the decrease in noise. The result is less spatial resolution.

The speed of the acquisition is due to a very long echo train (ie, 128); an infinite repetition time; and the ability to reconstruct images after acquiring only half of the phase-encoding steps. We use an echo time of greater than 800 msec to suppress signal from most extraductal structures including fat, eliminating the use of fat saturation. All the information is acquired in less than 2 seconds from approximately 128 echoes generated from a single 90° pulse. Imaging time for both single-section and multisection sequences is less than 30 seconds. Because all the image information from one section is acquired before proceeding to the next section, breath-hold and non-breath-hold techniques can be used. However, we prefer the breath-hold technique to avoid artifacts from respiratory motion and to avoid section misregistration. The combination of rapid sequences and the torso phased-array coil, which increases signal-to-noise ratio, makes

it possible to visualize ducts as small as 1 mm in diameter [14,15]. In addition, owing to the shorter spacing of the radio-frequency pulses, susceptibility artifacts (eg, from the intestine, clips, catheters, stents) are reduced with the single-shot fast spin-echo sequence. The multiplanar capability of MR imaging



**Fig. 2.** Normal cholangiographic findings. Thin section coronal SSFSE image depicts a normal CBD and intrahepatic confluence.

allows acquisition of multiple coronal oblique images of the pancreaticobiliary system. During the single-section acquisition, we obtain six or seven 20-mm-thick coronal sections through the porta hepatis and rotating around a point anterior to the portal vein.

This technique allows us to successfully “unravel” the obliquely oriented and sometimes tortuous extrahepatic bile duct and to obtain a cholangiographic image of the biliary system. The first coronal oblique image is through the tail of the pancreas, the second image is a straight coronal image, with subsequent sections obtained 15° apart. The anteriorly located common hepatic duct, left hepatic ducts, and proximal pancreatic duct are visualized on the straight coronal image and the initial LPO image obtained at a shallow angle; the more posteriorly located common bile duct, right hepatic ducts, and distal pancreatic duct including the ampulla are seen on the LPO images obtained at a steeper angle. During the thin-collimation, multisection acquisition, 5-mm sections in the straight coronal plane are obtained with a 100% intersection gap and a gap-and-fill technique during one breath hold of less than 30 seconds. With this technique, section misregistration artifacts and cross-talk from adjacent sections are avoided [16]. Although a cholangiographic display is not obtained with this sequence, the bile and pancreatic ducts can be easily followed sequentially through their entire course. It is important to educate the MR imaging technologists about the relevant

pancreaticobiliary anatomy for optimal results.

## NORMAL ANATOMY

The common bile duct can be visualized in up to 98% of patients by using either breath-hold or non-breath-hold techniques [2,17,18]. In addition, MRCP is 95% accurate in differentiation of normal from dilated ducts [2,17,18]. The peripheral intrahepatic ducts beyond the right and left hepatic ducts are infrequently seen because they are imaged in the physiologic, nondistended state.

As mentioned earlier, there is no consensus as to the optimal MRCP technique. It is unclear whether imaging in a fasting or postprandial state offers any advantage. Some argue that the fasting MRCP technique reduces unwanted fluid signal from the intestine, whereas others argue that fluid in the intestine, especially in the second portion of the duodenum, is a helpful landmark for the distal common bile duct and ampulla of Vater. We prefer to have the patient fast for 3 hours before the study because, in our experience, small amounts of fluid are always present in the duodenum, thus providing a landmark for the ampulla and reducing fluid signal from the stomach. It is only with the thick, single-section acquisition that fluid-filled intestine may be problematic because the high-signal-intensity fluid may be volume averaged with bile duct fluid, thereby obscuring disease.

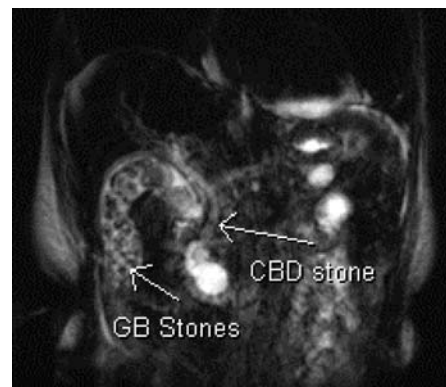
Because the pancreatic duct is curved and obliquely oriented, it is usually not seen in its entirety on a single source image; however, the entire length can usually be evaluated when reviewing sequential images. Although an image with thick collimation (2-3 cm) can demonstrate the duct in its entirety, overlap of ducts may mimic a pseudocyst [10] and volume averaging with adjacent fluid-filled intestine may obscure portions of the duct. Therefore, the multisection, thin-collimation images should be closely scrutinized. When the single-shot fast spin-echo technique is used, the main pancreatic duct in the head, body, and tail can be seen in up to 97%, 97%, and 83% of cases, respectively [1,19]. However, because of a decrease in spatial resolution, the pancreatic side branches are seen less frequently, with secondary branches in the head, body, and tail seen in 19%, 10%, and 5% of cases, respectively [19].

Because imaging is performed in the physiologic, nondistended state, nonvisualization of the duct at MRCP does not necessarily indicate disease. Secretin (1 clinical unit per kilogram intravenously) can be given to patients suspected of having pancreatic disease; this substance transiently

distends the duct [10] and allows better visualization of its morphologic features [10]. Maximum dilatation occurs 2 minutes after secretin injection, then the duct relaxes to baseline [10]. Persistent dilatation implies papillary stenosis, and dilatation of side branches suggests chronic pancreatitis [10].

## BILIARY OBSTRUCTION

MRCP is comparable with ERCP in detection of obstruction, with a sensitivity, specificity, and accuracy of 91%, 100%, and 94%, respectively [2]. It is 94% sensitive and 93% specific for detection of dilatation [20]. MRCP may also allow more accurate assessment of ductal caliber in the physiologic state, unlike ERCP, with which ductal caliber may be overestimated because of injection pressure [20].



**Fig. 3.** Cholelithiasis. Thin-section single-shot fast spin-echo MR image shows a stone in the distal common bile duct (arrow) and many stones in the gallbladder.

## CHOLEDOCHOLITHIASIS

MRCP is comparable with ERCP in detection of choledocholithiasis and superior to computed tomography (CT) or ultrasonography (US) [2,4]. Numerous studies have shown sensitivities of 81%-100% and specificities of 85%-100% for MRCP [21].

Because up to 15%-25% of patients with acute calculous cholecystitis have choledocholithiasis and 10%-15% have unsuspected choledocholithiasis at surgery, MRCP may play a role in the preoperative work-up of these patients [22]. However, patients with a high clinical suspicion of choledocholithiasis should undergo ERCP so that a potential intervention (eg, sphincterotomy) is not delayed.

Because of the very high signal-to-background ratio of bile, calculi are readily identified as dark filling defects within the high-signal-intensity fluid at MRCP. Calculi as small as 2 mm in diameter can be

visualized [14,23], and the accuracy of stone detection is greater with single-shot fast spin-echo techniques because of the reduction of motion and susceptibility artifacts. Small calculi may not cause secondary dilatation of the ducts [23] and are best seen on the axial images [23]. 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. In addition, an impacted stone in the ampulla may not be surrounded by high-signal-intensity bile and may thus be misinterpreted as a stricture [23].

The differential diagnosis of filling defects in the bile ducts most commonly includes stones and air bubbles; however, neoplasms, blood clots, concentrated bile, metallic stents, flow voids, and susceptibility artifact from surgical clips must be excluded [20]. Pneumobilia can be differentiated from a calculus by demonstrating a filling defect in the nondependent portion of the bile duct; the filling defect sometimes produces an air-fluid level on axial or sagittal images.

## BENIGN STRICTURES

More than 80% of bile duct strictures occur after an injury to the extrahepatic bile ducts during a cholecystectomy [24,25], with a minority attributable to other benign causes such as infection, pancreatitis, stone passage, trauma, primary sclerosing cholangitis, ischemia, chemotherapy, and acquired immunodeficiency syndrome. MRCP has been shown to be comparable with ERCP in demonstrating the location and extent of strictures of the extrahepatic bile duct, with sensitivities of 91%-100% [26-28]. However, the accuracy in detection of strictures of the intrahepatic bile ducts is under investigation. The extent of a high-grade, focal, extrahepatic or proximal intrahepatic ductal stricture may be overestimated with MRCP because the duct downstream from the obstruction is collapsed and may simulate disease. ERCP may be more accurate in demonstrating the extent of disease in these cases.

Sclerosing cholangitis is a fibrosing, inflammatory process of the bile ducts that leads to sclerosis and stenosis of both intrahepatic and extrahepatic bile ducts. Primary sclerosing cholangitis is usually due to ulcerative colitis, whereas secondary sclerosing cholangitis has a variety of causes, including bacterial and parasitic cholangitis, ischemia, intraarterial chemotherapy, and acquired immunodeficiency syndrome. Strictures are multifocal and alternate with slight dilatation

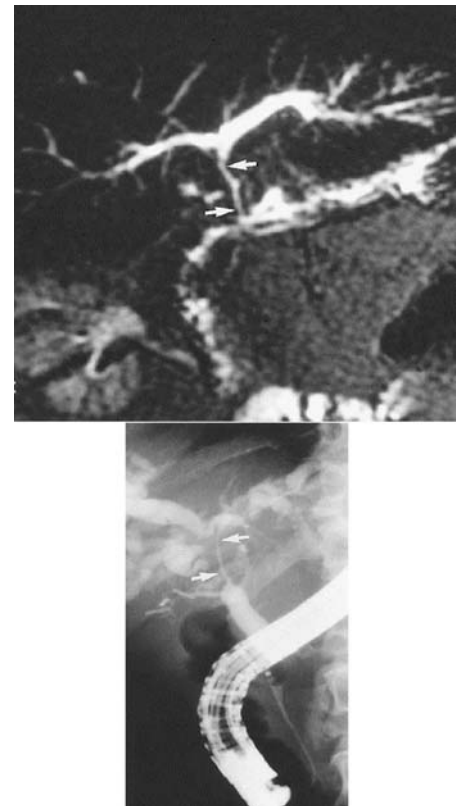
or normal-caliber bile ducts, producing a beaded or "pruned tree" appearance. Recent publications describe results comparable with those of ERCP for detection of primary sclerosing cholangitis and acquired immunodeficiency syndrome-related cholangiopathy [1,29]. However, because MRCP is probably not sensitive to the early peripheral ductal changes of sclerosing cholangitis, it should probably be reserved for diagnosis of complications or follow-up of more advanced cases. MRCP can be more accurate in demonstrating peripheral ductal abnormalities, especially when proximal strictures preclude adequate opacification of the peripheral biliary tree at ERCP.

## MALIGNANT STRICTURES

Malignant bile duct obstruction is usually due to pancreatic neoplasms. Cholangiocarcinoma, metastases, and lymphadenopathy are less common causes. Most malignant pancreatic neoplasms are adenocarcinomas and of ductal origin, usually manifesting as a focal mass in the pancreatic head. Dual-phase contrast material-enhanced CT is the method of choice for diagnosis and staging of pancreatic carcinoma, with MR imaging reserved for cases with equivocal results at CT and for patients who cannot receive iodinated contrast agents (eg, those with allergy or renal insufficiency). At MRCP, dilatation of both the pancreatic and bile ducts (the double duct sign) is highly suggestive of a pancreatic head malignancy [30]. 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. On dynamic gadolinium-enhanced T1-weighted images, pancreatic adenocarcinoma is seen as a focal, hypointense mass.

Because morphologic features of benign and malignant strictures overlap, most authors argue that ERCP should be the imaging modality of choice because of its increased spatial resolution and the opportunity to obtain a diagnostic sample with brush cytologic biopsy. However, other authors argue that the addition of conventional T1- and T2-weighted sequences to MRCP may further improve specificity by allowing visualization of extraductal structures [31-33]. MRCP has been shown to be accurate in demonstrating the cause of obstruction, with positive and negative predictive values of 93% and 94%, respectively, for benign causes and 86% and 98%, respectively, for malignant causes [2,17,20]. Holzkecht et al [20]

demonstrated malignant stenoses in 15 of 15 patients. In a recent article, MRCP performed with gadolinium-enhanced sequences accurately demonstrated the level



**Fig. 4.** Cholangiocarcinoma in a 29-year-old man with ulcerative colitis and primary sclerosing cholangitis who presented with jaundice and abdominal pain. (a) Single-shot fast spin-echo MRCP image shows a long, narrowed segment of the common hepatic and common bile ducts (arrows) with proximal ductal dilatation. (b) ERCP image shows a high-grade, long stricture of the common hepatic duct (arrows). Brush cytologic biopsy revealed cholangiocarcinoma. Note how the extent of the stricture was overestimated with MRCP because the common bile duct was collapsed.

and cause of neoplastic pancreaticobiliary obstruction in 84%-88% and 84%-91% of cases, respectively [34]. MR cholangiography can demonstrate the presence and extent of strictures; allow determination of the resectability of the lesion; and provide a road map for subsequent surgical, percutaneous, or endoscopic intervention. In addition, dynamic gadolinium-enhanced T1-weighted imaging has been shown to be sensitive in demonstrating the presence and extent of cholangiocarcinoma, which traditionally has been exceedingly difficult to diagnose with conventional cross-sectional imaging modalities such as CT or US [35].

Another advantage of MRCP is the capability

for assessing ducts upstream from a proximal obstruction in cases in which ERCP may be unsuccessful.

One limitation of MRCP is evaluation of the intrapancreatic portion of the common bile duct near the ampulla. Obstruction of the ampullary portion of the common bile duct can be due to ampullary carcinoma, inflammatory stenosis of the ampulla, sphincter of Oddi dysfunction, ampullary edema from recently passed stones or pancreatitis, or an impacted stone. ERCP has an advantage over MRCP in evaluation of this area because ERCP allows direct visualization of the ampulla and biopsy of any mass lesion. In addition, manometry of the sphincter of Oddi as well as fluoroscopic evaluation of bile flow dynamics can be performed.

### PANCREATITIS

Chronic pancreatitis is a chronic inflammatory process of the pancreas, which results in irreversible exocrine dysfunction and irreversible morphologic changes of the pancreas and pancreatic duct. Side-branch ectasia is the most prominent and specific feature of this disease process. Other changes of the main duct and side branches include multifocal dilatations and strictures; an irregular contour; pseudocysts; and filling defects from calculi, mucinous plugs, or

debris. Stones as small as 2 mm in diameter can be detected [1]. Comparisons between MRCP and ERCP in cases of chronic pancreatitis have revealed agreement of 83%-100% for identification of ductal dilatation, 70%-92% for identification of narrowing, and 92%-100% for identification of filling defects [8,36]. 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 pseudocysts are encapsulated collections of pancreatic fluid that can occur in association with acute or chronic pancreatitis. MRCP is more sensitive than ERCP in detection of pseudocysts because less than 50% of pseudocysts fill with contrast material at ERCP [37]. However, MRCP is less sensitive in demonstrating the site of communication with the pancreatic duct. Close scrutiny of the source images is necessary so that strictures or filling defects will not be overlooked, since portions of the pancreatic and bile ducts may be obscured by the high-signal-intensity pseudocysts on thick-section MRCP images.

### POST-SURGICAL ANATOMY

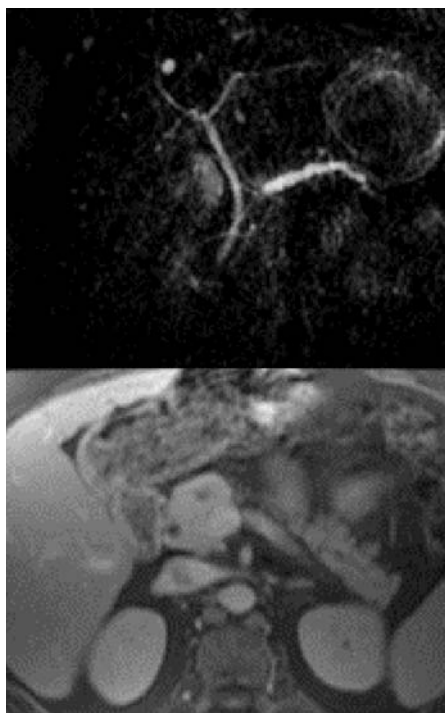
Biliary-enteric anastomoses such as choledochojunostomy, hepaticojejunostomy, and Billroth II anastomosis make it difficult or impossible to access the major papilla at endoscopy. In patients with such anastomoses, MRCP is the imaging modality of choice for the work-up of suspected pancreaticobiliary disease. It has been reported that MRCP is 100% sensitive in detection of anastomotic strictures and 90% sensitive in detection of biliary tract stones proximal to the

anastomosis [43]. MRCP is also 100% sensitive in demonstrating the choledochojejunal anastomosis after a Whipple procedure [1]. Close scrutiny of the source images is mandatory because the biliary-enteric anastomosis and stones can be obscured on the thick-section and MIP reconstruction images by the high signal intensity of the surrounding bile and bowel fluid. In addition, surgical clips and pneumobilia in these patients may mimic stones. Strictures may be overestimated on the MIP reconstruction images [43].

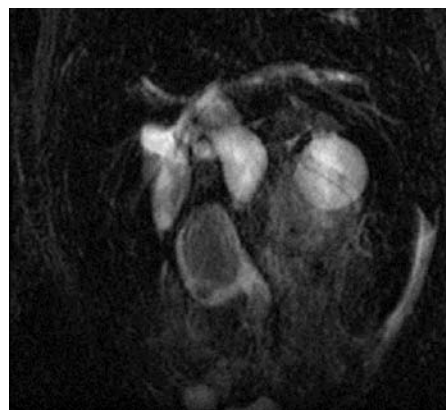
### CONGENITAL ANOMALIES

Variations from the commonly described anatomic pattern of the biliary tree occur in more than 50% of individuals [44]. MRCP has been shown to be 98% accurate in diagnosis of aberrant hepatic ducts and 95% accurate in diagnosis of cystic duct variants [7]. A potential use of MRCP is evaluation of bile duct anatomy before cholecystectomy. By demonstrating aberrant anatomy before surgery, the risk of bile duct injury should be reduced, especially during laparoscopic cholecystectomy, which is associated with double the risk of bile duct injury compared with that of open cholecystectomy [45]. Anatomic variants with a high potential for injury include an aberrant right hepatic duct with insertion into the common hepatic duct or cystic duct, a long intramural cystic duct parallel to the common hepatic duct, or a cystic duct inserting medially on the common bile duct [46].

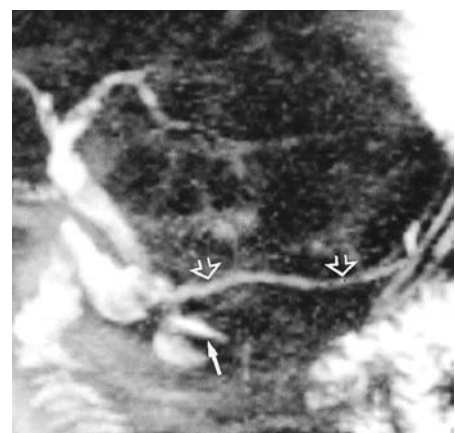
In normal individuals, the main pancreatic duct (duct of Wirsung) drains through the major papilla; this duct is the major drainage route of the pancreas in 91% of individuals. The accessory pancreatic duct



**Fig. 5.** Malignant pancreatic duct stricture. Thick slab SSFSE image depicts a distended pancreatic duct with acute cut-off in the proximal pancreas. Axial gadolinium-enhanced T1 GRE image depicts a small adenocarcinoma in the head of the pancreas (arrow).



**Fig. 6.** Thick section SSFSE image depicts a diffusely distended common bile duct in a 1 month old child consistent with a type 1 choledochocoele.



**Fig. 7.** Pancreas divisum. Fast spin-echo MRCP image shows the dorsal duct (open arrows) crossing anterior to the common bile duct to empty into the minor papilla. The more inferior ventral duct (solid arrow) is seen joining the distal common bile 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 increased prevalence of acute pancreatitis [9,47].

The larger, dominant dorsal pancreatic duct, which drains the pancreatic tail, body, and superior head, courses anterior to the common bile duct and drains into the minor papilla separately from the common bile duct, superior to the major papilla. The smaller ventral duct, which drains the inferior pancreatic head and uncinata process, accompanies the common bile duct into the major papilla. MRCP has been shown to have up to 100% accuracy for detection of pancreas divisum [6].

## PITFALLS & ARTIFACTS

Pitfalls include pseudo-filling defects, pseudodilatations, and nonvisualization of the ducts. Filling defects are usually due to stones, air, tumors, hemorrhage, or sludge. Infrequent causes of filling defects include susceptibility artifact from adjacent clips, metallic bile duct stents, folds, or flow voids [20]. Pseudodilatations can occur if the

cystic duct crosses the common bile duct or courses parallel to it or if extraductal fluid-filled structures (eg, intestine, pseudocysts, gallbladder) are volume averaged with the ducts. Nonvisualization of the intrahepatic bile ducts may be a normal finding due to nondistention; however, nonvisualization of the extrahepatic bile ducts may be due to obscuration by extraductal fluid-filled structures (eg, intestine, pseudocysts, gallbladder), intravenous administration of manganese, or pneumobilia.

Gastrointestinal air and metallic clips create susceptibility artifacts, which are particularly prominent on gradient-echo images. These artifacts can be reduced when images are acquired with shorter echo times, smaller voxel sizes, lower magnetic field strength, and fast spin-echo or single-shot fast spin-echo sequences because of narrower spacing of the radio-frequency refocusing pulses. In addition, fasting can decrease peristaltic motion, whereas fat saturation and negative oral contrast agents can decrease artifact from motion effects of the abdominal wall and bowel fluid, respectively. Single-shot fast spin-echo techniques can nearly eliminate motion effects because of very narrow spacing of radio-frequency refocusing pulses (4.4 msec) and rapid image acquisition (<2 seconds).

## CONCLUSION

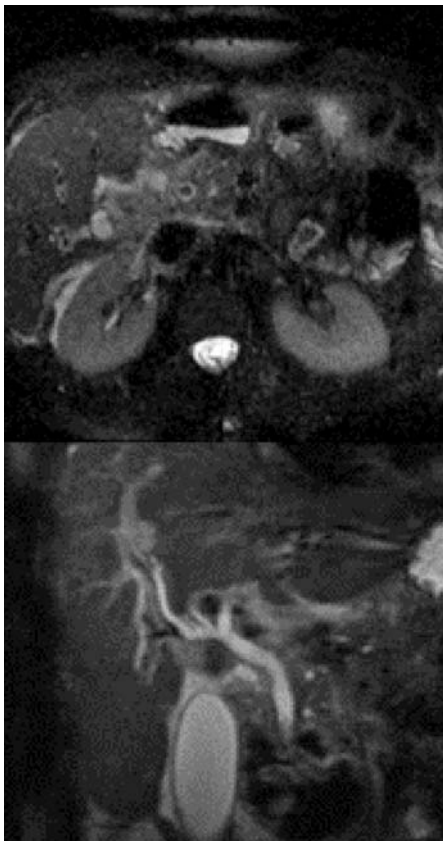
MRCP is comparable with ERCP in detection of extrahepatic bile duct abnormalities and has replaced diagnostic ERCP at some institutions. The role of MRCP in evaluation of intrahepatic bile duct abnormalities, especially in patients with sclerosing cholangitis, is under investigation. Finally, although MRCP is not as sensitive as ERCP in demonstrating the changes of chronic pancreatitis, MRCP may have a role in follow-up of this entity.

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**Fig. 8.** Pseudo-filling defect. Single-shot fast spin-echo MRCP image (top) shows a filling defect in the common bile duct (arrow). Coronal image depicts no filling defects.

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