MR Cholangiopancreatography of the Pancreas and Biliary System: A Review of the Current Applications

Sandy Hassan Hossary, MSc,[a] Ashraf Anas Zytoon, MD, PhD, FJRS,[b] Mohamed Eid, MD,[c] Ahmed Hamed, MD,[c] Mohamed Sharaan, MD,[d] and Ahmed Abd El-Maguid Ebrahim, MSc[a]

MR cholangiopancreatography (MRCP) is still a rapidly evolving technique, but it has been already accepted as clinically useful and is widely used to evaluate biliary or pancreatic diseases. The advantages of this technique are that it does not use contrast media or ionizing radiation, it is noninvasive and complication free, and the examination is relatively short. MRCP has high sensitivity and specificity for diagnosing biliary dilatation and for determining the site and cause of stenosis. With further improvements of hardware and technique, MRCP is expected to replace diagnostic endoscopic retrograde cholangiopancreatography to examine the biliary and pancreatic ducts in the near future. The other applications include evaluation of primary sclerosing cholangitis, stenosis after liver transplantation, and bilioenteric anastomoses. This article reviews the current applications of MRCP in the evaluation of the pancreas and the biliary system.

Evaluation of biliopancreatic diseases is a common radiologic problem. It requires a multimodality imaging approach.[1,2] Over the past 5 years, significant advances in MR technology have dramatically increased the role that MR plays in evaluating the biliary tract.[1]

MRCP combines the many obvious advantages of being a noninvasive imaging technique, not carrying the risks and complications associated with endoscopic retrograde cholangiopancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC), being less operator dependent, not requiring anesthesia or contrast material, and not using radiation.[3-5]

MRCP is the only modality that allows imaging of the biliary and pancreatic ducts in their basal state as extrinsic contrast agents are not used. This is done 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.[4,6]

MRCP Imaging Technique

Typical MR cholangiopancreatographic techniques exploit the relatively high signal intensity of static fluids in the biliary tract with heavily T2-weighted sequences, which also results in decreased signal from the background tissues such as solid organs and moving blood. The imaging obstacles of long acquisition times and respiratory motion artifact have largely been overcome with technical innovations such as short breath-hold T2-weighted acquisitions, parallel imaging, and sophisticated respiratory triggering mechanisms. The use of modern high–field strength magnets (1.5 T or greater) and multichannel surface coil technology are required for even shorter imaging times. Use of appropriate centering and a larger field of view minimizes wrap artifact.[3,7]

Patients should fast for 3-6 hours before examination to reduce residual fluid in the stomach and bowel, increase gall bladder filling, and decrease duodenal peristalsis. T1-weighted images obtained with and without gadolinium-based contrast material are also helpful

From the [a]Al-Ghad Colleges for Applied Medical Sciences, Dammam, Saudi Arabia; [b]Radiology Department, Faculty of Medicine, Menoufiya University, Menoufiya, Egypt; [c]Radiology Department, Faculty of Medicine, Alexandria University, Alexandria, Egypt; and [d]Surgical Department, Faculty of Medicine, Alexandria University, Alexandria, Egypt.
Reprint requests: Sandy Hassan Hossary, MSc, Al-Ghad Colleges for Applied Medical Sciences, Saudi Arabia. E-mail: ashradio@gmail.com.
Curr Probl Diagn Radiol 2014;43:1–13.
© 2013 Mosby Inc. All rights reserved.
0363-0188/$36.00 + 0
http://dx.doi.org/10.1067/j.cpradiol.2013.10.001

in characterizing biliary stones and local inflammation and in the staging of biliary malignancies. Current MR cholangiopancreatographic protocols generally consist of 2 techniques that provide complementary information, including a thick-slab single-section sequence and a thin-section multisection sequence.[3,7]

The thick-slab single-section sequence provides an overview of the biliary tract anatomy and is particularly useful for identifying upstream obstruction and strictures. This technique makes use of a heavily T2-weighted RARE sequence (echo time $\geq$ 700 ms) to acquire thick-section (40-90 mm) images in the coronal planes to fully depict the 3D nature of the pancreatobiliary tree. Each of these images is acquired during a breath hold lasting 3-7 seconds with a long effective echo time, a technique that minimizes background tissue signal, thereby providing water-only images similar to those obtained by ERCP.[3,7]

The thin-section multisection sequence helps visualize intraductal disease such as stones. Images are obtained with a single-shot, moderately T2-weighted RARE sequence (echo time $\leq$ 180 ms) with contiguous sections of 2-5 mm in size. Approximately 15-20 sections are required to cover the biliary tract during a breath hold lasting 20-28 seconds. Although single-shot RARE images can be acquired during free breathing, breath-hold imaging minimizes misregistration and motion artifacts, which may interfere with the imaging of small bile ducts. The primary advantages of this MR cholangiopancreatographic technique are short acquisition time and the high in-plane resolution of single-shot RARE images.

There are also disadvantages however, including the operator-dependent nature of the thick-slab sequence, which generally requires a skilled technologist or direct oversight by a radiologist to identify the complex relevant anatomy before placing the imaging slab. In addition, thin-section images may require multiple acquisition stacks to cover the entire biliary tract and differences in suspended respiration may lead to gaps or misregistration between stacks, which may be problematic for interpretation and postprocessing.[3,7]

Disease Processes—Benign Disease

Cystic Diseases of the Bile Duct

Choledochal cysts are anomalies of the biliary system characterized by dilatation of the extrahepatic or intrahepatic bile ducts. The Todani calcification was used to categorize cystic dilatation of the biliary duct into Todani type I choledochal cysts that are confined to the extrahepatic bile ducts (EBD) and subdivided into type IA (diffuse) cysts, which involve the entire EBD; type IB (focal) cysts, which involve only a focal segment of the EBD; and type IC (fusiform) cysts, which involve only the common bile duct (CBD). Todani type II choledochal cysts are true diverticula arising from the CBD. Todani type III choledochal cysts, also known as choledochoceles, are dilatations of the intraduodenal portion of the CBD. Todani type IV choledochal cysts are multiple intrahepatic and extrahepatic components or multiple extrahepatic cysts. Todani type V cysts, also known as Caroli disease, are multifocal cystic or saccular dilated intrahepatic bile ducts that may diffusely involve the liver or, less commonly, may involve only the left segment of the liver.[8,9]

ERCP is frequently used to study the biliary tree in patients with choledochal cysts. However, it is a diagnostic procedure that demands technical expertise and a number of safety measures, and it is not without complications. These include development of sepsis in an obstructed system, perforation of the viscera pancreatitis, and overdose of contrast agent.[8]

On MRI, the dilated and cystic biliary system appears hypointense on T1-weighted images and markedly hyperintense on T2-weighted images. After intravenous administration of gadolinium contrast material, the intraluminal portal vein radicals strongly enhance, which is a specific feature of Caroli disease.[10] In addition, the combination of MRCP and gadolinium-enhanced T1-weighted images is useful to diagnose associated findings such as gallstone disease and cancer. MRCP has been demonstrated to be effective in evaluating choledochal cyst, choledochocele, and Caroli disease[11] (Fig 1).

Anatomical Variants of the Biliopancreatic System

Bile Ducts

Drainage of the right posterior duct (RPD) into the left hepatic duct (LHD) before its confluence with the right anterior duct (RAD) is the most common anatomical variant of the biliary system. The direct drainage of the right posterior duct into the common hepatic duct (CHD), from either the right or left side, is a variant also known as an "aberrant hepatic duct." The so-called triple confluence is another common variant of the main hepatic biliary branches (seen in 11% of the population).[9]

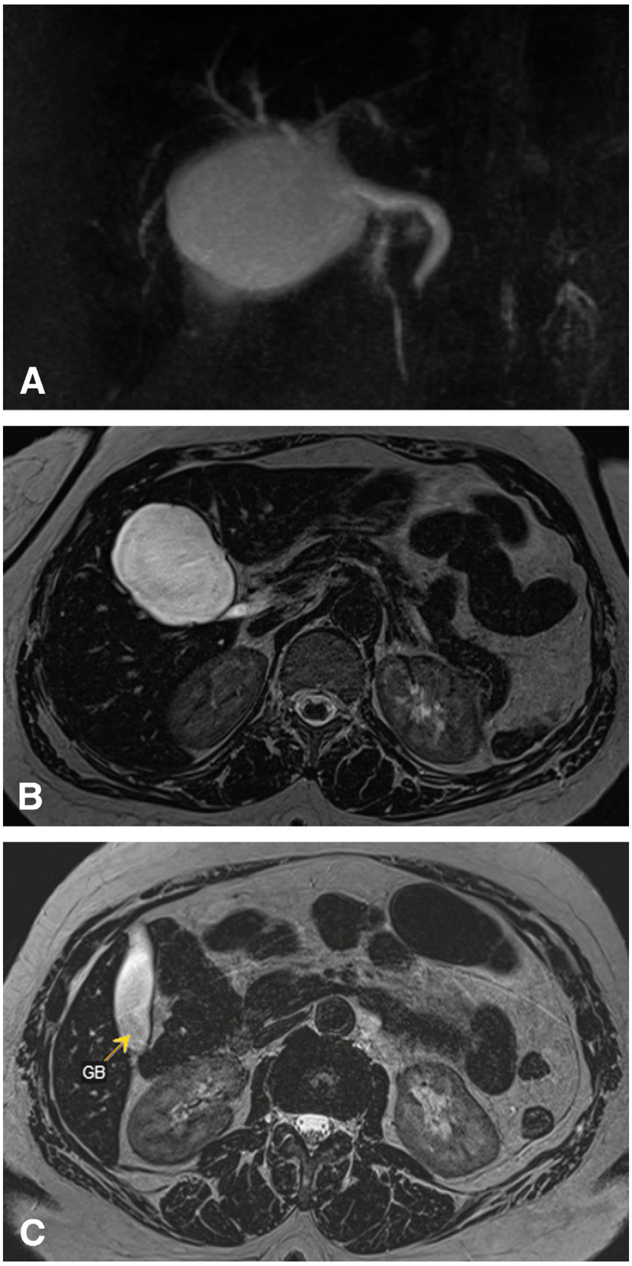

FIG 1. A 62-year-old woman with a choledocal cyst; Todani type II (large diverticulum of the CBD). (A) Coronal MIP image from 3D SSFSE T2-weighted image and (B) and (C) axial thin-section heavy T2 SSFSE image show a well-defined cystic lesion at the porta hepatis containing clear water signal that is freely communicating with the proximal CBD on one side of its wall with no intrahepatic biliary dilatation and normal configuration of gall bladder. (Color version of the figure is available online.)

Cystic Duct

The anatomical variants of the cystic duct have received much attention recently because of their higher risk of complications during cholecystectomy.[11] MRCP could accurately demonstrate various variants such as a low cystic duct insertion, a medial cystic duct insertion, and a parallel course of the cystic and CHD.[12,13]

Congenital Anomalies of the Pancreas

Pancreas Divisum

Pancreas divisum is the most common congenital pancreatic ductal anatomical variant, seen in approximately 3%-8% of cases using ERCP and 9% using MRCP.[14] As a result of this malformation, the pancreas has 2 separate ductal systems. On MRCP images, pancreas divisum can be diagnosed by the finding of dorsal dominant pancreatic duct running anteriorly to the CBD and draining into the minor papilla.[11]

Annular Pancreas

Annular pancreas is a rare anomaly in which a band of pancreatic tissue surrounds the descending duodenum, either completely or incompletely.[14,15] On MRI, the pancreatic parenchyma completely or partially encircles the descending duodenum at or below the level of the ampulla of Vater.[15]

On MR cholangiopancreatography, the aberrant pancreatic duct that encircles the duodenum is visualized. An annular pancreatic duct may drain into the intrapancreatic CBD, the duct of Wirsung, or the duct of Santorini.[9,15-17]

Cholelithiasis

Gallstones are found in about 10% of the general population.[18] The risk of complications is 1% per year. US is the most commonly used modality in the evaluation of gallstone disease.[19,20] On MRI, gallstones are best appreciated on T2-weighted MR images and MR cholangiopancreatography and appear as signal voids on T2-weighted images.[21]

MRI can also help distinguish between the different types of gallstones. Like cholesterol stones, pigment stones typically appear hypointense with T2-weighted sequences; unlike cholesterol stones, they usually have increased signal intensity on T1-weighted images[18,22] (Fig 2).

Choledocholithiasis

Ultrasonography has a sensitivity of only 21%-63% for intrabiliary stones. T2-weighted MR cholangiography is known to be highly sensitive and specific for the detection of biliary filling defects and for stones in

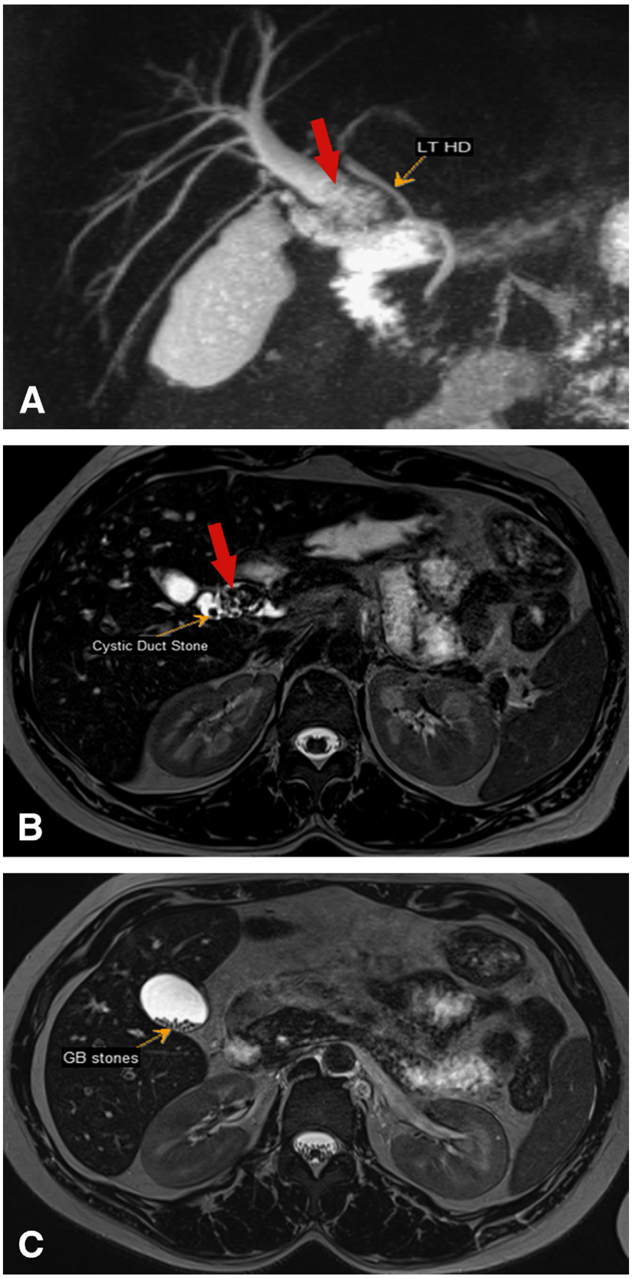

FIG 2. A 27-year-old woman presented with jaundice and choledocal cyst Todani type IA with CBD, cystic duct, and GB stones with mild intrahepatic and extrahepatic biliary back pressure changes. (A) Coronal MIP image from 3D SSFSE T2-weighted image and (B) axial thin-section heavy T2 SSFSE image show fusiform dilatation of the middle third of the CBD, it also harbors an aggregation of stones (red arrow), the cystic duct is mildly dilated and joins the CBD at the lateral aspect of the dilated segment. It also contains few small stones. The left hepatic duct joins CBD just distal to dilated segment (low insertion) (anatomical variant). (C) Axial thin-section heavy T2 SSFSE image shows a distended gall bladder, which is also harboring innumerable small stones. (Color version of the figure is available online.)

particular. Because of its very high contrast resolution, MR cholangiography can demonstrate calculi as small as 2 mm (Fig 2).[7]

Mirizzi Syndrome

Mirizzi syndrome is a rare complication of gallstone disease that is caused by an impacted stone in the gall bladder neck or the cystic duct, thereby leading to extrinsic compression and subsequent obstruction of the CHD.[23,24]

US and CT studies can usually demonstrate only the presence and level of biliary obstruction. Whereas MR cholangiopancreatography typically reveals an impacted gallstone in the cystic duct or gall bladder neck, with the level of obstruction at the junction of the cystic duct and CHD. Moreover, MR cholangiopancreatography can detect some anatomical variants that predispose to the development of the syndrome, such as a low insertion of the cystic duct or a long parallel cystic duct[18] (Fig 3).

Primary Sclerosing Cholangitis

Primary sclerosing cholangitis (PSC) is a chronic idiopathic fibrosing inflammatory disease of the bile ducts characterized by inflammation and fibrosis of both the intrahepatic and the extrahepatic bile ducts, leading to the formation of multifocal bile duct strictures, obliteration, cholestasis, and biliary cirrhosis.[25-28] The diagnostic criteria for PSC include (1) typical cholangiographic abnormalities; (2) appropriate clinical, biochemical, and hepatic histologic findings; and (3) the exclusion of secondary causes of sclerosing cholangitis.[26,29]

Traditionally, ERCP was regarded as the gold standard in diagnosing PSC. However, ERCP is an invasive procedure associated with complications that include pancreatitis, biliary sepsis, bleeding, perforation, and aspiration.[25] In contrast, MRI with T1-weighted fat-suppressed spin echo pulse sequences, with or without IV gadolinium, facilitates visualization of the bile duct wall. Peripheral wedge-shaped areas of high T2-weighted signal intensity in the liver parenchyma also may be observed in the disease.[13]

MRCP enables noninvasive imaging of the biliary and pancreatic trees and is sensitive for the strictures and obliterated ducts seen in PSC.[13,30] MRCP features of PSC are diffuse, multifocal short strictures in both the intrahepatic and the extrahepatic bile ducts. Strictured ductal segments alternate with normal or mildly dilated segments, producing an appearance similar to that of beads on a string. This pattern may be associated with mural irregularities and fibrous obliteration of intrahepatic duct branches, thus producing a "pruned-tree" appearance[23] (Fig 4).

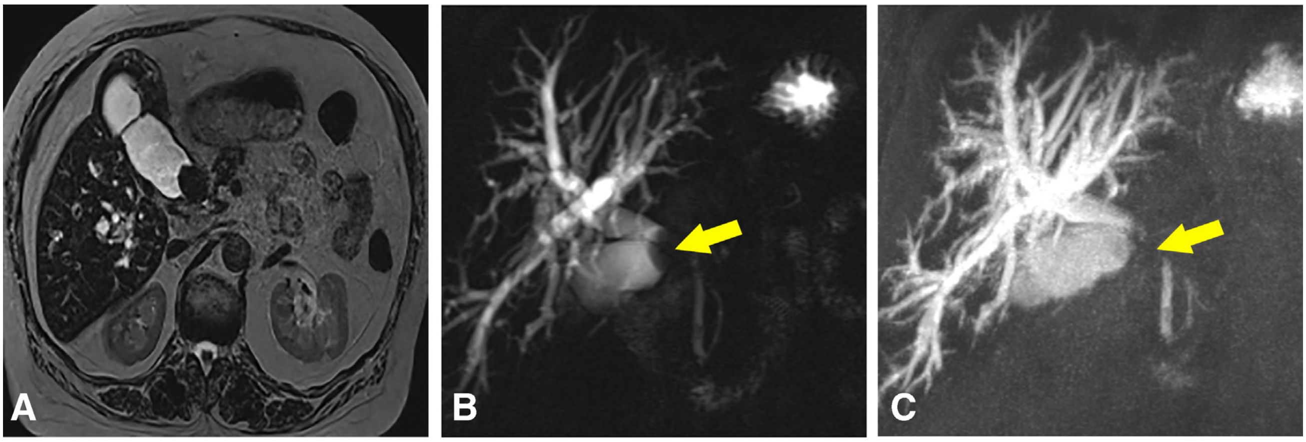

FIG 3. A 47-year-old woman presented with fever, jaundice, abdominal pain, and Mirizzi syndrome. (A) Axial thin-slab heavy T2 SSFSE image shows an impacted stone (low-signal filling defect) at the Hartmann pouch. (B) Thick-slab heavy T2 projectional image and (C) coronal MIP images show dilated intrahepatic bile duct with filling defect at the Hartmann pouch and CHD (arrow) with normal distal CBD.

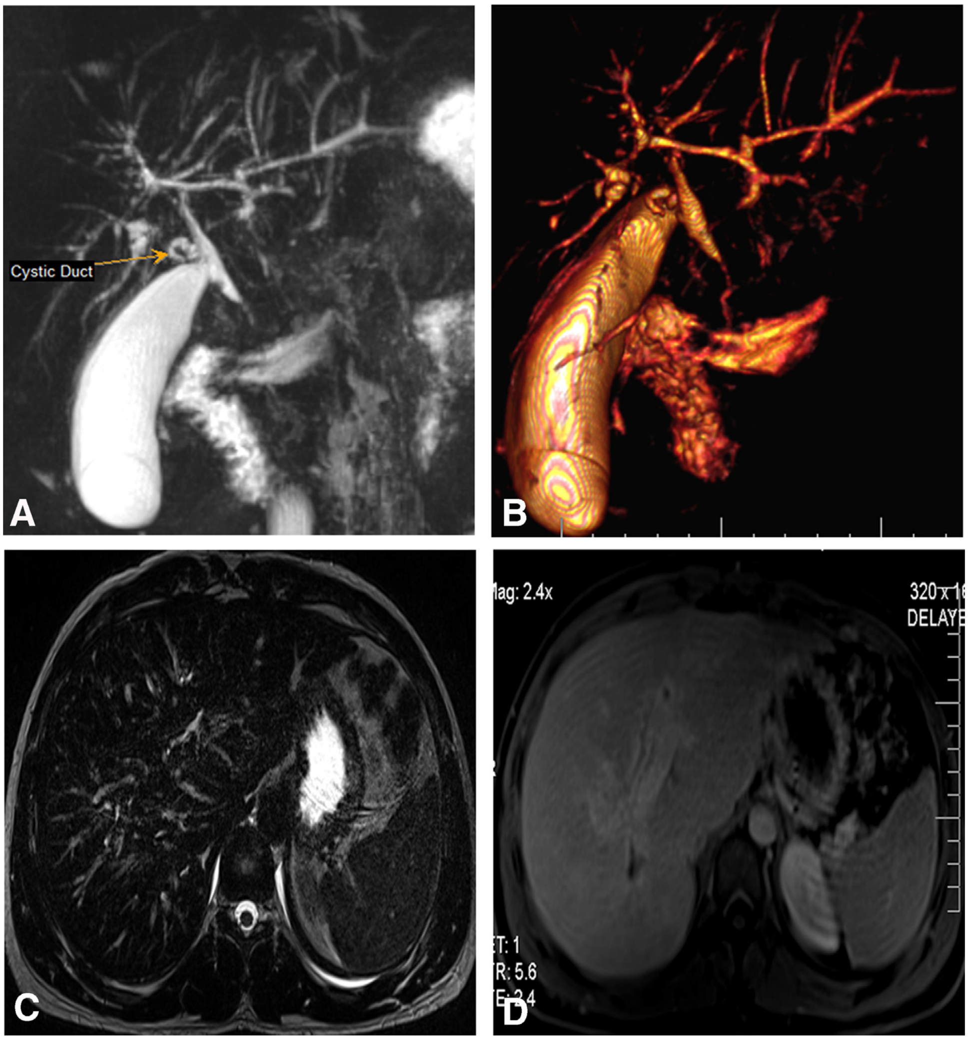

FIG 4. A 20-year-old man presented with jaundice and vomiting, sclerosing cholangitis. (A) Coronal MIP image from 3D T2-weighted MR cholangiographic data, (B) volume-rendered (VR) and (C) axial thin-slab T2 SSFSE images show multiple intrahepatic discontinuous biliary radicles with short strictures (irregular yellow arrow). (D) Axial Gd-enhanced T1-weighted image, delayed phase, shows delayed periportal enhancement (red arrow). (Color version of the figure is available online.)

Acute Pancreatitis

CECT is the mainstay of imaging in patients who have severe acute pancreatitis. It is particularly useful in assessing pancreatic necrosis and local retroperitoneal complications.[31] However, MRI that combines cross-sectional T2-weighted sequences and contrast-enhanced fat-suppressed T1-weighted sequences with MRCP was recently suggested as an alternative to contrast-enhanced CT for the initial staging of acute pancreatitis.[32]

It has the advantage of demonstrating possible choledocholithiasis; the presence or absence of ductal distention, disruption, or leakage of the pancreatic duct; and the size, location, and possible communication of a pseudocyst with the pancreatic duct. In addition, it better demonstrates local hemorrhage in or around the pancreas and helps assess the internal consistency and drainability of fluid collections, which may influence the choice of treatment[32] (Fig 5).

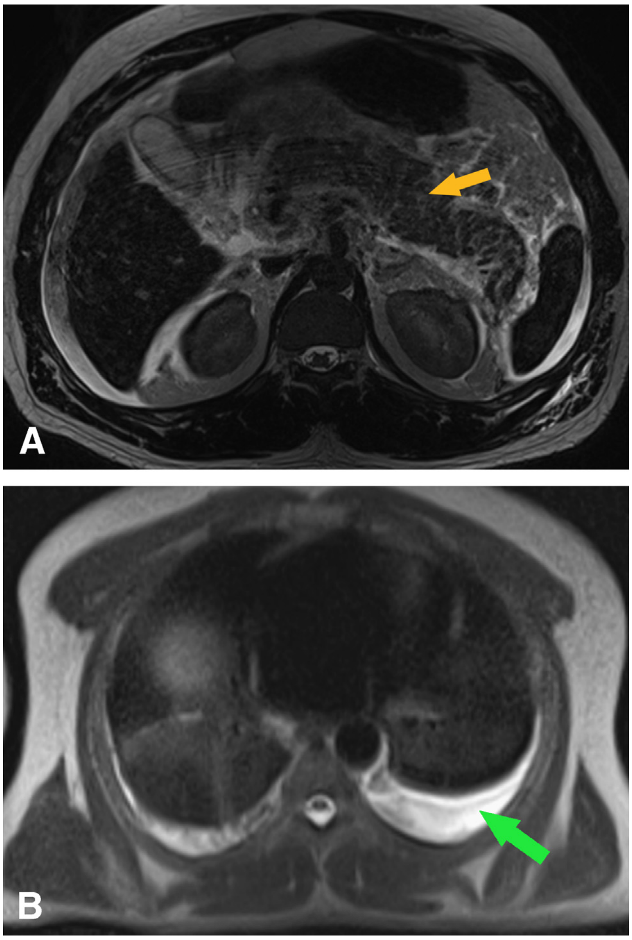

FIG 5. A 60-year-old man with acute pancreatitis (Balthazar E). (A) Axial thin-slab heavy T2 SSFSE image shows diffuse bulky pancreas with parenchymal and peripancreatic edema (arrow), multiple fluid collections in the peripancreatic and retroperitoneal spaces, and mild to moderate free ascites with edematous gall bladder wall. (B) T2 HASTE image shows bilateral pleural effusion, more on the left (arrow).

Chronic Pancreatitis

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.[33] The role of MRCP is to establish the diagnosis, to monitor possible complications (biliary involvement, pseudocysts, and fistulas), and to plan therapy.[32] MRI best depicts intraductal stones and duct obstruction. MRCP can show the dilated duct upstream from an obstructing stone. Still, CT is more sensitive than MRI for the detection of calcifications associated with chronic pancreatitis.[34]

Early findings of chronic pancreatitis include pancreas with low signal intensity on T1-weighted fat-suppressed images, decreased and delayed enhancement after IV contrast administration, and dilated side branches. Late findings include parenchymal atrophy or enlargement, pseudocysts, and dilatation and beading of the pancreatic duct often with intraductal calcifications.[34]

Chronic inflammation and fibrosis diminish the proteinaceous fluid content of the pancreas, resulting in the loss of the usual high signal intensity on T1-weighted fat-suppressed images.[34] The use of secretin in MR cholangiopancreatography helps improve the delineation of pancreatic duct architecture. Secretin stimulates the exocrine pancreas to secrete fluid and bicarbonate, which produces a transient increase in the diameter of the main pancreatic duct, with resultant improvement in the depiction of this structure.[23,35,36] Dynamic MR cholangiopancreatography performed with secretin also helps detect pancreatic duct stenoses or irregularities that occur without ductal dilatation.[23]

Bile Duct Injury Following Operative Procedures

Bile duct injuries are the most common and serious complications associated with surgery, especially laparoscopic cholecystectomy.[37] Bile duct injury following cholecystectomy is an iatrogenic catastrophe as it is associated with significant perioperative morbidity and mortality and reduced long-term survival and quality of life.[38]

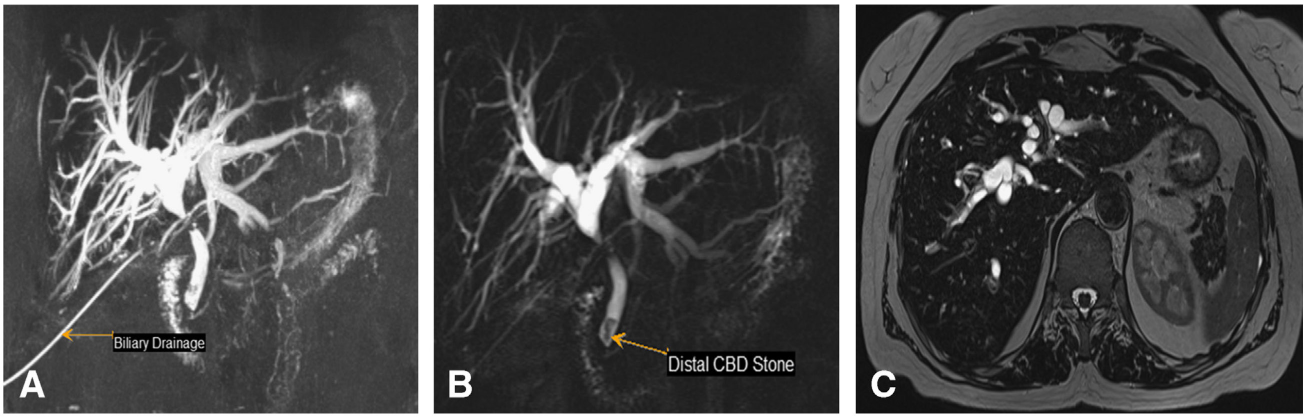

FIG 6. A 35-year-old woman with a history of cholecystectomy, now she presented with jaundice and postcholecystectomy CBD injury (Bismuth I) with a distal CBD stone. (A) Coronal MIP image from 3D T2 MR cholangiopancreatographic data, (B) thick-slab projectional image, and (C) thin-slab T2 SSFSE show moderate bilateral intrahepatic biliary dilatation with abrupt ending of the common hepatic duct about (2.3 cm) following the confluence, reflecting ligation injury (Bismuth I), the rest of the common bile duct is mildly dilated, harboring a 1-cm signal defect along its distal-most portion reflecting a stone. Biliary drainage is also seen with no actual biliary leakage. (Color version of the figure is available online.)

The most common postsurgical biliary complication is benign biliary stricture. MRCP can visualize the biliary tree distal and proximal to a high-grade stricture or complete obstruction. Thin-section source images must be used to evaluate the extent of high-grade stenoses.[11]

MRCP can accurately diagnose postoperative excision injuries of the biliary tree and can characterize and anatomically classify these injuries for planning reparative surgery. It can also suggest the presence of cystic duct leaks in patients who have undergone cholecystectomy.[39]

Traditionally, by using the Bismuth classification, bile duct injuries have been classified into the following types.[40-42]

Type I represents an injury more than 2 cm distal to the biliary confluence. Type II represents an injury less than 2 cm from the biliary confluence. Type III represents an injury of the entire CHD without involvement of the biliary confluence. Type IV represents complete or partial destruction of the biliary confluence. Type V represents an injury to a right variant segmentary branch, with or without injury to the main duct.

Excision injury is depicted on MRCP as a persistent discontinuity in a bile duct segment, a finding that should be confirmed by comparing MIP images with the source images.[40] In cases of complete obstruction of the bile duct, MRCP allows analysis of the biliary tract above and below the level of the obstruction, a capability essential for treatment planning and one that is not provided by either endoscopic retrograde cholangiopancreatography or percutaneous transhepatic cholangiography. In addition to MRCP, T1- and T2-weighted MRI may be performed to depict extrabiliary soft tissue structures and abnormalities, such as an abscess, tumor recurrence or metastasis, hematoma, or hemobilia.[40]

Other postsurgical biliary complications include retained bile duct stones, biliary leak, and biliary fistula. These conditions can be evaluated effectively by MRCP.[11]

In patients with biliary-enteric anastomoses, it may be difficult or impossible to perform ERCP. On the contrary, MRCP is very effective in evaluating the anatomy of the anastomosis, strictures of the anastomosis, strictures of the biliary ducts, and biliary stones proximal to the anastomosis in up to 100% (of patients[11] Figs 6 and 7).

Biliary Complications After Liver Transplantation

Biliary complications after liver transplantation are one of the leading causes of liver failure and occur in 10%-30% of patients who undergo transplantation.[43] These complications are the second most common cause of graft dysfunction (rejection is the most common). Biliary complications include stenosis, fistula, obstruction, stone formation, dysfunction of the Oddi sphincter, and recurrent biliary disease.[44]

MR cholangiography is the best noninvasive technique for evaluation of the biliary tree. Multiplanar MRI enables accurate analysis of the surgically altered biliary anatomy. A stricture is the most frequent

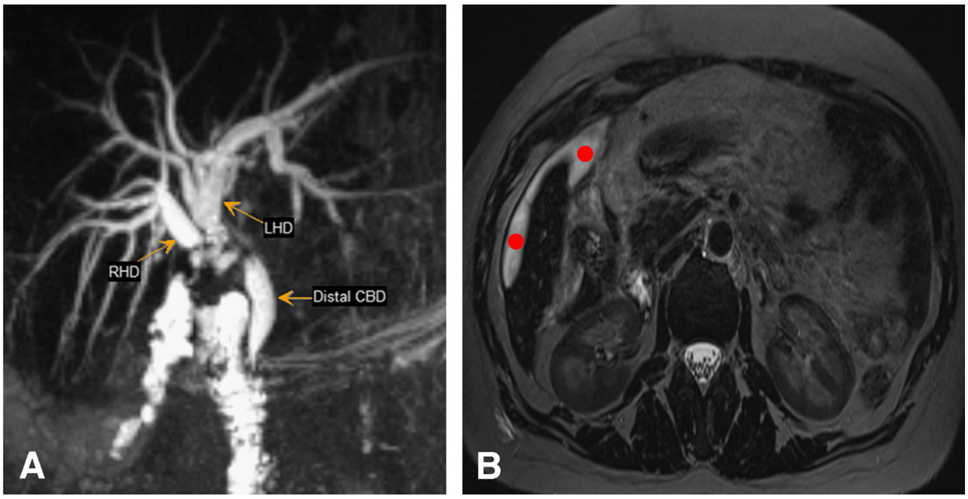

FIG 7. A 30-year-old woman with obstructive jaundice following cholecystectomy and Bismuth type IV CBD injury with biliary leakage. (A) Coronal MIP image shows irregular short segmental stricture involving the biliary hilar level and biliary confluence with partial loss of communication of the left and right hepatic ducts, this is associated with mild mainly central intrahepatic biliary radical dilatation while the distal CBD shows normal course and caliber. (B) Axial thin-slab heavy T2 SSFSE shows free subhepatic collection representing biliary leakage (red dots). (Color version of the figure is available online.)

complication during the late postoperative period after liver transplantation, it may arise within several months to several years [40] (Fig 8).

Blunt Trauma of the Biliopancreatic Tree

Biliary Injuries Following Blunt Trauma[45]

The most common location of biliary injury is the gall bladder, followed by the CBD and the intrahepatic ducts (Tables 1 and 2; Fig 9).

Neoplastic Biliopancreatic Diseases

Cholangiocarcinoma

Cholangiocarcinoma is classified anatomically as either intrahepatic or extrahepatic, and intrahepatic cholangiocarcinoma is further classified as either peripheral or hilar.

In the literature, a tumor that arises peripheral to the secondary bifurcation of the left or right hepatic duct is considered to be a peripheral cholangiocarcinoma, whereas a tumor that arises from 1 of the hepatic ducts

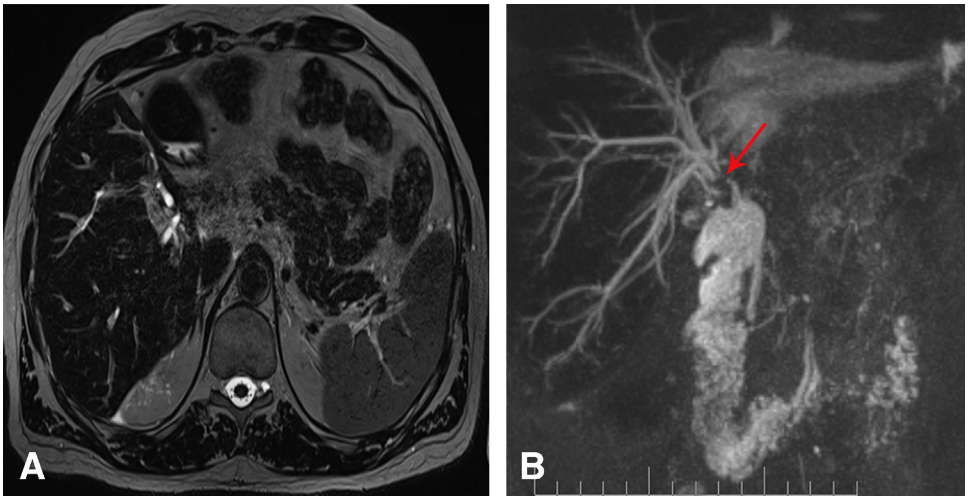

FIG 8. A 52-year-old man with biliary anastomotic stricture, with intrahepatic back pressure changes following a living donor liver transplantation. (A) Axial thin-slab heavy T2 SSFSE image and (B) coronal MIP image show mild diffuse intrahepatic biliary dilatation with short abrupt arrest at the level of the biliary anastomosis (arrow) with the recipients CBD, where a 5-mm long, tight stricture is noted. The rest of the CBD shows normal course and caliber, with no signal defects identified.

TABLE 1. Imaging findings in gall bladder injuries due to blunt trauma[45]

A collapsed gall bladder in a fasting patient
An ill-defined or thickened gall bladder wall
Active extravasation of intravenous contrast material due to transection of the cystic artery
Pericholecystic fluid
Dense intraluminal fluid
Mass effect on the duodenum
Free intraperitoneal fluid
Complete avulsion
Associated injuries (eg, to the liver, spleen, duodenum, and ribs)

TABLE 2. Imaging findings in intrahepatic and extrahepatic bile duct injuries due to blunt trauma[45]

Active extravasation of bile on hepatobiliary scintigraphy
Focal perihepatic or subhepatic fluid collections
Ascites
Intrahepatic fluid collections
Liver lacerations
Duodenal and splenic injuries

or the bifurcation of the CHD is considered to be a hilar cholangiocarcinoma (Klatskin tumor).[46]

According to the morphologic classification system proposed by the Liver Cancer Study Group of Japan, intrahepatic cholangiocarcinomas can be divided into 3 types based on morphologic appearance: mass-forming, periductal infiltrating, and intraductal growth types.[47]

MRCP can demonstrate the bile duct proximal to the obstructing site. Special emphasis is made on T1-weighted fat-suppressed spoiled gradient echo images acquired 2-5 minutes following gadolinium administration because it is the most consistent technique to demonstrate a cholangiocarcinoma, which appears as a moderately enhancing tissue.[11]

Mass-Forming Type of Intrahepatic Cholangiocarcinoma

The MRI feature of a mass-forming cholangiocarcinoma is an irregular margin with high signal intensity on T2-weighted images and with low signal intensity on T1-weighted images.[47] Both the peripheral and the centripetal enhancements prominent on the equilibrium phase or delayed phase MR images are similar to those taken by contrast-enhanced CT.[47-49]

Periductal Infiltrating Type[47]

Periductal infiltrating cholangiocarcinoma is characterized by growth along a dilated or narrowed bile duct without mass formation and manifests as an elongated, spiculated, or branchlike abnormality. On CT and MR images, diffuse periductal thickening and increased enhancement due to tumor infiltration can be seen, with an abnormally dilated or irregularly narrowed duct and peripheral ductal dilatation. This type of tumor is rare in intrahepatic cholangiocarcinomas, but most hilar cholangiocarcinomas are of this type.

Intraductal Type of Cholangiocarcinoma[47,50]

Imaging patterns include diffuse and marked duct ectasia with a grossly visible papillary mass, diffuse and marked duct ectasia without a visible mass, intraductal polypoid mass within the localized ductal dilatation, intraductal castlike lesions within a mildly dilated duct, and focal stricturelike lesion with mild proximal ductal dilatation.

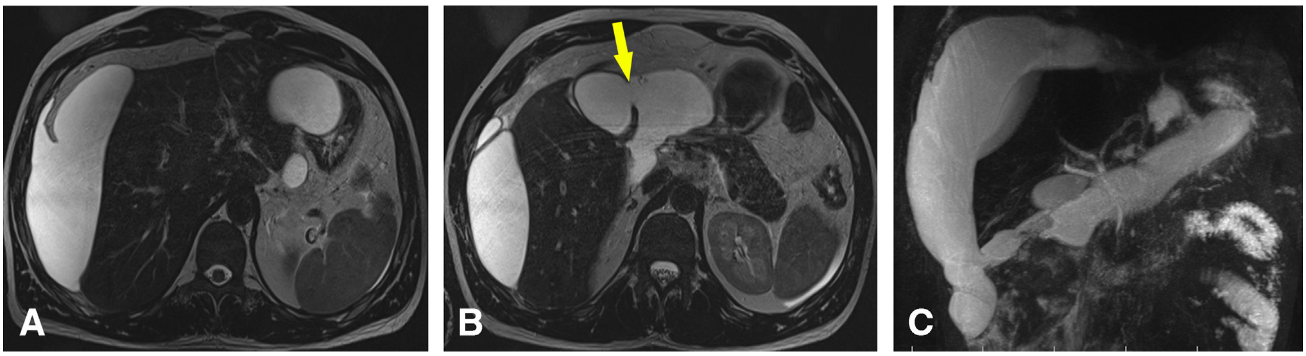

FIG 9. A 36-year-old woman with recent history of trauma, now she presented with jaundice, abdominal pain, and a lacerated gall bladder with large biliary leak, leading to subcapsular and subhepatic biliary collections. (A and B) Axial thin-slab heavy T2 SSFSE images and (C) coronal MIP image show multiple perihepatic fluid signal collections at the subcapsular space indenting the liver surface and perisplenic region with a pyriform structure at the anatomical site of the gall bladder, connection with the cystic duct and its medial wall is defective, freely communicating with the subhepatic collection (arrow).

Hilar Cholangiocarcinoma

Although hilar cholangiocarcinomas have been subsumed under the heading of intrahepatic cholangiocarcinoma, their clinical and radiologic features as well as surgical management are more similar to those of extrahepatic cholangiocarcinomas. Therefore, in some textbooks, both entities are described as "large duct cancer" or "carcinoma of the bile duct."[46]

Infiltrating Hilar Cholangiocarcinoma

Infiltrating hilar cholangiocarcinoma is the most common type of hilar cholangiocarcinoma (more than 70% of cases).[46] Infiltrating perihilar lesions (Klatskin tumors) have been further classified by Bismuth and Corlette according to the extent of ductal involvement into type I involving the CHD; type II involving the CHD and the junction of the RHD and LHD; type IIIA involving the CHD, biliary junction, and RHD; type IIIB involving the CHD, biliary junction, and LHD; and type IV involving the CHD and the biliary junction, with extension to both the RHD and LHD or a multifocal bile duct tumor.[51]

The imaging features of Klatskin tumors and extrahepatic cholangiocarcinomas on MRCP are dilatation of the proximal biliary tree with stricture or abrupt termination at the tumor, typically showing a shoulder sign. Irregularity of the ductal wall is indicative of infiltration and raises a high suspicion of malignancy. Occasionally, tumors can show intraluminal papillary growth presenting as a filling defect on MRCP images. An advantage of MRCP in combination with conventional MRI is that it can visualize the biliary tree proximal to an occlusion, which often is not possible or advisable with ERCP, as well as detect distant disease such as liver metastases

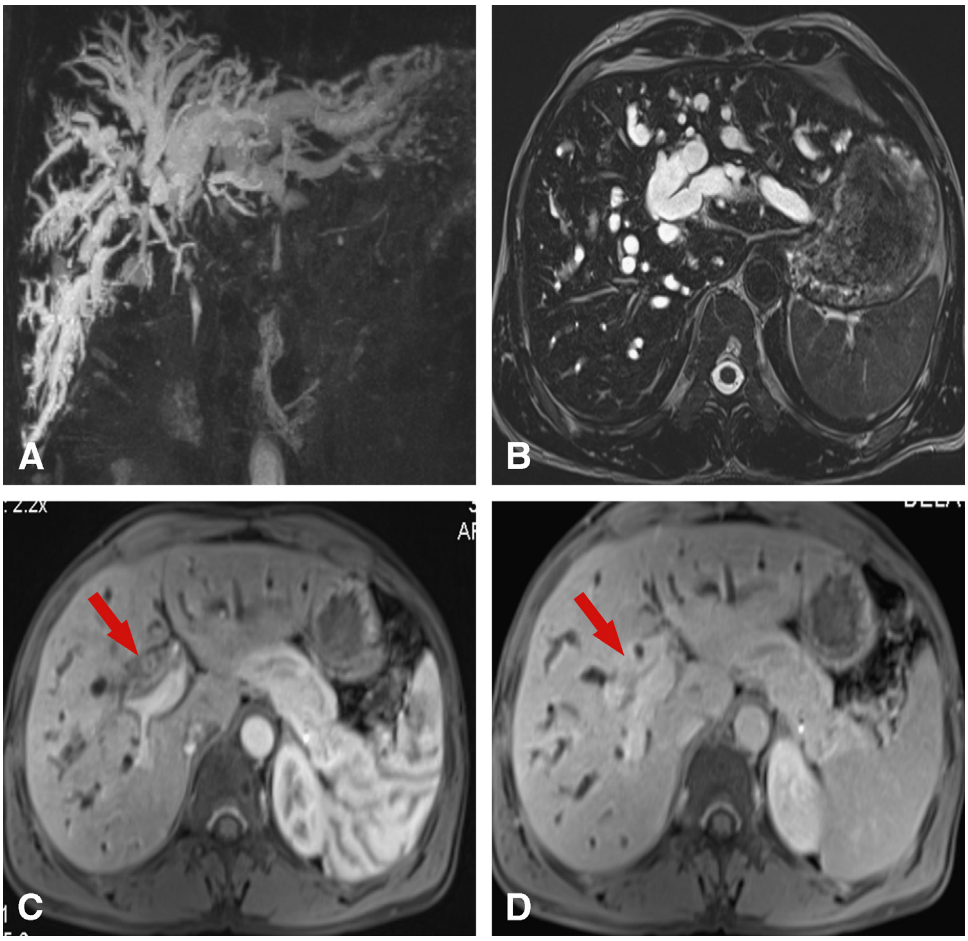

FIG 10. A 53-year-old man with central cholangiocarcinoma (Klatskin tumor). (A) coronal MIP image and (B) axial thin-slab heavy T2 SSFSE images show marked diffuse dilatation of the intrahepatic biliary tree with abrupt arrest at the level of the porta hepatis disconnecting the main biliary ducts, this arrest is caused by a large central perihilar mass lesion. (C) and (D) Axial Gd-enhanced T1-weighted images, arterial and delayed phases, respectively, show gradual slow enhancement of this mass till the delayed phases (arrow). The mass infiltrates the right and left biliary ducts till the secondary confluences.

or lymph node involvement. On T1-weighted MR images with or without fat suppression, cholangiocarcinomas appear mildly to moderately hypointense but may also be isointense relative to the liver parenchyma. On T2-weighted images, they are isointense or mildly hyperintense[52] (Fig 10).

Ampullary Adenoma and Carcinoma

Ampullary adenoma and adenocarcinoma are neoplasms that arise from the glandular epithelium of the ampulla of Vater. Enlargement of the papilla with a nodular appearance of the overlying mucosa that is associated with erosion or an ulcer is a typical endoscopic finding in ampullary carcinoma.[20] Secondary findings such as marked bile duct dilatation, in association with mild to moderate dilatation of the pancreatic duct, can usually be seen on CT images.[53]

Larger ampullary tumors usually manifest as infiltrative or polypoid masses. A polypoid mass is seen as an intraductal soft tissue mass that is hypoattenuating relative to the hepatic parenchyma.[53] With the development of modern MRI techniques, including MRCP, several imaging findings typical of ampullary carcinoma have been reported, including ampullary mass, papillary bulging, irregular and asymmetric narrowing of the CBD, and proportional biliary dilatation.[54]

Intestinal-type ampullary carcinomas more commonly manifest with a nodular shape, an area of isointense to high signal intensity compared with that of the adjacent duodenum on T2-weighted MR images, an oval filling defect at the distal end of the CBD on MRCP images, and an extramural protruding appearance with a papillary surface on endoscopic examinations.[54] Pancreatobiliary-type ampullary carcinomas more commonly exhibited an infiltrative area of hypointensity on T2-weighted MR images with irregular, tapered narrowing of the distal CBDs.[54]

Pancreatic Adenocarcinoma

Pancreatic adenocarcinoma accounts for 85%-95% of all pancreatic malignancies.[55,56] Of these tumors, 60%-70% are located in the pancreatic head, 10%-20% in the body, and 5%-10% in the tail. Diffuse glandular involvement occurs in 5% of cases.[57] Nonresectable disease is seen at presentation in 75% of patients, with metastases (mainly to the liver and peritoneum) present in 85% of them. Surgery is the only cure, with a postoperative 5-year survival rate of 20%.[55]

Tumors in the pancreatic head may cause dilatation of both the CBD and the main pancreatic duct (MPD), known as the "double duct sign," whereas tumors in the pancreatic body may cause upstream main pancreatic duct dilatation. Atrophy of the pancreas proximal to the tumor is noted in chronic obstruction. A circumferential soft tissue cuff around the peripancreatic vessels with loss of the perivascular fat plane denotes vascular invasion.[55]

Metastases are most commonly found in the liver and the peritoneum. Adenocarcinoma has low signal intensity on T1- and T2-weighted MR images secondary to its scirrhous fibrotic nature with a thin peritumoral rim of greater enhancement.[55]

REFERENCES

1. Baron RL, Tublin ME, Peterson MS. Imaging the spectrum of biliary tract disease. Radiol Clin North Am 2002;40(6):1325-54.
2. O'Connor OJ, O'Neill S, Maher MM. Imaging of biliary tract disease. Am J Roentgenol 2011;197(4):551-8.
3. Zhong L, Xiao SD, Stoker J, et al. Magnetic resonance cholangiopancreatography. Chin J Dig Dis 2004;5(4):139-48.
4. MacEneaney P, Mitchell MT, McDermott R. Update on magnetic resonance cholangiopancreatography. Gastroenterol Clin North Am 2002;31(3):731-46.
5. Halefoglu AM. Magnetic resonance cholangiopancreatography. Elsevier 2008;282-9.
6. Halefoglu AM. Magnetic resonance cholangiopancreatography: a useful tool in the evaluation of pancreatic and biliary disorders. World J Gastroenterol 2007;13(18):2529-34.
7. Yeh BM, Liu PS, Soto JA, et al. MR imaging and CT of the biliary tract. Radiographics 2009;29(6):1669-88.
8. Schneider G, Grazioli L, Saini S. Imaging of the biliary tree and gallbladder diseases. MRI of the Liver. 2nd ed. Heidelberg, Germany: Springer; 2005, p. 237-66.
9. Mortelé KJ, Rocha TC, Streeter JL, et al. Multimodality imaging of pancreatic and biliary congenital anomalies. Radiographics 2006;26(3):715-31.
10. Mortelé KJ, Ros PR. Cystic focal liver lesions in the adult: differential CT and MR imaging features. Radiographics 2001;21(4):895-910.
11. Motohara T, Semelka RC. MR cholangiopancreatography. Radiol Clin North Am 2003;41:89-96.
12. Taourel P, Bret PM, Reinhold C, et al. Anatomic variants of the biliary tree: diagnosis with MR cholangiopancreatography. Radiology 1996;199:521-7.
13. Heller SL, Lee VS. MR imaging of the gallbladder and biliary system. Magn Reson Imaging Clin N Am 2005;13(2):295-311.
14. Yu J, Turner MA, Fulcher AS, et al. Congenital anomalies and normal variants of the pancreaticobiliary tract and the pancreas in adults: part 2, pancreatic duct and pancreas. Am J Roentgenol 2006;187(6):1544-53.
15. Lee NK, Kim S, Jeon TY, et al. Complications of congenital and developmental abnormalities of the gastrointestinal tract

in adolescents and adults: evaluation with multimodality imaging. Radiographics 2010;30(6):1489-507.
16. Sandrasegaran K, Patel A, Fogel EL, et al. Annular pancreas in adults. Am J Roentgenol 2009;193(2):455-60.
17. Maier M, Wiesner W, Mengiardi B. Annular pancreas and agenesis of the dorsal pancreas in a patient with polysplenia syndrome. Am J Roentgenol 2007;188(2):150-3.
18. Catalano OA, Sahani DV, Kalva SP, et al. MR imaging of the gallbladder: a pictorial essay. Radiographics 2008;28(1): 135-55.
19. Sherlock S, Dooley J. Gallstones and inflammatory gallbladder diseases. In: Sherlock S, Dooley J, editors. Diseases of the Liver and Biliary System. 11th ed. Malden, Mass: Blackwell; 2002. p. 597-628.
20. Horton JD, Bilhartz LE. Gallstone disease and its complications. In: Fedelman M, Friedman LS, Sleisenger MH, editors. Sleisenger & Fortran's Gastrointestinal and Liver Disease: Pathophysiology/Diagnosis/Management. 7th ed. Philadelphia, PA: Saunders; 2003. p. 1065-90.
21. Gore RM, Yaghmai V, Newmark GM, et al. Imaging benign and malignant disease of the gallbladder. Radiol Clin North Am 2002;40(6):1307-23.
22. Tsai HM, Lin XZ, Chen CY, et al. MRI of gallstones with different compositions. Am J Roentgenol 2004;182(6): 1513-9.
23. Patel HT, Shah AJ, Khandelwal SR, et al. MR cholangiopancreatography at 3.0 T. Radiographics 2009;29(6):1689-706.
24. Erben Y, Benavente-Chenhalls LA, Donohue JM, et al. Diagnosis and treatment of Mirizzi syndrome: 23-year Mayo clinic experience. J Am Coll Surg 2011;213(1):114-9.
25. Chapman R, Fevery J, Kalloo A, et al. Diagnosis and management of primary sclerosing cholangitis. Hepatology 2010;51(2):660-78.
26. Vitellas KM, Keogan MT, Freed KS, et al. Radiologic manifestations of sclerosing cholangitis with emphasis on MR cholangiopancreatography1. Radiographics 2000;20(4): 959-75.
27. Shanbhogue AK, Tirumani SH, Prasad SR, et al. Benign biliary strictures: a current comprehensive clinical and imaging review. Am J Roentgenol 2011;197(2):295-306.
28. Vitellas KM, Enns RA, Keogan MT, et al. Comparison of MR cholangiopancreatographic techniques with contrast-enhanced cholangiography in the evaluation of sclerosing cholangitis. Am J Roentgenol 2002;178(2):327-34.
29. Gulliver DJ, Baker ME, Putnam W, et al. Bile duct diverticula and webs: nonspecific cholangiographic features of primary sclerosing cholangitis. Am J Roentgenol 1991;157(2):281-5.
30. Dave M, Elmunzer BJ, Dwamena BA, et al. Primary sclerosing cholangitis: meta-analysis of diagnostic performance of MR cholangiopancreatography. Radiology 2010;256(2): 387-96.
31. Saokar A, Rabinowitz CB, Sahani DV. Cross-sectional imaging in acute pancreatitis. Radiol Clin North Am 2007; 45(3):447-60.
32. Matos C, Cappeliez O, Winant C, et al. MR imaging of the pancreas: a pictorial tour. Radiographics 2002;22(1):2-5.
33. Vitellas KM, Keogan MT, Spritzer CE, et al. MR cholangiopancreatography of bile and pancreatic duct abnormalities with emphasis on the single-shot fast spin-echo technique. Radiographics 2000;20(4):939-57.
34. Miller FH, Keppke AL, Wadhwa A, et al. MRI of pancreatitis and its complications: part 2, chronic pancreatitis. Am J Roentgenol 2004;183(6):1645-52.
35. Akisik MF, Sandrasegaran K, Aisen AA, et al. Dynamic secretin-enhanced MR cholangiopancreatography. Radiographics 2006;26(3):665-77.
36. Sandrasegaran K, Lin C, Akisik FM, et al. State-of-the-art pancreatic MRI. Am J Roentgenol 2010;195(1):42-53.
37. Lee NK, Kim S, Lee JW, et al. Biliary MR imaging with Gd-EOB-DTPA and its clinical applications. Radiographics 2009; 29(6):1707-24.
38. Lau WY, Lai EC, Lau SH. Management of bile duct injury after laparoscopic cholecystectomy: a review. ANZ J Surg 2010;80(12):75-81.
39. Khalid TR, Casillas VJ, Montalvo BM, et al. Using MR cholangiopancreatography to evaluate iatrogenic bile duct injury. Am J Roentgenol 2001;177:1347-52.
40. Hoeffel C, Azizi L, Lewin M, et al. Normal and pathologic features of the postoperative biliary tract at 3D MR cholangiopancreatography and MR imaging. Radiographics 2006; 26(6):1603-20.
41. Chartrand-Lefebvre C, Dufresne MP, Lafortune M, et al. Iatrogenic injury to the bile duct: a working classification for radiologists. Radiology 1994;193(2):523-6.
42. Mercado MA, Domínguez I. Classification and management of bile duct injuries. World J Gastrointest Surg 2011; 3(4):43-8.
43. Valls C, Alba E, Cruz M, et al. Biliary complications after liver transplantation: diagnosis with MR cholangiopancreatography. Am J Roentgenol 2005;184(3):812-20.
44. Caiado AH, Blasbalg R, Marcelino AS, et al. Complications of liver transplantation: multimodality imaging approach. Radiographics 2007;27(5):1401-17.
45. Gupta A, Stuhlfaut JW, Fleming KW, et al. Blunt trauma of the pancreas and biliary tract: a multimodality imaging approach to diagnosis. Radiographics 2004;24(5): 1381-95.
46. Han JK, Choi BI, Kim AY, et al. Cholangiocarcinoma: pictorial essay of CT and cholangiographic findings. Radiographics 2002;22(1):173-87.
47. Chung YE, Kim MJ, Park YN, et al. Varying appearances of cholangiocarcinoma: radiologic-pathologic correlation. Radiographics 2009;29(3):683-700.
48. Valls C, Guma A, Puig I, et al. Intrahepatic peripheral cholangiocarcinoma: CT evaluation. Abdom Imaging 2000; 25(5):490-6.
49. Asayama Y, Yoshimitsu K, Irie H, et al. Delayed-phase dynamic CT enhancement as a prognostic factor for mass-forming intrahepatic cholangiocarcinoma. Radiology 2006; 238(1):150-5.
50. Lim JH, Yi CA, Lim HK, et al. Radiological spectrum of intraductal papillary tumors of the bile ducts. Korean J Radiol 2002;3(1):57-63.
51. Sainani NI, Catalano OA, Holalkere NS, et al. Cholangiocarcinoma: current and novel imaging techniques. Radiographics 2008;28(5):1263-87.

52. Bader TR, Semelka RC. Gallbladder and biliary system. In: Semelka RC, editor. Abdominal-Pelvic MRI. 2nd ed. Hoboken, NJ: Wiley; 2006. p. 447-507.
53. Kim S, Lee NK, Lee JW, et al. CT evaluation of the bulging papilla with endoscopic correlation. Radiographics 2007; 27(4):1023-38.
54. Chung YE, Kim MJ, Park MS, et al. Differential features of pancreatobiliary-and intestinal-type ampullary carcinomas at MR imaging. Radiology 2010;257(2):384-93.
55. Low G, Panu A, Millo N, et al. Multimodality imaging of neoplastic and nonneoplastic solid lesions of the pancreas. Radiographics 2011;31(4):993-1015.
56. Brennan DDD, Zamboni GA, Raptopoulos VD, et al. Comprehensive preoperative assessment of pancreatic adenocarcinoma with 64-section volumetric CT. Radiographics 2007; 27(6):1653-66.
57. Horton KM, Fishman EK. Adenocarcinoma of the pancreas: CT imaging. Radiol Clin North Am 2002;40(6):1263-72.