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MRCP in the evaluation of pancreaticobiliary disease in children

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Abstract *Background*. Radiologic assessment of pancreaticobiliary ductal disease (PBDD) in children currently consists of physiologic tests (radionuclide examinations) or invasive anatomic studies (ERCP and PTC). An accurate noninvasive and reproducible examination that can direct the subsequent need for more invasive studies would be helpful in this patient group.
Objective. To determine the effectiveness of MRCP as a screening tool for PBBD in the pediatric population.
Materials and methods. Over the last year, 33 patients ranging from 7 months to 20 years of age were prospectively evaluated with MRCP on a 1.5 T magnet. One patient was examined twice, several months apart. Thirteen patients had liver transplants. Coronal SPGR and heavily T-2W FSE cross-sectional images were obtained. Standard and oblique 2- to 6-cm-thick slab SSFSE (single-shot fast spin echo) acquisition and 3D MIP reconstruction of 2D FSE images were obtained in the planes of the CBD and pancreatic duct. Nine studies were performed with the patient under sedation with chloral hydrate or nembutal and fentanyl with quiet respiration, and the non-sedated patients were assessed with single breath hold or quiet respiration. Three patients received secretin. MRCP results were correlated with ERCP (9), PTC (7), liver biopsy (13), clinical information (6), surgery (3), and autopsy (2).
Results. All 34 studies performed were considered diagnostic. Periportal fluid, proximal bowel fluid, and gallbladder distention did not significantly diminish the diagnostic information in any cases. Motion artifact did not cause serious degradation in image quality. MRCP depicted abnormalities including stones, stricture, intraductal tumor, and extrinsic compression, all of which were confirmed at ERCP, PTC (two unsuccessful in patients with non-dilated ducts by MRCP), surgery, liver biopsy, and autopsy. There were no false-negative examinations. Normal pancreatic studies performed to exclude pancreas divisum were followed without additional clinical or laboratory evidence of pancreatitis. Secretin administration increased the conspicuity of the pancreatic duct in two of three patients.
Conclusion. MRCP is a fast non-invasive method of evaluating the pancreatic duct and biliary tree in children. A normal MRCP may obviate the need for PTC or ERCP. Abnormalities detected on MRCP can direct the type of intervention.

Introduction

In the pediatric population, biliary tree and pancreatic duct pathology is initially accessed by laboratory data, ultrasound, and/or CT. When these techniques fail to provide an accurate diagnosis, endoscopic retrograde cholangiopancreatography (ERCP) is often performed. In specific instances when sclerosing cholangitis and pancreas divisum need to be excluded, ERCP has been the mainstay of diagnosis. The indications for percutaneous transhepatic cholangiography (PTC) currently are few, and it is performed predominantly as a prelude to intervention, or in patients when ERCP is unsuccessful. In addition, ERCP is not technically feasible in patients with biliary enteric anastomoses. However, PTC is becoming more common as the liver transplant population grows because of the need for a prompt diagnosis of biliary obstruction, which is a well-recognized cause of graft failure. Both ERCP and PTC are invasive and can be associated with significant morbidity, even in the most experienced hands.

Magnetic resonance cholangiopancreatography (MRCP) is a new, non-invasive technique for evaluating the biliary tree and pancreatic duct. While the technique was developed in the early 1990 s, it has not been used as a routine clinical tool until the last several years. Because of long scan times and required long breath-holds, this study could only be performed in extremely cooperative patients, which consequently has limited its use in the pediatric population. The development of respiratory trigger and a non-breath-hold technique used with a 2D FSE with 3D maximal intensity projection (MIP) has made it possible to perform this study in less cooperative patients. However, scan times can approach 10 min for this sequence, which is sensitive to respiratory misregistration. It also requires post-processing time.

Recently, a SSFSE technique has been developed to acquire MRCP images. This is a volume acquisition that is performed in approximately 2 s. These extremely short scan times make it possible to examine the child without breath-holding. This has prompted us to investigate this technique in the sedated child where breath-holding is not possible and to determine if it is an effective screening tool for pancreatic and biliary tract disease in the pediatric population. The purpose of this report is to present our experience with SSFSE MRCP in children.

Materials and methods

Since October 1997, 33 children (age 7 months to 20 years) were prospectively evaluated using MRCP. Thirty-four studies were performed. Twenty-five examinations were performed predominantly to evaluate the biliary tree (magnetic resonance cholangiography or MRC), and 13 of these patients had undergone orthotopic liver transplant (OLTx). The other nine studies were primarily performed to evaluate the pancreatic duct (magnetic resonance pancreatography or MRP). Three of these studies were performed with secretin. Nine studies were performed under sedation, eight using IV Nembutal and fentanyl and one with p. o. chloral hydrate, while the other 25 were split between single breath-hold and quiet respiration. Non-sedated children and those unable to breath-hold receive specific instructions on low tidal volume breathing.

All studies were performed on a 1.5 T Signa magnet (GE, Milwaukee, Wis.). Infants were placed in the head coil, and a phased array torso coil was used in older children. Fasting for 4–6 h was the only necessary patient preparation.

An initial coronal Fast SPGR/90 localizer is performed using a TR/TE: 120/1.6, 6.0 mm slice/2.0 mm gap, 256 × 128 matrix, variable FOV, 1 NEX with a scan time of 16 s. An axial T2W FSE anatomic localizer for the MRCP is performed using TR/TE: 5000/100 Ef (12–16 ETL), 6.0 mm slice/2.0 mm gap, 256 × 256 matrix, 16–25 FOV, 4 NEX, fat saturation, respiratory trigger, with a scan time of 5–6 min.

A single-shot FSE (SSFSE) is then performed using a TE:1000 Ef (there is no repetition time because it is a single acquisition), 20- to 50-mm slab (currently 20–30 mm), 256 × 256 matrix, 0.5 NEX, breath-hold or quiet respiration, with a scan time of 2 s. Initial slabs are performed in the plane of the porta hepatis, which is oriented in the coronal or coronal oblique planes, with additional slab images performed with varying thicknesses and planes as the individual cases require. In the segmental liver transplants, the slabs are positioned in a more sagittal plane due to the more anteroposterior orientation of the neo-porta hepatis.

All studies were evaluated for motion artifact, periportal fluid, proximal bowel fluid, and gallbladder distension. All patients had previously undergone CT or ultrasound imaging except the following: Two patients with pancreatitis and one child with ulcerative colitis went directly to MRCP. Findings were correlated with the following: 13 liver biopsy, 8 ERCP, 7 PTC, 4 clinical, 3 surgery, 2 autopsy, and 1 MRCP.

Secretin was administered in three studies (youngest patient was 7 years old). Secretin is initially given as a test dose (0.1–1 unit IV). If no local skin hypersensitivity reaction is witnessed, secretin 1 μm/kg is injected over 1 min. MRP is then performed every 2 min for 20 min in the plane the pancreatic duct was best visualized.

Results

Thirty-two out of 34 studies were of high quality. Two studies were considered suboptimal primarily because of poor plane selection rather than other technical factors. Fluid that could potentially obscure the biliary tree (periportal, proximal bowel, and ascitic fluid, or a distended gallbladder) did not diminish the diagnostic information in any of our cases. Owing to coincidental patient selection, periportal and portahepatic fluid amount was not significant in any patient. Intraluminal fluid (bowel and gallbladder) was avoided by adjusting slab thickness and plane selection not to include these structures in the MRCP image. Substantial motion occurred intermittently in a single post-secretin study, but did not seriously degrade image quality. No significant difference in image quality or duct conspicuity was observed between the studies performed with a non-

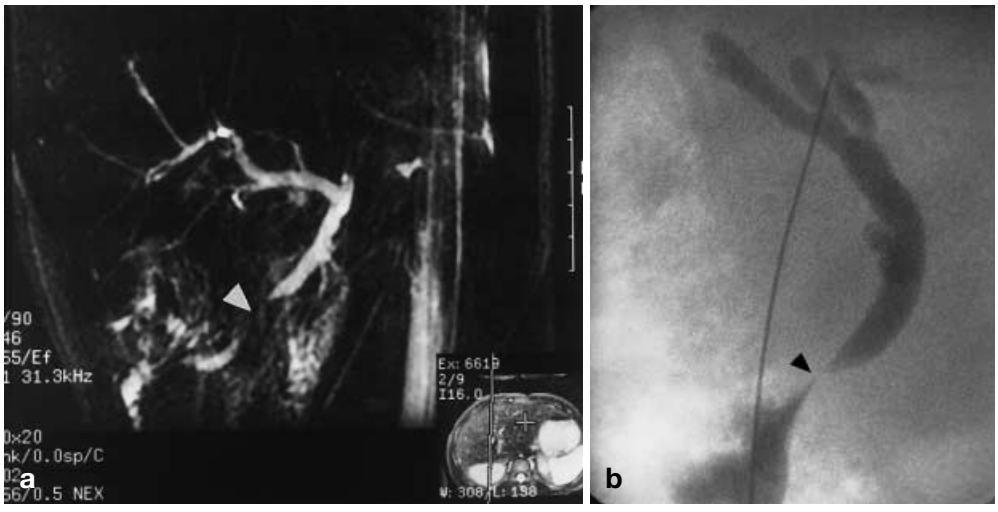

Fig. 1 Twelve-year-old boy with a left lateral segmental liver transplant × 2. MRC (**a**) performed in the direct sagittal plane demonstrates suspected biliary enteric anastomotic stricture (*arrowheads*) comfirmed by PTC (**b**)

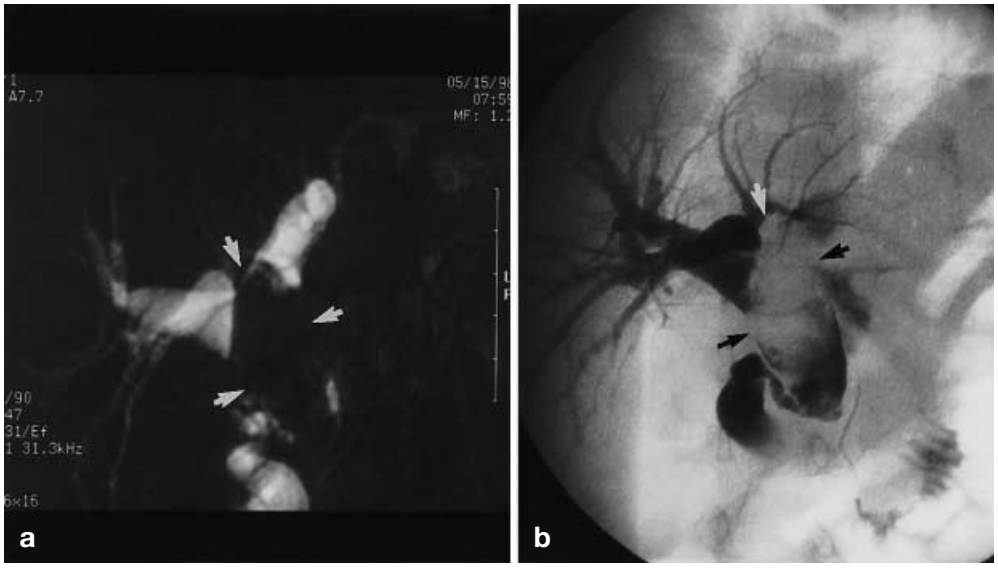

Fig. 2 Three-year-old boy with multifocal hepatoblastoma. MRC (**a**) and PTC (**b**) demonstrate a distended common bile duct (CBD) with a large intraluminal filling defect (*arrows*) compatible with intraductal tumor. Note that the left ductal system is less well visualized on PTC secondary to a right ductal puncture and central obstruction

breath-hold technique (either under sedation or conscious) or single breath-hold.

MRC

MRC findings correlated with PTC findings in seven out of seven cases. Two biliary-Roux loop anastomotic strictures (Fig. 1 a,b), one cystic duct remnant mucocele, one central ductal stricture secondary to hepatic arterial occlusion, and one intraductal tumor suspected by MRC were confirmed at PTC (Fig. 2 a,b). Two PTCs were unsuccessful in patients with non-dilated ducts by MRC, and no conflicting data were found at clinical follow-up.

MRC demonstrated a normal biliary tree in three patients, one central ductal narrowing in a cirrhotic liver (Fig. 3 a,b), two cases of suspected sclerosing cholangitis in children with inflammatory bowel disease, and one choledocholithiasis (Fig. 4 a,b). Findings were confirmed by ERCP in six out of seven cases.

Two suspected cystic duct remnant mucoceles and one tied off accessory left hepatic duct in a segmental OLTx diagnosed by MRC were all confirmed at surgery. On pre-MRC CT, a 1.5 cm mucocele was felt to represent a small biloma, and the second mucocele was not prospectively appreciated. In retrospect, owing to the small size of the second cyst, the spherical nature of the mucocele is not appreciable on CT. Two normal MRC studies demonstrated normal ducts at autopsy.

Liver biopsies were performed in 13 patients. Two patients with suspected sclerosing cholangitis were confirmed at biopsy. The remaining patients had normal

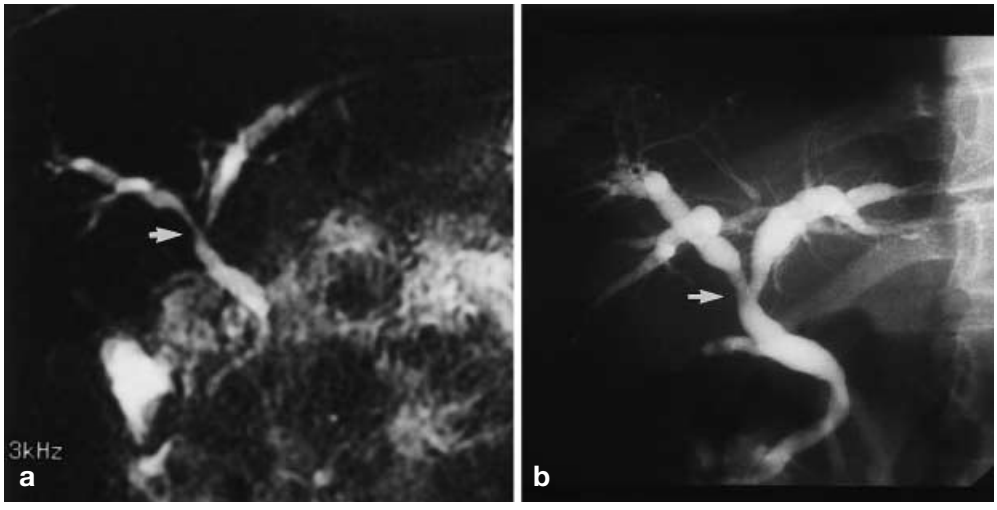

Fig. 3 Thirteen-year-old girl with cirrhosis. MRC (**a**) and ERCP (**b**) demonstrate central ductal narrowing (*arrows*). Note that the peripheral ducts are less well visualized on the MRC. Note that the true physiologic state of the peripheral ductal system is better demonstrated on MRC, as ductal distention occurred secondary to the pressure of the contrast injection during ERCP

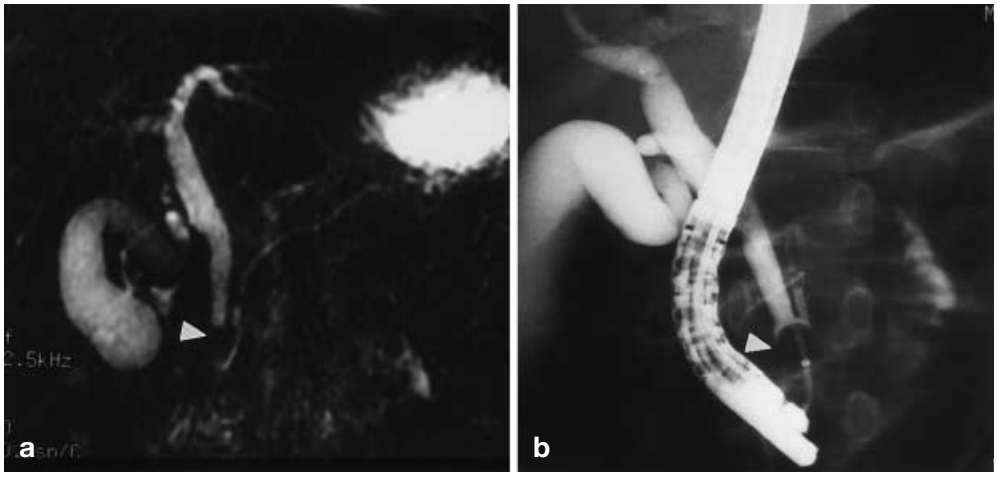

Fig. 4 Five-year-old boy who presented with abdominal pain and vomiting. An outside ultrasound demonstrated biliary tract obstruction without a cause. MRC (**a**) shows a filling defect in the distal common bile duct (*arrowhead*). ERCP (**b**) confirmed the suspected CBD stone (*arrowhead*), which was removed endoscopically

MRC and demonstrated rejection in five cases, and the remainder demonstrated normal findings, hepatitis, inflammation, mild fibrosis, and cholangitis.

MRP

MRP findings correlated with ERCP in four out of five cases. The discrepant case was normal by MRP and was interpreted as mild chronic pancreatitis by ERCP. However, pancreatic reserve was not evaluated with secretin and secondary ductal anatomy was not visualized on review of the ERCP, both of which are ERCP criteria for chronic pancreatitis. One dilated pancreatic duct with stones and three normal ducts were confirmed at ERCP. Two patients with normal MRP had unremarkable clinical follow-up. One patient with a normal MRP had a normal duct at autopsy. Secretin increased the conspicuity of the pancreatic duct in two out of three patients.

Discussion

MRCP is a water-based imaging technique that images fluid in the biliary tree by using heavily T2W images (TE = 1 s). At this echo time, signal has decayed in all body substances except those that have an extremely long T2 (i.e., water). This technique provides optimal contrast between the biliary tree and the background. However, periportal fluid will be isointense with bile and can potentially obscure anatomy. Bile in the distended gallbladder can be obscurative, but this problem can usually be minimized by choosing a plane that does not include the gallbladder, by fasting, or the use of ferric-based negative contrast agents. This potential problem did not cause interpretive difficulties in any cases.

Experience in children has been limited because most previous studies have required breath-holding, which is not feasible in the sedated child. It has been demonstrated that reliable images of the biliary tree

could be obtained using a non-breath-hold technique using 2D FSE imaging with 3D MIP with multiple samples to compensate for signal loss due to respiratory motion [1, 2]. This same 2D FSE imaging is currently being performed with respiratory trigger, which has decreased the motion artifact associated with this technique. However, this sequence can take up to 10 min to perform, which then requires post-processing. At the onset of the study, we performed both 2D FSE with 3D MIP reconstruction along with SSFSE. We found the overall image quality and duct conspicuity with the SSFSE superior to the 2D FSE with 3D MIP reconstruction [3]. We soon abandoned the 2D FSE technique and currently only use the SSFSE. The 2-s image acquisition allows this sequence to be performed on all patients regardless of whether they are sedated or unable to hold their breath. We found no difference in image quality between studies performed with single breath-hold or quiet respiration.

The extrahepatic and main bile ducts and the main pancreatic duct were visualized in all patients. The tail of the pancreatic duct is visualized less consistently. One must realize that with this technique one is visualizing ductal anatomy only within the volume of the slab selected. Peripheral ducts are less well seen. However, with MRCP, one is examining the pancreaticobiliary tree in its physiologic state. The ducts can be distended by the pressure of contrast injection during ERCP and PTC. Duct opacification with PTC depends on which system is punctured, while both right and left systems can be visualized equally well on MRC.

It has been shown that the sensitivity for the detection of choledocholithiasis by MRC is 95 % (comparable to ERCP) [4]. The sensitivity for the detection of biliary duct stricture by MRC is 94–100 % (comparable to ERCP) [5]. However, owing to its inferior spatial resolution compared to conventional radiography, MRC cannot distinguish between a benign and malignant stricture, a problem virtually non-existent in the pediatric population. The most common cause of stricture in the pediatric population is secondary to sclerosing cholangitis in patients with ulcerative colitis. In our two patients with this diagnosis, luminal irregularity and beading of the central intrahepatic bile ducts were suggestive and were comfirmed by ERCP. In a patient with a distal stricture, opacification of more proximal ducts may not be possible with ERCP. This is not a problem with MRC.

We have found MRC particularly useful in the liver transplant population. Biliary obstruction may occur secondary to a biliary enteric anastomotic stricture or owing to central ductal strictures secondary to hepatic artery occlusion. We also correctly diagnosed two cases of cystic duct mucoceles, causing extrinsic compression of the distal common bile duct. Prompt diagnosis is of paramount importance because a delay in treatment is associated with increased graft failure. Early in the course, CT and ultrasound may be unrevealing. ERCP is not possible in patients with biliary enteric anastomoses, and PTC has been the mainstay of diagnosis. Our findings were in complete agreement with correlative studies. Imaging plane selection is of particular importance in the segmental liver transplant. The neoporta hepatis is usually oriented in a more anterior/posterior direction; consequently, the slab must be oriented in sagittal/sagittal oblique plane rather than the usual coronal/coronal oblique plane. A normal MRC will likely obviate the need for a PTC. Laor et al. [6] and Norton et al. [7] found similar utility in imaging children with liver transplants with MRC.

Other uses for MRCP include evaluation of the jaundiced neonate and infant. MRCP may have the potential to differentiate biliary atresia from neonatal hepatitis. By demonstrating the entire extrahepatic bile ducts, one can reliably exclude biliary atresia [8]. MRCP has also been shown to have a 100 % sensitivity in the detection of choledochal cyst using the SSFSE technique and may demonstrate an anomalous pancreaticobiliary junction [9]. In the study by Chan et al. [10] demonstration of the pancreatic duct, and consequently the elongated common channel, in patients with choledochal cyst was less reliable. However, a 2D FSE with MIP reconstruction technique was used in this study. The use of secretin may increase the sensitivity in the detection of these ductal junction abnormalities. MRC has also successfully demonstrated the biliary and renal abnormalities associated with congenital hepatic fibrosis [11].

Acute pancreatitis in children is rare. Etiologies include trauma (accidental or inflicted injury), infection, drugs, stones, hereditary hyperlipidemia, and systemic disease (cystic fibrosis and sickle cell disease). In the absence of a definable cause, or in the case of recurrent pancreatitis, children will undergo an ERCP to evaluate for anomalous pancreaticobiliary junction or pancreas divisum. Hirohashi et al. [12] showed that MRP may be helpful in defining these ductal abnormalities in children, particularly those with recurrent pancreatitis. ERCP is expensive, technically difficult, requires general anesthesia in children, and can result in pancreatitis in up to 7 % of cases. Bret et al. [13] demonstrated a pancreas divisum in 6 of 108 patients, confirmed by ERCP with 100 % accuracy. MRP may reduce or eliminate the need for an endoscopic procedure.

Secretin is administered to improve the delineation of the pancreatic duct. It also adds physiologic data by examining how duct caliber changes under the influence of secretin. A normal response is improved visualization of the pancreatic duct with interval increase in duodenal fluid and then return of the duct to its pre-secretin state within 15 min. Persistent dilation suggests papillary stenosis, distal stricture, or dysfunction of the sphincter of Oddi [14].

To interpret MRCPs accurately, one must recognize potential shortcomings. Just as biliary sludge, blood clot, and air bubbles cause non-specific filling defects in contrast, they can decrease the signal in the bile and simulate stone [15]. Air is a potential problem in patients with OLTx because of the cholodochojejunostomy; however, to date we have not found this to be a problem in clinical practice. Hepatic arterial impressions can simulate a focal stricture. Folds in ducts can cause psuedofilling defects, which may be resolved by changing to thin 3- to 5-mm slices.

The advantages of MRCP are that it is non-invasive, has a lower complication rate than ERCP, is less expensive, requires no radiation or contrast injection, and is more physiologic. The disadvantages of MRCP is potentially poor definition of the peripheral biliary tree, and the inherent poor spatial resolution compared to conventional radiography.

Current indications for MRCP include unsuccessful ERCP, evaluation of biliary enteric anastomosis, and as a roadmap for therapeutic intervention. It has the potential to replace diagnostic ERCP and PTC. A normal study may obviate the need for the more invasive study. Abnormalities detected on MRCP can then direct the type of therapeutic intervention (ERCP, PTC, or surgery). This technique is feasible in the sedated child and in the child who can quietly breathe. In conclusion, it is an important addition to our imaging armamentarium in children with suspected pancreaticobiliary disease.

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