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MR cholangiopancreatography at 3.0 T in children: diagnostic quality and ability in assessment of common paediatric pancreatobiliary pathology

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Objective: To assess the diagnostic quality of MR cholangiopancreatography (MRCP) at 3.0 T in children and to assess its diagnostic ability in answering the clinical query. Also, to determine the frequency of artefacts and anatomic variations in ductal anatomy.

Methods: Consecutive MRCPs performed in children using a 3-T scanner were retrospectively reviewed to note indications, findings, imaging diagnosis, normal variants, quality and artefacts. Analysis was performed based on the final diagnosis assigned by pathology or the combination of clinical, laboratory, imaging features and follow-up to determine whether it was possible to answer the clinical query by MRCP findings.

Results: There were 82 MRCPs performed at 3.0 T on 77 children. 42/82 (51%) MRCPs were of good quality, 35/82 (43%) MRCPs were suboptimal but diagnostic and the remaining 5/82 (6%) MRCPs were non-diagnostic. MRCP answered the clinical query in 61/82 (74%) cases; however, it did not answer the clinical query in 11/82 (14%) cases and was equivocal in 10/82 (12%) cases. There was significant association between the quality of MRCP and the ability of MRCP to answer the clinical query ($p < 0.0001$). 64/82 (78%) MRCP examinations had at least 1 artefact. Variation in the bile duct anatomy was seen in 27/77 (35%) children.

Conclusion: MRCP performed at 3.0 T is of diagnostic quality in most cases and is able to provide an answer to the clinical query in the majority of cases.

Advances in knowledge: 3-T MRCP is feasible and useful in the assessment of pancreatobiliary abnormalities in children.

MR cholangiopancreatography (MRCP) is a radiation-free non-invasive imaging tool that is useful for evaluation of a variety of paediatric pancreatobiliary diseases [1–7]. These reported studies were performed using 1.5-T MRI scanners. The inherent improved signal available with 3-T scanners, which were introduced for clinical use in the last decade, is expected to improve the quality of MRCP [8]. MRCP at 3.0 T has been found to be superior in contrast-to-noise ratio and overall image quality in adult healthy volunteers and adult patients [9–12]. Paediatric MRCP is likely to benefit at 3.0 T even more because of the smaller calibre of ducts seen in young children. Its image quality and utility in the evaluation of paediatric pancreatobiliary abnormalities, however, have not been reported so far to the best of our knowledge.

We retrospectively reviewed MRCPs performed in children using a 3-T scanner, with the aim of assessing the diagnostic quality of MRCP at 3.0 T and of assessing its diagnostic ability in answering the clinical questions in a variety of pancreatobiliary diseases. We also reviewed MRCPs to determine the frequency of artefacts and variation in ductal anatomy.

PATIENTS AND METHODS

Institutional research ethics board approval was obtained for the study, with waiver for the need for individual patient consent. We retrospectively analysed all MRCPs performed in children on our 3-T scanner between January 2008 and June 2011. The patient list was obtained from a search of our database that records all patients scanned on the 3-T scanner.

MRCP technique

All MRI examinations were performed on a 3-T scanner (Achieva; Philips Medical Systems, Best, Netherlands). Each MRCP included the following sequences. (1) Respiratory-triggered three-dimensional (3D) T_2 weighted fast spin echo (FSE) with fat saturation [repetition time (TR) 3168 ms, echo time (TE) 700–900 ms, field of view (FOV) 250–380 mm, matrix 288×288 and slice thickness 2 mm with a 1-mm gap]. (2) Single-shot FSE

radial slabs in the coronal plane (TR 5764 ms, TE 740 ms, FOV 250–380 mm, matrix 320×320 and slab thickness 30–40 mm). These slabs were acquired with breath-hold in older children and during a shallower phase of respiration in younger children. (3) Coronal and axial single-shot FSE with moderate TE and thin section (TR 3000 ms, TE 160 ms, FOV 250–320 mm, matrix 256×256 and slice thickness 3 mm without any gap). These thin sections with moderate TE are very useful for visualising small ductal anomalies and connections and small biliary stones. (4) Axial T_1 weighted fat-saturated T_1 weighted high-resolution isotropic volume examination (THRIVE) sequence for pancreas (TR 3.1 ms, TE 1.4 ms, FOV 250–350 mm, matrix 192×192 and slice thickness 3 mm with a gap of 1.5 mm). This sequence shows pancreatic parenchyma as the bright structure in the upper abdomen. Gadolinium-based contrast medium and secretin were not administered.

Imaging review

All MRCP images were evaluated independently by a paediatric radiologist (6 years of experience) and a paediatric radiology fellow (2 years of experience). Differences were resolved by consensus reading. Both were aware of the clinical features but were blinded to the final diagnosis. MRCP examinations were reviewed, and the following information was recorded for each examination: clinical indication, diagnostic quality of the examination, major imaging findings, presence and type of artefacts, presence of an abnormal pancreatobiliary junction (PBj; the junction outside the duodenal wall with presence of a long common channel), anatomic variations in the hepatobiliary tree and the diagnosis based on MRCP (called MRCP diagnosis).

The diagnostic quality of the examination was graded as follows: (1) non-diagnostic (when both 3D FSE and single-shot radial slabs were completely degraded by artefacts); (2) suboptimal but diagnostic (partial degradation by artefacts with large pathology unlikely to be missed but quality not enough to exclude small duct variations, duct wall irregularities or tiny filling defects); and (3) good quality (3D FSE, radial slabs or both are of

good quality without significant artefacts with good visibility of small ducts).

Patient chart review

Charts were reviewed to note the clinical features, available pathology and final diagnosis. At this stage, assessment was also done to see whether, on review of MRCP, it was possible to answer the clinical query or not. These answers were noted as follows: “yes” when the MRCP diagnosis matched the final diagnosis, MRCP assessed progression/improvement in the known disease processes or MRCP depicted the anatomy clearly, for example in known cases of choledochal cyst; “no” when the MRCP was non-diagnostic or when the findings were missed on diagnostic MRCP as shown by other tests such as endoscopic retrograde cholangiopancreatography (ERCP); and “equivocal” when a definitive answer was not obtained.

Statistical analysis

Statistical analysis was performed to assess the correlation between ability to answer the clinical query and quality of the MRCP using Fisher’s exact test.

RESULTS

This retrospective study included 82 MRCPs in 77 children (47 males and 30 females, aged 19 days–18 years, average age 11 years). 16/82 MRCPs were performed in children younger than 5 years old (12 under sedation/anaesthesia and 4 awake), 8/82 examinations were performed in children aged 5–8 years (all awake) and the remaining 58/82 examinations were performed in children older than 8 years (56 awake and 2 examinations under anaesthesia in 1 child).

Indications for MRCP were broadly grouped into five major categories, including primary sclerosing cholangitis (PSC; [Figure 1](#)), pancreatitis ([Figure 2](#)), choledochal cyst ([Figure 3](#)), calculus disease ([Figure 4](#)) and miscellaneous. These are presented and summarised in [Table 1](#).

Final diagnosis

An attempt was made to assign each case a final diagnosis based on the clinical features, laboratory and imaging findings, pathology in available cases and follow-up. [Table 2](#) displays the final diagnosis in 77 cases. There were four cases in which a final diagnosis has not yet been established despite all work-up. Two of these

Figure 1. Primary sclerosing cholangitis in a 17-year-old male. Coronal radial slab MR cholangiopancreatography image shows mild dilatation of the extrahepatic bile duct (arrowhead), irregularity and beading of the intrahepatic ducts (short arrows) and a normal pancreatic duct (long arrows). GB, gall bladder.

four cases had equivocal findings for PSC, and one each had questionable common bile duct (CBD) stricture and normal MRCP with a history of pancreatitis.

Quality of MRCP

42/82 (51%) MRCPs were of good quality, 35/82 (43%) MRCPs were suboptimal but diagnostic and the remaining 5/82 (6%) MRCPs were non-diagnostic. Of the 77 diagnostic MRCPs, 16 were normal and did not show any abnormality.

Ability to answer the clinical query

MRCP answered the clinical query in 61/82 (74%) cases; however, it did not answer the clinical query in 11/82 (14%) cases and it was equivocal in the remaining 10/82 (12%) cases. Of the 11 cases in which MRCP did not answer the clinical query, 6 MRCPs were of non-diagnostic quality, 3 patients had primary sclerosing cholangitis–autoimmune hepatitis (PSC–AIH) overlap, 1 patient had multiple conditions including biliary atresia, neonatal sclerosing cholangitis and choledochal cyst, and the remaining 1 patient had a tiny stone in the distal CBD seen on ERCP. Of the 10 cases in which MRCP was equivocal, 4 patients had an unclear final diagnosis and 2 had PSC. The remaining cases had PSC–AIH overlap, pancreas divisum, xanthogranulomatous cholecystitis

Figure 2. Chronic pancreatitis in a 15-year-old female. (a) Coronal radial slab MR cholangiopancreatography image shows a markedly dilated and tortuous pancreatic duct (PD) with dilated side branches (arrows). GB, gallbladder. (b) Axial T_2 weighted image shows atrophy of the pancreas with a dilated tortuous PD (arrows). Arrowheads indicate the normal common bile duct.

(a)

(b)

and one had multiple conditions including biliary atresia, neonatal sclerosing cholangitis and choledochal cyst. The child with multiple conditions (biliary atresia, neonatal sclerosing cholangitis and choledochal cyst) had MRCPs on two occasions.

On statistical analysis using Fisher's exact test, there was a significant association between the quality of the MRCP and the ability of MRCP to answer the clinical query ($p < 0.0001$).

Figure 3. Choledochal cysts (CDCs). (a) Coronal radial slab MR cholangiopancreatography image in a 14-year-old female shows a type I CDC with a mildly dilated common hepatic duct (arrowhead). There is a long common channel (long thin arrow) after the pancreatobiliary junction. The short thick arrow indicates the pancreatic duct (PD). GB, gallbladder. (b) Coronal maximum intensity projection image from three-dimensional MRCP in an 11-year-old male shows a choledochoceles (thin long arrow). There is also pancreas divisum with the PD (short thick arrows) opening separately at the minor papilla (curved black arrow) instead of joining the common bile duct (arrowhead). dd, duodenum.

(a)

(b)

Figure 4. Choledocholithiasis in a 3-month-old male with biliary obstruction. (a) Coronal maximum intensity projection image from three-dimensional MR cholangiopancreatography shows marked dilatation of the common bile duct (arrowhead) with a sharp cut-off distally (arrow). (b) Coronal thin section (3 mm) T_2 weighted image with echo time 200 ms shows a round black filling defect (arrow) in the distal common bile duct (CBD) causing dilatation of the CBD (arrowhead). (c) Axial THRIVE T_1 weighted fat-saturated image shows the distal CBD stone as a bright round structure (short thick arrow) in the head of the pancreas (thin long arrow). dd, duodenum; GB, gallbladder.

Abnormal pancreatobiliary junction

5/77 children showed an abnormal PBJ with a long common channel (Figure 5). If a single duct was seen after the joining of the CBD and the pancreatic duct (PD), it was considered to be a long common channel. The length of the common channel varied from 6 to 15 mm (average 9.25 mm). Three out of the five children with an abnormal PBJ had a choledochal cyst, one had pancreatitis and the remaining one had both a choledochal cyst and pancreatitis. Three out of the five children had subsequent ERCP that confirmed the finding.

Anatomic variations

Intrahepatic bile duct variations were documented in 27/77 (35%) children and included a right posterior duct joining the left hepatic duct in 10 children

(Figure 6a), a right anterior duct joining the left hepatic duct in 5 children, a right posterior duct joining the common hepatic duct in 4 children, a triple confluence (right anterior, right posterior and left hepatic duct joining at the same level to form common hepatic duct) in 6 children and small extra ducts joining a confluence in 2 children. The cystic duct insertion was called a low insertion when the cystic duct was seen running parallel to the hepatic duct down towards the head of the pancreas (Figure 6b). 6/77 children showed low cystic duct insertion, with 2 of them showing an anteromedial insertion rather than the usual lateral insertion. PD variations were seen in four children, including pancreas divisum in two and one case of ansa pancreatica and one case of a large side branch of the PD. Ansa pancreatica is a rare ductal anomaly in which an accessory PD is obliterated at its junction with the ventral

Table 1. Indications for MR cholangiopancreatography (MRCP) in 82 cases

Indication	Number of MRCPs (%)
Primary sclerosing cholangitis (10 known cases, 29 suspected)	39 (48)
Pancreatitis (one or more episodes of pancreatitis, to assess the pancreatobiliary tree and possible cause)	16 (20)
Choledochal cyst (known or suspected choledochal cysts from previous imaging)	15 (18)
Calculus disease (suspected from clinical features or known from ultrasound)	8 (10)
Miscellaneous (2 MR cholangiopancreatographies in the same child with a duodenal haematoma and 1 each with suspected biliary atresia and Rosai–Dorfman disease)	4 (5)

Table 2. Final diagnosis in 77 cases

Diagnosis	Number of cases
Primary sclerosing cholangitis	17
Primary sclerosing cholangitis/autoimmune hepatitis overlap syndrome	7
Autoimmune hepatitis	5
Choledochal cyst	12
Chronic pancreatitis (PD stone, pancreas divisum, ansa pancreatica with <i>SPINK</i> gene with PD stone)	3
Acute/recurrent pancreatitis (5 with no cause, 3 biliary stones and 6 with different reasons)	14
Hereditary spherocytosis (1 with stone and the other after laparoscopic cholecystectomy)	2
Gallbladder stones	2
Common hepatic duct stricture in previous laparoscopic cholecystectomy	1
Hereditary elliptocytosis	1
Biliary hamartomas with gastritis	1
Transient dilatation of the bile ducts of unknown cause	1
Duodenal duplication cyst	1
Duodenal haematoma	1
Rosai–Dorfman disease	1
Neonatal hepatitis	1
α_1 -antitrypsin deficiency	1
Choledochal cyst and biliary atresia complicated with neonatal sclerosing cholangitis	1
Ulcerative colitis (normal biliary tree)	1
Not yet diagnosed	4

PD, pancreatic duct; *SPINK*, serine protease inhibitor Kazal Type 1.

PD and replaced by an arched duct that runs from the ventral PD anteriorly and ends in or around the minor papilla.

Artefacts

Significant artefacts were seen in 64 cases. Artefacts included patient and respiratory motion, overlap of excess fluid containing structures such as bowel with ducts, heterogeneity of signal, wrap, Moiré fringe and chemical shift artefacts.

Artefactual apparent narrowing in the region of confluence or the common hepatic duct was seen in 11/82 MRCPs. This can be mistaken for bile duct stricture unless correlated with the review of other sequences. On reviewing other images including axial and coronal T_2 weighted images, narrowing in 9/11 was caused by

hepatic arterial branch crossing (Figure 7) and in 2 cases by portal vein crossing.

DISCUSSION

3-T MRI scanners were introduced for clinical use several years ago to take advantage of the inherent higher signal-to-noise ratio present at 3.0 T than at 1.5 T. This increased signal can be used to improve the resolution by increasing the matrix or to reduce the scan time. This high signal is expected to benefit many MR applications including MRCP. Actual improvement in the image quality of MRCP at 3.0 T has been shown in adults [9–12]. Given the reduced anatomic size of the biliary ducts and the reduced amount of bile contained, the improved high signal is likely to be of more benefit for paediatric MRCPs. It would be ideal to do an inpatient comparison of MRCP at 3.0 T and 1.5 T to

Figure 5. A long common channel in a 5-year-old male with a choledochal cyst and a history of pancreatitis. (a) Coronal radial slab MR cholangiopancreatography image shows a long common channel (thin long arrow), dilated extrahepatic duct (arrowhead) in keeping with a type I choledochal cyst and a normal pancreatic duct (PD; thick short arrow). dd, duodenum; GB, gallbladder. (b) Coronal endoscopic retrograde cholangiopancreatography image shows a dilated extrahepatic duct (arrowhead), normal PD (short arrow) and a long common channel (thin long arrow).

(a)

(b)

assess the change in the image quality and clinical benefits. However, this is difficult and may not be feasible in the paediatric population, especially when one

Figure 6. Ductal variations. (a) Coronal radial slab MR cholangiopancreatography image shows the right posterior duct (arrow) joining the left hepatic duct (2) instead of joining the right anterior hepatic duct (1). Arrowhead indicates the common bile duct. dd, duodenum. (b) Axial T_2 weighted fat-saturated image shows low insertion of the cystic duct (short thick arrow) running parallel to the common bile duct (arrowhead) in the head of the pancreas. Long thin arrow indicates the pancreatic duct. dd, duodenum.

(a)

(b)

considers the frequent need for sedation. We attempted to assess the image quality of 3-T MRCPs and its effect on answering the clinical query. Overall, only 6% of MRCPs were non-diagnostic. The remaining 94% of MRCPs were either good quality or suboptimal but diagnostic. This indicates a slight improvement compared with the study at 1.5 T by Delaney et al [2] in which 85% of MRCPs were diagnostic. In our study, MRCP was able to answer the clinical query in 74% of cases. As expected, there was a significant correlation between the quality of

Figure 7. Artefactual narrowing at the hepatic ducts confluence in a 15-year-old female with a duodenal haematoma. (a) Coronal maximum intensity projection image from three-dimensional MR cholangiopancreatography shows apparent narrowing (long arrows) at the confluence of the right (1) and left (2) hepatic ducts. There is mild dilatation of the common bile duct (arrowhead) and pancreatic duct (PD; short thick arrow). There is also a variation in the PD, with an unusual large branch arising in the body (curved arrow). (b, c) Coronal thin T_2 weighted fat-saturated images show the right hepatic artery (broken arrows) crossing the confluence. 1, right hepatic duct; 2, left hepatic duct; GB, gallbladder.

the MRCP and its ability to answer the clinical query ($p < 0.0001$).

PSC was the most common indication for MRCP in children in our study. All the PSC cases were truly primary and did not include any secondary causes such as Langerhans cell histiocytosis. This was followed by the evaluation of choledochal cysts and work-up of children with one or more episodes of pancreatitis. MRCP is performed in children with pancreatitis to rule out structural abnormalities of the pancreatobiliary tree and biliary calculi as they predispose to pancreatitis. It is also performed in the evaluation of chronic pancreatitis. MRCP is also useful for the evaluation of choledochal cysts and biliary calculus disease as shown in our study. In addition to showing the pancreatic parenchyma very well, a 3D T_1 gradient echo sequence such as THRIVE/volumetric interpolated breath-hold examination (VIBE) also helps to detect stones in the distal CBD. Most pigment stones are bright on this sequence (Figure 4c) [13].

The junction of the CBD and PD is considered to be abnormal when it is outside the sphincter of Oddi with a common channel visible after the junction. The abnormal junction outside the sphincter is thought to allow reflux of pancreatic secretions into the biliary tree and vice versa and probably plays a role in the pathogenesis of choledochal cysts as well as pancreatitis [7,14]. Some authors are of the view that, in a long common channel, hypertrophy and spasticity of the

sphincter choledochus inferior resulting in increased pressure in the bile duct rather than reflux of pancreatic juices results in the formation of a choledochal cyst [15]. A common pancreaticobiliary channel of >15 mm in length is considered to be abnormal in adults [16]. However, there are limited data on the normal length of the common channel in children, with only one recent study using 5 mm as a cut-off value [17]. We found an abnormal PBJ in 5/77 children, with ERCP confirmation in 3. The common channel in five children ranged from 6 to 15 mm in length, with an average of 9.25 mm. All of these children had choledochal cyst or pancreatitis supporting the role of an abnormal PBJ in the pathogenesis of choledochal cysts as well as pancreatitis. Anatomic variations in bile ducts are common and were seen in 35% of children in our study.

Significant artefacts were seen on 64/82 (78%) MRCPs. The majority of artefacts were related to breathing and other motions. The use of proper respiratory compensation techniques, such as respiratory triggering in small children and breath-hold in older children, helps to eliminate these artefacts significantly. Practising breath-hold techniques with children before starting the scan helps to improve the image quality. 4–6 h of fasting in older children can reduce the fluid content in the upper gastrointestinal tract and improves image quality in MRCP. Selection of the smallest coil appropriate for the size of the child and selection of an adequate FOV to improve the signal-to-noise ratio and reduce incidences of dark MRCP images are also helpful.

The limitations of our study included it being a retrospective review and having a relatively small sample size for each pathology type. Nonetheless, this study gives an indication of the utility of MRCP performed at 3.0 T in a variety of actual clinical cases.

CONCLUSION

MRCP performed at 3.0 T is of diagnostic quality in most cases and is able to provide an answer to the clinical query in the majority of cases. At least one artefact was seen in most MRCPs. Variation in bile duct anatomy was seen in 35% of children.

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