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REVIEW

Pancreatitis and the role of US, MRCP and ERCP

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Abstract Imaging plays a crucial role in the diagnosis of acute and chronic pancreatitis in children. Ultrasound (US) is the primary imaging modality. The US study can be improved by incorporating high resolution imaging, color Doppler, harmonic imaging and panorama view. Computer tomography (CT) is widely used for further evaluation. MR imaging in combination with MR cholangiopancreaticography (MRCP) is emerging as the modality of choice. It is non-invasive and radiation-free. It has high potential to replace endoscopic retrograde cholangiopancreaticography (ERCP), too. The latter is becoming more of an interventional tool. This review discusses the current status and comparative diagnostic potential of US, MRCP and ERCP.

Keywords Pancreatitis · Diagnostic imaging · Ultrasound · MRI/MRCP · ERCP

Introduction

Acute and chronic inflammatory disorders of the pancreas in children and adolescents cause significant morbidity and mortality. Acute pancreatitis is characterized by sudden onset abdominal pain and rise in pancreatic enzymes with ultimate complete structural and functional restitution. Chronic pancreatitis results in structural changes, encompassing chronic inflammatory cell infiltration and gland fibrosis, with endocrine and exocrine function loss.

Acute pancreatitis, though less frequent in children compared to adults, appears to be on the rise. Nydegger et al. analyzing the data of a major pediatric referral center found a significant increase in the incidence of acute pancreatitis over the past decade from 24.6 to 31.2 cases per year [1]. In a review of published data, spanning almost four decades and comprising 589 pediatric patients, the mean age of acute pancreatitis was 9.2 years (range 1 week–21 years) with a male to female ratio of 1:2 [2]. The main presenting symptoms of acute pancreatitis include abdominal pain (87%), abdominal tenderness (77%) and abdominal pain and vomiting (64%) [2]. Serum amylase and lipase levels need to increase threefold or more to be considered significant for diagnosis [3]. Up to 40% of children have normal amylase level with pancreatitis. The most common etiologies are idiopathic (23%), trauma (22%), structural anomalies (15%), multisystem diseases (14%), drugs and toxins (12%) and viral infections (10%) [2]. Recurrence is reported in 9% of patients. The mortality rate of acute pancreatitis is almost 10%.

Pediatric data on incidence and prevalence of chronic pancreatitis is limited. The etiology of chronic pancreatitis in children comprises cystic fibrosis, fibrosing pancreatitis, hereditary chronic pancreatitis and inborn errors of metabolism [3, 4]. Abdominal pain can be marked. In later stages steatorrhea and weight loss will manifest. The complications of chronic pancreatitis include pancreatic pseudocyst, pseudoaneurysm, splenic vein thrombosis, pancreatic fistula, common bile duct and duodenal obstructions. The lifetime risk of pancreatic adenocarcinoma is reported to be 4% but approaching 40% in those with hereditary pancreatitis [3].

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Diagnostic imaging for pancreatitis plays an important role in the initial diagnosis, follow-up, screening for endoscopic studies and surgical planning. The fact that in 81% of acute pancreatitis in children the diagnosis was based on ultrasound (US) underlines the importance of imaging study [2]. It is US and computer tomography (CT), due to their widespread availability, non-invasiveness, and familiarity to practitioners that are primarily used in the diagnosis of pancreatitis [3, 5]. CT not only lacks poor sensitivity to identify ductal abnormalities and subtle parenchymal changes, but has high radiation dose [3, 6]. Thus more advanced US and magnetic resonance imaging (MRI) including MR cholangiopancreaticography (MRCP) are having increasing importance in the imaging of pancreatitis in children. Endoscopic retrograde cholangiopancreaticography (ERCP) is becoming more of an interventional tool and less a diagnostic examination. This review presents the advances and current diagnostic potential of US, MRI/MRCP and ERCP in the imaging of pancreatitis in children and adolescents.

Ultrasonography [US]

When pancreatitis is suspected in children US is usually the initial imaging modality. Smaller size of patients, lack of fat and prominence of left hepatic lobe make US of the pancreas more feasible than in adults. In non-emergent cases the study is carried out after the patient has fasted at least 4 h or in infants before the next meal. Usually patients presenting with acute pancreatitis have had no oral intake for sometime. The patient is scanned in supine position. In case of inadequate visualization of the pancreas, depending on the condition of the patient, a scan is carried out after the patient is given some water to drink. The water-filled stomach serves as an acoustic window and the patient can in addition be scanned in right and left lateral decubitus positions. The US study should incorporate high-resolution transducers, harmonic imaging and color Doppler.

There is lack of comparative studies assessing the diagnostic accuracy of US for the diagnosis of pancreatitis in children. In adults sensitivities of 62–67% and 50–80% have been reported for acute and chronic pancreatitis, respectively [3]. It is obvious that there is great variation in the diagnostic potential of US depending on the type, etiology, stage and presence of complications of pancreatitis. The echogenicity of the normal pancreas in children is predominantly iso- or hyperechogenic (90%) to the liver. Only in 10% of cases it is hypoechogenic [7]. The distribution of the echogenicity in pancreatitis is similar and thus not a helpful diagnostic feature. The measurement of the size of the pancreas is age-dependent [7]. The normal pancreas has a similar sized head and tail with a thinner body. The enlargement of the pancreas in pancreatitis can be diffuse or focal (Fig. 1). However, pancreatic enlargement has been reported to be absent in about half of the cases [7]. A recent study in 51 children with pancreatitis found significant difference in the diameter of the body of the pancreas in patients with acute pancreatitis compared to age-matched controls [8]. This was not true for patients with chronic pancreatitis. In healthy children the pancreatic duct diameter is 1.65±0.45 mm. Chao et al. found the mean diameters of the pancreatic duct in acute and chronic pancreatitis to be 2.34±0.47 mm and 2.84±0.67 mm, respectively [8]. Pancreatic ducts with diameters greater than 1.5 mm in children between 1 and 6 years, greater than 1.9 mm at ages 7–12 years, or greater than 2.2 mm at ages 13–18 years were significantly associated with the presence of acute pancreatitis. Thus for the evaluation of acute pancreatitis size and echogenicity are least reliable and the documentation of the pancreatic duct with high resolution transducers is the most useful feature to assist with the diagnosis. US is useful in the depiction of pseudocysts, the main complication of pancreatitis. Pseudocysts are usually solitary, located within or outside of the pancreas and appear anechoic with well-defined borders and posterior reinforcement [9]. Hemorrhagic pancreatitis has variable presentation depending on the phase of the disease, hyperechoic mass-like appearance in the early phase to a cystic one in the later stage. Calcifications of the pancreas and intraductal stones can be depicted with US in chronic pancreatitis.

There are a number of recent advances in sonographic imaging of pancreatitis. One of them is the use of intravenous US contrast agent. Contrast-enhanced US was

Fig. 1 A 5-year-old boy with acute pancreatitis. The US examination using harmonic imaging (*THI*) shows a swollen pancreas. The head of the pancreas (*arrows*) is more edematous and hyperechogenic than the rest (normal maximal values for age: head 19 mm, body 10 mm, tail 16 mm). There is no pancreatic duct dilatation

compared with non-contrast US and CT in the diagnosis of acute pancreatitis in adults [10]. Pancreatic necrosis was detected in both contrast-enhanced US and CT in 8/31 (26%) of patients. This was possible in only two (6%) of cases with native US. In US elastography pressure is applied to tissue and resulting differences in distortion between hard and soft tissues are used for real-time visualization of the hardness of various tissues. The images represent tissue elasticity information reflecting histopathologic differences. The comparison of gray-scale US alone and gray-scale US combined with elastography showed in 23 adult patients with chronic pancreatitis correct diagnosis rates of 73.9% and 95.7%, respectively. Endoscopic US (EUS) is increasingly gaining access in the diagnostic imaging of pancreaticobiliary disorders in children [12]. The high diagnostic accuracy and the low complication rate (1%) compared to ERCP are the driving forces for its use. It can also be combined with fine needle aspiration. In one study in children EUS was technically feasible in those as young as 5 years of age [12]. EUS enabled to preclude the need of ERCP in 9/14 (65%) of the patients including six with recurrent pancreatitis. The advances in US for diagnosis of pancreatitis are in their early stages in adults or just starting to be transferred to pediatric diagnosis and show promise of making significant positive change.

MR cholangiopancreatography [MRCP]

MRCP has the main advantage of being non-invasive and without radiation. Unlike ERCP it can be performed in the acute stage of pancreatitis. At MRCP the ducts are visualized in their normal physiologic state, whereas at ERCP they are imaged under pressure. MRCP can provide a comprehensive morphology of the biliary and pancreatic ducts. It is possible to visualize ducts as small as 1 mm [13]. However, MRCP in children is limited by small-caliber non-dilated ducts, poor signal and patient motion. In one large retrospective study of MRCP in children pancreatitis was found to be the main indication [14].

MRCP needs to be carried out using the smallest receiver coil that fits the patient. A quadrature knee, head or flexible surface coils can be employed for imaging neonates and infants. Negative oral contrast in non-sedated children can decrease bright signal from stomach and duodenum (ferumoxsil oral suspension (Gastromark, Mallinckrodt Medical, Raleigh, NC) or pineapple juice) [14]. Respiratory triggering is important as breath-hold techniques are difficult in younger children. Heavily T2 weighted sequence is the main one for the MRCP in a coronal or coronal oblique plane so that the entire pancreatic ducts and their mergence in the papillae are included. A comprehensive technical review of MRCP in children has been presented by Chavhan et al. [13].

Secretin, a polypeptide hormone, induces increased fluid signal in pancreatic duct and subsequent fluid excretion into the duodenum. It is administered intravenously slowly over 1 minute at a dose of 0.2 μg/kg body weight (maximum16 μg) [13]. T2 coronal images along the pancreatic duct are repeated every 30 s for 10 min. The normal response is increase in signal and diameter of pancreatic duct up to 3 mm in 3–5 min with progressive decline to baseline in 10 min. Secretin is probably more important in children than in adults as it increases the detectability of the normally smaller pancreatic ducts. 15 children, 6–17 years old, with idiopathic chronic pancreatitis underwent MRCP before and after secretin administration [15]. The number of main pancreatic duct segments visualized on MRCP was 24/45 (53%) before and 42/45 (93%) after administration of secretin. The visualization of the duct of Santorini increased from 1/15 (7%) to 8/15 (53%) of patients after secretin administration. The detection of side branches increased from 20% to 47%, too. The conspicuity of cavities and main pancreatic duct contour irregularity improved, too.

MRI combined with MRCP has been shown to be a reliable alternative to contrast-enhanced CT for assessing severity of acute pancreatitis and predicting its outcome in adults (Fig. 2) [16]. MRCP with secretin allows the detection of pancreatic duct disruption, something difficult to do with CT. In 39 adult patients with pancreatitis MRCP was followed by ERCP within a month (mean 13 days) [17]. The biliary and pancreatic ducts were divided in segments for the evaluation. Of the total 196 segments analyzed 17 were not seen at MRCP (sensitivity 91%). Of the segments visualized 14 were incorrectly characterized (accuracy 92%). At ERCP 42 segments in 19 patients were not seen. In 75% the results between MRCP and ERCP

Fig. 2 MRI of acute necrotizing pancreatitis. Post-contrast T1-weighted sequence with fat saturation shows the massive swelling and then non-enhancing parts of the pancreas

were concordant. In 16 children MRCP was followed by ERCP within 2 months. The two studies were concordant in 81% [14]. The comparison of MRCP with endoscopic US in 99 adult patients suspected of having chronic pancreatitis revealed the sensitivity of MRCP (65%) to be lower than that of endoscopic US (93%), whereas there was no significant difference of the specificity [18]. MRCP has been shown to be useful in identifying and ruling out structural abnormalities of the pancreaticobiliary tract in children suspected of having acute pancreatitis (Fig. 3) [19]. MRCP has 100% accuracy in the evaluation of choledochal cyst and 40–83% detection rate of abnormal pancreaticobiliary junction [13].

There are promising advances in MR that may further enhance the diagnostic potential for pancreatitis. 3T MR of the pancreas in adults has been shown to increase more the signal-to-noise ratio for the post-contrast imagings than for the pre-contrast ones [20]. Currently, MRCP is more challenging at 3T and the maximum image quality possible has not been yet achieved [21]. MR with diffusion-weighted imaging showed the apparent diffusion coefficients (ADC) values to be reduced in patients with chronic pancreatitis [22]. MR with pre- and post-contrast sequences including MRCP is emerging as the next possible diagnostic imaging step after US (Fig. 4).

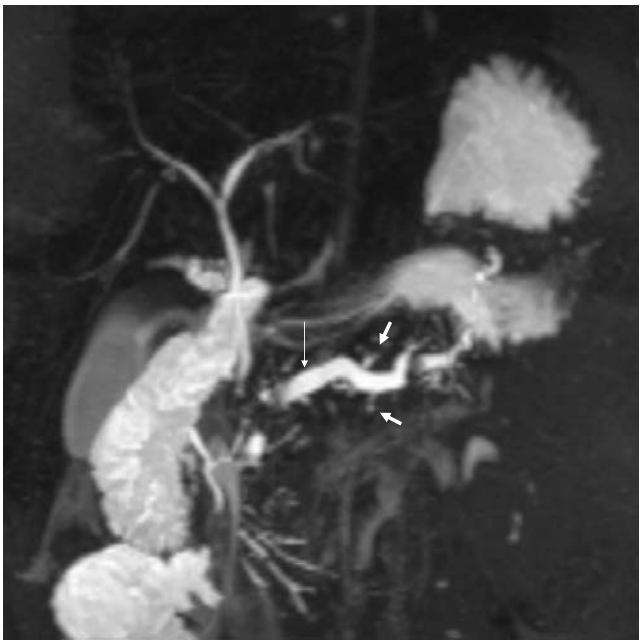

Fig. 4 Fourteen-year-old-girl with chronic pancreatitis. Coronal MIP of the MRCP shows the dilated pancreatic duct (*long arrow*) with irregular outpouchings representing pancreatic dilated side branches (*short arrows*)

Endoscopic retrograde cholangiopancreaticography [ERCP]

ERCP is difficult to perform in young children and is not widely available. The complication rate of ERCP reported in the literature ranges from 0–11%, and is more common with therapeutic intervention (17%) and particularly when manometry (11–22%) of biliary and pancreatic sphincters is performed [23]. The most common indications for ERCP in children are biliary obstruction and pancreatitis [23, 24]. For the procedure general anesthesia is necessary in 27–60% of the patients with the rest receiving some form of sedation [23, 24]. The success rate of the procedure in children with cannulation of the ampulla has been reported to be 94–97% [23, 24]. Overall in about on-third of cases the ERCP turns out to be normal. Sphincterotomy with or without stone extraction are carried out in 45% of ERCPs in children. In a small study incorporating 17 children ages 3–16 years the use of ERCP was evaluated in recurrent acute (13) and chronic (four) pancreatitis [25]. In 52% of patients the ERCP altered the therapy. The comparison of ERCP with MRCP has been outlined above. The NIH state-of-the-science statement on ERCP for diagnosis and therapy states: “ERCP has no role in the diagnosis of acute pancreatitis except when biliary pancreatitis is suspected” and “ERCP with appropriate therapy is beneficial in selected patients who have either recurrent pancreatitis or pancreatic pseudocyst” [26]. The role of ERCP in the era of MRCP has become more of an interventional tool.

In conclusion, US and MRI are increasingly becoming the radiation-free modalities of choice for the diagnosis of acute and chronic pancreatitis in children. MRCP provides comprehensive morphological depiction of the biliary and

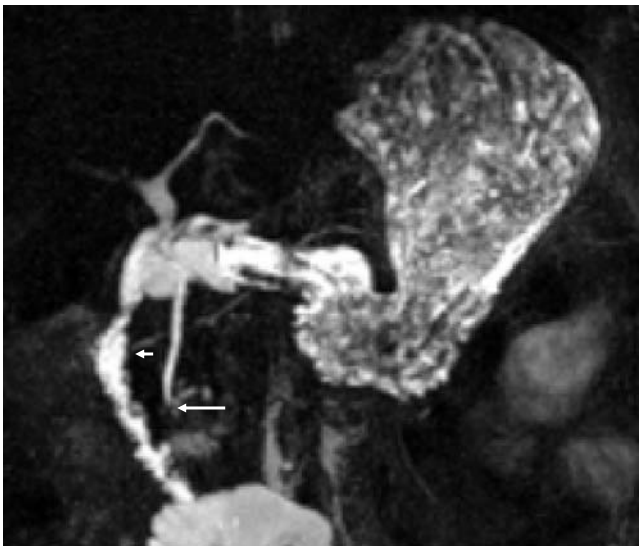

Fig. 3 Pancreas divisum in a case of chronic pancreatitis. Coronal MIP of the MRCP demonstrates separate drainage of the main pancreatic duct (*short arrow*) and the common bile duct (*long arrow*)

pancreatic duct making ERCP unnecessary for diagnostic purposes.

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