Introduction

The use of MRI to investigate the pancreas has undergone an important evolution owing to the improved performance of gradient and phased-array coils as well as advances in fast MRI techniques. Indeed, there is now the possibility of acquiring respiratory-free T2-weighted and breath-hold T1-weighted high-resolution scans to investigate the pancreatic parenchyma, in combination with single-shot MRCP for ductal assessment, in less than 5 minutes. Furthermore, the addition of extracellular contrast agents (gadolinium chelates) and/or hormonal stimulation with secretin enables morphology and exocrine function evaluation to be combined in a single examination. Finally, the possibility of acquiring high-b-value diffusion weighted images with acceptable signal-to-noise ratios (SNRs) has the potential to extend the performance of MRI in investigating the pancreas.

Imaging of the Parenchyma

Our current imaging protocol to investigate the pancreatic parenchyma includes a combination of turbo spin-echo (TSE) T2-weighted and gradient-echo (GRE) T1-weighted sequences. To increase flexibility and minimize patient cooperation, TSE T2-weighted scans are acquired with respiratory triggering (during free breathing) and include the whole liver and pancreas. If a peripancreatic exudate is suspected, we acquire a more heavily T2-weighted scan instead of applying fat suppression that may decrease the conspicuity of pancreatic contours. With these sequences, fluid-filled lesions in or around the pancreas can be seen.
The bile and pancreatic ducts are also shown on cross sections and this may be useful to choose the best plan for MRCP series. T1-weighted scans are generally obtained in the transverse plane during breath hold. Dependent on patient cooperation and anatomy, 2D (shorter acquisition time) or 3D (longer acquisition time, better spatial resolution, possibility of multiplanar reconstructions) GRE sequences can be used in combination with fat suppression. On T1-weighted scans, fat suppression a) improves the delineation of pancreatic borders and the pancreas itself, which appears homogeneously bright compared with the surrounding low-intensity fat; b) is excellent in demonstrating focal disease and c) is suitable for contrast-enhanced studies. However, in the presence of diffuse inflammatory conditions, as in chronic pancreatitis, T1-weighted sequences with fat suppression are less accurate, because of the diffuse low signal intensity of the pancreas, and gadolinium-enhanced studies should be performed. After intravenous gadolinium administration, three multiphase scans (arterial, portal venous and delayed) are acquired. The 3D sequence allows multiplanar reconstructions and multiphase MR angiography renderings. The normal pancreas enhances maximally during the pancreatic arterial phase (15-20 seconds) and becomes isointense to the liver during the later phases.

We can now add routinely to these “conventional” sequences high-b value (b=1000) diffusion-weighted scans. Diffusion sequences are performed in the axial plane before gadolinium administration and we use STIR for fat suppression. Although non specific, this approach may help in identifying the disease and in the differential diagnosis between pancreatic cancer and pancreatitis.

**Imaging the ducts**

MRCP renderings are achieved with heavily T2-weighted imaging that selectively display static fluid-filled structures (bile ducts, gallbladder, pancreatic ducts, stomach and
duodenum) with high signal intensity. We perform a breath-hold projection that can be obtained in any chosen plane in less than 3 seconds. No exogenous contrast is needed and the final image resembles the conventional image obtained during endoscopic retrograde cholangiopancreatography (ERCP). With projection technique, possible overlap of pancreatic ducts and fluid containing structures may occur. In such conditions the ingestion of a negative contrast agent that eliminates the signal of the superimposed structure may help in defining the pancreatic ducts. Furthermore the short acquisition time of this technique allows sequential acquisitions during a single breath hold after exogenous secretin stimulation. Alternatively 3D TSE T2-w sequences (thinner slices and post-processing capabilities) may be used as a problem-solving tool namely for cystic lesions to demonstrate a possible communication with the main pancreatic duct.

**Functional imaging with secretin (S-MRCP)**

The exogenous administration of secretin stimulates the secretion of fluid and bicarbonate by the exocrine pancreas. Consequently the volume of fluid in the pancreatic ducts increases, and their delineation is improved on MRCP. It has been shown that secretin administration improves the visualization of the entire course of the main pancreatic duct (mpd), the detection of anatomic variants such as pancreas divisum, and the detection of side branches and accessory pancreatic duct. Endoscopic manometry studies have shown that the effect of secretin stimulation on pancreatic fluid flow and the associated increase in mpd pressure is transient, and in normal subjects an almost complete return toward basal values is observed after 5 minutes. To evaluate these pancreatic flow dynamics, once the appropriate MRCP projection has been defined (usually coronal that shows the entire course of the mpd, the biliary tract and the duodenum), the scan is repeated every 15-30 seconds during 10-15 minutes after intravenous secretin administration. Secretin is administered at the dose of 1
CU/ Kg of body weight (standard dose). Indeed the use of secretin during S-MRCP investigations significantly increases the cost of the examination. In this setting, we have demonstrated that the stimulating effect of 0.3 CU/kg of body weight is comparable to the standard dose and it considerably reduces the costs of S-MRCP.

In normal subjects, during the first 2-3 minutes after secretin injection, the mpd enlarges followed by a return to near baseline diameter as pancreatic juice fills the duodenum. As already shown by ERCP and also by conventional MRCP, the diameter of the mpd significantly increases with age in absence of biliary and pancreatic disease. On S-MRCP, we considered abnormal the diameter of the mpd when greater than 3 mm at the body of the gland at the end of the stimulation period in patients younger than 60 years old. However, other variables such as the percentage of diameter variation, the time to reach the maximum diameter, the presence of a prolonged dilatation of the mpd and of side branches and the occurrence of a progressive enhancement of the parenchyma are more useful when assessing an impaired response of pancreatic ducts to secretin stimulation. Qualitative evaluation of pancreatic secretory response may also be assessed by monitoring the duodenal filling. In a previous study, we showed that a reduced duodenal filling was specific, but less sensitive for detecting an impaired exocrine function. Recently, several methods have been described to quantify non-invasively pancreatic exocrine secretions using S-MRCP. These methods are based on a linear relationship between MR signal intensity and fluid volume and all require a calibration procedure. In one of our recent studies, normal reference values were obtained for pancreatic flow output (PFO) (6.8 ml/min ± 1.4) and total excreted volume (after 15 minutes: 97 ml ± 22) that were in the range of those reported by previous endoscopic studies. We also demonstrated that in patients with chronic pancreatitis and an impaired exocrine function (PFO <5.4 ml/min), endoscopic procedures, performed to relieve pain by draining the obstructed mpd, significantly improved pancreatic exocrine secretion outflow.
Diffusion-weighted imaging has been used to monitor changes in ADC values during secretin stimulation. A peak increase in ADC was observed in the first 2 minutes following secretin administration in normal subjects and between 4-8 minutes in chronic pancreatitis patients. Pancreatic regional blood flow can be quantified non-invasively using contrast-enhanced MR imaging techniques. Several pharmacokinetic models can be used to analyse the concentration-time course measured in the tissue. In a recent study, we used a one-compartment model to calculate perfusion parameters. In this study performed on healthy volunteers we demonstrated the feasibility of the technique and its sensitivity to depict changes in regional pancreatic perfusion during exogenous secretin stimulation.

**Clinical applications and challenges**

Combining the information provided by S-MRCP renderings with unenhanced and contrast-enhanced MRI has expanded the clinical applications of the technique. In acute pancreatitis it is as accurate as CE-CT in establishing the prognosis of the disease and more accurate in demonstrating local haemorrhage and the internal content and structure of large fluid collections. Moreover S-MRCP is highly accurate in demonstrating CBD stones and can reveal sphincter of Oddi dysfunction, mpd strictures, disruption or the presence of fistulous tracts.

In advanced chronic pancreatitis MRI and S-MRCP are suitable to establish a road map of the pancreatic ducts (determine the presence of obstructive strictures/stones and the presence of anatomic variants), quantify pancreatic exocrine secretions and assess possible complications (CBD stricture and pseudocysts) before endoscopic therapy or surgery. In the early stages of chronic pancreatitis, the accuracy of S-MRCP for the depiction of the pathognomonic side-branches is still unknown. Although gadolinium enhancement characteristics and secretin induced filling of the mpd may help, the differentiation of a focal inflammatory mass from
pancreatic cancer remains a challenge. Diffusion-weighted imaging may also help in this setting and its role is presently under evaluation.

MRCP has been reported as sensitive as ERCP in detecting pancreatic adenocarcinoma limited to the mpd and MRI may challenge helical CT for detection and staging. However, prediction of tumor nonresectability is poor and related to the unreliable detection of small metastatic lymph nodes and mesentery invasion.

Although the vast majority of cystic tumors present characteristic MRI features, in the presence of a single cystic lesion without obvious clinical and morphological hallmarks of pancreatitis and no definite communication with the mpd, its characterization by MRI and S-MRCP has limited success.

References


MA Bali et al Evaluation of the stimulating effect of a low dose of secretin compared to the standard dose on the exocrine pancreas with MRCP: preliminary results in normal subjects. Abdom Imaging 2007; Jan 26 [Epub ahead of print]


