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Magnetic Resonance Cholangiography: past, present and future: a review

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Abstract. – *Introduction:* **Magnetic resonance cholangio-pancreatography (MRCP) is a valuable method for the evaluation of biliary and pancreatic diseases and a valuable alternative to endoscopic retrograde cholangiopancreatography (ERCP). It is noninvasive and does not require the use of contrast material or ionizing radiation. Since its introduction in 1991, this technique has significantly improved in spatial resolution, now allowing the accurate assessment of the major bilio-pancreatic diseases.**

State of the Art: **MRCP is commonly performed with heavily T2-weighted sequences in order to highlight static fluids, as those contained in dilated pancreatic and biliary ducts. Newest MR equipments allow to perform MRCP within 10-15 minutes, due to the availability of ultra-fast sequences. Currently, MRCP is widely performed as a primary imaging modality for the assessment of obstructive jaundice and other benign or malignant bilio-pancreatic ducts abnormalities. The primary MRCP application is the evaluation of biliary obstructions due to choledocholithiasis, iatrogenic strictures, cholangiocarcinoma or pancreatic carcinoma. Other MRCP applications include the assessment of the exocrine pancreatic function, following secretin stimulation. Whenever needed, the MRCP may be completed with a conventional contrast-enhanced magnetic resonance imaging (MRI) of the upper abdomen and functional studies as well, thus providing an all-in-one mophological and functional study of the pancreas and biliary system. More recent applications include the possibility of 3D reconstructions and the use of hepato-biliary contrast agents, that provide a higher definition of the biliary tree, both in pathologic and normal conditions. The introduction of 3Tesla magnets could provide higher anatomic detail.**

Conclusions: **In the next years the role of MRCP will further expand, due to the availability of faster sequences, 3D imaging and functional studies.**

Key Words:

MRCP, Bile ducts, Biliary stones, Pancreatic ducts.

Introduction

Since its first clinical introduction, dated 1991[1], magnetic resonance (MR) cholangio-pancreatography (MRCP) has proved to be a reliable technique in the evaluation of biliary and pancreatic ducts obstruction. In the early phases of its clinical application it was considered as a second level examination in the diagnostic work up of the obstructive jaundice, following percutanous trans-hepatic cholangiography (PTC) and endoscopic retrograde cholangio-pancreatography (ERCP), considered as first level examinations.

During the last two decades, this imaging technique has significantly increased its diagnostic role in the diagnosis of obstructive jaundice. Several papers[2-5] have demonstrated the extremely high diagnostic accuracy of MRCP in the detection of biliary duct stones, benign biliary strictures as well as malignant lesions of the biliary tree, particularly the Klatskin tumor.

MRCP is nowadays widely diffuse and used as a primary non invasive imaging modality in the diagnosis of obstructive jaundice. It plays a primary role in the work up and therapeutic operative planning of the obstructive jaundice. In presence of a severe obstructive jaundice, the choice of a surgical, rather than an endoscopic or percutaneous treatment is usually founded on the analysis of MRCP results. Currently, the role of invasive procedures, such as PTC or ERCP, is interventional rather than diagnostic.

The objective of this paper is to review the main current indications of MRCP and to show its future perspectives in the evaluation of biliary and pancreatic diseases.

State of the Art

The magnetic resonance imaging (MRI) display of the biliary tree is usually obtained by acquiring

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heavily T2-weighted sequences. Such sequences highlight static fluids, including those present in the dilated pancreatic and biliary ducts, that appear markedly hyperintense on T2-weighted images. Coronal T2-weighted images can be viewed as thin collimation sourve images (3-5 mm), and subsequently processed to obtain a MIP (maximum intensity projection) image which is a chilangiogram-like prjectional image. Otherwise a coronal thick slab (30 to 50 mm) can be obtained, to produce the same effect in a very short time (<5 seconds). Usually both imaging technique are associated and reviewed, to achieve the higher accuracy[6].

The MR cholangiographic effect is therefore obtained with T2 weighetd sequences in presence of moderately to markedly dilated biliary or pancreatic ducts, without the use of any contrast material or ionizing radiation. Visualization of ducts at MR cholangiography, in fact, exclusively depends on the presence of fluid (bile) within the lumen: a marked duct dilation contains more bile which provides higher ductal display at MRCP.

The evidence of dilated ducts is increased by adding suppression of the background fat tissue: in this way the dilated biliary or pancreatic ducts are greatly enhanced with respect to adjacent tissues and organs. By using ultrafast T2 weighted sequences, nowadays available in the newest MR equipments, the overall examination time is approximately less than 15-20 minutes.

Contrast agents are not strictly necessary to obtain MRCP images. However, negative oral contrast agents (so called "superparamagnetic" agents) can be usefully employed to reduce the brightness of the gastric and intestinal fluids, in order to enhance the evidence and brightness of the biliary tree and pancreatic ducts.

MRCP is, therefore, a noninvasive and safe imaging technique in the evaluation of bile duct dilation. New technical advances will likely provide a satisfactory visualization of normal anatomy and non dilated biliary ducts as well.

The MRCP examination can be completed with a conventional MRI examination whenever needed, with or without intravenous injection of a Gadolinium chelate, particularly in presence of pancreatic o biliary neoplastic obstruction.

Finally, MRCP offers the added possibility of a functional study, if performed during the intravenous administration of secretin, which physiologically stimulates the exocrine pancreas.

The secretin rapidly increases the production of pancreatic fluids, thus increasing the duct size and producing an excellent display of the entire pancreatic ductal system (main and secondary ducts). Moreover, by acquiring consecutive MRCPs every 10 seconds from time 0 to 10 minutes after secretin injection, it is possible to evaluate the total amount of increased duodenal fluid, which is a reliable index of the exocrine pancreatic function[7-11].

The primary current clinical applications of MRCP include all the main causes of ductal obstruction, such as main bile duct lithiasis, iatrogenic strictures, cholangiocarcinoma, and pancreatic adenocarcinoma.

The overall accuracy of MRCP in the evaluation of bile duct stones is extremely high, with sensitivity and specificity values ranging from 96 to 100%[2-6]. Stones appear as dark filling defects of variable shape, round or prismatic, within the biliary tree or gallbladder, less frequently in the pancreatic ducts (Figure 1).

Possible pitfalls include air bubbles, blood clots, hypertrophy of the Oddi sphincter, that mimic biliary duct stones.

MR cholangiography can accurately evaluate malignant obstruction of the biliary ductal system by identifying the exact site of the obstruction and the length and type of the stricture. All malignant strictures usually appear as marked narrowings with proximal bile duct dilatation. The sensitivity of MR cholangiography for the detection of bile ducts strictures is approximately 95%[12]. Malignant obstruction occurring at the *porta hepatis* are usually secondary to a cholangiocarcinoma (Figure 2), metastatic disease, periportal lymph nodes or invasive gallbladder carcinoma[13]. The extrahepatic biliary tract may be obstructed by lymphadenopathy from neoplasms arising in adjacent organs (e.g., gallbladder, pancreas, stomach, colon)[14,15], whereas neoplastic obstructions of the intrapancreatic distal portion of the common bile duct is more frequently caused by carcinoma of the head of the pancreas or ampullary carcinoma[14]. Malignant lesions usually manifest as irregular strictures with shouldered margins, whereas benign stenoses tend to have smooth borders with tapered margins[12]. MR cholangiography can be valuable in the evaluation and therapeutic planning of patients with biliary-enteric anastomoses. The failure rate of endoscopic retrograde cholangiopancreatography in these patients varies between 10% and 48%[16,17], as compared with 3%-5% in patients with normal anatomy[17]. MR cholangiography clearly depicts the site of the biliaryenteric anastomosis and demonstrates the status of the intrahepatic ducts[18,19].

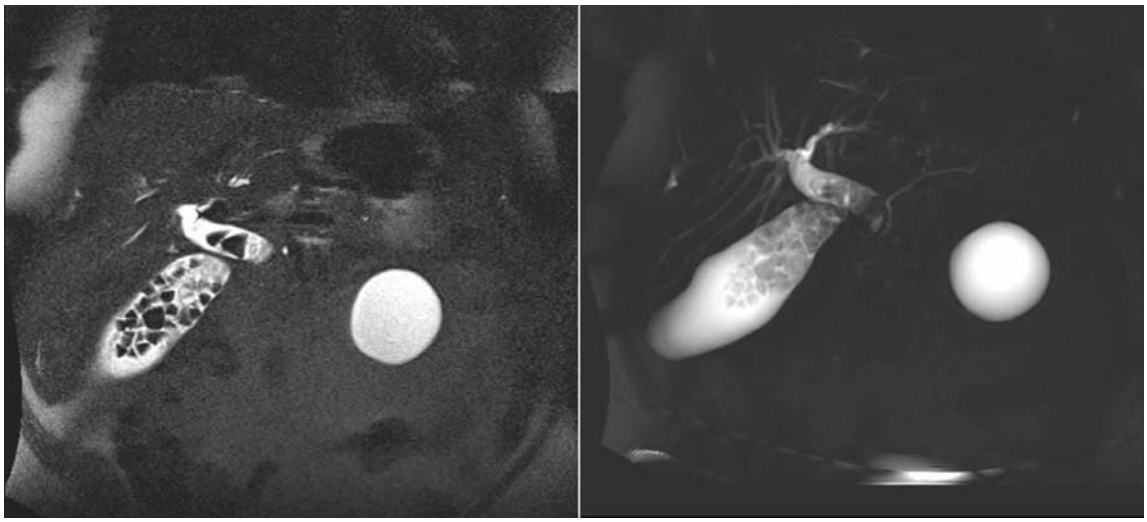

Figure 1. CPRM in a patient with main bile duct and biliary stones. ***A,*** The thick-slab (40 mm) T2 weighted coronal image provides a panoramic view of the intra-hepatic and extra-hepatic biliary tree, clearly showing multiple stones within the main bile duct and gallbladder. A large left renal cyst is depicted as well, due to the typical bright signal intensity. ***B,*** The thin slice (3 mm) T2 weighted coronal image allows a more detailed display of the multiple stones within the main bile duct and gallbladder, clearly showing their typical prismatic shape. This image is more defined, but less panoramic than the other one.

MRCP is a reliable diagnostic tool to detect and monitor primary sclerosing cholangitis. It has been found that primary sclerosing cholangitis occurs in up to 7.5% of patients with ulcerative colitis. The classical appearance is the presence of multiple diffuse short strictures that alternate with slightly dilated segments[6].

Future Perspectives

The MRCP more recent advances are focused to optimize the evaluation of the biliary tree under normal condition. MRCP reliably depicts the main extrahepatic and intrahepatic bile ducts, but it does not accurately visualizes the segmental intrahepatic ducts, unless they are dilated. The seg-

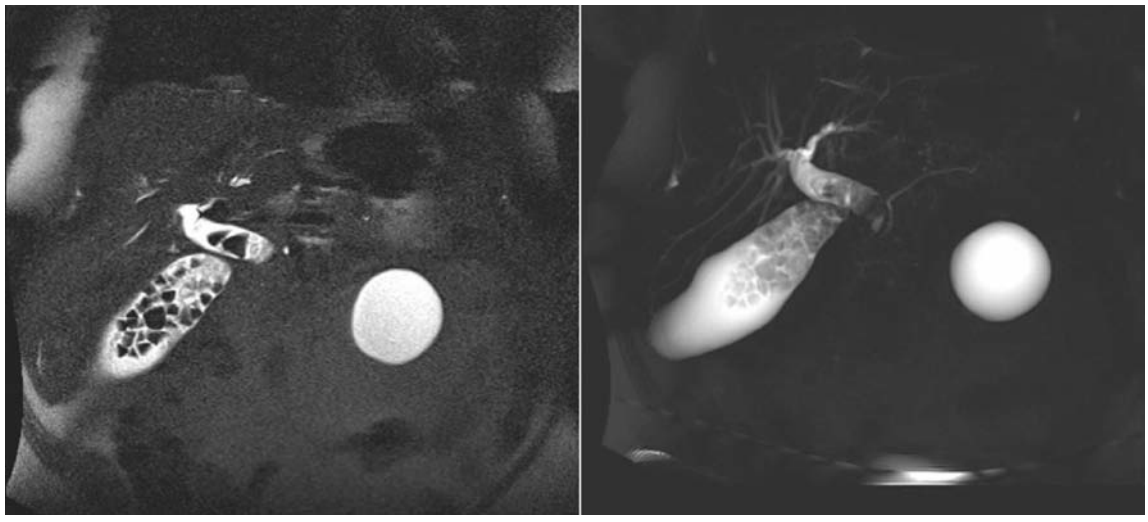

Figure 2. Klatskin Tumor. ***A,*** Coronal T2 weighted image thin slice (3 mm) showing an irregular tissue growth within the hepatic duct and carrefour. ***B,*** The thick slab (40 mm) coronal image better shows the high dilatation of both intra-hepatic (left and right) biliary ducts, due to the hilar obstruction, The main hepatic duct, distally to the lesion, shows a normal caliber.

mental anatomy can be hardly depicted with conventional MRCP, due to the limited spatial resolution and low signal-to-noise ratio achievable with standard MR pulse sequences[20]. However, visualization of the normal non-distended biliary system is necessary for the evaluation of donor candidates for living related liver transplantation. Assessment of normal bile ducts may be necessary in case of bile duct leakages following biliary or liver surgery.

For this purpose, several Authors have proposed the intravenous administration of pharmacological agents able to contract the Oddi sphincter; such action can improve image quality by increasing the pressure and distention of the biliary and pancreatic ducts. Some Authors have proposed morphine administration[20], others have proposed the use of fentanyl[21], both being able to produce sphincter of Oddi contraction. Both techniques are promising and particularly helpful for the evaluation of patients with primary sclerosing cholangitis and malignant neoplasms, such as cholangiocarcinoma and cystic benign pancreatic neoplasms[20].

Secretin magnetic resonance imaging is similarly used to obtain a better display of the pancreatic duct system. In fact, soon after i.v. injection (02 mcg/kg of body weight), it stimulates pancreatic fluid secretion and simultaneously increases the Oddi sphincter tone for a few minutes, thus producing a mild dilation of the main and secondary ducts. In a second phase, the Oddi sphincter relaxes, the pancreatic fluid passes in the duodenal lumen; by quantifying the amount of pancreatic fluids in the duodenum, it is possible to directly assess the pancreatic exocrine function, the so-called cholangiopancreatography quantification (MRCPQ); it correlates well with steatorrhoea and conventional, non-invasive functional tests.

There is an increasing interest in the use of hepatobiliary contrast agents, such as mangafodipir trisodium (Teslascan, Nycomed, Oslo, Norway), or gadoxetic disodium acid (Primovist, Schering co., Berlin, Germany) or Gadobenate dimeglumine (MultiHance, Bracco, Milan, Italy). These agents are hepatocyte-selective T1 weighted MR agents that are administered intravenously and excreted primarily through the biliary system[21-24]. The direct visualization of the biliary tree starts after 20 to 100 minutes following injection, according to the different agent, and lasts for 1-2 hours. The use of these contrast agents should provide both anatomic information and functional data. In particular, this technique has been used to detect post-surgical bile ducts leaks and to evaluate the biliary anatomy for right hepatic lobe living donors.

Tridimensional imaging is a recently developed method of image acquisition, which produces thinner slices with higher contrast. These slices can be post-processed in order to produce projectional images in all spatial planes, as well 3D reconstructions. So far they required a longer acquisition time, although breath hold 3D images should became available in a short time.

The recent introduction of 3Tesla magnets will likely provide an increased spatial resolution, although data are not still conclusive.

Conclusions

In the next years the role of MRCP will further expand, due to the availability of faster sequences, 3D imaging, specific contrast agents and functional studies. MRI examination of the biliary and pancreatic system will provide an excellent anatomical display in both normal and pathologic conditions. Functional imaging will further progress allowing information on both biliary and pancreatic functions.

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