CONTINUING EDUCATION PROGRAM: FOCUS

MRI of cholangitis: Traps and tips

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Abstract There are many limitations to the examination of the bile ducts by magnetic resonance imaging, which may be four orders: (1) technical, requiring analysis of Maximum Intensity Projection (MIP) three-dimensional (3D) volume reconstructions as well as native images, the use of T1-weighted sequences obtained in 3D to avoid entry slice phenomena, and knowledge of the inherent limits of the method, the spatial resolution of which is still less than optimal; (2) anatomical: you need to know the appearance of flow artefacts within the bile ducts and the traps that the presence of air or bleeding into the bile ducts can create; you also need to know the characteristic appearance of the indentation caused by the hepatic artery on the bile ducts and the variants and modifications seen in cases of portal biliopathy; (3) semiological: the terms used to describe bile duct abnormalities seen in MRI are often derived from imprecise descriptions used in retrograde cholangiography: irregularities of the bile ducts, a beaded ‘string of pearls’ appearance, a ‘dead tree’ appearance; (4) related to a complex disease, cholangitis which is a complex pathological condition, with possible overlaps between different conditions, such as primary sclerosing cholangitis (PSC), secondary sclerosing cholangitis, autoimmune cholangitis. In any case, the diagnosis of cholangiocarcinoma associated with PSC is always difficult. These limitations can be circumvented by using a precise exploration technique comprised of 3D magnetic resonance cholangiography sequences, which allow volume analysis, examination of native slices and of thick or thin MIP reconstructions, and heavily T2-weighted and T1-weighted 3D sequences with and without gadolinium injection, which is not always essential. The examination must be interpreted according to a stereotyped plan that includes (1) examination of the bile ducts, searching for and describing any stenosis, the presence or absence of dilatation, (2) a systematic search for any intrahepatic calculus, (3) examination of the heterogeneity of the liver parenchyma, investigation to find any liver dysmorphia and signs of portal hypertension, (4) analysis of the enhancement of the liver parenchyma and any enhancement of the wall of the bile ducts.

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Magnetic resonance imaging (MRI) has become the standard method for morphological examination of the bile ducts, particularly for diagnosing cholangitis. Percutaneous or retrograde direct opacification is no longer used for diagnosis. Ultrasound, which is still a very sensitive examination for detecting intrahepatic calculi, cannot provide complete morphological results in the event of cholangitis. There is virtually no indication for computed tomography, even though it can show calcified stones and pneumobilia. However, MRI of the bile ducts, which is not limited to magnetic resonance cholangiography sequences, is a method that requires a methodical apprenticeship. There are many traps and pitfalls related to the technical limitations, the specific anatomical features, the semiological limitations and the complex nature of intrahepatic bile duct diseases.

The risk of error can be considerably reduced by adopting a precise exploration technique and a stereotyped interpretation plan.

**Technical limitations**

**Two-dimensional or three-dimensional magnetic resonance cholangiography**

When the first magnetic resonance cholangiography images appeared with the possibility of obtaining fast spin echo sequences and simultaneous reading of several lines or the whole of the Fourier plane [1,2], they were the result of two-dimensional (2D) acquisitions. The principal advantage of these 2D sequences is a short acquisition time of a few seconds (feasible within a single breath-hold), so that they are not very sensitive to motion artefacts and, by being repeated, allow dynamic analysis particularly of the end of the common bile duct. Furthermore, these 2D sequences do not require post-processing and can be interpreted immediately. On the other hand, they require a certain amount of cooperation by the patient with breath-holding, which has to be repeated many times. The plane of the slice must be predetermined, and therefore requires a degree of expertise and is exposed to a risk of error. But above all, these 2D sequences run the risk of a partial volume effect because, by definition, acquisition only concerns one slice plane. This is why we generally associate thick (usually 20 mm) with thin slices. However, three-dimensional (3D) sequences have resulted in significant advances in diagnostic possibilities; their principal advantage is that acquisition is obtained with a virtually isotropic voxel, providing high resolution in all three spatial planes allowing multiplanar reconstructions with an excellent signal/noise ratio.

The disadvantages of the 3D sequence are a relatively long acquisition time, performed with free breathing (thus, requiring sufficiently deep and regular inspiration) and the need to analyse the native slices and produce multiplanar reconstructions. That said, with modern machines, 3D sequences seem to be definitely superior to 2D sequences, which only maintain the advantage of making dynamic acquisitions that are often difficult but rarely essential [3]. 3D acquisitions require a strict interpretation plan, with examination of the entire volume, native slices and thick and thin Maximum Intensity Projection (MIP) reconstructions.

The examination of native slices or very thin MIP reconstructions is absolutely essential for looking for small calculi that can easily not be seen on a thick reconstruction or a volume reconstruction (Fig. 1). The correct position of the analysis volume must also be verified. On modern machines, this volume is sufficiently thick for it to be difficult to be wrongly positioned. It should also be noted that even if the voxel is almost isotropic, image quality is best in the plane selected for the native slices. Thus, in the majority of cases, 3D magnetic resonance cholangiograms are obtained using native images acquired in the coronal plane. Examination of the pancreas is, however, often of better quality with acquisition of native images in the transverse plane (Fig. 2).

**T2-weighted sequences**

There are many T2-weighted sequences where the TE can be shorter or longer, with or without fat saturation. B0 acquisition of diffusion sequences can also be used [4–6].

For bile duct examination, sequences with a very long echo time are generally used, without fat saturation.

**T1-weighted sequences**

Unlike T2-weighted sequences, which could be considered optional if the magnetic resonance cholangiography is of good quality, the T1-weighted sequence is absolutely essential in biliary disease for looking for intrahepatic calculi. Indeed, the majority of intrahepatic calculi produce T1-weighted hyperintensity more likely due to the presence of haemoglobin degradation products than to the high cholesterol content of some calculi. It is really recommended to use T1-weighted sequences obtained during 3D acquisition with fat saturation.

T1-weighted sequences acquired with the 2D technique can, in fact, mean exposure to entry slice phenomena with intense signals from certain circulating vessels, which considerably impair the search for intrahepatic calculi (Figs. 3 and 4). The entry slice phenomenon is significantly reduced or removed in the 3D acquisition method, mainly because of the oversampling generally applied. Fat saturation improves the diagnostic possibilities, particularly, for the bile ducts close to the hilum of the liver, which is often rich in fat.

There is another risk of error with the false positive diagnosis of intrahepatic calculi when a contrast agent is used in the digestive tract, intended to reduce the signal from the digestive liquid [7,8]. For example, the ingestion of pineapple juice, which is very effective in reducing the signal from digestive structures on T2-weighted images, causes hyperintensity of the digestive liquid on T1-weighted images. When there is a sphincterotomy or a biliiodigestive anastomosis, reflux of pineapple juice into the bile ducts can sometimes be observed which must not be confused with stone formation (Fig. 5).

**Inherent limitations of MRI of the bile ducts**

Whether T1-weighted, T2-weighted or magnetic resonance cholangiography sequences are involved, the inherent limitation of bile duct MRI is still its suboptimal spatial resolution. Precise examination of the distal bile ducts is still
incomplete and is at present the last remaining limitation of magnetic resonance exploration (Fig. 6).

**Anatomical limitations**

**Contents of the bile ducts**

On very heavily T2-weighted 2D slices, particularly on slices using half-Fourier single-shot turbo spin echo (HASTE), flow phenomena are frequently observed in the bile ducts, particularly in the common bile duct, that can result in an absence of signal that should not be taken for a calculus (Fig. 7). This lack of signal is central, usually rounded and surrounded by peripheral hyperintensity, this distinguishes it from a real calculus which, in any case, is not found on other sequences, magnetic resonance cholangiography sequences in particular. The presence of pneumobilia secondary to a biliodigestive anastomosis or sphincterotomy may also complicate examination of the bile ducts and produce a false positive diagnosis of a gallstone, especially when analysing magnetic resonance cholangiography sequences in the coronal plane. In the transverse or sagittal planes, the air/fluid level characteristic of pneumobilia can be easily seen (Fig. 8).

The existence of haemobilia, especially when the bile ducts are explored following surgery, can be the cause of gaps in them, which should not be taken for stones (Fig. 9). Finally, the spontaneously high signal from the bile on heavily T2-weighted sequences can be altered if there is a magnetic susceptibility artefact, particularly, when ferromagnetic clips are present, for example after a laparoscopic cholecystectomy.

**Vascularisation of the bile ducts**

Compression of the upper part of the common bile duct or the terminal part of the right or left hepatic ducts [9,10] by a hepatic artery must not be mistaken for a stenosis (Fig. 10). This image of an indentation often varies from one examination to another (Fig. 11). When there is portal vein thrombosis with the development of a portal cavernoma, substitute hepatopetal routes result in considerable development of the peri- and para-biliary veins, which can cause multiple indentations on the common bile duct. When the cavernoma has an intrahepatic extension, these indentations can be seen on the right and left hepatic ducts, even on the intrahepatic bile ducts (Fig. 12).

**Semiological limits**

Analysis of the signs in biliary MRI and particularly in magnetic resonance cholangiography sequences initially used semiological classifications derived from retrograde cholangiography [11,12], which described three stages that
Figure 2. Comparison of results obtained with 3D resonance cholangiography with coronal native images (a) and transverse native images (b); a–b: for examination of the main pancreatic duct, performance is better with transverse native image acquisition; c: by comparison, the reconstruction in the transverse plane of native images obtained in the coronal plane is of poor quality.

Figure 3. Intrahepatic calculus. a: on the 2D T1-weighted sequence, many entry slice phenomena can be seen at the inferior vena cava, the greater mesenteric vein and intrahepatic vessels, which considerably hinder the examination and the search for intrahepatic calculi; b: On the 3D T1-weighted sequence with fat suppression, examination of the bile ducts is much simpler.

included irregularities of the bile ducts, a beaded ‘string of pearls’ appearance and ‘dead tree’ biliary rarefaction. These signs are imprecise. They give rise to a risk of the false positive diagnosis of cholangitis due to irregularities simply because of the suboptimal spatial resolution of the method. Similarly, the ‘string of pearls’ appearance can seem to be observed, mistakenly, on distal bile ducts when spatial resolution is suboptimal and respiratory gating has not been perfect (Fig. 13). Finally, the description of the intrahepatic bile ducts as a ‘dead tree’, which is specific enough for retrograde cholangiography which, despite injection under pressure, could not fill the bile ducts, is not well suited to magnetic resonance cholangiography sequences (Fig. 14). To avoid this imprecise and poorly reproducible semiotic analysis, we propose, in the following, an analysis based on the precise description of stenoses and any dilatations.

Complex nature of the condition

Inflammatory diseases of the bile ducts are complex pathological conditions, with possible overlap between one
Figure 4. Intrahepatic calculi. a: intrahepatic calculi are visible on the native magnetic resonance cholangiography images; b: these calculi are the source of hyperintensity on the T1-weighted images; c: these calculi are the source of hypointensity on the T2-weighted sequences.

Figure 5. Biliodigestive anastomosis with pneumobilia and reflux of pineapple juice into the bile ducts. a: the pneumobilia is clearly visible in a CT scan; b: on T1-weighted images, pineapple juice reflux is visible as hyperintensity in the right hepatic duct (arrow) with an air-fluid level.

condition and another and entities, which have probably still not been completely defined [13]. For example, in primary sclerosing cholangitis (PSC), there are probably several entities between certain very inflammatory diseases, which evolve rapidly, causing major alterations to the bile ducts with parenchymal repercussions ending in secondary biliary cirrhosis, and indolent, quiescent or very slowly progressing conditions. There is also what is known as small duct cholangitis, without there being any real morphological abnormality of the bile ducts visible in magnetic resonance
cholangiography [14]. There is definitely an overlap between some occurrences of PSC, a disease which certainly has an autoimmune component, and quite different forms of cholangitis, today referred to as ‘autoimmune cholangitis’ and which responds well to corticosteroid treatment [15].

Based solely on the morphological examination of the bile ducts, it is often very difficult to differentiate between PSC and secondary sclerosing cholangitis, particularly secondary ischaemic cholangitis.

Figure 6. Primary sclerosing cholangitis. Even with good quality MIP reconstructions, examination of the distal bile ducts is still somewhat less than optimal.

Figure 7. A flow artefact in the bile duct can be mistaken for a calculus.

Figure 8. Pneumobilia with sphincterotomy. a: on the MIP volume reconstruction, the mid-part of the common bile duct is not seen (arrow); b: on the T2-weighted transverse sequence the air-liquid level is clearly seen (arrow); c: away from the sphincterotomy the pneumobilia has disappeared.
Figure 9. Haemobilia in a liver transplant patient. a: on the magnetic resonance cholangiography MIP volume rendering image, there are many gaps that are difficult to interpret but lead one to envisaging a diagnosis of ischaemic cholangitis; b: on the heavily T2-weighted sequence in the transverse plane, there are also diffuse abnormalities of the bile ducts; c: these anomalies are not found on the follow-up magnetic resonance imaging performed 15 days later.

Figure 10. Indentation formed by the hepatic artery on the origin of the common bile duct. a: this indentation produces an image of pseudostenosis of the origin of the common bile duct on the magnetic resonance cholangiography MIP volume rendering image (arrow); b: on the transverse slice after gadolinium injection, the relationships can be seen between the portal branch, the hepatic artery (black arrow) and the origin of the common bile duct (white arrow).
Figure 11. Variability of the image of hepatic artery indentation depending on the degree to which the bile ducts are filled. a: on the first acquisition, an indentation caused by the hepatic artery can be seen forming an image of pseudostenosis, particularly of the right hepatic duct; b: on a control magnetic resonance imaging scan, the bile ducts are filled more and the indentation is no longer visible.

Figure 12. Portal biliopathy. On the T1-weighted sequence after gadolinium injection in the coronal plane, a proliferating portal cavernoma can be clearly seen (arrow a), continuing intrahepatically (b); c: indentations caused by the peri- and para-biliary vessels on the bile ducts can be seen on the magnetic resonance cholangiography MIP volume rendering image as diffuse irregularities of the bile ducts.

In addition, in cirrhosis of the liver, particularly in macronodular cirrhosis, real irregularities of the bile ducts occur due to their being compressed by architectural modifications linked to the cirrhosis, and these irregularities should not be considered as a primary bile duct disease (Fig. 15). It is also often difficult to differentiate with what is known as PSC from the autoimmune cholangitis solely on the basis of the morphological imaging data, even though lesions to the bile ducts are more often central than peripheral in autoimmune cholangitis and can be associated.
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Figure 13. ‘String of pearls’ appearance. a: the ‘string of pearls’ appearance can indeed be suspected on the MIP volume rendering reconstruction; b: actual appearance of a string of pearls.

Figure 14. ‘Dead tree’ appearance. a: rarefaction of the intrahepatic bile ducts on this magnetic resonance cholangiography MIP volume rendering image that is indeed reminiscent of a ‘dead tree’; b: actual appearance of a dead tree.

with involvement of other organs, particularly with autoimmune pancreatitis, with lesions in the main pancreatic duct (Figs. 16 and 17).

To conclude, the great difficulties in diagnosing cholangiocarcinoma in PSC must be emphasized [16–18]. It is actually extremely difficult to make this diagnosis. Cholangiocarcinoma should be suspected, if, when monitoring PSC, a dilated biliary sector appears, but this localised dilatation of the bile ducts may also result from localised fibrosis of the inflammatory biliary lesion, in the absence of cholangiocarcinoma (Fig. 18).

Precise exploration technique

The difficulties described above can be reduced by using a precise exploration technique. We consider the following three sequences essential for analysing the biliary tract where there is suspected inflammatory bile duct disease or when monitoring a known condition:

- a 3D magnetic resonance cholangiography sequence, which should be examined on the volume reconstruction, on native slices and on thick and thin MIP reconstructions;
- a heavily T2-weighted transverse sequence, with or without fat suppression, providing another representation of bile duct abnormalities and allowing examination of the heterogeneity of the liver parenchyma signal and investigation of liver dysmorphia;
- a T1-weighted 3D sequence with fat suppression, absolutely essential for investigating the presence of intra and extrahepatic calculi.

We do not think that performing a sequence after gadolinium injection is essential in all cases. It is certainly unnecessary in bile duct MRIs requested for looking for bile duct abnormalities in cases where liver function tests have
altered, if the previous sequences have shown nothing. In PSC, it can be useful in the initial examination, to detect heterogeneous enhancement of the liver parenchyma and contrast uptake by the wall of the bile ducts. It is not certain that it is essential in regular monitoring of PSC. Gadolinium injection can also be used in monitoring PSC when dilatation of the bile ducts appears, to look for anything indicating cholangiocarcinoma, even though contrast uptake by the cholangiocarcinoma is generally very similar to uptake by a local fibrous stenosis.

Stereotyped interpretation plan

A stereotyped interpretation plan improves diagnostic performance and reduces intra- and inter-observer inconsistency. The following should therefore be examined, sought or analysed in succession:

- the morphological appearance of the bile ducts: we talk of stenosis being moderate when it is less than 75% and severe when it is greater than 75%; short when it is less than or equal to 2 mm, long when it exceeds 10 mm, and intermediate when between 2 and 10 mm; we talk of involvement of the bile ducts being localised when less than 25% of the intrahepatic bile ducts are involved, and diffuse when more than 25% are affected;
- large or moderate dilatation of the common bile duct, right and left hepatic ducts and intrahepatic bile ducts should be sought systematically, as should calculi on the native magnetic resonance cholangiograms and on T1-weighted sequences;
- the homogeneity or heterogeneity of the liver parenchyma signal: we should look for dysmorphism and any portal hypertension;
- when gadolinium is injected we should analyse the homogeneity of enhancement of the liver parenchyma and any abnormal enhancement of the walls of the bile ducts.

Figure 15. Macronodular liver cirrhosis. a: on the T2-weighted sequence considerable architectural changes to the liver can be seen; b: these architectural changes are the cause of bile duct irregularities that should not be considered as a primary disease of the bile ducts on magnetic resonance cholangiograms in the coronal plane.

Figure 16. Primary sclerosing cholangitis at an advanced stage a: on the magnetic resonance cholangiography image in MIP volume rendering mode, there are multiple tight stenoses of the common bile duct, right and left hepatic ducts and intrahepatic bile ducts, plus dilatations of the intrahepatic bile ducts; b: there is a considerable loss of volume of the right lobe of the liver, which can also be analysed on the T2-weighted transverse sequence.
TAKE-HOME MESSAGES

Limitations of MRI exploration of forms of cholangitis

Technical limitations
- the need to examine 3D volume reconstructions and also native images and the thick or thin MIPs;
- the need to obtain T1-weighted 3D sequences with fat suppression, to avoid entry slice phenomena;
- spatial resolution is still less than optimal.

Anatomical limitations
- traps created by flow artefacts in the bile ducts and by the presence of air in, or bleeding into, the bile ducts;
- traps created by indentation of the bile ducts by the hepatic artery.

Semiological limitations
- description of signs is often imprecise, derived from the descriptions of retrograde cholangiography that talk of irregularities, a beaded ‘string of pearls’ appearance, a ‘dead tree’ appearance;
- complex pathological conditions, with partial overlap between PSC, secondary sclerosing cholangitis and autoimmune cholangitis; difficulty of diagnosing cholangiocarcinoma in PSC.

Precise exploration technique
- cholangiography by 3D MRI with analysis of native images, volume reconstructions and thick or thin MIP reconstructions;
- heavily T2-weighted sequence;
- T1-weighted 3D sequence with fat suppression;
- sequence after gadolinium injection optional.

Stereotyped interpretation plan
- examination of the bile ducts, looking for and describing stenosis and dilatation of the bile ducts;
- systematic search for intrahepatic calculi;
- examination of the homogeneity of the liver parenchyma signal, any liver dysmorphia and signs of portal hypertension;
- analysis of enhancement of the liver parenchyma and any abnormal enhancement of the wall of the bile ducts after injection of gadolinium.

Clinical case

This 35-year-old man has been treated with corticosteroids for Crohn’s disease with an ileal topography since the age of 17. Due to the recent occurrence of episodes of cholangitis, biliary MRI (Fig. 19) was performed.

Questions
1. What were the sequences performed?
2. Were these sequences sufficient?
3. Describe the abnormalities. What is your diagnosis?
4. Is a liver biopsy essential?

Answers
1. 3D magnetic resonance cholangiography reconstructed in MIP volume rendering mode (Fig. 19a). Long TE T2-weighted sequence without fat saturation (Fig. 19b). T1-weighted 3D sequence with fat saturation (Fig. 19c).
2. These sequences were sufficient. Gadolinium injection could also have been performed.
3. There is a long stenosis in the common bile duct, a tight stenosis of the right and left hepatic ducts of intermediate length and diffuse lesions to the intrahepatic bile ducts. There are many intrahepatic calculi better seen on the T1-weighted sequence. There is no hepatic dysmorphia or signs of portal hypertension. Diagnosis is of PSC.
4. There is no point of performing a liver puncture biopsy because the magnetic resonance cholangiography appearance is typical for a patient with IBD.
Figure 18. Evolving appearance of primary sclerosing cholangitis. a: at the first examination, a tight stenosis of the common bile duct and right hepatic duct was particularly evident. The distal bile ducts were less affected; b–c: as it evolved, massive dilatation of the common bile duct and intrahepatic bile ducts appeared, clearly visible on the magnetic resonance cholangiogram (b) and in the transverse plane (c). The first diagnosis to consider was cholangiocarcinoma. In fact this was fibrosclerosing evolution of inflammatory disease of the lower part of the bile duct.
Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


Figure 19. Biliary magnetic resonance imaging. a: Three-dimensional magnetic resonance cholangiography reconstruction in MIP volume rendering mode; b: Long TE T2-weighted sequence without fat saturation; c: It is T1-weighted 3D sequence with fat saturation.


