Hepatic MRI Technique Overview

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MRI techniques continue to evolve rapidly, but the most of the basic components of an hepatic MRI examination, and the clinical role of each component, have persisted. The three most important considerations for choosing techniques for imaging the abdomen continue to be contrast between normal and pathological tissues, motion artifact and coverage. In clinical practice, an MRI of the liver is expected to include comprehensive imaging of the abdomen, including other viscera. A routine examination of the abdomen still includes T1-weighted images, T2-weighted images, chemical shift techniques to definitively identify lipid-containing tissues and, in most cases, contrast-enhanced images. However, the specific techniques used to obtain these images on a modern MRI system continue to evolve. In particular, the approach to motion has evolved from averaging to motion compensation to suspended respiration and/or subsecond imaging. Additional techniques have been added, such as diffusion weighted imaging.

Whenever possible, it is best to image the principal region of interest during a single breath hold sequence. The advantages of single breath hold coverage include simplicity and avoidance of misregistration. Single breath hold imaging is essential for dynamic multiphasic imaging; the crucial arterial phase can only be acquired during a brief interval of about 20 seconds. A combination of image acceleration techniques can be utilized to allow repeated whole-liver acquisitions 2 or more times during a single suspended respiration

Localizer Images
The first set of images obtained is usually a rapid sequence with moderately large field of view. These are usually coronal, or a 3-plane localizer. Although T1-weighted images are commonly used for localizer images, we recommend using pulse sequences that depict T2-contrast. Either single-shot fast spin echo and balanced steady state free precession techniques are recommended. The latter can be implemented as a rapid motion-insensitive 3-plane comprehensive initial survey. The torso phased array coil should be used for all sequences, including the localizer images. They can then be used to confirm positioning of the torso coil by making certain that all parts of the liver are included within the sensitive volume of the coil.

Single Shot Fast Spin Echo (SSFSE)
SSFSE images are nearly always of high quality and high information content, as long as SNR is adequate. When used as a coronal localizer sequence, the images should be acquired using a 32 - 40 cm square FOV and 5 mm image sections, in two or more breathholds if necessary. Using a large FOV allows additional imaging of the abdomen and much of the lower chest and upper pelvis in a single breathhold, and provides added assurance against wrap-around artifact. Using parallel imaging allows the echo train to be reduced, which decreases blurring on SSFSE images

Next, axial SSFSE images should be obtained with heavy T2-weighted, with TEef of about 180 msec. These images are invaluable for identifying fluid within ducts and collections, and for characterizing solid versus nonsolid masses.

SSFSE is also used for MR CholangioPancreatography (MRCP). In our routine abdominal exam, we obtain a set of radially oriented, thick slab MRCP images near the end of the examination; previously administered gadolinium contrast agents will slightly lower the signal intensity of blood on these heavily T2-weighted images, reducing background signal. These should have effective TEs of at least 500 msec, often chosen as the final echo in the echo train. The field of view can be as small as 26 cm; wrap-around artifact will not be a problem because solid tissue has minimal signal intensity because of the long effective TE and fat suppression. The epicenter of rotation should be the common bile duct or pancreatic duct, depending on the application.

Balanced Steady State Free Precession (balanced SSFP, true FISP, balanced fast field echo, FI-ESTA)

These rapid motion-insensitive images depict moving and stationary fluid as bright, and therefore provide an effective survey of vascular and ductal structures, bowel, and fluid collections. While balanced SSFP images are less effective than heavily T2-weighted SS-FSE images for distinguishing solid tissue from fluid, and for depicting ducts, they are obtained more rapidly, have higher SNR, depict blood vessels better and may have other desirable attributes. The shortest possible TR should be used to reduce artifacts from heterogeneous susceptibility.

Dual Gradient Echo Axial In-Phase And Out-Of-Phase

These should be obtained as a dual-echo sequence. At 1.5 T, the TEs should be approximately 2.25 and 4.5 msec at 1.5 T, although on some systems the software may be configured to yield slightly different TEs, with acceptable results. At different field strengths, inversely proportionally changes to the TEs must be implemented to generate in-phase and opposed-phase images. For example, at 3T, the TEs are about 1.15 and 2.3 msec. The opposed phase image should always be the first echo, so signal decay due to T2* vs. chemical shift differences have opposite effects. Either 2D multi-slice or 3D technique may be used. Because 3D techniques utilize a lower flip angle, we have found that imaging at 3T favors use of the 3D technique.

Dynamic Multi-Phasic 3D Fat-Suppressed Spoiled Gradient Echo (VIBE, THRIVE, LAVA)

Optimal dynamic scanning technique for detection and characterization of liver lesions is best accomplished if the entire liver can be imaged one or more times during a single suspended respiration. We recommend at least four separate sets of images, corresponding to four separate physiologic phases relative to the dynamic bolus administration of contrast material. TR and TE should be as short as possible, and flip angle should be 10º – 15º.

1. Baseline pre contrast images are essential to determine if technical quality and anatomic coverage are adequate. Also, these images provide a basis of comparison to determine the presence or absence of perfusion, which in turn allows confident differentiation between fluid and tissue. The fat suppressed T1-weighted contrast also facilitates identification of hemorrhage.

2. Arterial (capillary; pre-sinusoidal) phase images are especially important for detection of hypervascular malignancies, and for depicting arteries. For some applications, multiple arterial phases may be obtained during the first breathhold, at the expense of reduced spatial resolution or SNR. This may be useful if improved characterization of lesion hemodynamics improves diagnostic specificity.

3. Blood pool (portal venous) phase images show maximal contrast between liver and hypovascular lesions, and are best for depicting the portal venous system. Since most administered contrast material is present throughout the vascular system at this time, these images are analogous to blood-pool phase images.

4A. Extracellular (delayed; late dynamic) phase images are acquired three or more minutes after injection of extracellular space contrast material, by which time contrast material has diffused into the interstitium of non-CNS tissues. Delayed contrast enhancement is particularly prominent in edematous tissues such as in neoplasms and areas of inflammation, and within fibrosis. If lipid signal is suppressed via frequency-selective saturation, interstitial enhancement is particularly conspicuous.

4B. Hepatobiliary phase images are acquired about 15 minutes after injection of hepatobiliary contrast material such as gadoxetic acid. Late dynamic phase images three or more minutes after injection, as in 4A, may also be acquired, but these are not effective for enhancing the interstitial space.

Moderately T2-Weighted FSE With Fat Suppression, or STIR

Short TI (tau) inversion recovery (STIR) images include a desirable combination of T2-weighting and inverse T1-weighting. Since liver lesions usually have lower T1 and higher T2 than does liver, STIR images often depict these liver lesions with greater contrast than do fat suppressed T2-weighted images. For liver imaging, STIR images should be moderately T2-weighted, with a TE between 50 and 70 msec. The disadvantage of STIR images compared with comparable fat suppressed T2-weighted is that the inversion time

involves increased acquisition time, and decreased signal. Therefore, the superior tissue contrast of STIR comes at a cost of a combination of increased time, lower SNR, and lower resolution. If STIR images are used, they should not be obtained before administering extracellular space gadolinium chelates, since tissues that enhance have shorter T1, and therefore less signal on STIR images.

When we obtain moderately T2-weighted FSE images in the abdomen for liver imaging, we prefer to obtain them after, rather than before, gadolinium administration. Other than causing lower signal intensity of kidneys and renal collecting structures, the previously administered gadolinium will have little effect on the image, although there may be slightly improved conspicuity of solid liver lesions. Other advantages of performing this sequence after contrast agent administration include obtaining the important contrast-enhanced images earlier, and allowing a longer interval before obtaining the delayed post-contrast images.

If hepatobiliary contrast material is used, we recommend obtaining post-contrast STIR. This technique is highly effective for depicting liver lesions because hepatic parenchymal signal is suppressed due to its shortened T1.

Diffusion-weighted Images

On modern equipment, these should be a routine component of hepatic MRI exams. They are complementary to the more traditional pulse sequences described above. A non-diffusion-weighted set of images is obtained, including an image with b=0, one with low b value such as 20, or both. An image with b=20 resembles an image with b=0, but signal from bulk fluid motion in blood vessels is suppressed, facilitating identification of liver lesions compared with hepatic vessels. A moderately diffusion-weighted set of images, such as with b=500, will generally have acceptable image quality but will better depict tumor and inflammation due to relatively lower diffusion-related signal loss. While there are many studies showing correlation with disease of measured Apparent Diffusion Coefficient (ADC), it has not been determined that measuring ADC can be useful for routine image-based clinical decision making in individual cases.