Modern Imaging Evaluation of the Liver

Emerging MR Imaging Techniques and Indications

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KEYWORDS

• Liver • Hepatic MRI • Diffusion-weighted imaging • Liver fibrosis • Hepatic steatosis • MR elastography • MR spectroscopy • Hepatocellular contrast

KEY POINTS

- Modern MR imaging evaluation of the liver includes a comprehensive morphologic and functional assessment of the liver parenchyma, hepatic vessels, and biliary tree and thus aids in the diagnosis of both focal and diffuse liver diseases.
- Diffusion-weighted imaging (DWI) provides useful and additional information for the evaluation of the liver, in the identification and characterization of both focal and diffuse diseases, and should be integrated into routine MR imaging protocol.
- MR elastography (MRE) is a promising and emerging technique that has become widely accepted for the evaluation of liver fibrosis. Potential indications that are undergoing active research include evaluation of inflammation (hepatitis), differentiation between benign and malignant focal liver lesions, and assessment of portal hypertension.
- MR imaging is an accurate and reproducible noninvasive technique for the quantification of liver fat and iron deposition and may limit the use of liver biopsy in the diagnosis and follow-up of patients with steatosis and iron overload.
- Newer combined contrast agents combine the extracellular properties of traditional contrast agents with hepatobiliary-specific information and have become a key component of the standard work-up of focal liver lesions. Understanding of their unique pharmacologic properties and the MR imaging technique is fundamental, however, to achieve optimal performance. There is also a potential role for the use of these contrast agents in the anatomic and functional evaluation of the liver.

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INTRODUCTION

During the past decade, there has been growing excitement and optimism regarding new technologic advances in the field of MR imaging, as well as emerging MR imaging applications, and new contrast agents that have been developed and approved for the evaluation of the liver. Although the superiority of MR imaging has long been acclaimed over other imaging techniques, particularly with regard to its lack of ionizing radiation and its higher sensitivity and specificity for detection and characterization of a broad range of hepatic conditions, it has become even more accessible and more widely available. Hepatic MR imaging allows for a comprehensive morphologic and functional assessment of the liver parenchyma, hepatic vessels, and biliary tree and thus aids in the diagnosis of both focal and diffuse liver diseases.

This article reviews some of these techniques and advances, including accepted and potential applications of DWI, MRE, and MR spectroscopy (MRS), as well as, in more detail, the evaluation of fat and iron deposition in the liver. Finally, the recently approved hepatospecific contrast agent, gadoxetate disodium (Eovist), and its clinical applications are discussed.

DIFFUSION-WEIGHTED IMAGING

DWI is an MR technique that exploits the normal brownian movement of the water molecules, or lack thereof. In pure water, molecules undergo free diffusion[1–3] whereas in tissues, water molecule movement is modified by interactions with cell membranes and macromolecules. DWI derives its contrast based on the difference in mobility of water molecules between tissues. Pathologic processes that alter the volume ratio of the physical nature of the intracellular and extracellular spaces affect the diffusion of water molecules. In highly cellular tissues (eg, tumors), abscesses, and cytotoxic edema, there is restricted diffusion due to the tortuosity of the extracellular space and higher density of cell membranes. In contrast, there is free diffusion of water molecules in cystic or necrotic tissues,[4] where cell membranes have been disrupted. Recent advances in hardware and software of the new-generation magnets (gradients, parallel and echo-planar imaging, coils with multiple channels, and movement-correction solutions) allowed the use of DWI in routine clinical evaluation of the abdomen.[3] Currently, DWI is used for detection and characterization of focal lesions, combined with conventional sequences. Emerging DWI applications include post-therapy tumor assessment (thermal ablation and CyberKnife), evaluation of inflammatory conditions, as well as in the diagnosis and quantification of liver fibrosis and cirrhosis.[5,6]

Technique

DWI can be performed as a breath-hold or a free-breathing sequence. In breath-hold DWI, the whole abdomen can be evaluated in 2 apneas of only approximately 20 to 30 seconds each. The main disadvantages of the breath-hold acquisition, however, are (1) low signal-to-noise ratio (SNR), (2) lower spatial resolution, (3) wider section thickness, (4) distortion and ghosting artifacts, and (5) limited number of b values. Conversely, in free-breathing DWI, the liver is evaluated in 3 to 6 minutes. The main advantages of the free-breathing technique include (1) improved SNR, (2) higher spatial resolution, (3) thinner image sections, and (4) the possibility to use more b values. Besides the longer acquisition time, other disadvantages include slight image blurring, breathing artifacts, and volume averaging. Free breathing may be combined with respiratory triggering, either by placing a 2D navigator at the level of the liver dome on free-breathing sagittal and coronal scout images, or placement of respiratory sensor device over the area of greatest abdominal wall motion. In the left lobe of the liver, cardiac motion usually causes artifacts, which can be minimized by using pulse or cardiac triggering. In summary, respiratory-triggered DWI improves liver lesion detection, image quality, SNR, and apparent diffusion coefficient (ADC) quantification compared with the breath-hold technique but significantly increases the acquisition time and, therefore, is more prone to artifacts.[5]

Interpretation of DWIs requires the generation of ADC maps. The calculation from the native b-value images is a semiautomated process on most commercial MR imagers or workstations. The assessment can be qualitative, by visual assessment, or quantitative, by drawing regions of interest (ROIs) to record the mean ADC values in the tissue of interest. A major limitation for the widespread use of quantitative measurements is the variability in the results as a consequence of varying hardware and human and biologic factors. DWI standardization is needed, to allow comparison of the results and facilitate multicenter studies.

At the authors' institution, DWI of the liver is used routinely in all patients. Although there are different possible protocols, a suggested image acquisition scheme using breath-hold and respiratory-triggered techniques, as performed at the authors' institution, is summarized in **Table 1**.