Research Highlight

Hepatic fat assessment using advanced Magnetic Resonance Imaging

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Magnetic Resonance Imaging is capable of providing clinically-valuable images for hepatic diseases such as the fatty liver and has become a promising noninvasive method in evaluating human liver under normal and diseased conditions (1-9). Fatty liver is one of the most common abnormalities. Recent surveys have shown that it affects up to 15% of the general population and it is higher among those with obesity and high alcohol consumption (10-12). Fatty liver is commonly associated with alcohol overuse, obesity, hyperlipidemia and hepatitis, and will cause steatosis within hepatocytes (13-17), which may progress to steatohepatitis and then cirrhosis (18-20). Liver biopsy is considered the diagnostic reference standard for the assessment of fatty liver, however it is invasive and prone to complications and is no longer considered as mandatory as first line screening tools for fatty liver (21). MRI provides different contrast between the different tissues of human abdomen, and has potential to quantitatively assess the hepatic liver in patients with fatty liver and predict the degree of steatosis of liver (22-34). Some quantitative imaging methods have been proposed for evaluating the hepatic fat, such as, Dixon method (22-24,34-38), the in-phase, opposed phase gradient echo MR imaging method (25,32), and proton MR spectroscopy method. However the insufficient image resolution and long acquisition time limit its quantitative capability. In addition, the motion artifacts caused by breathing and heartbeat become a major problem in further improvement of hepatic image quality in practice. It is highly demanded to increase the imaging speed and also the image resolution, which is challenging in present liver MRI routines. Recent years, high and ultrahigh field MRI (39-50,51-64), such as 7T, has shown its inherent ability to improve signal to noise ratio in human head imaging (42-45,48,49), prostate imaging (50,65), spine imaging (46,54) and abdominal imaging (51,59,66). It is expected to achieve better signal to noise ratio (SNR) and thus high resolution in liver imaging. However, transferring liver imaging protocols to ultrahigh fields faces many practical difficulties and technical challenges in both RF coil design and sequence design for human liver imaging due to the pronounced radiation losses, chemical shift, motion artifacts and B_1 variation (31) at high fields. There is an urgent demand for technical development for liver imaging in both MR hardware and fast acquisition strategies using ultrahigh field MR.

Recent years, the microstrip transmission line (MTL) RF coils (40,55,67-69) have shown advantages in high and ultrahigh field MR applications with high frequency operation capability, high quality factors, reduced radiation losses and improved MR sensitivity. Its unmatched decoupling feature is essential for high field RF transmit/receive array designs. An example is the flexible transceiver array developed for ultrahigh field 7 T MR applications by using the first and second order harmonics of the microstrip resonator (55,70). The mixed harmonic MTL resonator technique greatly improves the decoupling performance, reduces noise correlations between resonant elements, and enhances parallel imaging performance. This technique does not require physical connection or decoupling network between array elements, which is commonly used in conventional coil array designs for implementing decoupling. Consequently the geometry and size of the microstrip flexible array can be conveniently adjusted to best fit patients, achieving the best filling factor and therefore the increased signal to noise ratio for human liver imaging.

In fast imaging methods, parallel imaging has demonstrated the unique capability in accelerating MR imaging by using the different sensitivity profiles of RF coil array elements to replace the phase encoding. The undersampled raw data can be reconstructed using a special reconstruction method to achieve a correct image with significantly reduced aliasing (71-76). Our previously proposed flexible microstrip array can be readily utilized for parallel imaging to accelerate the hepatic imaging and thus help reduce the motion artifacts. On the other hand, parallel transmission is able to shorten the RF pulse width for spatial selective excitation by using transceiver coil arrays and the sensitivity information (77-81). Although the specific absorption ratio (SAR) grows with the acceleration rate, the SAR can be optimized using different strategies such as variable sampling rate or optimized k-space trajectories (78,82,83). In human liver imaging, the power deposition is always an important safety issue while the imaging speed is critical to imaging quality. Parallel transmission strategy thus provides effective ways to help making a tradeoff between the power deposition and imaging speed for hepatic imaging.

Recently the compressed sensing (84) MRI which can greatly reduce the raw data size required for image reconstruction and shorten the imaging time by using significantly undersampled k-space demonstrates great potential to perform fast imaging with high image quality and enhanced image resolution (85-99). This is very helpful for liver imaging because motion artifacts caused by breathing and heartbeat often deteriorate liver image quality. Unlike the parallel imaging, compressed sensing technique basically does not require any new hardware for implementation. However, at the high acceleration rate, the contrast to noise ratio (CNR) normally decreases quickly due to the use of significantly undersampled k-space data. This is not desired in liver imaging because the tissue contrast plays an important role in differentiating normal and diseased liver tissues. The interpolated compressed sensing (iCS) MR image reconstruction method proposed recently would be possible to improve CNR and even SNR at high acceleration rates for multi-slice 2D imaging applications (98). For a significantly undersampled slice some missed raw data can be estimated by using the raw data from the neighboring slice convolved by a weighting function. This strategy helps improve the CNR and also SNR of the images of multi-slice 2D MRI. It would be advantageous to apply the iCS method to hepatic imaging and develop specialized MR pulse sequence and reconstruction method to dramatically shorten the acquisition time while maintain the CNR. This would provide an efficient imaging tool for quantitatively assessing the liver fat and monitoring therapy outcome of the fatty liver non-invasively.

In summary, the advanced MRI techniques such as ultrahigh field, novel RF transceiver arrays, parallel imaging techniques, parallel transmission and compressed sensing would be advantageous in augmenting its quantitative capability and gaining better diagnosis and characterization of fatty liver diseases. To realize this and provide clinically-valuable images, dedicated RF transceivers, specific imaging sequence and reconstruction methods have to be explored and investigated to satisfy the clinical requirements.

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