Ultrashort TE (Lung, Liver, Iron)

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Highlights

- The very short T2* of some tissues (eg lung) and pathologies (eg hemochromatosis) make traditional proton imaging difficult
- Using ultra-short echo times (UTE) can dramatically increase signal in these tissues
- Robust UTE acquisitions using commercially available 1.5T and 3T scanners are feasible
- Differentiating tissue components based upon their T2* is not only feasible but may be necessary to develop robust quantitative MRI techniques for monitoring treatment effect or disease progression

Target Audience: Thoracic radiologists and MRI physicists interested in imaging of short T2* tissues or conditions

Objectives

1. To provide an overview of the benefits and challenges of UTE MRI of soft tissues, in particular the lung and liver
2. To summarize the principal strategies for implementing UTE MRI, with an emphasis on methods achievable with commercially available hardware
3. To suggest how UTE might be used to improve quantitative assessment of iron deposition disease and fibrosis
4. To show examples of state-of-the-art applications of UTE to abdominal and lung MRI

Background

MRI of short T2 or T2* soft tissue components is often limited by low signal from these components due to data acquisition beginning after much of their transverse magnetization has already decayed. This low signal is often further obscured by the much higher signal of long T2 or T2* components in the same tissue. An excellent review of the strategies for imaging short T2 and T2* tissue components, with an emphasis on musculoskeletal tissues, is provided in Reference (1).

As early as 1991, medical physicists recognized the potential of radial acquisition methods to decrease echo times and avoid some of the T2* signal decay in the lungs (2). More recently several research groups have further optimized ultra-short echo time (UTE) methods to the lungs, with promising results in both small animals (3-5) and in humans (6-8).

In the abdomen, a great deal of progress towards truly quantitative imaging has been made over the past decade, particularly with respect to the liver (9). Quantification of liver iron is clinically important, both in isolation and in combination with fatty liver disease, and relies principally on precise measurements of liver R2* (1/T2*). The feasibility of detecting liver disease based upon T2* effects using a UTE sequence was demonstrated more than 10 years ago (10). Now that robust 3D UTE methods are more widely available and optimized for human imaging, there is great potential for these methods to improve liver R2* mapping and perhaps quantification of hepatic fibrosis.

Methods

When used to image cartilage or cortical bone, most UTE work has focused on achieving echo times in the microsecond range. The T2* of the lungs and the iron-overloaded liver, while very short, is

significantly higher than the T2* of these musculoskeletal tissues. Thus, UTE MRI of these organs can be very effective with echo times in the 10-100 μs range. This is possible on commercially available hardware.

A 3D radial pulse sequence allows data read-out to begin immediately after transmit-receive switching is complete, without the need for any preparatory phase-encode gradients. It is also inherently quite robust to the motion artifacts that are commonly encountered in lung and liver imaging. UTE approaches usually begin sampling data at the center of k-space immediately after the radiofrequency (RF) excitation, with data acquisition occurring while the read-out gradient is ramped up. The minimum switching time between transmit and receive allows the use of a slab selective RF and accommodates a small prewinder gradient to ensure that the beginning of the readout starts at the center of k-space. The use of a slab selective RF can decrease the amount of radial streak artifact arising from excited tissues outside of the imaged field of view (FOV). Use of variable density rather than trapezoidal gradients can improve signal-to-noise by virtue of the fact that the center of k-space is inherently oversampled using 3D radial trajectories.

Results

UTE MRI of the lungs has been used successfully to directly image a variety of lung pathologies in both small animals as well as in humans. By increasing the baseline lung signal above the level of noise, UTE MRI also enables several other approaches, including direct lung T1 or T2* mapping, magnetization transfer to differentiate tissue types within the lungs, and the use non-traditional contrast agents. UTE imaging of the liver is less well developed than in the lung. However, the rationale and potential role for UTE in quantitative evaluation of iron overload and perhaps fibrosis will be described. Finally, the potential benefit of UTE to vascular imaging will be illustrated using some recent experimental results.

Discussion

Although UTE MRI of the lungs has been gaining significant traction over the last several years, the use of UTE to image other visceral organs and vascular structures remains in its infancy. The growing availability of robust high-resolution 3D UTE methods is likely to prove very useful to the maturing field of quantitative liver imaging by improving the assessment of iron overload and potentially hepatic fibrosis.

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