

Ultra-Short Echo Time MRI of the Lung

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Highlights

- The very short T2* lungs (~1 ms) makes proton-based structural lung MRI very challenging
- Using ultra-short echo times (TE < 0.1 ms) can dramatically increase lung signal
- 3D radial acquisitions are able to achieve this on commercially available 1.5T and 3T scanners.
- Care must be taken to avoid respiratory motion and radial streak artifacts
- Variable read-out gradients can be used to further increase signal-to-noise ratio

Target Audience: Thoracic radiologists and MRI physicists interested in lung MRI

Objectives

1. To provide an overview of how ultra-short echo time (UTE) lung MRI can dramatically improve the performance of proton-based MRI of the lungs in humans.
2. To summarize the principal strategies for implementing UTE MRI, with an emphasis on the 3D radial approach
3. To suggest some important technical challenges and solutions specific to UTE MRI of the lungs in humans.

Background

MRI of the lungs has been limited by the very low proton density and short T2* (~1 ms) of the lungs. As early as 1991, medical physicists recognized the potential of radial acquisition methods to decrease echo times and avoid some of this T2* signal decay¹. As clinical echo times have progressively decreased into the sub-millisecond range, many clinicians and researchers have begun to notice that lung disease becomes more apparent. Motivated by these observations and also by the results of research over the past decade in the field of microsecond echo time imaging of extremely short T2* tissues such as cartilage and cortical bone², several research groups have begun to apply these ultra-short echo time (UTE) methods to the lungs, with promising early results in both small animals^{3,4} and in humans⁵.

Methods

When used to image cartilage or cortical bone, most UTE work has focused on achieving echo times in the microsecond range. This is beyond the capability of unmodified commercial scanners, principally due to the extremely fast switching necessary between transmit and receive modes. Fortunately, the T2* of the lungs, while very short, is significantly higher than these musculoskeletal tissues, opening up the possibility to perform UTE MRI of the lungs with echo times in the 10-100 μ sec range on commercially available hardware.

A 3D radial spoiled gradient echo (SPGR) 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 respiratory and cardiac motion artifacts that are commonly encountered in lung imaging. Through careful pulse sequence design, including the use of variable read-out gradients to improve signal-to-noise, large slab instead of non-selective excitation, and adaptive prospective respiratory gating, it is possible to optimize a 3D radial SPGR sequence for UTE MRI of the human lungs. The 3D radial approach is inherently inefficient in its sampling of k-space, oversampling the center and undersampling the periphery. This can lead to relatively long scan times; however, with the use of adaptive prospective respiratory gating, it is possible to obtain high-quality images with a 5-min free-

breathing scan. In fact, being able to perform a free-breathing exam can be a practical advantage when imaging patients with lung disease who are more likely to have difficulty performing breath-holds.

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 negative-contrast tracer agents to visualize the distribution of inhaled or injected agents. Some examples of recent research in these applications will be presented to provide some insight into the potential impact of the technique.

Discussion

UTE MRI of the lungs offers the potential of providing a non-irradiating alternative to CT, especially in pediatric populations in whom radiation risks are greater than in adults. The strength of lung MRI has traditionally been in the realm of functional imaging using an extrinsic contrast mechanism to provide the signal (e.g. injected gadolinium for perfusion or inhaled hyperpolarized gases). A weakness of these approaches has been a relative lack of a structural correlate for these functional measures. Ultrashort echo time MRI of the lungs is poised to not only provide this structural reference for use with functional lung MRI studies, but to itself offer novel methods of distinguishing disease that are unavailable from computed tomography (CT), the current workhorse of clinical cross-sectional lung imaging.

References

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