MR/Clinical Case Study

Lung Imaging Using Multi-Echo Ultrashort TE Technique

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Introduction

MRI is a highly valuable and noninvasive imaging tool used to assess lung diseases and abnormalities, providing detailed insights into the lungs and surrounding structures. However, the implementation of lung MRI in routine clinical practice presents challenges due to susceptibility and motion artifacts caused by respiration and cardiac pulsations. Moreover, imaging the lung parenchyma using traditional MR techniques is exceptionally difficult due to its inherent short T2* properties and low proton density.

To overcome these challenges, specific techniques are employed during lung MRI, such as breath-holding, electrocardiographic gating (ECG), and respiratory control. One innovative approach is Ultrashort TE (UTE) imaging, which utilizes an extremely short echo time (TE) of less than 0.1 ms. This technique enables the capture of signals from anatomical structures with short T2* properties that are typically challenging to image using conventional MRI sequences.

By employing a multi-echo UTE sequence, a series of images with varying TEs can be generated, allowing for T2* mapping. This multi-echo UTE sequence has been carefully optimized and validated using a phantom with known T2* values. Furthermore, its application has been extended to studying the lungs of both healthy individuals and those affected by diseases, providing valuable insights into lung conditions.

Multi-Echo UTE T2* Mapping for Lung

Protocol optimization was performed on five healthy volunteers (46 ± 23 years) after obtaining IRB-approved written informed consent. After the protocol optimization, 10 healthy (38 ± 8 years) and 10 volunteers (post-COVID19 or asthma) (50 ± 8 years) subjects were scanned on a clinical 3T imager (Vantage Galan, version 6, Canon Medical, Japan) after obtaining IRB-approved written informed consent. Images were acquired using body SPEEDER and spine SPEEDER coils. The scanning protocol included the following series:
(a) 3D UTE without fat suppression (TE/TR = 0.096 ms/3.7 ms, NEX = 1, FA = 5°); (b) multi-echo UTE (six TEs = 0.096 ms / 2.3/4.5/6.7/8.9/11.1 ms, with fat suppression: five SPectral Adiabatic Inversion Recovery (SPAIR) pulses per 64 segments were applied, resulting in approximately one SPAIR per 36 UTE lines, TR = 16.9 ms, NEX = 1, FA = 4°); All study series were acquired with the respiratory bellows during the expiratory phase of the cycle and shared the same geometric parameters: coronal orientation, FOV = 40×40 cm, matrix size 256×256. The time-dependent signal curve for each voxel inside the phantom insert was fitted using least squares into the equation:

$$S(t) = S(0) \cdot exp\,(-t/T_2^*) + S' \quad ,$$

where the offset parameter S′ was introduced to account for long T2* components, to reduce the partial volume effect and the signal noise floor.

Average lung volumes, measured from the segmentation of UTE images obtained during inspiration and expiration phases, were 3.25 ± 0.13 liters and 2.68 ± 0.08 liters, respectively. The average T2* for the lung was 0.90 ± 0.08 ms. An example of the colormap superimposed over the first echo image is shown in Figure 1.

Figure 2 shows the voxel-wise T2* colormaps of lungs superimposed over the first echo of the 3D UTE image for two healthy (left panel) and two post-COVID-19 (right panel) subjects. The average T2* of the entire lungs of the healthy subjects was 1.09± 0.21 ms which is similar to the previous reports. In post-COVID-19 subjects, multiple regions with abnormally high T2* were observed possible due to the possible presence of water and mucus.

While lung MRI presents certain technical difficulties, advancements such as the multi-echo UTE sequence with its ultra-short TE have shown promise in overcoming these challenges. This innovative technique contributes to improving our understanding of lung health and enhancing diagnostic capabilities for lung diseases in both research and clinical settings.

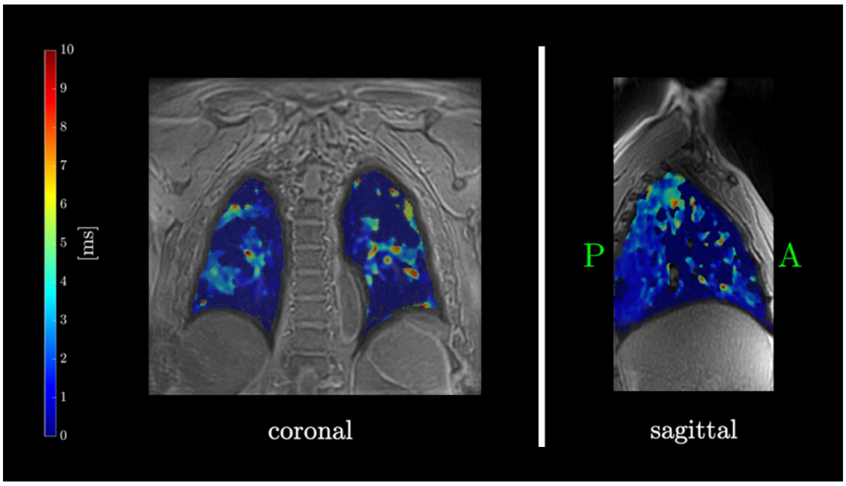

Figure 1: Representative UTE T2* maps on a healthy subject.

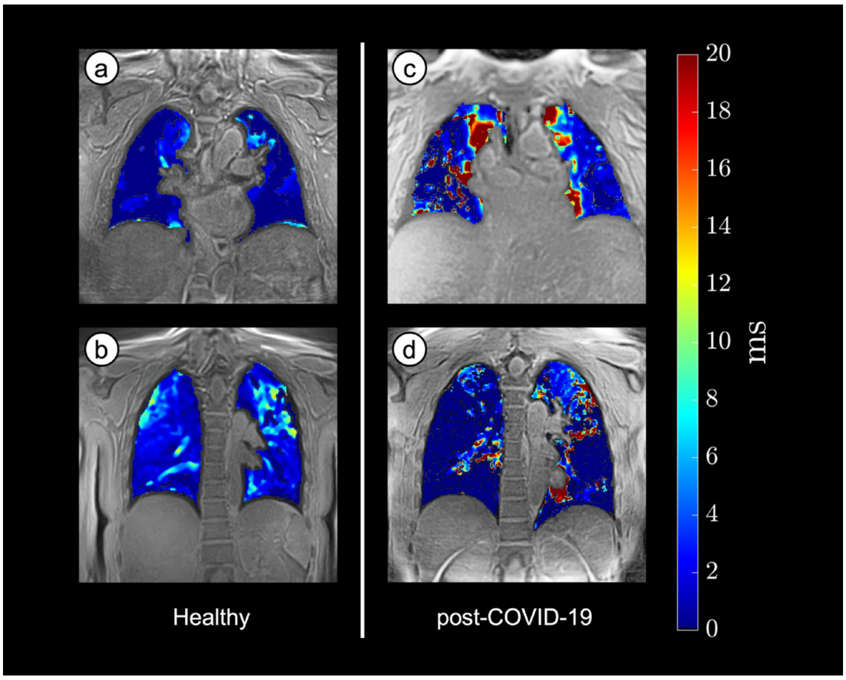

Figure 2: UTE T2* maps of healthy subjects (a, b) and post-COVID-19 subjects (c, d). Abnormally high T2* observed in post-COVID-19 subjects may be due to the possible presence of water and mucus.

Summary

Successful visualization and T2* mapping of lungs in post-COVID-19 adults is achieved using free-breathing 3D multi-echo UTE MR imaging techniques. Calculated T2* maps provide additional valuable information.

The clinical results, performance and views described in this paper are the experience of the author. Actual results and performance of Canon Medical's product may be materially different due to clinical setting, patient presentation, BMI, and other factors.

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