

## Ultrashort echo time MRI of lung pathology in humans

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**INTRODUCTION:** MRI evaluation of structural human lung disease has traditionally been limited both by the lungs' inherently low proton density and its very short T2\* caused by B0 inhomogeneities related to the vast number of air-tissue interfaces. Even at conventional echo times of as low as 1ms, the low signal from the lung parenchyma, severely limits the ability of MRI to evaluate lung structure. Over the past several years, ultrashort echo time (UTE) techniques have been developed and have show great promise, especially in the evaluation of cortical bone, cartilage, and other short T2\* structures [1]. Extension of these methods to lung imaging in animals has been very promising [2-5]. The purpose of this work is to demonstrate the feasibility of evaluating human lung disease using a 3D radial UTE sequence with commercially available hardware.

**METHODS:** In this HIPAA-compliant IRB-approved study, 5 subjects with lung disease (scleroderma x2, lung cancer, aspiration pneumonia, and cystic fibrosis) were scanned using a dual-echo ("outward-inward") 3D radial pulse sequence. The "outward" echo was obtained with an ultrashort TE and the "inward" echo with a conventional TE. Two subjects were scanned at 3T (MR750, GE Healthcare, Waukesha, WI) and three were scanned at 1.5T (MR450w, GE Healthcare, Waukesha, WI). An 8-channel phased-array cardiac coil was used for all subjects. Prospective respiratory gating was used during the ~5.5min free-breathing scan. No contrast was administered to the cystic fibrosis subject. The other four subjects received 0.15mmol/kg of gadobenate dimeglumine (Bracco Diagnostics, Inc) immediately prior to the UTE acquisition. Scan parameters included: flip angle=5°, resolution=1.25mm isotropic, axial slab excitation, TE1/TE2/TR =0.08/2.0/4.2ms, 1ms readout, and 38,000 projections.

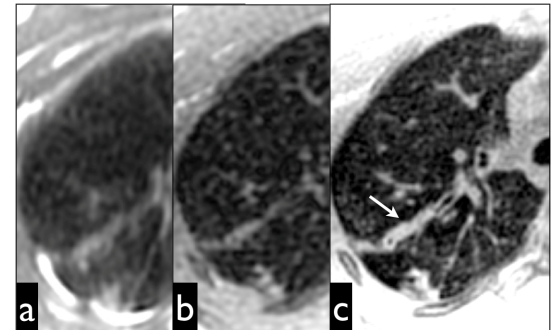
The UTE and conventional TE images for all subjects were scored using a consensus methodology in a randomized order by 2 radiologists. The following pathologic features were evaluated using a 5-point Likert scale (1=excellent→5=not present): reticular patterns, nodules and masses, regions of decreased signal intensity (cysts, bulla, emphysema, mosaic attenuation), regions of increased signal intensity (ground glass, consolidation, mosaic attenuation), and bronchiectasis. Image noise was graded on a 5-point scale from 1(minimal) → 5(unacceptable); motion artifacts were graded on a 4-point scale from 1(none)→4(severe); and overall image quality and parenchymal signal were assessed on 5-point scales from 1(excellent) → 5(unacceptable). Scores for the UTE and the conventional TE images were compared using a Wilcoxon rank sum test. P-values < 0.05 were considered statistically significant.

**RESULTS:** All scans were completed without difficulty. Figures 1-3 show examples of the image quality achieved with 3D radial UTE. While the average scores for all pathologic features were higher on the UTE images than on conventional TE images, only the visualization of reticular patterns met the threshold for statistical significance (p=0.04), likely due to small sample size. Image noise and motion artifacts were similar with either method (p=0.32, p=0.18). Parenchymal signal and overall image quality were significantly better on UTE images than on conventional TE images (p=0.04).

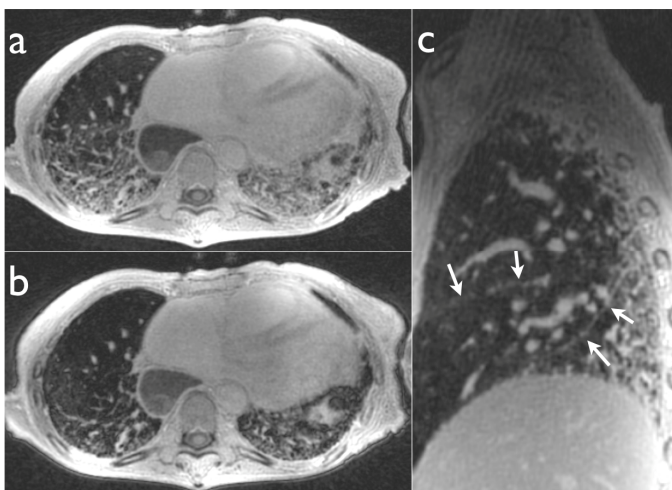
**DISCUSSION:** UTE images of the lungs show improved visualization of structural lung pathology and are strikingly similar to CT. As the 3D radial trajectories oversample the center of k-space, the method is insensitive to motion artifact. The use of respiratory gating allows a free-breathing acquisition – a significant advantage in pediatrics and when evaluating lung pathology in patients with pulmonary disease who may be dyspneic.

**CONCLUSION:** In this preliminary study, 3D radial UTE imaging of the pathologic lung is clinically feasible and well tolerated by sick patients. The method showed improved visualization of structural lung pathology when compared to conventional echo time imaging.

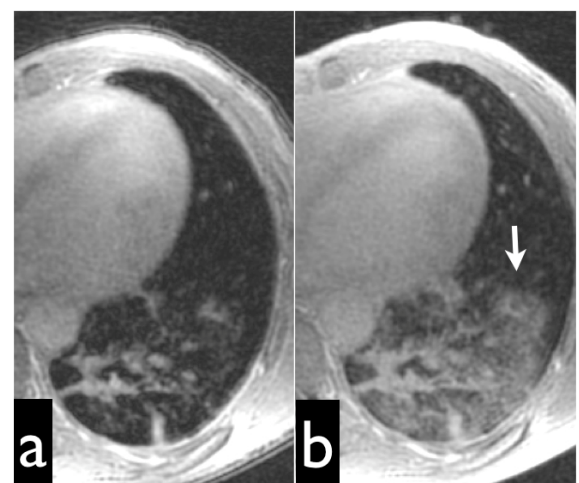
**REFERENCES:** [1] DJ Tyler, et al, JMRI 25:279-289 (2007) [2] SL Gewalt, et al, MRM 29:99-106 (1993) [3] M Takahashi, et al, JMRI 32:326-333 (2010) [4] O Togao, et al, MRM 64:1491-1498 (2010) [5] O Togao, et al, JMRI 34:539-546 (2011)



**Fig. 1. Cystic fibrosis.** Bronchiectasis with mucus plugging (arrow) is much better seen on the (c) free-breathing 3D radial UTE than on conventional breath-held (a) 2D SSFSE or (b) 3D SPGR images.



**Fig. 2. Scleroderma.** (a) 3D radial UTE images show markedly improved image quality and visualization of the extent of fibrosis than the (b) conventional TE images acquired simultaneously and windowed identically. Note the visualization of the pleural disease along the fissures on the (c) sagittal image (arrows).



**Fig. 3. Aspiration pneumonia.** (a) Conventional TE vs (b) UTE images acquired simultaneously in a dyspneic patient with aspiration pneumonia following cardiac arrest. Note the wide extent of the ground glass airspace disease (arrow) visible only on the UTE image.