Feasibility of 3D radial ultra-short echo time (UTE) MRI of the lungs in healthy subjects

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INTRODUCTION: Although CT is the gold standard method for evaluating lung structure, the associated radiation is concerning, especially in young patients and in patients who need repeated surveillance. Proton lung MRI has traditionally been limited principally by very short T2* and low proton density. Recent animal data utilizing ultrashort echo time (UTE) techniques for lung imaging have shown great promise [1,2]. The purpose of this study is to demonstrate the feasibility of using a novel 3D radial UTE acquisition and commercially available hardware to evaluate lung structures in humans.

METHODS: After IRB approval and informed consent were obtained, 9 healthy subjects were scanned on a clinical 1.5T scanner (MR450w, GE Healthcare, Waukesha, WI) using a commercial 8-channel phased-array cardiac coil. A dual-echo ("outward-inward") 3D radial UTE pulse sequence was used in order to allow comparison of UTE images with conventional echo time images. An ultrashort TE (0.08ms) was used for the "outward" echo (Echo 1) and a conventional TE (2ms) was used for the "inward" echo (Echo 2). Subjects were scanned both before and immediately following intravenous injection of a 0.05mmol/kg dose of gadobenate dimeglumine (Multihance, Bracco Diagnostics) in order to determine the effect of contrast on UTE image quality. Scan time for each acquisition was 5:35 min, during which the patients were allowed to breathe freely. Other relevant imaging parameters include: prospective respiratory gating, flip angle=5°, resolution=1.25mm isotropic, TE1/TE2/TR =0.08/2.0/4.2ms, 1ms readout, 38000 projections.

The pre- and post-contrast UTE and conventional TE image sets for all subjects were scored using a consensus methodology in a randomized order by 2 radiologists. The following features were scored: fissure visualization, interlobular septa, pleura/subpleural regions, centrilobular region, large bronchi, small bronchi, pulmonary arteries, and mediastinal soft tissue contrast. The following 5-point Likert scale was used: 0=excellent, 1=good (slight restriction of assessment), 2=fair (poorly defined structures), 3=uninterpretable (severely reduced image quality), and 4=not applicable or not present on images. 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). Comparisons between the pre- and post-contrast UTE images and between the post-contrast UTE and post-contrast conventional TE images. A Wilcoxon signed-rank test was used with p-values < 0.05 considered statistically significant.

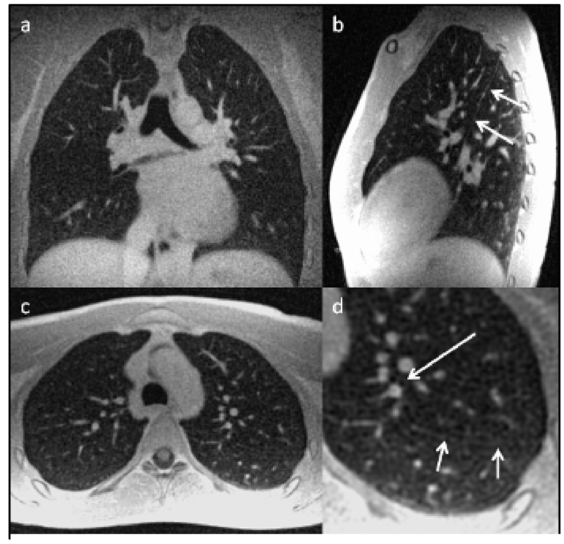

Fig. 1. Healthy Volunteer. (a) Coronal and (b) sagittal reconstruction clearly demonstrates the major fissure (arrows). (c) Axial image demonstrates detailed evaluation of the subsegmental pulmonary arteries, (d) small airways (long arrow), and major fissure (small arrows).

RESULTS: Figure 1 demonstrates an example of a post-contrast 3D radial UTE acquisition. Images demonstrate excellent visualization of the lung parenchyma and airways. The high isotropic resolution (1.25mm) allow the images to be reformatted in any plane. Motion artifacts are non-existent, a consistent feature of all the 3D radial acquisitions. Table 1 lists mean scores obtained for pre-contrast UTE, post-contrast UTE, and post-contrast conventional TE images with associated p-values located between the means. Post-contrast UTE images were superior to either pre-contrast UTE or post-contrast conventional TE images in visualizing the pleural/subpleural and centrilobular regions as well as pulmonary arteries. The airways are better seen with UTE than with conventional TE images. Mediastinal soft tissue contrast was limited with UTE. No statistically significant differences in image noise or motion artifacts were seen. Overall image quality of post-contrast UTE was superior to both pre-contrast UTE and post-contrast conventional TE.

DISCUSSION: UTE imaging of the lungs results in higher signal from the lung parenchyma and associated structures with resultant improved evaluation compared to conventional echo times. The normal fissures were poorly visualized by all methods, likely due to insufficient spatial resolution, not unlike early CT exams. The use of 3D radial trajectories along with prospective respiratory gating makes the sequence extremely insensitive to motion artifact. The application of adaptive prospective respiratory gating allowed a free-breathing acquisition, which is likely to be very important in clinical implementation in pediatric and adult patients with lung disease who are unable to perform extended breath-holds.

CONCLUSION: 3D radial ultra-short TE imaging of the lungs is a viable option for evaluation of the lungs and can be performed using commercially available hardware.

ACKNOWLEDGMENTS: We gratefully acknowledge GE Healthcare and the Department of Radiology for their assistance.

REFERENCES: [1] O Togao, JMRI 34:539-546 (2011). [2] M Takahashi, JMRI 32:326-33 (2010).

	Pre-con UTE	p-value	Post-con UTE	p-value	Post-con conv. TE
Fissures	4	0.068	2.6	0.295	3.2
Septa	4	1	4	1	4
Pleural/Subpleural	1.67	***0.012****	0.6	***0.008****	1.9
Centrilobular	1.67	***0.012****	0.6	***0.005****	2.1
Large Bronchi	0.22	0.655	0.1	***0.018****	1.4
Small Bronchi	2	0.068	1.4	***0.008****	2.6
Pulmonary arteries	2.11	***0.008****	0.9	***0.028****	1.5
Mediastinum	1.33	***0.042****	2.2	***0.018****	1.1
Noise	2.11	0.686	2.1	0.068	2.6
Motion artifact	0.33	0.317	0.2	0.317	0.1
Parenchymal Signal	1.78	***0.012****	0.5	***0.005****	2.5
Gravitational dep.	1.44	***0.028****	0.7	0.109	1.1
Overall Image Quality	1.78	***0.018****	0.6	***0.005****	2.5

Table 1. Median image quality scores of image quality. Low numbers represent better visualization. In almost all of the cases in which a statistically significant difference was observed, post-contrast UTE images depicted structures better than either pre-contrast UTE or post-contrast conventional TE images. Statistically significant ($p<0.05$) numbers are indicated in ***bold****.