Breath-hold UTE Lung Imaging using a Stack-of-Spirals Acquisition

John P. Mugler, III[1], Samuel W. Fielden[2], Craig H. Meyer[2], Talissa A. Altes[1], G. Wilson Miller[1], Alto Stemmer[3], Josef Pfeuffer[3], and Berthold Kiefer[3]

[1]*Radiology & Medical Imaging, University of Virginia, Charlottesville, VA, United States,* [2]*Biomedical Engineering, University of Virginia, Charlottesville, VA, United States,* [3]*Siemens Healthcare, Erlangen, Germany*

Target audience: Imaging scientists and clinicians interested in emerging approaches for lung MR imaging.

Introduction & Purpose: In recent years, there has been renewed interest in ultrashort echo time (UTE) techniques for imaging the lung with its intrinsically short T2* relaxation time. While substantial progress has been made using 3D radial-based methods[1,2], these acquisitions typically require several minutes because radial *k*-space trajectories are relatively inefficient. The purpose of this work was to implement a breath-hold UTE acquisition based on an optimized 3D stack-of-spirals acquisition[3], and to perform a proof-of-concept evaluation of the method for detection of small lung nodules.

Methods: Qian and Boada[3] demonstrated that a 3D stack-of-spirals acquisition can achieve very short echo times by minimizing the duration of each through-plane phase-encoding (PE) gradient waveform while simultaneously minimizing the TE such that, in the center of *k*-space, the minimum TE is limited only by RF excitation events or hardware switching delays, and increases toward the edges of *k*-space along the through-plane PE direction. In comparison to 3D radial, the variable TE introduces some blurring along the through-plane PE direction, in exchange for the sampling efficiency of spiral trajectories.

A commercial version of 3D spoiled gradient-echo imaging (VIBE, Siemens) was modified to support a stack-of-spirals acquisition. In addition, the excitation RF pulse was replaced by a short, rectangular RF waveform, which permitted minimum TE values of less than 100 µs, compared to the minimum TE of 600 µs achieved by Qian and Boada[3] (using slab-selective excitation). The basic operation of the pulse sequence (spiral UTE VIBE) was verified using phantoms and healthy subjects. The spiral UTE VIBE was then tested in three subjects with COPD who had one or more small lung nodules confirmed on CT. Imaging parameters for the COPD subjects included: TR 4.2 ms; flip angle 5°; matrix 256x256x56; voxel 2x2x5 mm^3; 64 interleaves @ 2.48 ms each; 15-s acquisition time. The TE (measured from the center of the RF pulse) varied during the acquisition from 50 µs (TE_{min}; for PE plane through center of *k* space) to 270 µs (for PE planes at edges of *k* space). Imaging was performed on a 1.5T scanner (Avanto, Siemens) using body-array and spine-array RF coils. Informed consent was obtained prior to imaging.

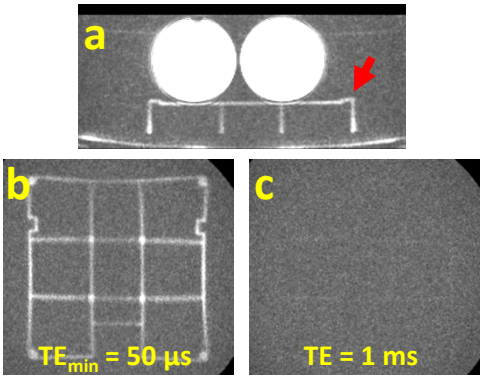

Figure 1. (**a**) Axial spiral UTE VIBE image from a 3D acquisition showing two water bottles on a hard plastic frame (red arrow). (**b**, **c**) Coronal images through the hard plastic frame for TE_{min} = 50 µs (b) and TE = 1 ms (c).

Results: **Figure 1** illustrates imaging of a hard-plastic frame using spiral UTE VIBE. The frame is clearly seen using TE_{min} 50 µs (Fig. 1b), but is barely visible using a TE of 1 ms (Fig 1c). Lung nodules, confirmed on CT, were visible in all three of the COPD subjects; all nodules detected with CT (ranging from approximately 3-mm to 1-cm) were apparent on MRI. Due to the relatively low sensitivity of spiral trajectories to motion and the low flip angle used, no significant motion artifacts were observed from the heart or major vessels. **Figure 2** shows some of the nodules detected in each subject with MR and CT, including ones in the right apex of subject 1, the left apex of subject 2, and in two locations in subject 3 (right apex, left anterior apex at chest wall). The 6-mm nodule in subject 2 was more conspicuous on MR than CT because of the low signal from the surrounding structures. In addition, the severe emphysema in subject 3 along the periphery of the right lung is apparent on MRI although less conspicuous than on CT.

Conclusions: Breath-hold ultrashort TE imaging of the lung has been demonstrated using an optimized 3D stack-of-spirals acquisition, without requiring additional acceleration such as parallel imaging. The results from our proof-of-concept study suggest that the method may have potential for detection of pulmonary nodules. The next step for this application is a prospective evaluation of the technique's sensitivity compared to chest CT.

References: **1.** Johnson KM et al. Magn Reson Med 2013; 70:1241-1250. **2.** Miller GW et al. NMR Biomed 2014; doi: 10.1002/nbm.3156. **3.** Qian Y, Boada FE. Magn Reson Med 2008; 60:135-145.

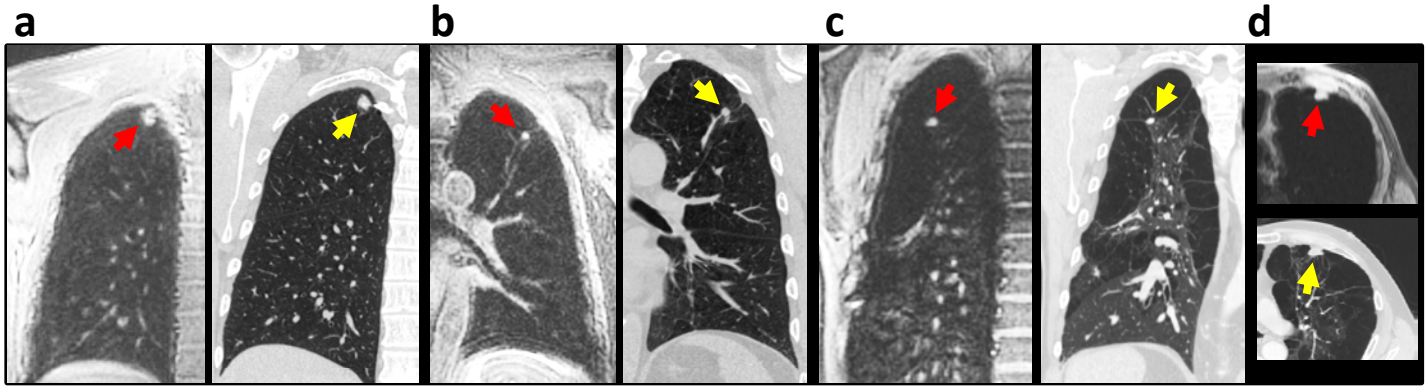

Figure 2. Pulmonary nodules detected in three subjects with COPD by MR (red arrows) or CT (yellow arrows): (**a**) Subject 1; (**b**) Subject 2; (**c**-**d**) Subject 3.