Evaluation of Free Breathing Ultra-Short TE 3D MRI for Oxygen Enhanced Imaging of the Human Lung

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Introduction: The Centers for Disease Control (CDC) has recently updated projections that chronic obstructive pulmonary disease (COPD) is now the 3rd leading cause of death in the US. Traditionally, medical imaging has not been used to clinically manage COPD. Instead, pulmonologists have relied on pulmonary function tests (PFTs) to provide information for staging and following response to therapy. Computed tomography has shown some promise for demonstrating gas trapping and deterioration of lung structure, but is not attractive for frequent use due to radiation dose considerations. 1H magnetic resonance imaging has had limited value in the lung due to short T2*in spite of research showing that functional information can be obtained with oxygen enhanced MRI [1]. Recently, advances in ultra-short TE (UTE) pulse sequences [2] have begun to provide the ability to image the lung parenchyma. In this work we evaluated whether UTE MRI could be used for oxygen-enhanced 3D imaging of human lungs during free breathing.

Methods: Subjects were recruited under an IRB approved protocol. For oxygen enhanced imaging an IND was obtained upon US FDA consultation. Subjects were imaged using the body matrix and spine coils under three conditions in a 3T MRI system (Siemens Tim Trio) using two breathing mixture conditions: 1) 21% oxygen (room air), 2) 100% oxygen, 3) repeat 21% oxygen (room air). Gas source was selected using electronic switching with a custom made apparatus and commercially available monitoring equipment and was delivered to the subject through a tightly fitting non-rebreathing mask with attached sensors measuring exhaled C02 and O2. The UTE pulse sequence (Siemens Corp. UTE WIP) used 3D radial ½ k-space sampling with the ends of the radial k-space readout lines describing a spiral on the surface of a unit sphere from the pole to the equator. Pulse sequence parameters were 128 radial samples, 30,000 trajectories, TR/TE/Flip angle=2.54ms/0.07ms/4^o, field-of-view=400mm, slice thickness=3.125mm, 128 radial samples, 30000 k-space trajectories, 128^3 reconstruction matrix (isotropic voxels), bandwidth=630Hz/pixel. Images were smoothed with a 3x3x3 convolution filter and an oxygen enhancement ratio image was calculated: (Soxy-Sair)/Sair. The intensity of the tissue outside the lungs was reduced by thresholding to enhance visualization of the lung.

Table 1: OER in Apex of Right Lung	Condition	OER (SD)
Subj 1	Normal	0.07 (0.07)
Subj 2	Reactive Airway	0.03 (0.05)
Subj 3	Asthma	0.05 (0.04)
Subj 4	Asthma	0.03 (0.02)

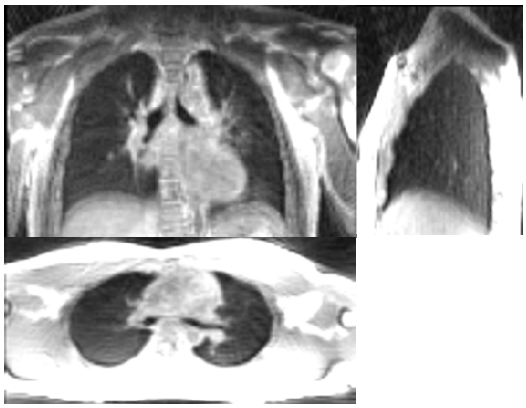

Figure 1: UTE image of the lungs of a subject with mild asthma

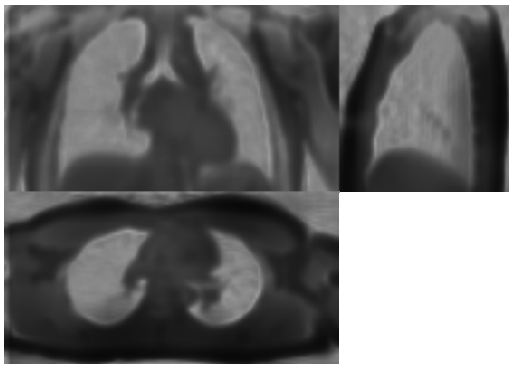

Figure 2: OER image of the same subject as in Figure 1

Results: A coronal UTE image of a subject with mild asthma is shown in Fig. 1 windowed to show the lung parenchyma. The corresponding OER image is shown in Fig. 2. Table 1 gives the value of the OER in a spherical region-of-interest (3.75cm dia) in the apex of the right lung for four subjects.

Discussion: Taking into account that these images were acquired during free breathing, with no techniques used to minimize motion artifacts, the images are generally of good quality, although they show streak artifacts that are mainly visible outside the subject and some blurring near the diaphragm. For a ½ k-space 3D radial sampling of 128 samples, the rule-of-thumb is that $2\pi(128)^2$~100000 k-space rays are needed, thus this acquisition is under-sampled. Hence the streak artifacts are likely due to a combination of view under-sampling and respiratory motion during the acquisition. Although the images showed enhancement due to the oxygen effect, the measured OER was not as high as has been reported by others [3] who report values in the 10-15% range. This may have been due to the choice of flipangle=4^o, which is slightly larger than the Ernst angle for lung and thus the sequence may not have had sufficient T1-weighting. In spite of this the 3D UTE sequence produced encouraging results that may be improved by optimization of the flip angle and incorporation of motion reduction methods such as self-gating.

References:[1] Ohno Y, Am J Respir Crit Care Med Vol 177. pp 1095–1102, 2008; [2] Nielles-Vallespin S., MRM 57:74-81(2007); [3] Kruger S.J., Proc. Intl. Soc. Mag. Res. Med. 20(2012) #1344