Quantitative Evaluation of Emphysema in COPD Patients via CT and UTE MR Image Analysis

David J. Roach[1,2], Yannick Crémillieux[3], Suraj Serai[4], Robert Thomen[1,5], Sadia Benzaquen[6], and Jason C. Woods[1,2]

[1]Center for Pulmonary Imaging Research, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States, [2]Pulmonary Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States, [3]Centre de Résonance Magnétique des Systèmes Biologiques, Université de Bordeaux, Bordeaux, France, [4]Radiology, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States, [5]Physics, Washington University in St. Louis, St. Louis, Missouri, United States, [6]University of Cincinnati College of Medicine, Cincinnati, Ohio, United States

Target Audience: Researchers in the field of lung imaging.

Purpose: Chronic obstructive pulmonary disease or COPD is an irreversible airflow obstruction and is a heterogeneous disease affecting the airways, parenchyma, and vasculature with different severities during the course of the disease. COPD is a leading cause of morbidity and mortality worldwide.[1,2] HRCT is currently the gold standard imaging technique for the diagnostic and the grading of emphysema lung disease. The increasing diagnostic value of magnetic resonance imaging (MRI) for lungs is largely due to developments and advances in ultrashort echo-time (UTE) sequences and Fourier decomposition techniques.[3,4,5] In this study, we investigated whether lung UTE MRI could generate reliable imaging biomarkers for patients diagnosed with COPD. We imaged both clinically diagnosed COPD patients and healthy control subjects via UTE MRI and compared these images to chest CTs, both qualitatively and quantitatively.

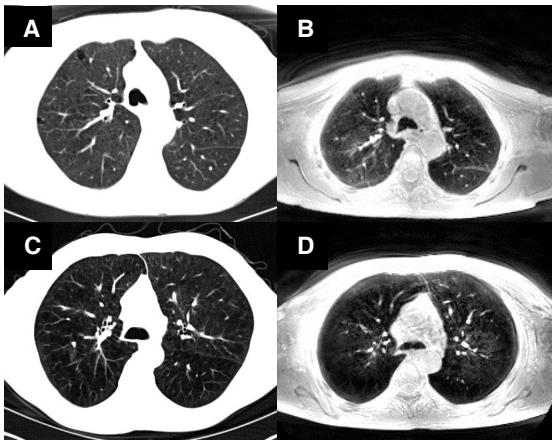

Figure 1: Representative axial (A) CT and (B) UTE MR images of COPD06. In (A) the CT EI is 0.4% and in (B) the UTE MRI EI is 7.0%. Representative axial (C) CT and (D) UTE MR images of COPD02. In (C) the CT EI is 48% and in (D) the UTE MRI EI is 31%.

Methods: Ten medically stable subjects with clinically diagnosed COPD (mean age 62.6 years ± 8.5, 5M/5F), and two healthy female subjects (ages 50 and 51 years), with clinically indicated thoracic CT were scanned on a 3T whole-body MRI scanner using a 32 channel chest array (Philips, Achieva) with IRB approval and written consent. A UTE navigator triggered imaging sequence was employed during quiet breathing while supine: Field of view (FOV) = 400 mm x 400 mm, TR = 2.69 ms, TE = 0.172 ms, flip angle = 5°, bandwidth = 1810 Hz/pixel, image matrix = 288 x 288, 10-15 m total acquisition time. For both CT and UTE MR images, whole lung analysis was performed using a commercially available software program (Amira). Absolute and normalized signal intensities (normalized to mean soft-tissue signal) were measured globally in MR images. Similar methods were used to extract information from CT images. Based on the clinical CT emphysema index (EI) routinely used for quantifying emphysema extent (using a threshold of < -950HU), we defined, in an attempt to generate an emphysema MR imaging biomarker, a similar index for UTE MRI lung images. The threshold, fixed to <10.5% of the mean whole body signal, proved to correlate extremely well with the CT EI. Finally, correlations between MRI signal parameters and CT parameters were evaluated and compared to spirometry.

Results: Representative axial CT and UTE MR images of COPD02 and COPD6 are displayed in Figures 1. For all subjects Table 1 lists mean lung densities, FEV_1 percentages, and emphysema indexes determined from CT and UTE MRI, which are plotted in Figure 2. UTE MRI signal intensity was lower in the COPD group ($p<0.001$) and EI was higher ($p<0.006$). EI of MRI correlated well with EI calculated via CT ($R^2=0.82$).

Discussion: Differences in lung density can be qualitatively assessed from subjects with varying degrees of emphysema, which are displayed in Figure 1. Despite the difference in lung inflation, identical lung structures such as vessels and bronchi can be identified in the CT and MR images. Image analysis of both CT and UTE MRI identified that COPD patients 02, 08, and 10 have more emphysema than small-airway obstructions compared to other patients. The high correlation between the two emphysema indexes ($R^2 = 0.82$) indicates that the difference in lung inflation between the two techniques is not a major hurdle for quantifying emphysema extent. The results demonstrated a significant positive correlation between lung density assessed with HRCT and MRI, and to our knowledge is the first quantitative validation of UTE MRI as a biomarker for tissue destruction associated with COPD.

Conclusions: UTE MRI is particularly useful in imaging disease/patients who are vulnerable or sensitive to ionizing radiation. The results of this study demonstrate that UTE MRI can be employed to quantify tissue losses in emphysema patients, and may serve as a biomarker for COPD extent and severity.

References:

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Figure 2. Emphysema Index CT vs UTE MRI

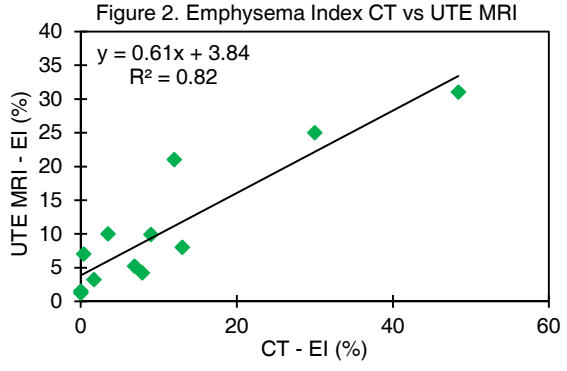

Table 1. UTE MRI and CT Results

Subject	UTE FRC (Normalized Intensity)	CT TLC (g/ml)	FEV_1	EI via CT	EI via UTE MRI (10.5% body signal)
Control01	0.451	0.148	81%	0.02%	1.5%
Control02	0.435	0.229	110%	0.01%	1.2%
COPD01	0.361	0.123	76%	1.7%	3.2%
COPD02	0.188	0.070	20%	48%	31%
COPD03	0.279	0.123	31%	9.0%	9.9%
COPD04	0.329	0.071	67%	13%	8.0%
COPD05	0.359	0.166	48%	6.9%	5.2%
COPD06	0.310	0.158	86%	0.4%	7.0%
COPD07	0.303	0.123	49%	3.5%	10%
COPD08	0.250	0.120	33%	30%	25%
COPD09	0.383	0.125	85%	7.9%	4.2%
COPD10	0.198	0.114	29%	12%	21%