Normalized T1 Relaxation Time Mapping for Improved Lung Imaging in Cystic Fibrosis Patients

Lan Lu[1], Elliott C Dasenbrook[2], David Weaver[2], Peter M Jakob[3], Mitchell L Drumm[2], Michael W Konstan[2], and Chris A Flask[1]

[1]*Department of Radiology, Case Western Reserve University, Cleveland, OH, United States,* [2]*Department of Pediatrics, Case Western Reserve University, Cleveland, OH, United States,* [3]*Department of Physics, University of Wurzburg, Wurzburg, Germany*

Purpose: Oxygen Enhanced (OE)-MRI, has been previously shown to provide a quantitative assessment of focal lung disease for cystic fibrosis and other lung diseases [1-2]. The OE-MRI method measures lung T1 relaxation times while breathing room air and supplemental oxygen in succession. The OE-MRI techniques have the translational advantage of identifying lung disease without paramagnetic or hyperpolarized gas contrast agents. OE-MRI also is obtained without the ionizing radiation of CT. One current limitation of the OE-MRI technique is the requirement to acquire multiple T1 maps as well as image co-registration for accurate quantification. OE-MRI also requires non-rebreathing ventilation equipment which can be extremely problematic for sedated pediatric patients. In this study, we have developed a method to normalize the T1 relaxation time for each subject to limit the effects of anatomic variation. Therefore, OE-MRI technique has been greatly simplified by acquiring T1 data only while breathing ambient room air which 1) reduces the acquisition time to 5 seconds / imaging slice, 2) eliminates the need for image co-registration making this technique ideally suited as a rapid screening tool for adult and pediatric CF patients.

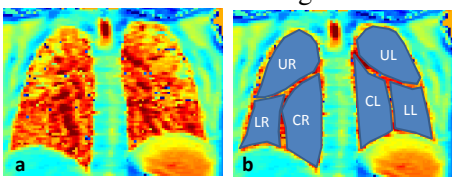

Fig. 1: (a) A representative T1 map from a CF patient and (b) overlaid ROIs.

Methods: Multislice, pulmonary T1 relaxation time maps were obtained for 6 adult CF patients and 5 healthy non-CF control subjects using a Look-Locker acquisition (TR/TE=1.8/0.8ms, 40cm x 40cm FOV, 40 images / T1 map) [2]. The absolute T1 relaxation time maps were normalized by dividing the mean T1 relaxation time in the central lung region of each subject where CF lung disease is not generally present (**Fig. 1**). (UR=upper right lung, UL=upper left lung, CR=central right lung, CL=central left lung, LR=lower right lung, LL=lower left lung). Linear regression was used to compare the mean normalized T1 relaxation times with clinical pulmonary function tests (PFTs: FEV_1, % predicted) for all subjects. Student's t-test analysis was used to compare the mean normalized T1 times in the upper and lower airways for the CF and healthy volunteer groups.

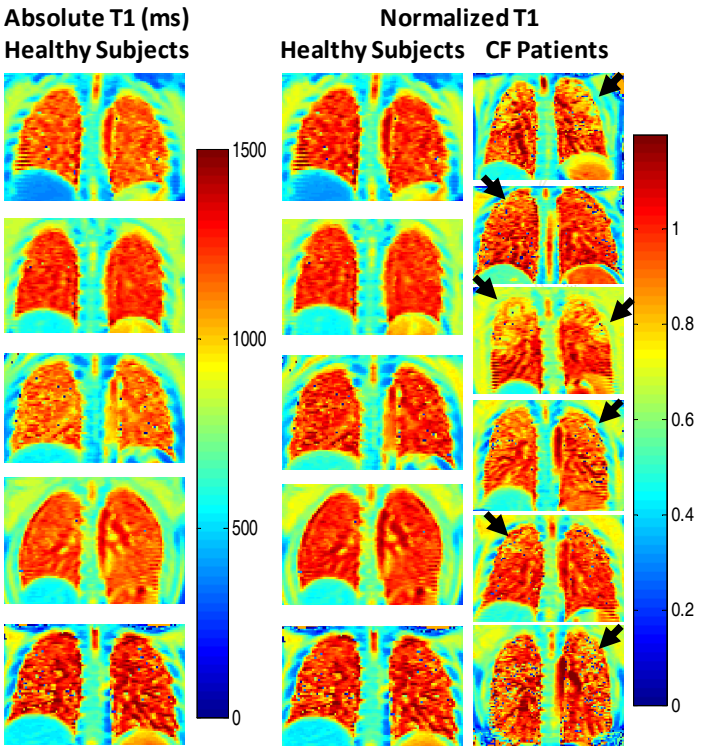

Fig. 2: Absolute (left) and normalized (middle) T1 maps from each of five healthy non-CF control subjects. The normalized T1 maps show much less variation than the corresponding absolute T1 maps. Normalized T1 maps (right) from 6 CF subjects clearly show regional lung disease (black arrows)

Results: The normalized T1 relaxation times showed decreased subject-to-subject variation in healthy volunteers (**Fig. 2**). The mean normalized T1 in the upper airways of all subjects exhibited a significant correlation ($r = 0.76$ / $p < 0.01$) with PFTs. No significant correlation was observed for the mean absolute T1 times. Student's t-test analysis of the normalized T1 values in the upper airways demonstrated a significant difference between all CF patients and the healthy controls ($p < 0.001$). Importantly, a significant difference in mean normalized T1 was observed between early-stage CF patients (FEV1, % predicted > 85%) and healthy controls ($p < 0.001$) despite no difference in PFTs (**Fig. 3**).

Discussion and Conclusions: Normalized T1 relaxation times show reduced subject-to-subject variation in healthy controls and correlates with "gold-standard" PFTs in CF patients and controls. The normalized T1 times also are able to differentiate early-stage CF patients (>85% FEV_1) from healthy controls. Together these results suggest that 1) CF lung disease can be reliable assessed with a single T1 measurement while breathing ambient air; and 2) the normalized T1 method may be more sensitive than the current clinical gold-standard in detecting early-stage CF lung disease. Further studies are needed to determine the exact mechanism of this decrease and to extend the utility of this technique to infant and pediatric CF patients. The simplicity of this technique may also be applied to other chronic lung diseases.

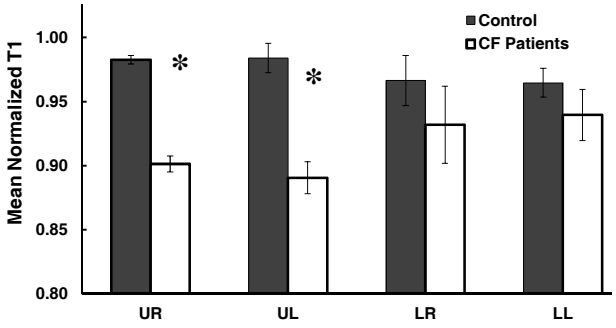

Fig. 3: Normalized T1 times in the upper airways of early-stage CF patients (n=3, FEV_1, % predicted = 85-100%) were significantly different (*$p < 0.001$) from healthy controls (n=5) despite no significant difference in the clinical lung function tests ($p > 0.2$)

References: [1] Edelman et. al. Nat Med 1996 [2] Jakob PM et. al, MRM 2004.