Comparison of Normalized T1 and Pulmonary Blood Flow Assessments in Cystic Fibrosis Lung Disease

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Target Audience: This work targets those who are interested in quantitative MRI assessments of cystic fibrosis lung disease.

Purpose: Our research team has recently developed a normalized T1 (nT1) method to safely and effectively assess the extent of early lung disease in cystic fibrosis (CF) patients[1]. This novel and straightforward MRI method may serve as an ideal routine evaluation for lung disease in CF patients as it is fast (~5 seconds/imaging slice), quantitative, no ionizing radiation, and requires no exogenous contrast agent. The mechanism of observed nT1 changes in CF patients is currently unknown. However, we hypothesize the nT1 changes are associated with altered pulmonary blood flow. In this mechanistic study, we compared nT1 directly with pulmonary blood flow obtained with our arterial spin labeling – fast imaging with steady-state free precession (ASL-FISP) acquisition in CF patients.
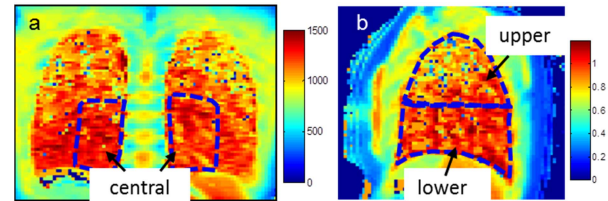

Figure 1: (a) A representative coronal absolute T1 map from a CF patient with ROIs indicated for the central lung regions. (b) A representative sagittal nT1 map for a CF subject with manual ROI selection on upper lung and lower lung region.
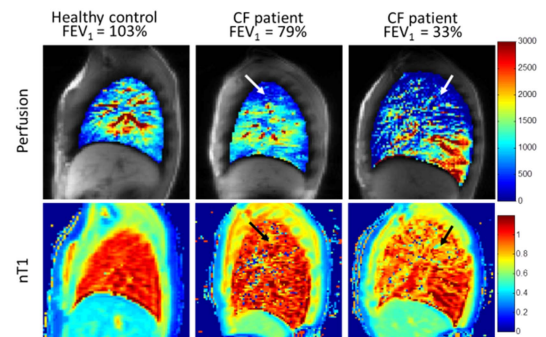
Methods: T1 and ASL MRI measurements were performed on nine CF patients with a range of lung function (FEV_1 %predicted = 25-127%) and five healthy non-CF control subjects. A rapid Look-Locker acquisition was used to acquire the lung T1 maps (TR/TE = 1.8/0.84 ms, FOV = 400 x 400 mm, resolution = 64 x 128, flip angle = 8°, slice thickness = 15 mm, 40 images acquired in ~5 seconds)[1,2]. Coronal and sagittal T1 maps were acquired. Our ASL-FISP acquisition was used to obtain sagittal pulmonary perfusion maps. ASL-FISP combines a FAIR (flow-sensitive alternating inversion recovery) ASL preparation with a centrically-encoded FISP imaging readout (TI = 1.3 sec; FISP: TR/TE = 4.2/2.1 ms, TH = 15 mm, 1 slice, FOV = 400 x 400 mm, number of averages = 15, acq time ~5min) to limit banding artifacts typical of True FISP acquisitions. The measured absolute T1 values in each voxel were divided by the mean T1 value in the central lung region (Fig. 1a) to generate sagittal nT1 maps as described (Fig. 1b)[1]. Upper and lower lung region of interests (ROIs) were manually selected on the sagittal nT1 and ASL-FISP perfusion maps for each subject (Fig. 1b). Mean nT1 and pulmonary perfusion values for the upper and lower lung regions were calculated and compared using a Student's t-test. The correlation between the mean perfusion and nT1 in the upper right lung region of the CF patients was primarily investigated as CF lung disease is known to originate in the right upper lung regions.

Figure 2: Representative perfusion maps (upper row) and nT1 maps (lower row) from a healthy control and two CF subjects. Regional lung disease (white and black arrows) was observed in both nT1 and perfusion maps for CF lungs.
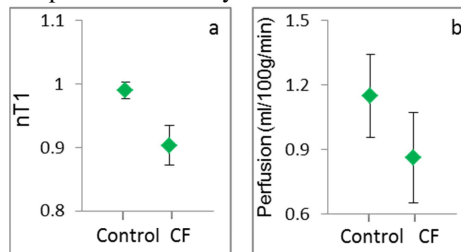
Results: Representative perfusion maps and nT1 maps from a healthy control and two CF subjects are shown in Fig. 2. Note the spatial heterogeneity in the nT1 maps of the CF patients in comparison to the uniform nT1 map of the healthy control. More importantly, for the CF patients, the regions of decreased nT1 (black arrows) matched well with the regions of decreased blood flow indicative of diseased lung (white arrows). A significant reduction ($p < 0.05$) in both mean nT1 and pulmonary perfusion was observed in the upper right lung regions for CF patients (Fig. 3). A significant correlation between the perfusion and nT1 values in the upper right lung region was also observed ($p < 0.05$), suggesting nT1 is related to pulmonary blood flow (Fig. 4).

Figure 3: Mean (a) nT1 and (b) perfusion values in the right upper lung region for CF patients and healthy control subjects.
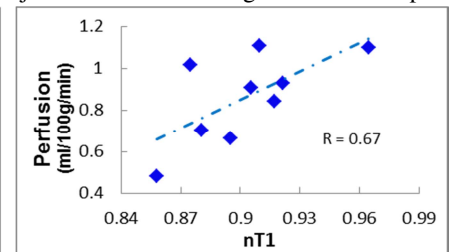

Figure 4: Correlation between ASL perfusion and nT1 values in the upper right lung region of CF patients (n=9, p<0.05).

Discussion and Conclusions: This study suggests that the observed nT1 reductions in the upper lung regions of CF patients are related to corresponding reductions in pulmonary blood flow assessed by ASL. These results demonstrate that both nT1 and pulmonary blood flow were significantly reduced in CF patients in comparison to healthy controls. In addition, nT1 generated a significant correlation with pulmonary perfusion. These results are consistent with prior results suggesting that pulmonary perfusion is reduced in CF lung disease.[3] Overall, these results confirm that nT1 may be an ideal screening tool for chronic lung disease progression in CF patients.

References: [1] Dasenbrook EC et. al., Plos One 2013. [2] Jakob PM et. al, MRM 2004. [3] Schraml C et. al., MAGMA. 2012.