INTRODUCTION: Early detection of chronic obstructive pulmonary disease (COPD) has been thwarted in part by the large inherent variability in pulmonary function test (PFT) results in the presence of small airway disease. MRI of inhaled hyperpolarized $^3$He gas has emerged as a promising technique for non-invasive evaluation of the structure and function of the lungs. $^3$He MRI can be used to probe several key aspects of lung function such as regional ventilation and perfusion; in particular, it can be used to assess the homogeneity of oxygen uptake in the alveoli by measuring alveolar partial pressure of oxygen ($pO_2$). Due to additional $T_1$ relaxation of $^3$He caused by oxygen, the alveolar $pO_2$ can be calculated from the images as reported by [1]. By measuring local $pO_2$ values, $^3$He MRI allows quantification of the structural changes based on heterogeneity of the lungs, and can become a much more sensitive marker of the disease onset compared to the current methodologies. Our hypothesis is that this method can be used to identify early stages of chronic obstructive pulmonary disease (COPD) in humans with a potential to provide a better means for the longitudinal assessment of the disease progression and therapeutic interventions.

METHODS: Seven human subjects were selected between the ages of 40 and 70 years old. Four non-smokers, two healthy smokers, and one subject with early COPD underwent $^3$He MRI imaging and measurements of pulmonary function that were repeated three times within a two-week interval. A physical test was administered to evaluate their eligibility for the study and the pulmonary function was measured in the hospital pulmonary function laboratory according to ATS criteria. During the MRI session, each subject was provided with a mixture of hyperpolarized helium and oxygen gases to inhale (4:1), and 4 sets of $^3$He images with 12 slices per set were acquired. The corresponding $pO_2$ maps of the 12 slices were generated by a $pO_2$ mapping methodology introduced by Hamedani et al. [1].

RESULTS AND DISCUSSION: Table 1 shows the mean values and standard deviations of all $pO_2$ maps for each subject and demonstrates the high variability within the groups. Figure 1 shows $pO_2$ maps of a COPD patient’s and a healthy subject’s lungs. The COPD subject’s $pO_2$ map indicates a lower partial pressure of oxygen compared to the healthy counterpart, as illustrated by the darker areas within the image. Figure 2 represents these maps as histograms where the difference is clearly visible as the COPD subject’s histogram shows a markedly wider and lower distribution (95.8±36.7 vs. 102.6±27.4 [mmHg]). Figure 3 shows analyses of the $pO_2$ map could potentially be used as a non-invasive metric for not only identifying and diagnosing early lung disease, but could also enable longitudinal tracking of the progression of the disease and monitoring of the therapeutic advances.

CONCLUSION: Based on these results, $pO_2$ mapping utilizing HP $^3$He MRI is a viable method for the quantification of human lung heterogeneity. In the presence of early disease which begins to alter the lung parenchyma but has not yet reached the detection limit of the current diagnostic methodologies, this technology may prove invaluable to the early diagnosis of COPD. The standard deviation of the $pO_2$ map could potentially be used as a non-invasive metric for not only identifying and diagnosing early lung disease, but could also enable longitudinal tracking of the progression of the disease and monitoring of the therapeutic advances.