Tobacco smoke exposure reduces lung T_1 in COPD patients

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Target audience: Researchers and clinicians with interest in MRI of the lungs, and especially in chronic obstructive pulmonary disease (COPD).

Purpose: Cigarette smoking is the main contributing factor for development of COPD. COPD is a heterogeneous disease where enhanced non-invasive characterization of lung pathology, such as MRI, will facilitate the development of new treatments. T_1 measurements of the lung are often performed in connection to lung function assessments [1]. In a COPD cohort we found that the degree of disease affected T_1 [2]. Therefore, we decided to analyze this cohort further by investigating whether tobacco smoke (TS) exposure leads to measureable changes on lung T_1.

Methods: Lung T_1 measurements from 23 COPD patients and 11 age-matched healthy non-smokers were extracted from an institutional review board approved study. The COPD subjects had smoking histories ranging from 12 to 102 pack-years (number of years or equivalent years in which 20 cigarettes a day was smoked, PY). The T_1 measurements were performed during free breathing and repeated a week later to test the T_1 reproducibility by intraclass correlation coefficient analysis (ICC) in 27 subjects. An inversion recovery half Fourier acquisition single shot turbo spin echo (IR-HASTE) sequence was carried out on a 1.5 T Philips Achieva MR system (Philips Healthcare, Best, the Netherlands). The imaging parameters were: TR=5500 ms, TE=3 ms, FOV=450^2 mm^2, matrix=128^2, 68 phase-encoding steps, coronal section with slice thickness=10 mm, FA=90° at a range of inversion times (TI 50, 300, 1100, 2000 and 5000 ms) with a 4 min scan time. Non-linear registration was used to correct for breathing-induced motion. The lungs were extracted using a semi-automatic segmentation method based on intensity thresholding, which also allowed the large pulmonary vessels to be excluded in the quantification. T_1 and proton density (M_0) [3] were calculated by fitting the inversion recovery signal equation pixel-by-pixel over the image. Median T_1 and M_0 values were obtained for each subject for the entire lungs. Student's unpaired t-test was applied for statistical analysis, where $p<0.05$ was considered as significant.

Results: Figure 1 shows representative lung T_1 maps for a healthy non-smoker and a COPD smoker. A good level (ICC=0.72) of T_1 reproducibility was observed between repeated scans acquired at two visits (Figure 2). Thus, mean T_1 from the two visits was used for evaluation. The lung T_1 (mean ± SD) was significantly lower (10%, p=0.0003) for the COPD smokers (927 ± 62 ms) than in the healthy non-smokers (1052 ± 58 ms). The lung T_1 decreased significantly (p=0.0005) with increasing PYs (Figure 3). This T_1 shortening remained with an adjustment for age as a covariate (p=0.0008). Additionally, the mean lung M_0 was significantly lower (29%, p=0.006) for the COPD smokers than in the healthy non-smokers. There was no statistical correlation between M_0 and PYs.

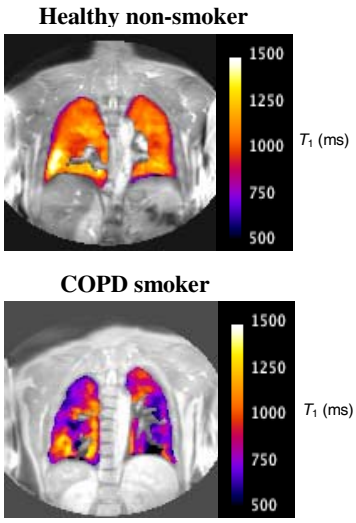

Figure 1. Representative coronal T_1 map of a healthy non-smoker and COPD smoker.

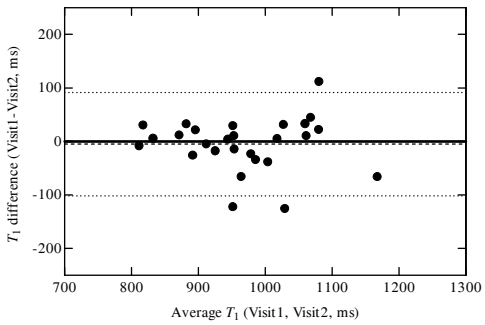

Figure 2. Bland-Altman plot for the mean T_1 from the two visits indicated good reproducibility with a mean difference close to zero.

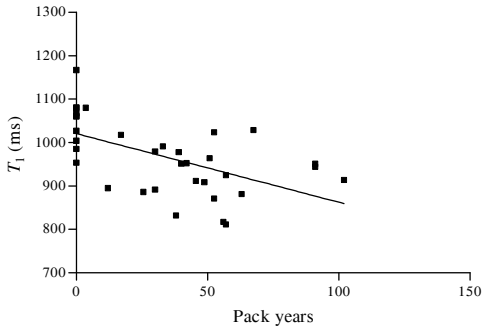

Figure 3. Strong significant correlation between T_1 and PYs was observed (p=0.0005).

Discussion and Conclusion: There was a significant lung T_1 decrease for TS exposed COPD patients compared to healthy age-matched non-smokers. The strong correlation between PYs and T_1 may be related to smoking-induced lung pathology such as structural pulmonary changes, destruction of vasculature, emphysema and fibrosis [4,5]. Alternatively, the presence of impurities and tar in the extracellular tissue water present in the lung may affect T_1 as a direct consequence of smoking. Additionally, the decreased lung M_0 [3] may correspond to emphysematous changes [6]. The IR-HASTE T_1 mapping protocol showed good reproducibility and sensitivity to pick up the small T_1 reduction. Consequently, the smoking history of a patient is an essential factor when T_1 is used as a readout in studies of lung diseases.

References: [1]. Morgan AR *et al*. Eur J Radiol 2014;83:2093-101. [2]. Hubbard P L *et al*. Proc. ISMRM 2011;19:542. [3]. Zhang W-J *et al*. Radiology 2014 (In press). [4]. Stadler A *et al*. MRM 2008;59:96-101. [5]. Stadler A *et al*. JMRI 2005;21:759-764. [6]. Olsson LE *et al*. JMRI 2007;25:488-494.