

MEDICAL DEVICE DEVELOPMENT TO QUANTIFY LUNG STIFFNESS IN SMOKERS USING MAGNETIC RESONANCE ELASTOGRAPHY

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Introduction

Tobacco smoking is responsible for 80 % of lung cancer in Europe [1] and in 2040 the European commission aims to achieve a tobacco-free Europe. Smokers develop symptoms as a function of tobacco use estimated by the number of pack-years [2]. Current medical test is Computed Tomography (CT) to evaluate the morphological lung changes. However, CT uses X-rays, limiting regular follow up of patients. Based on our experience in fibrotic tissues [3], we have developed magnetic resonance elastography (MRE) to quantify the mechanical properties of smoker lung. Of note, tobacco-related pathologies are the most preventable diseases and thus early detection and regular monitoring methods are essential. Our goal is to provide personalized cartography of lung stiffness which would 1) become a biomarker to prevent future lung disease and 2) trigger an awareness of the patient regarding the state of their lung function through a visual color scale.

Methods

Thirty smokers referred for a lung CT test were recruited for a clinical study (#A01496-33). They were divided into 2 groups of smoking pack-years (PY) with a threshold of 20 PY, considered as a high risk of lung cancer [2].

CT was performed with pixel size 0.73 mm, slice thickness 0.62 mm and 100-140 kV. A senior radiologist subjectively analyzed the structural properties (bronchial thickness,...). Moreover, the slice level where the intermediate trunk was clover-shaped in appearance was identified for future MRE assessment on the same lung region. CT density was calculated by converting the measured Hounsfield number into density units [4]. MR lung density obtained from a fast gradient-echo sequence was calibrated with a Gadolinium-doped water phantom placed on the sternum, and validated with the CT density values. MRE test performed on a 1.5 T MRI, in 22 s, with a driver placed on the right lung inducing mechanical shear waves (50 Hz). A spin-echo echo-planar sequence with motion-encoding gradient was applied to obtain the stiffness in 4 axial slices, as well as the shear wave displacement. Mechanical properties of the right lung were measured within a contour drawn by 2 operators. Then, the true lung stiffness was calculated from the displacement images using multi-model direct inversion and a homemade post-processing (pixel-wise correction for density,...). All values were expressed as mean \pm standard deviation. Statistical analysis (R software) was performed with the Mann-Whitney test.

Results

Smokers belonging to a study including 77 volunteers with known lung pathologies were assessed via MRE. Based on previous work [5], healthy lung stiffness was found to be about 1 kPa. Figure 1 shows an increase in the wavelength inducing an increase in the lung stiffness (μ : shear modulus) as a function of the PY. A significant ($P < 0.001$) difference was found between both smoker groups ($\mu_{PY < 20} = 1.34 \pm 0.25$ kPa vs $\mu_{PY > 20} = 1.83 \pm 0.35$ kPa). For the MR and CT densities, a higher trend was found for patients with a PY > 20. Inter-operator agreement at 95 %-confidence for the lung stiffness was excellent (Intraclass Correlation Coefficient: 0.84-0.98).

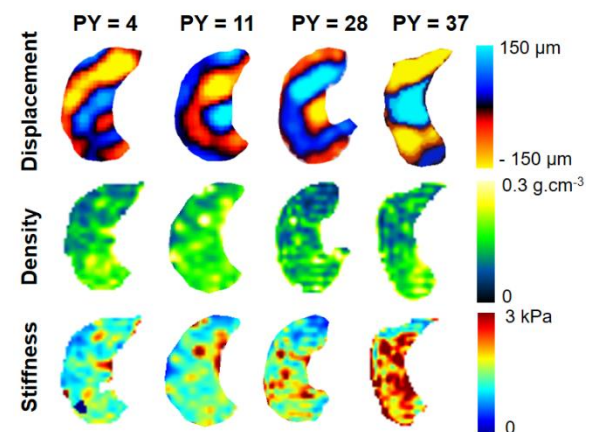


Figure 1: Displacement image (top row), MR density (middle row) and stiffness (down row) personalized cartographies of the right lung for four smokers in function of the use of pack-years (PY).

Discussion

The originality of this work is to personalize the mechanical result using the own patient lung density which vary from one person to another. Also, this study has demonstrated the utility of MRE as a non-invasive method to better predict lung pathogenesis as a result of smoking. Regular uptake of this assessment in smokers has the potential to prevent future disease resulting in both economic and social impacts. In addition, MRE could help tobacco specialists to better understand the recovery of the lung following smoking cessation.

References

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