

Assessment of Relative Regional Lung Compliance in Patients with Chronic Obstructive Pulmonary Disease

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INTRODUCTION Lung diseases such as chronic obstructive pulmonary disease (COPD) often lead to changes in pulmonary mechanical properties, such as the tissue compliance [1]. Pulmonary function tests (PFTs) which are often used to assess such altered lung function can only provide information on a whole organ level. Computed tomography (CT) can provide high resolution structural images, but has an undesirable associated radiation dose, and cannot provide direct information about altered local lung mechanics in disease. A number of different magnetic resonance imaging (MRI) methods have been developed in attempts to gain such information, including grid-tagging [2] and non-linear registration of structural lung images [3]. However, many of these methods have required either special equipment or breath-holding manoeuvres which can be difficult for patients to carry out. A method utilising free-breathing proton MRI images in conjunction with finite element image registration was recently introduced, allowing exploration of relative regional lung compliance and dynamics without invasive procedures or exogenous contrast agents [4]. This method has been applied in a cohort of healthy volunteers and COPD patients with varying disease severity in order to investigate regional changes in lung dynamics and compliance in disease, the results of which are presented here.

METHODS The details of this method have been previously described in [4]. In brief, serial structural 2D coronal lung images were acquired using a cardiac triggered HASTE sequence. Ordering of the images into a representative composite breathing cycle was carried out in a semi-automatic fashion, using an active shape model (ASM) [5] to find the diaphragm position in each image. Images were then registered with a group-wise affine image registration [6] using a triangulated finite element mesh of control points defined over the lung. Control point positions at different points in the breathing cycle allowed measures of local lung motion to be found as well as local lung expansion/contraction through changes in mesh element area during respiration. By examining the relationship between local and global area changes, relative regional compliance could then be calculated for each element of the lung. Local lung motion was illustrated using vector field maps of maximum magnitude of motion over the breathing cycle. The log of relative regional compliance was mapped over the lung, with any elements with an unphysical negative compliance removed – most likely caused by through plane motion or fixed points at lung edges/vessels causing element contraction rather than expansion in inspiration. 24 COPD patients (12 severe 12 moderate) and 12 age-matched healthy volunteers attended two scanning sessions. Spirometry was also performed in all subjects. At the analysis stage, one healthy volunteer was excluded due to cardiac trigger failure, and two healthy volunteers and a patient with severe COPD were removed because of registration failure due to the diaphragm leaving the field of view at end-inspiration.

RESULTS Vector field maps and relative regional compliance maps were compared visually between groups. Examples of the results obtained are shown in Figure 1 for a selection of patients and controls. Vector field maps of regional motion in healthy volunteers illustrated a relatively smoothly increasing magnitude of motion from lung apices to the diaphragm as expected. There was symmetrical motion from left to right lungs in the majority of cases. In the vector field maps of COPD patients there was a dramatic loss of symmetry of lung motion in some cases indicating one lung was more affected than the other. In other cases, areas of reduced motion could indicate possible regions of disease in the upper parts of the lung. Compliance maps for the healthy volunteers were found to be essentially homogenous in the majority. An increased overall heterogeneity was evident in the compliance maps of COPD patients compared with healthy volunteers, with regions of increased/decreased relative regional compliance indicating likely diseased lung areas. Examples of repeat visits for patients with good slice matching are also shown in Figure 1. A qualitative visual assessment shows that the reproducibility between visits is good, with both the relative regional compliance maps and the vector fields indicating similar regions of abnormality in both visits.

CONCLUSIONS An image warping method has been used to investigate pulmonary motion and relative regional compliance in healthy volunteers and COPD patients of varying disease severity. In the majority of cases, clear differences could be seen between COPD patients and healthy volunteers with vector field maps illustrating areas of reduced motion and a loss of symmetry in the patients. Regions of high/low relative regional compliance in patient maps may be associated with regional pathological changes within the lungs. Visual assessment of patient maps from two separate visits indicated similar regions of likely disease, confirming the results of the method are reproducible.

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