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Regional Lung Ventilation Analysis using Temporally Resolved Magnetic Resonance Imaging

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Interstitial and also obstructive lung diseases often affect the compliance of the lung, impeding normal ventilation and thus the oxygen uptake. Global changes in lung ventilation can be quantified by spirometry and body plethysmography. However, in order to locate regional impairments, thoracic imaging is essential. Temporally resolved MRI sequences and associated image reconstruction techniques for the application in thoracic imaging are continually improving and therefore considered increasingly frequent, as they provide an alternative to CT and SPECT while being free of ionizing radiation.

In this work, computer aided methods have been developed for quantification of regional tissue motion in 4D MRI. Measurements of lung ventilation in small regions provide insight to regional differences in lung compliance. The measurements are based on established pulmonary function tests but allow a separated analysis of arbitrary regions, for example in each lung lobe. Comprehensible visualizations of a regional ventilation analysis were created to provide an overview of motion inhomogeneities inside the lung volume. An atlas coordinate system of the lung was defined to enable a simple transfer of anatomical locations between different modalities.

For volumetric measurements of the entire lung, thoracic MR images were segmented using a model-based algorithm, which has been extended by a 4D motion model. The resulting estimation of surface movement was then used as initialization for a temporal deformable image registration. Anatomical landmarks on the lung surface defined a reference system in which regional tissue motion was quantified and could be compared regionally in multimodal image data. Ventilation analyses were performed on 4D MR images of several patients that were diagnosed with interstitial lung diseases, and additionally on 4D CT images in patients free of pulmonary diseases. The comparison between computed regional ventilation analysis and diagnostic CT images in the same patients showed a good correlation in conspicuous regions. 4D MRI based flow-volume-loops and spirograms visualize the free breathing behavior.

This thesis describes the concept and implementation of a system for quantification and visualization of regional lung ventilation. It was demonstrated in image data of patients with fibrosis and of patients with healthy lungs. The proposed coordinate system was shown to be suitable for comparison of multimodal images in one patient. Further results suggest the potential for probabilistic lung lobe detection.