1.5 Tesla can do too – measuring quantitative regional lung ventilation by AVI (Alveolar Ventilation Imaging) – Phantom data and results of a feasibility study in 10 patients

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Introduction: During the last decade tremendous efforts have been made to visualize the ventilated lung spaces by MRI. The use of hyperpolarized noble gases like 3He is one promising approach (1). True FISP imaging at low field strength is the another (2,3). However, this method was up to now not applicable for high-field scanners, limiting its clinical use.

Methods and patients: In our former attempts (2,3) we used a 'real-time' trueFISP sequence at 0.2 Tesla (Siemens Magnetom Open). For the actual study a HASTE sequence (TE 30ms, TR 2000ms, FOV 128x128) at a field-strength of 1.5 T (Siemens Avanto) was used. A major problem is the strong perfusion signal at this field-strength, which was compensated for (equalized) by ecg-gated cardiac triggering using every third cardiac cycle.

Each individual image in the sequence is registered to one selected reference image. The algorithm computes a dense deformation field by composition of small displacements. These displacements are designed to maximize the local correlation between the intensity values of the current (floating) image and the reference image. This local similarity measure allows coping with non-stationary behaviours in the intensity profiles of MR images. Regularization is achieved by low-pass filtering of the resulting displacement fields (4). Ventilation was calculated according to our previously released equations (3). For the phantom study we used the same lung phantom (cubic compressible sponge soaked with silicon oil (Merck Nr 7742)) as in our low-field-study, which allows the calculation of its real ventilation according to its volume change.

Second, we took a cohort of 10 persons (6-35, mean 17 years) with and without pulmonary disease. Patients were investigated at spontaneous deep breathing over 50 acquisitions. Imaging time depending on the heart rate was up to 3 min. After registration of the images regions of interest were chosen manually and the mean signal values and the background noise were determined during the ventilatory cycle. According to our theoretical considerations the absolute and the actual values for the local pulmonary ventilation was calculated.

The mean signal values were determined during the ventilatory cycle for upper (uF) middle (mF) and lower lung fields (lF) bilaterally. The square ROI's (11x11cm) were placed in the center of the upper, middle and lower third of the lung The values for the local pulmonary ventilation were calculated for each ROI and each voxel. With the values in the different ROIs ventilation curves were calculated for the six different areas (Fig.4). Ventilation changes for each voxel were displayed in ventilation videos (Fig. 3). An increase in air content was coded green in the ventilation maps a decrease in air content was coded red.

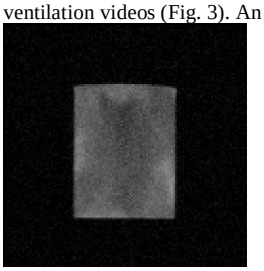

Fig. 1 MR image of phantom 20x5x12.5 cm sponge soaked with Silicon oil Merck Nr 7742.

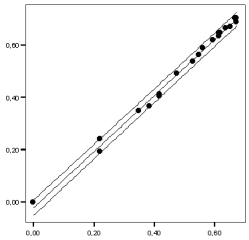

Fig. 2 Comparison of the measured and calculated ventilation. Linear Regression +/- standard error of the estimate (r^2=1.0)

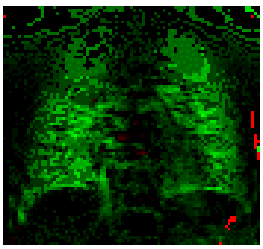

Fig. 3 Color coded ventilation map in a 25 years old male volunteer (one out of 50 images)

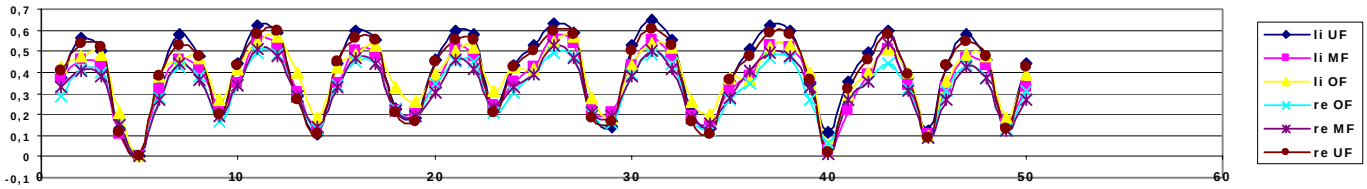

Fig.4: The ventilation cycle of a 32 years old male volunteer, the y-scale counting ml air/ ml lung parenchyma, 0 indicates maximum expiration, the x-scale numbering the pictures taken

Results: In the phantom experiment there was an excellent correlation between the ventilation values calculated from the volume variation of the sponge and the "ventilation" measured by the MRI method (r=0.99; $p \leq 0.001$)(Fig.1 and 2). It can be concluded that the method correctly determined the ventilation of the pulmonary phantom at high field strength.

In all patients the registration procedure was successful. Ventilation videos could be produced for each patient (Fig. 3) The investigation of the mean ventilation values revealed a mean lung ventilation of 0,5ml air/ml lung parenchyma which is concordant with our previous results at 0.2 Tesla (Fig.4)

Discussion: In this study we present a novel technique for quantitative evaluation of regional pulmonary ventilation. The measured values were in concordance to the phantom experiment, the clinical expectations and the lung function studies. We were able to develop a method that secondary to physical limitations was only applicable at low field-strength is now available for high-field scanners, too. In our opinion this fact is of major advantage as now. the application is applicable for a larger group of researchers and clinicians and could be easily introduced into clinical routine. The cardiac gating and the slightly thinner slices do not cause major problems as compared to low-field ventilation imaging. The registration was even optimized. With this method there is still no need to apply any external contrast agents, which may influence the pulmonary ventilation. Ventilation maps demonstrate local ventilation. Although further studies are undoubtedly necessary our data suggest that the AVI-method could become an promising alternative for functional lung MRI.

Bibliography:

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