High resolution morphology, ventilation, and perfusion of the human lung by ^{1}H imaging at 3.0 T

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Introduction

Lung imaging is a challenging modality in MRI due the low ^{1}H density and short relaxation times which lead to reduced SNR. Furthermore, respiratory and cardiac motion have to be considered. Obtaining functional information about the lung without administration of contrast agents is even more demanding. However, the recently introduced Fourier Decomposition (FD) technique [1] enables the assessment of ventilation and perfusion weighted lung images by means of regular ^{1}H imaging without breathholds or ECG triggering. The spatial resolution is hereby limited due to the necessary temporal resolution (3 images/second) to capture the pulmonary spin density variations caused by the cardiac action. Retrospectively DC signal gated lung imaging [2,3,4] allows for spatially high resolved morphological images. As has been shown, a quasi-random sampling scheme of the PE steps is advantageous [4]. In this proof of principle, we propose to combine DC gated imaging with the FD approach to obtain highly resolved anatomical and functional (ventilation and perfusion) images using standard ^{1}H imaging of the human lung. To verify our functional images, a comparison to established methods was performed (ventilation: standard FD, perfusion: DCE-MRI).

Figure 1*: Ventilation-weighted image from the combination of DC gated imaging and FD (middle) and standard FD (right). A DC gated reconstruction is given on the left as morphological reference. The definition of the lung periphery in our method is superior to standard FD. Furthermore, neither pulmonary vessels nor the aorta are visible, indicating that no perfusion-weighting contributed to this contrast.*

Methods

A FLASH sequence with quasi-random sampling according to [4] was utilized for data acquisition. 2D data of six healthy volunteers (4m/2f, age 23-27) were acquired at 3.0 T (Magnetom Trio, Siemens Healthcare, Erlangen, Germany). Imaging parameters: 32 channel array (In Vivo, Gainesville/FL, USA), asymmetric readout, TR=2.50 ms, TE=0.70 ms, α=8°, FOV 450x450 mm^2, 128x128, ST=20mm, 128,000 acquired PE steps. For functional weighting, the data were retrospectively gated using the DC signal. In case of ventilation, a gating range was chosen and shifted between minimum and maximum of the DC signal. Thereby, a complete respiratory cycle depicting the ventilation related spin density variations could be obtained. These data were then registered [5] to remove respiratory motion. For perfusion, the data were gated according to the cardiac phase for a fixed respiratory position (first gating range). Therefore, a second gating range was shifted to cover different phases of the cardiac cycle, thereby depicting the spin density variation of the heart action. Ventilation and perfusion weighted images were finally obtained by FFT along the temporal dimension of the reconstructed respiratory/cardiac cycle. For additional DCE-MRI, a 3D FLASH sequence was utilized, imaging parameters: same scanner, same coil, T_R=1.69ms, T_E=0.64 ms, α=19°, af=3 (GRAPPA) asymmetric readout, FOV 480x435x140 mm^3, 382x128x28, 18 timeframes, Gadovist® 1.0 mmol 4 ml (Bayer Healthcare, Leverkusen, Germany).

Results

Exemplary data from a 23-year old male volunteer are shown in Figures 1 and 2. Figure 1 demonstrates that the proposed technique leads to equivalent ventilation weighting as standard FD. However, the contrast between background and lung periphery in the proposed method is superior to FD. The perfusion weighting of the combination of DC gated imaging and FD is in good agreement with the respective DCE-MRI data (see Figure 2). Please note that the large pulmonary vessels and the thoracic aorta visible in the perfusion-weighted image (Figure 2) cannot be observed in the ventilation-weighted image (Figure 1), indicating correct retrospective gating for both functional modalities.

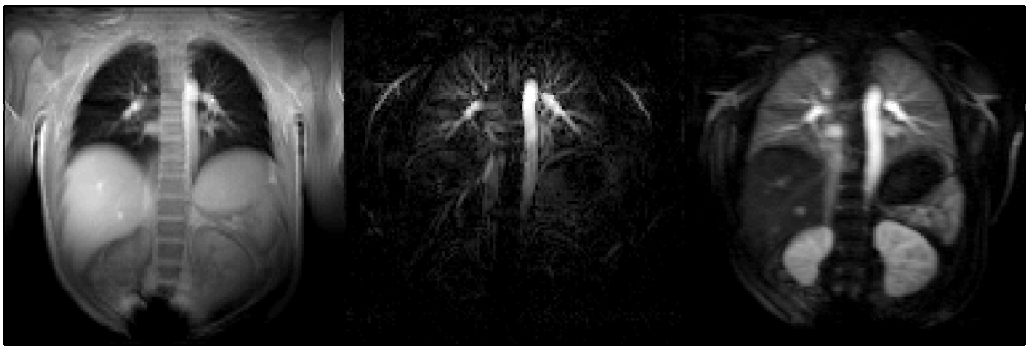

Figure 2*: Comparison of a perfusion-weighted image obtained with our proposed method (middle) and a DCE-MRI acquisition (right, MIP after baseline subtraction). Please note the similar appearance of the large pulmonary vessels and the aorta. A morphological DC gated reconstruction is given on the left as reference.*

Discussion and Conclusion

This proof of principle showed that functional and anatomical information with high spatial resolution can be obtained by the proposed combination of DC gated imaging and FD. The functional information could be verified by standard FD and DCE-MRI. The suppression of large pulmonary vessels in the ventilation-weighted image indicates that no perfusion signal compromises the ventilation information. The amount of data in this pilot study can be reduced by further optimizing the number of PE steps necessary to reliably obtain the functional information and the use of parallel imaging. In a next step, patients will be studied to investigate the diagnostic potential of our method. Future work will transfer the technique to 3D imaging; furthermore, quantification is of great interest to early diagnose or monitor the course of diseases.

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