BLOOD VOLUME FRACTION IMAGING OF THE HUMAN LUNG USING A ECG-SYNCHRONIZED STEAM-PREPARED HASTE SEQUENCE

Flavio Carinci[1,2], Cord Meyer[2], Felix A Breuer[1], Simon Triphan[1,3], and Peter M Jakob[1,2]

[1]*Research Center Magnetic Resonance Bavaria (M.R.B.), Würzburg, Germany,* [2]*Department of Experimental Physics 5, University of Würzburg, Würzburg, Germany,* [3]*Department of Diagnostic and Interventional Radiology, University Hospital Heidelberg, Heidelberg, Germany*

Introduction: Knowledge of the regional blood volume fraction [1,2] in the lungs is of particular interest for the assessment of lung functionality and the diagnosis of several lung diseases, as well as for the T_1 and T_2 quantification when using multi-compartmental models. In this work a non-contrast enhanced MR-technique for *in-vivo* imaging of the blood volume fraction in the human lung is presented.

Methods: A HASTE sequence with STEAM-preparation [3,4], as shown in Fig. 1, was implemented on a 1.5T MR-scanner. The gray-shaded gradients in the slice selection direction (A ~ 9.5 ms·mT/m) allow for an attenuation of the flowing blood signal, depending on the separation time TM. This is due to the effect of the resulting first gradient moment $m_1 = A \cdot TM$ on flowing spins [5]. In the lung parenchyma the effect is further enhanced by the presence of internal magnetic field gradients due to the inhomogeneous distribution of magnetic susceptibilities. Therefore, the sensitivity of the sequence to blood microcirculation can be regulated by changing the value of TM and the cardiac phase used for acquisition. Two images (S_1,S_2) were acquired in a single breath-hold using different TMs in conjunction with cardiac triggering: 1) S_1 (non-blood-suppressed) acquired in diastole with TM_1 = 2 ms; 2) S_2 (blood-suppressed) acquired in end systole with TM_2 = 40 ms. A two-compartment model was used to quantify the blood volume fraction (f_{blood}) in the lung:

$$S_1 \propto f_{blood}\, exp\left(-\frac{TM_1}{T_1^{blood}}\right) + (1 - f_{blood}) exp\left(-\frac{TM_1}{T_1^{parenchyma}}\right)$$

$$S_2 \propto (1 - f_{blood}) exp\left(-\frac{TM_2}{T_1^{parenchyma}}\right)$$

$$f_{blood} = 1 - \frac{S_2}{S_1} exp\left(\frac{TM_2 - TM_1}{T_1^{parenchyma}}\right)$$

The exponential term in the last equation accounts for the different T_1 weighting of the two images, due to the different TM. However, since $T_1^{parenchyma}$ ~ 1000 ms [6] >> TM_2-TM_1 = 38 ms, this term is ~ 1.0 and can be neglected in the quantification of f_{blood} in the lung.

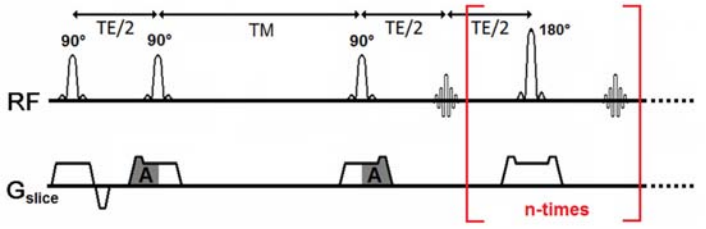

Fig. 1 Schematic pulse diagram of the STEAM-prepared HASTE sequence used for blood volume fraction imaging. The refocusing pulse and the signal readout are repeated n-times (n=number of phase-encoding steps).

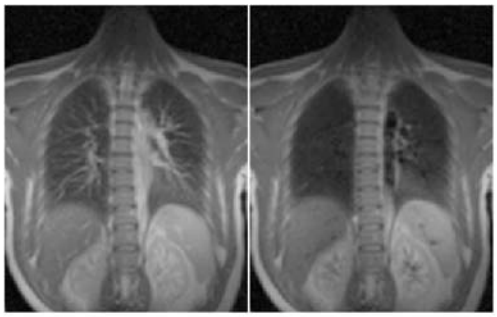

Fig. 2 Magnitude images of the human lung obtained from the STEAM-prepared HASTE sequence with different values of TM and different cardiac phases: S_1 acquired in diastole with TM_1=2ms (left) and S_2 acquired in end-systole with TM_2=40ms (right).

In-vivo experiments were performed on healthy volunteers. Imaging parameters: FOV=500x500mm^2, matrix=128×128, slice thickness=10mm, partial Fourier factor=5/8, TR=6000ms, breath-hold duration~10s. Several slices were acquired in the coronal orientation.

Results and Discussion: Fig. 2 shows a representative example of the images S_1 and S_2. Different attenuation of the blood signal is observed. In S_2 the blood signal is suppressed due to fast blood flow in end systole and to the high gradient moment m_1. In S_1 the blood signal attenuation is negligible for opposite reasons. Fig. 3 shows the parametric maps of f_{blood} obtained in six different coronal slices. Fig. 4 shows the histogram of the statistical distribution of f_{blood} within the lung parenchyma. An average value of 35% and a standard deviation of 16% were obtained. This is in good agreement with previous reports obtained using a contrast-agent-based technique (values between 31% and 33% reported in [1]).

Conclusion: The presented method offers an easy and reproducible way to obtain the blood volume fraction in the human lung without the need for contrast agents. It is therefore a good candidate for clinical studies on patients with lung diseases.

References: [1] Lehmann J, Magma, 1997, **5**; [2] Schwarzbauer C, Magn Reson Med, 1993, **29**; [3] Frahm J, J Magn Reson, 1985, **65**; [4] Burstein D, Conc Magn Reson, 1996, **8**; [5] Nguyen TD, J Magn Reson, 2008, **28**; [6] Stadler A, J Magn Reson, 2005, **21**.

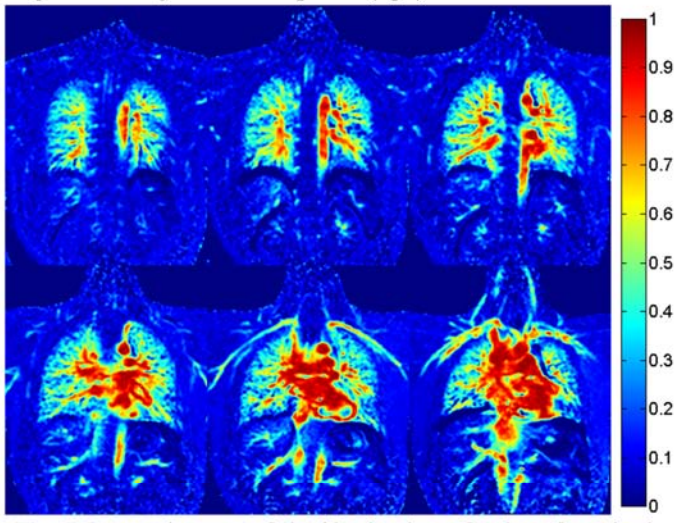

Fig. 3 Parametric maps of the blood volume fraction (f_{blood}) in the human lung acquired at 1.5 T. Six different coronal slices are shown.

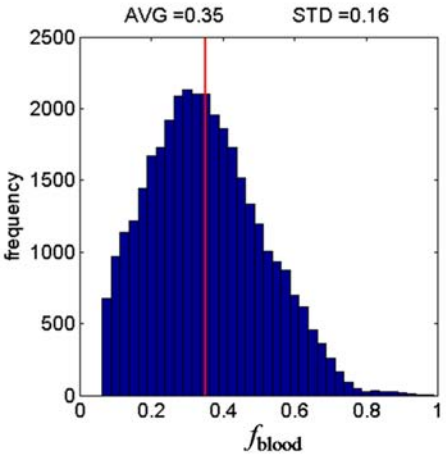

Fig. 4 Statistical distribution of f_{blood} within the lung parenchyma (using the six coronal slices of Fig. 3).

Acknowledgements: SIEMENS Healthcare, Pulmonary Imaging Network (PINET) funded by the 7th Framework Program of the European Union (PITN-GA-2010-264864), Competence Network Asthma/COPD funded by the Federal Ministry of Education and Research (FKZ 01GI0881-0888).