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

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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 T₁ and T₂ 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 m₁ = A·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 (S₁, S₂) were acquired in a single breath-hold using different TMs in conjunction with cardiac triggering: 1) S₁ (non-blood-suppressed) acquired in diastole with TM₁ = 2 ms; 2) S₂ (blood-suppressed) acquired in end systole with TM₂ = 40 ms. A two-compartment model was used to quantify the blood volume fraction (f_blood) in the lung:

\[
S₁ \propto f_{\text{blood}} \exp \left(-\frac{TM₁}{T₁}\right) + (1-f_{\text{blood}}) \exp \left(-\frac{TM₁}{T₁^{\text{parenchyma}}}\right)
\]

\[
S₂ \propto (1-f_{\text{blood}}) \exp \left(-\frac{TM₂}{T₁^{\text{parenchyma}}}\right)
\]

\[f_{\text{blood}} \approx 1 - \frac{S₂}{S₁} \exp \left(-\frac{TM₂-TM₁}{T₁^{\text{parenchyma}}}\right)\]

The exponential term in the last equation accounts for the different T₁ weighting of the two images, due to the different TM. However, since T₁^{\text{parenchyma}} ~ 1000 ms [6] >> TM₂-TM₁ = 38 ms, this term is ~ 1.0 and can be neglected in the quantification of f_blood in the lung.

In-vivo experiments were performed on healthy volunteers. Imaging parameters: FOV=500x500mm², 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 S₁ and S₂. Different attenuation of the blood signal is observed. In S₁ the blood signal is suppressed due to fast blood flow in end systole and to the high gradient moment m₁. In S₂ 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 proposed 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.


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. S₁ acquired in diastole with TM₁=2ms (left) and S₂ acquired in end-systole with TM₂=40ms (right).

Fig. 3 Parametric maps of the blood volume fraction (f_blood) in the human lung acquired at 1.5T. 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).