Self-gated 3D FLASH imaging of the human lung under free breathing using DC signals

S. Weick[1], M. Oechsner[1,2], M. Blaimer[3], F. Breuer[3], H. Köstler[2], D. Hahn[2], M. Beer[2], and P. M. Jakob[1,3]

[1]Experimental Physics 5, University of Würzburg, Würzburg, Germany, [2]Institut für Röntgendiagnostik, University of Würzburg, Würzburg, Germany, [3]Research Center Magnetic Resonance Bavaria e.V., Würzburg, Germany

Introduction

Multiple air-tissue interfaces and the intrinsically low proton density make human lung MRI challenging. Additionally, motion artefacts due to respiration or blood flow can degrade image quality and restrict the acquisition time. There are several techniques to avoid respiratory motion artefacts. External measurement devices such as an ECG or a respiration belt can be applied to synchronise data acquisition with motion [1]. Navigator echoes can be acquired to monitor respiratory and cardiac motion [2]. This method needs additional RF pulses which saturates parts of the imaged volume and extent the acquisition time. A time-efficient concept is to use the DC signal for self-gating [3-5]. In this work, examinations of the human lung were performed during free respiration using the DC signal for self-gating. The acquisition of the DC signal was implemented into a 3D FLASH sequence and high resolution images were reconstructed retrospectively. The advantages are that neither external measurement devices nor additional RF Pulses for respiratory gating were needed.

Materials and methods

All measurements were performed on a 1.5 T clinical MR scanner (Magnetom Symphony, Siemens Healthcare, Erlangen, Germany). Data analysis was done using Matlab (The MathWorks, Inc., Natick, MA, USA). A respiration curve was acquired using a spirometer system (Viasys Healthcare, Würzburg, Germany) as a reference to the sampled DC Signal. The acquisition of the DC signal was implemented into a 3D FLASH sequence (TE/TR/α = 1.7ms/5.4ms/5°, 3.5mm slice thickness, 52 coronary slices, slice resolution = 73%, matrix: 239 x 384, FOV = 450 x 490 mm^2, BW = 480 Hz/ pixel, resolution: 1,3 x 1,9 x 3,5 mm^3). After the excitation pulse, 20 points of the FID were sampled to obtain the DC signal. 18 consecutive measurements under free breathing conditions were performed resulting in a total scan time of 15 min. Data were acquired using an eight channel phased-array coil. To evaluate fluctuations in the DC signal resulting from respiratory and cardiac motion, all coils were analysed separately [4]. Threshold values in percent of the total signal difference between expiration and inspiration were defined to select data for image reconstruction. Multiple accepted k-space lines were averaged.

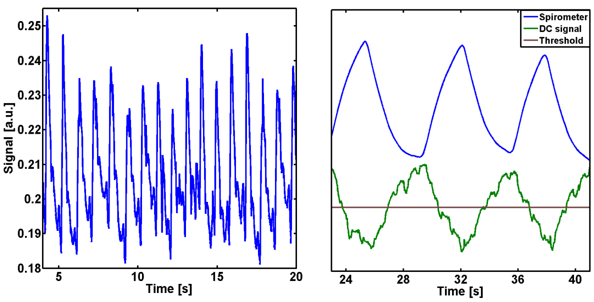

Fig.1: Cardiac and Respiratory variations of the DC signal

Results

In Fig.1 the DC signal of a coil element near the heart is shown (left) which represents signal oscillations dominated by cardiac motion as described in [4]. On the right, the tidal volume, recorded simultaneously with the spirometer, the DC signal received in a coil with best respiratory motion characterstic and a calculated threshold value of 50% are shown. Maxima of the DC signal correspond to end expiration, minima to full inspiration in the spirometer graph. Image reconstructions derived with different threshold values are shown in Figure 2. In the left image 14% of the acquired data were used for reconstruction resulting in low SNR but without blurring at tissue borders, however corrupted by artefacts due to not sampled lines. Using 64% of the data results in increased SNR and no undersampling artefacts (middle image, Fig.2). A soft threshold (87% of data accepted) leads to even higher SNR, however increasingly blurred structures can be observed (right image, Fig.2). In Fig. 3 three partitions of the 3D volume reconstructed with medium threshold are shown. High SNR images with low blurring artefacts even in slices near the heart can be seen.

Fig.2: Effects of different thresholds. From left to right 14%, 64%, and 87% of the acquired data were used for image reconstruction

Fig.3: Three different reconstructed coronary slices with 64% of data accepted

Discussion

The spirometer graph (Fig.1 right) indicates that the DC signal can indeed be used for respiratory self-gating. Thus, this concept was applied to 3D FLASH experiments of the human lung under free breathing condition. Different threshold values for data rejection were used, resulting in high SNR images because every phase encoded line was acquired several times; for low threshold values, artefacts due to undersampling can occur. This method is performed under free breathing condition; therefore, it is also applicable to lung disease patients. To reduce scan time the DC signal can also be used for prospective gating [4, 5]

References

[1] Arnold et al., MRM 58:1092-1098 (2007)
[2] Ehman et al., Radiology 173:255-263 (1989)
[3] Crowe et al., MRM 52:782-788 (2004)
[4] Buehrer et al., MRM 60:683-690 (2008)
[5] Brau et al., MRM 55:263-270 (2006)