APPLICATION OF A NON-CPMG SINGLE-SHOT TURBO SPIN ECHO SEQUENCE TO MULTI-CONTRAST IMAGING OF THE HUMAN LUNG AT 1.5T

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INTRODUCTION: Proton MRI of the human lung is challenging due to low proton density, short T_2^*, respiratory and cardiac motion. Single-shot turbo spin-echo (ssTSE) sequences can be used to mitigate the effects of T_2^* decay and T_1 saturation and to achieve short acquisition times. This provides good signal-to-noise ratio (SNR) in the lungs and motion artifacts suppression. However, preparation schemes that induce phase shifts of the transverse magnetization, such as diffusion and T_2^* preparation, can result in the violation of the CPMG conditions and generate severe artifacts [1]. Here the application of a non-CPMG ssTSE sequence [2] to diffusion-weighted (DW) and T_2^*-weighted imaging of the human lung is presented. It is shown that this approach allows for apparent diffusion coefficient (ADC) and T_2^* mapping of the human lung in a single 10s breath-hold.

METHODS: The non-CPMG ssTSE pulse sequence described in [2] was implemented on a 1.5T MR-scanner (Avanto, Siemens Healthcare, Erlangen, Germany). The sequence is based on a quadratic modulation of the phase cycle of the refocusing pulse train. This provides a stable signal amplitude along the echo train for both the in-phase and out-of-phase components. Due to phase sign oscillation, two images need to be separately acquired from odd and even echoes and combined. Centric reordering was adopted to maximize the SNR. GRAPPA reconstruction [3], with acceleration factor 2, was used to reduce blurring due to T_2 decay and specific absorption rate (SAR). The sequence was played with: **a**) diffusion sensitive preparation [4], based on the standard Stejskal-Tanner configuration, and **b**) T_2^* preparation, using an asymmetric spin echo scheme [5]. This was obtained by increasing the time between the excitation pulse and the first refocusing pulse by ΔTE. *In vivo* experiments were performed on a healthy volunteer using a six-channel phased-array body matrix in combination with a spine matrix. Imaging parameters: TR=6000ms, FOV=500x500mm^2, matrix size=128×128, voxel size=3.9×3.9mm^2, receive bandwidth=800Hz/pixel, inter-echo time=3.55ms, TA=480ms. For each kind of contrast (diffusion and T_2^*) a breath-hold of less than 10s was sufficient to acquire two images, using: **a**) b=0-200s/mm^2 for diffusion-weighting (with TE=45ms), and **b**) ΔTE=0-1ms for T_2^*-weighting (with TE=16.5-17.5ms). ECG triggering in the diastolic phase was used to minimize the effect of blood pulsation on the signal refocusing. A separate breath-hold was necessary to acquire the calibration scan for GRAPPA reconstruction, using a standard gradient echo (GRE) sequence.

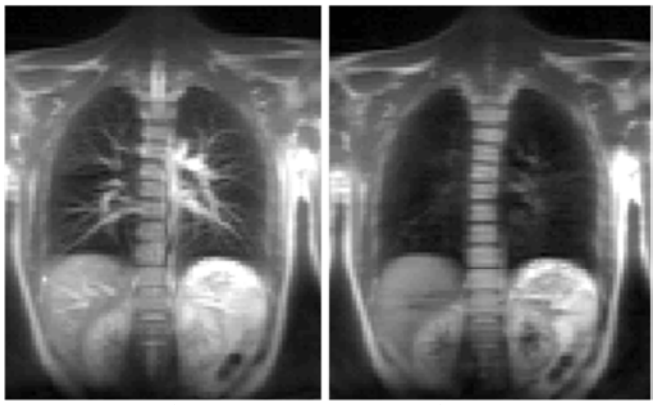

Fig.1 *In vivo* images of the human lung obtained at 1.5 T from the non-CPMG ssTSE with diffusion preparation, using b=0s/mm^2 (left), b=200s/mm^2 (right).

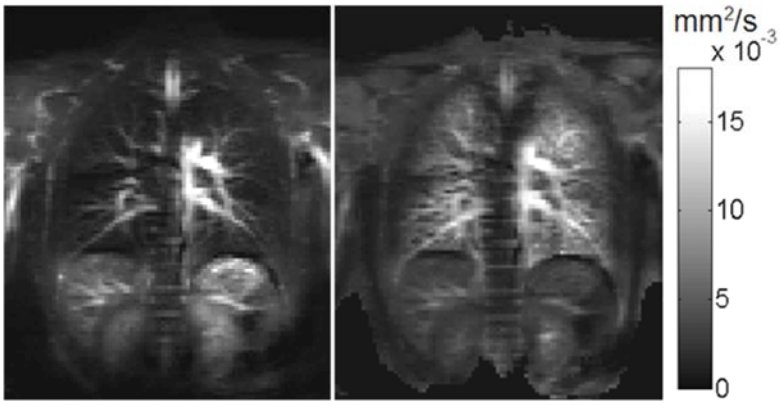

Fig.2 Difference (left) and ADC map (right) of the images obtained with diffusion preparation, using b=0s/mm^2 and b=200s/mm^2.

RESULTS and DISCUSSION: Fig. 1 shows the results obtained from the non-CPMG ssTSE with diffusion preparation. Left: the reference image, acquired with b=0s/mm^2, presents a detailed view of the vasculature of the lung. In the fact ECG triggering in the diastolic phase allows a good signal refocusing of flowing blood, even with a long echo time of 45ms. Right: the DW-image, acquired with b=200s/mm^2, presents an overall signal attenuation due to diffusion. The signal from the vessels is almost completely suppressed, due to the effect of perfusion which dominates in the low b-values regime used here [6]. Fig. 2 shows the results obtained combining the images of Fig. 1. Left: the difference of the two images highlights the distribution of the vessels within the lung. Right: the resulting ADC map provides a reliable perfusion-weighted contrast in the lung. Fig. 3 shows the results obtained with T_2^* preparation. Left: the T_2^*-weighted image, acquired with ΔTE=1ms, presents the typical signal attenuation at tissues interfaces, given by T_2^* decay. Right: the T_2^* map obtained in the lung shows a good quantitative agreement with the values previously reported in the literature [7], with a mean value of 1.8±0.1ms in the right lung.

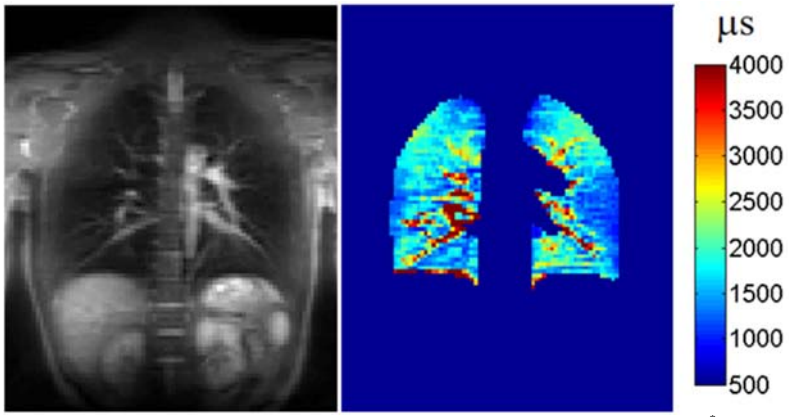

Fig.3 *In vivo* image of the human lung obtained at 1.5 T from the non-CPMG ssTSE with T_2^* preparation, using ΔTE=0-1ms (left) and resulting T_2^* map (right).

CONCLUSIONS: The non-CPMG single shot turbo spin echo sequence proposed by Le Roux [2] resulted to be an excellent candidate to perform fast diffusion and T_2^* weighted imaging of the lung at 1.5T. The results obtained from diffusion imaging show that ADC mapping using proton MRI provides perfusion contrast in the lung. The results obtained from T_2^* mapping present a good quantitative agreement with the results previously reported using a standard multi-echo GRE sequence. This technique may therefore represent a valid option for oxygen enhanced imaging, where the change of the susceptibility differences induced by oxygen, appears in the change of T_2^*.

REFERENCES

[1] Alsop DC, Magn Reson Med **38** (1997); [2] Le Roux P, J Magn Reson **155** (2002); [3] Griswold MA, et al., Magn Reson Med **47** (2002); [4] Bastin ME, et al., Magn Reson Med **48** (2002); [5] Heinrichs U, et al., Magn Reson Med **62** (2009); [6] Le Bihan D, et al., Radiology **168** (1988); [7] Pracht ED, el al., Magn Reson Med **53** (2005)

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