Design of a spin echo sequence for Fourier decomposition pulmonary MRI at 3T

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Introduction: Fourier decomposition (FD) pulmonary MRI is an established non-invasive method to obtain functional perfusion and ventilation maps of the lung [1]. As all proton MRI approaches, the FD technique too suffers from a low signal to noise ratio (SNR) in the lung parenchyma. Therefore, an extension of the method to higher field strengths seems reasonable. However, the standard sequence used in the FD approach is a bSSFP, which using the current hardware cannot reach echo times below around 500µs [2]. Unfortunately due to the shortening of T_2* and additional SAR constraints, recent results of FD pulmonary MRI at 3.0T using a bSSFP sequence [3] are worse compared to lower field strengths. We present an alternative to using a bSSFP sequence in the standard FD framework at higher field strengths.

Subjects and Methods: Spin echo techniques that are commonly used for morphological imaging of the lung such as TSE or HASTE are the most promising candidates to design a sequence that is both fast enough to sample multiple images in a free breathing experiment while also providing sufficient SNR. To compare the proposed HASTE sequence to the bSSFP sequence at 3T five healthy volunteers were examined. The SNR in the lung parenchyma was determined with a ROI placed in the upper right lobe of the lung. Additionally, functional ventilation maps were obtained using the standard FD procedure [1].
The measurements were performed on a 3.0T scanner (Magnetom Trio, Siemens Healthcare, Erlangen, Germany) using a 6 channel body coil and a 24 channel spine coil. The timing of the bSSFP sequences was TR/TE = 1.6/0.7 ms with a sampling speed of 3 images per second. The standard flip angle used for FD MRI at 1.5T had to be reduced from 75° to 40° due to SAR constraints. The timing of the HASTE sequence was TR/TE = 1050/48 ms with a sampling speed of 1 image per second. A full data set used for the FD method was acquired with both sequences in approximately 1 minute which resulted in 180 (bSSFP approach) and 60 images using the HASTE approach. Imaging parameters for both sequences were: FOV = 450 x 450 mm^2, matrix size = 128 x 128, slice thickness = 10mm and a GRAPPA acceleration factor of 2 in phase direction.

Results: To enable a quantitative and visual comparison between the two sequences, the data and images acquired with the bSSFP sequence were averaged with a factor of 3 to account for the faster sampling speed. Overall the SNR in the lung parenchyma was increased by approximately 60% using the HASTE compared to the bSSFP sequence. The SNR measured in 5 volunteers is shown in figure 1. Exemplary images of one volunteer are shown in figure 2 (bSSFP) and 3 (HASTE). Both figures show the morphology (left) and the ventilation maps calculated by the FD method (right) for two different slices of the lung. Our results show that even though the sampling speed of the bSSFP sequence is much higher compared to the HASTE approach, which results in a much cleaner mapping of the respiratory cycle, the lower SNR causes problems in the registration and produces functional maps with noticeably more artifacts and inconsistencies.

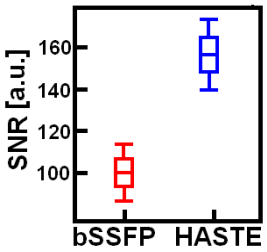

Fig. 1. SNR comparison of both sequences in the lung parenchyma.

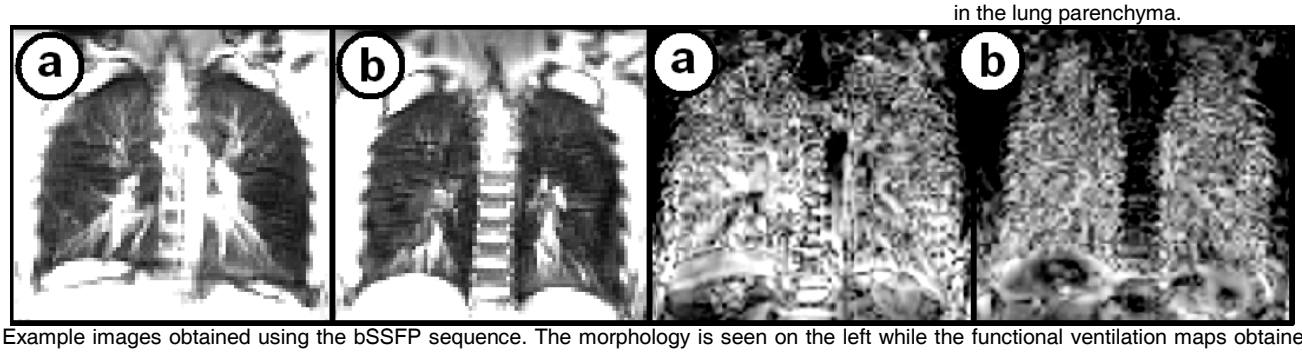

Fig. 2. Example images obtained using the bSSFP sequence. The morphology is seen on the left while the functional ventilation maps obtained using the FD method are shown on the right. (a) and (b) denote the two different slices of the lung.

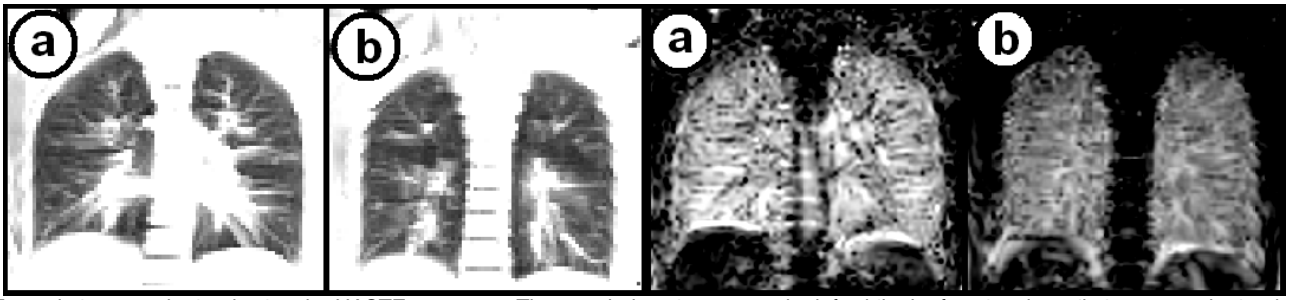

Fig. 3. Example images obtained using the HASTE sequence. The morphology is seen on the left while the functional ventilation maps obtained using the FD method are shown on the right. (a) and (b) denote the two different slices of the lung.

Discussion/Conclusion: Overall the HASTE approach outperforms the standard bSSFP sequence at 3 Tesla. The increased SNR results in smoother morphological and functional images. However, there are still a few problems to consider. Firstly, the ability to achieve perfusion images is lost due to the slower sampling speed. Since other techniques such as DCE-MRI and ASL usually outperform FD in this modality, losing the ability to achieve functional perfusion images is minor. Secondly, the slower sampling speed causes problems in areas with large movement. Specifically, slices covering large portions of the heart are affected by this. In the future this could probably be averted using self-triggering approaches [4] while not significantly affecting the sampling rate.

References: [1]: Bauman G, MRM 2009, 62(3):656-64; [2]: Bieri O, MRM 2013, 70:657-663; [3]: Fischer A, Proc. of ISMRM2012, p.1339; [4]: Weick S, JMRI 2013, 37:727-732; **Acknowledgements:** Funding from EU FP7 (ITN-FP7-2010) 264834 (PINET)