Fast Synchronous 3He/1H Dynamic Lung Imaging

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Introduction

Dynamic imaging of hyperpolarised (HP) gases allows assessment of gas-flow dynamics within the airways [1, 2], giving a unique insight into lung ventilation and physiology with the ability to detect disease related processes such as air-trapping in COPD and asthma. Dynamic ^{1}H MRI can also give additional information on lung wall motion and regional lung flow-volume information [3,4]. In this work, dynamic ^{3}He and ^{1}H images were acquired in a synchronised scan during inhalation providing regional gas flow with spatially and temporally registered lung anatomy motion. Lung ventilation is very fast (air reaches lung periphery within 1s) and demands fast sequences that can capture the rapid flow of ^{3}He gas in lung airways. Compressed Sensing (CS) was used to assess the feasibility of accelerated synchronous ^{3}He/^{1}H acquisition.

Materials and Methods

The study was performed on a 3 T whole body system (Achieva, Philips) with rapid switching between helium frequency (97 MHz) and proton frequency (128 MHz). The ^{1}H body coil (quadrature birdcage) was used for ^{1}H transmit/receive (T-R) and was detuned during ^{3}He T-R, while a quadrature birdcage elliptical coil (Rapid) was used for ^{3}He T-R. Two healthy volunteers (m 25 y and f 27 y) inhaled a dose of 300 ml of ^{3}He, polarised to ~ 25% with spin exchange apparatus (GE), which was mixed with 700 ml N_2 in a 1 l bag. One coronal slice was acquired in an interleaved fashion (acquiring both ^{3}He and ^{1}H signal for each phase encode step [5]) in dynamic mode in a total of 10 frames during slow inhalation of the gas. Sequence parameters were: FOV (384 × 384 mm^2), voxel size (30 × 3 × 3 mm^2, 128 × 128 in-plane resolution), BW (500 Hz/pixel) and 9°/10° flip angle for ^{3}He/^{1}H respectively. TE 1.02 ms, TR 20 ms. Acceleration was investigated with 3 fold CS sampled on a random pattern, a projection in the phase-encode direction from the centre of *k*-space of the fully sampled data was used to order the phase-encode schedule depending on decreasing hyperpolarised signal intensity [6].

Image Reconstruction

Images were reconstructed off-line using Matlab software. Homodyne reconstruction was performed in the readout direction on the asymmetric echo. For each time frame, 3× CS reduced data were reconstructed separately. The performance of the sampling method used was then compared to the standard random sampling pattern. ^{1}H images were also reconstructed using the same undersampling pattern per frame as ^{3}He images.

Results

Figure 2 shows ^{3}He and ^{1}H dynamic images acquired with a temporal resolution of 1.3 s. The spatio-temporal registration of the ventilation and anatomical images is clear. The images acquired with CS in Fig. 2 show the possibility to increase the temporal resolution up to 3 times the actual rate for both ^{3}He and ^{1}H images.

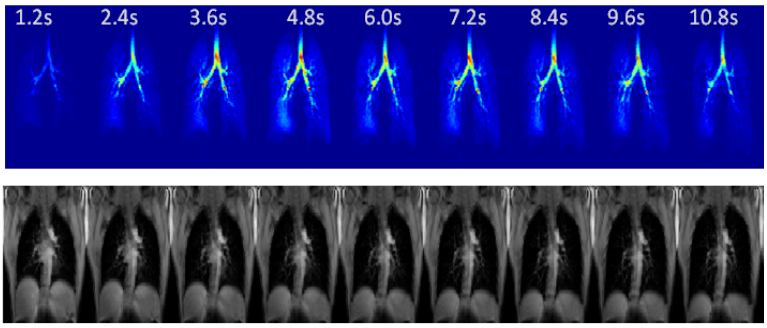

Figure 1: Dynamic ^{3}He (above) and ^{1}H (below) images acquired simultaneously in 10 successive frames upon slow inhalation of ^{3}He gas. The spatial and temporal registration of the mutual anatomical features (e.g. major airways and diaphragm) in the images is apparent.

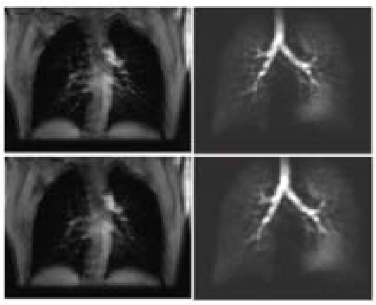

Figure 2: Example of ^{3}He (left) and ^{1}H (right) images at one frame time for fully sampled (top) and 3× CS subsampled data.

Conclusions

A dual nucleus dynamic imaging acquisition strategy for simultaneous imaging of lung ventilation and anatomical motion in the same sequence is demonstrated. The simultaneous information from the diaphragm and lung wall motion could help with image registration of the HP gas images for parametric mapping of gas flow. The temporal resolution achieved with this prototype ^{1}H-^{3}He sequence was about 1.3s which was reduced when combined with CS and phased-encoded ordered patterns achieving a 3 fold acceleration without major compromise to either ^{1}H or ^{3}He image quality. The method could have applications in imaging other dynamic processes where motion of the organ from the ^{1}H anatomical image and dynamic functional information from the other nucleus (e.g. ^{3}He, ^{129}Xe, ^{13}C) offer mutual information.

Acknowledgements

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References [1] MRM, 49:991-7 (2001) [2] MRM, 46:667-77 (2001) [3] MRM, 57:636-42 (2007) [4] Acad. Radiol, 15:799-808 (2007) [5] NMR Biomed, 24(2):130-4 (2011). [6] Proc. ISMRM 2011, p3032.