Simultaneous acquisition of 3He ventilation images, ADC, T2* and B1 maps in a single scan with Compressed Sensing

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Introduction
In previous work anatomical correlation between the 3He ADC and T2* in lungs was observed at 1.5T [1]. However, the study was limited by the fact that images were acquired from two separate scans and breath-holds, which did not allow a perfect registration of the parameter maps. The use of a single-scan for combining ventilation information with simultaneous measurement of other functional parameters has been previously reported [2-4]. This work presents a sequence that allows acquisition of ventilation images, T2*, ADC and B1 maps in a single breath-hold scan and in a very short time (~7 s) with Compressed Sensing (CS) [5].

Methods
A four interleave sequence was implemented on a 3T system (Philips, Achieva) tuned to 3He at 97 MHz, with a Transmit/Receive linear Helmholtz coil (Pulseteq, UK). 3He gas was polarised to 25% with rubidium spin-exchange apparatus (GE). Three healthy volunteers inhaled 300 ml of 3He mixed with 700 ml N2, imaging was performed with ethics and regulatory approval. The first interleave with the shortest echo time (TE1 = 1.6ms) was used for the ventilation image. The second was acquired with a longer echo time (TE2 = 6.6ms), to derive T2* maps, while the third interleave included diffusion weighting gradients (b = 2.86 s.cm⁻²) at TE2 with interleave 2 used as a reference scan (b=0), for the ADC maps. The first three scans acquire the same phase-encoding lines with a centre-out encoding order. Whereas, the fourth interleave, (otherwise identical to the first interleave) was acquired in a reverse centric order to compute the flip angle map as described in [6], using a 2D SPGR sequence. Imaging parameters applicable to all four interleaves were: 384x384 mm² FOV, 64x64 matrix, 20 mm slice thickness, TR = 12ms, BW/pixel = 500 Hz. Two sets of images were acquired, one set with full phase encoding, and one set with two-fold under-sampling in the phase direction using Compressed Sensing (CS) as described in [7]. Five axial slices were acquired, with 10 mm gap with a flip angle of 5° for the fully sampled data and 7° for the two fold under-sampled CS data to obtain the same k-space filter due to RF depletion.

Results & Discussion
Good agreement was obtained between the fully sampled and under-sampled data as shown in fig. 1 and 2. Note also, the improvement of ventilation images after correction with B1 flip angle maps fig.1. The computed ADC values are in agreement with those previously reported with the same diffusion times, as shown in table 1. The mean T2* obtained in a previous study at 3T was 14.4 ± 2.6 ms for ~4 mm pixel size [10]. Here, lower values were found (mean 7.59 ms), with a pixel size of 6 mm. One explanation may be that T2* increases when voxel size decreases due to length scale dependent intra-pixel dephasing from background gradients [11]. Simultaneous measurements of ADC and T2* allows a precise anatomical comparison of the parameters as the data are inherently spatially and temporally registered. The proposed method conserves gas, which is advantageous due to the increasing price and limited supply of 3He. Combination of the sequence with CS reduces the scanning time by two, or allows an increase in image resolution of the ventilation, T2* and ADC maps.

Conclusion
A novel sequence is presented that allows acquisition of 3He ventilation, ADC, T2* and B1 maps simultaneously in-vivo. The sequence was tested in three healthy volunteers and the values of parameters obtained are in accordance with those published previously.

References

Acknowledgement
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<table>
<thead>
<tr>
<th>Study</th>
<th>Mean ADC</th>
<th>S.D. ADC</th>
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<tr>
<td>Current (full/CS)3T</td>
<td>0.182/0.184</td>
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<td>Evans et al.[9] 3T</td>
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