COMPRESSED SENSING FOR HYPERPOLARIZED ^{3}HE 3D ADC MEASUREMENTS

L. V. Søgaard[1], T. Dorniok[1], F. Hengstenberg[1,2], S. Karpuk[3], J. Vestbo[2], P. Åkeson[1], and P. Magnusson[1]

[1]Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital, Hvidovre, Denmark, [2]Department of Cardiology and Respiratory Medicine, Copenhagen University Hospital, Hvidovre, Denmark, [3]Institute of Physics, University of Mainz, Germany

Introduction: Hyperpolarized ^{3}He apparent diffusion coefficient (ADC) measurements provide information about the lung microstructure and can be used to evaluate the grade of emphysema. In a clinical setting a high spatial resolution is necessary especially to monitor (regional) progression over time [1]. To achieve this 3D acquisitions can be used. However, the MR data must be acquired during breath-hold which limits the resolution that can be obtained with traditional sampling schemes. Here we investigate the possibility of applying compressed sensing (CS) methods [2] for 3D hyperpolarized ^{3}He ADC measurements to reduce the acquisition time. Cartesian sampled 3D diffusion data were randomly undersampled and CS reconstruction was applied. ADC maps derived from the undersampled data were compared to the ADC maps derived from the fully sampled k-space data set.

Materials and methods: Data were acquired on a Siemens Vision MR scanner 1.5 T equipped with a ^{3}He/^{1}H chest coil (Fraunhofer Institute, St. Ingbert, Germany). One healthy volunteer (female, age 56y) and three COPD patients (female, age 62-66y, FEV1 31-74%) were scanned during breath-hold at total lung capacity (TLC) after inspiration of a bolus of ~250 ml hyperpolarized ^{3}He followed by normal room air. The ^{3}He gas was polarized in Mainz, Germany and shipped to Copenhagen by air transport [3]. A 3D gradient echo sequence acquired two image volumes, one without (b = 0 s/cm^2) and one with (b = 1.6 s/cm^2) diffusion sensitization using a bipolar gradient (g = 19.5 mT/m, diffusion time = 1.5 ms), with the parameters TR = 8.6 ms, TE = 5.7 ms, flipangle = 1.1 deg., FOV = 470x353x240 mm^3, matrix = 128x51x20. Total imaging time was 16.6 s. The k-space data were zero-filled before reconstruction to obtain the final images (128x64x32). For the CS reconstruction the k-space was undersampled by randomly choosing phase-encode lines with a variable density (4th power of the distance from the origin). The undersampling factors applied were: 60%, 39%, 19% ((number of phase encode lines)/(20x51)). After CS reconstruction of the non-diffusion weighted (b=0 s/cm^2) and diffusion weighted (b=1.6 s/cm^2) images using a wavelet transform, the ADC maps were calculated, and histograms of ADC distributions generated

Results: Representative ADC maps calculated based on the fully sampled k-space and using CS with three different undersampling factors for the healthy volunteer and a COPD patient are shown in Fig.1. Corresponding histograms are shown in Fig.2 for all four subjects. For all subjects the mean ADC derived with CS was larger than the mean ADC calculated from the fully sampled k-space. With increasing acceleration the histograms broadened as revealed by an increasing standard deviation.

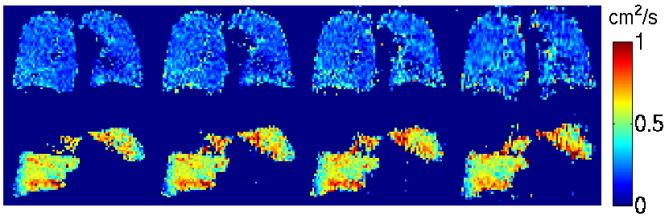

Figure 1 *ADC maps for the healthy volunteer (top row) and a COPD patient (bottom row) calculated from fully sampled data set (1st column) and by CS with undersampling factors 60%, 39% and 19% (2nd, 3rd and 4th column)*

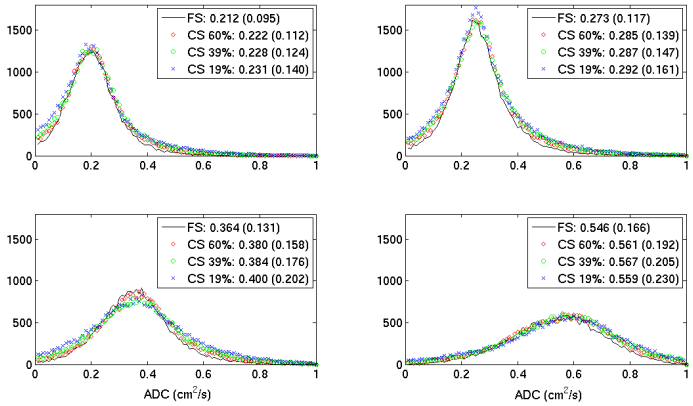

Figure 2 *ADC histograms for the whole lung volume for the healthy volunteer (upper left) and the three COPD patients. Data are shown for the fully sampled (FS) data set (line) and the CS reconstructed data (red diamonds: 60%, green circles: 39%, blue crosses: 19%). Numbers in the legend are mean (std) in cm^2/s.*

Discussion and conclusion: The feasibility of applying CS to hyperpolarized ^{3}He ADC measurements has been demonstrated. The overall pattern and distribution of ADC values in the lung appear to be largely unaffected by the undersampling. The differences in mean values and standard deviations of the distributions are comparable to those found in reproducibility studies [1,4]. However with high acceleration factors the ADC distribution appears to widen as seen in Figs. 1 and 2. The change is, however, not large and the advantage of a higher resolution could be more important than a slightly higher variation of the ADC [1]. The method can be used either to decrease imaging time and thus the length of the breath-hold required, or/and to increase the spatial resolution. Both are important clinically, but especially important in longitudinal patient studies to detect progression of emphysema. For such studies it is much more important that the method is standardized than what the actual ADC values are.

References:

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