Parallel Acquisition as a Key for Rapid High Resolution 3He-ADC Imaging

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Introduction

A large variety of lung diseases, such as emphysema, result in severe destruction of the lung's alveoli walls. Determining the Apparent Diffusion Coefficient (ADC) of hyperpolarized ^{3}He-gas in lungs is a proven method of non-invasively probing the integrity of the lung's microstructure [Chen, Morb1]. The essential problem of the efficiency of 3He ADC-imaging of lungs as the diagnostic tool in comparison with HRCT is the poor localisation of integrity defects caused by typically low spatial resolution of ADC-maps. The low resolution originates from (i) breath hold time restriction limiting the amount of phase encodings and (ii) limited SNR of diffusion encoded image. The solution of both problems can be achieved by using multi-channel phased arrays in combination with parallel imaging acquisition. This increase the SNR of acquired images due to high sensitivity of array elements and, simultaneously, acceleration of image acquisition by reducing the number of phase encoding steps (typically by factor 2-8). The principal advantage of using phased arrays for hyperpolarized ^{3}He is the possibility to compensate for the unavoidable SNR loss because of parallel acquisition, by increasing the flip angle. The purpose of the current study is to demonstrate the possibilities, which provides the phased array parallel acquisition for improving the efficiency of ADC-measurements with hyperpolarized 3He as well as to compare different methods of image reconstruction (e.g. mSENSE and GRAPPA) in terms of optimal ADC image quality

Materials and method

The 3He ADC measurements were performed on Siemens Avanto Tim MR-scanner (Erlangen, Germany), and an in-house built 32 channel phased array. Pilot measurements were performed using an ex-vivo pig lung phantom with ca 1.5 full lung capacity. 100ml of hyperpolarized 3He (polarisation P=65-70%) mixed with 700 ml N_2 has been used. The phantom lungs were preliminary washed out with N_2. In-vivo measurements were done on healthy male volunteer with approval of local ethics committee. 250/650 ^{3}He/N_2 mixture was applied using Tedlar bag. Bipolar diffusion encoding SGRE-sequence in 2D and 3D variant was used to acquire images. The imaging parameters are shown in figures caption. Acceleration factors 2 and 4 as well as two methods of reconstruction (mSENSE and GRAPPA) were used.

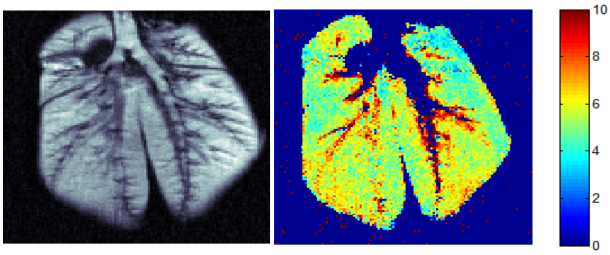

Fig 1. Phantom lungs image TR/TE/TD/FA=9.2ms/6ms/3/5^0, matrix 128x128, 12 « ADC-slices » thickness=5mm, FOV 250 mm^2, acceleration factor R=2 (16 ref. lines), acquisition time 0.7sec/slice, peak SNR ref image =50

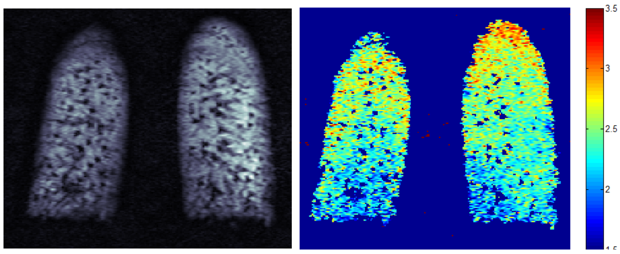

Fig 2. Human lung image TR/TE/TD/FA=10ms/7ms/3/4^0, matrix **256x128**, no acceleration, slice =10mm, FOV=310mm^2, measurement time 1.2 sec/slice, peak SNR ref image =60

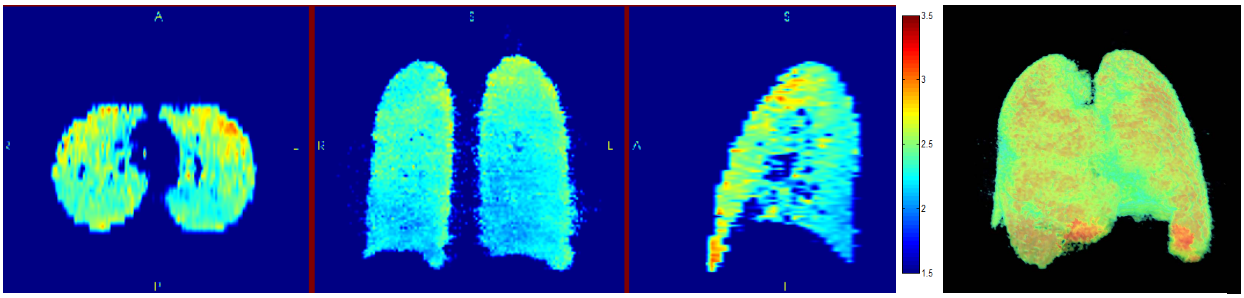

Fig 3 3D-ADC-images of human lung : TR/TE/TD/FA=9.6ms/7ms/3/3^0 matrix 128x128x48(=24 ADC) FOV=313mm^{2}x192mm (8 mm effective slice thickness), acceleration factors R=2x2, total measurement time **19** sec. Arbitrary slice orientation reconstructions and 3D rendered ADC-images (surface, volume, MIP, etc) are possible.

Results

The test images obtained using lung phantom is shown on Fig 1. The 2D and 3D in-vivo human lung ADC-map images are demonstrated on Fig 2 and 3 respectively.

Discussion

The results of the experiments shows that using multi-channel phased array acquisition may provide a very significant increase of the spatial resolution and time performance for 2D ADC measurements in comparison conventional with single-coil acquisition. Using under-sampling accelerated parallel imaging it possible to acquire 3D images providing both morphological and ADC information with the resolution and time and SNR performance better than conventional multiple slice acquisition using a single coil. Therefore, both high resolution morphology and ADC information can be acquired in full-3D mode within single 20 seconds scan. The disadvantage of parallel acquisition is the high sensitivity of the ADC-map precisions and its artefacts to the proper balance of image resolution, acceleration factor, SNR, and flip angle. The important role plays also the proper choose of images reconstruction method (e.g. using adaptive channel combination) as well as reconstruction algorithm.

References

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