Proton Acquisition with Variable Flip Angle to Simulate and Optimized Hyperpolarized ^{3}He MRI with Parallel Acquisition

J. Rivoire[1], M. Terekhov[1], and L. M. Schreiber[1]

[1]Department of Diagnostic and Interventional Radiology, Section of Medical Physics, Johannes Gutenberg University Medical Center, Mainz, Germany

Introduction:

MRI using hyperpolarized ^{3}He is an effective and powerful tool to study morphological, functional, and mechanical and other properties of lungs. The price of the ^{3}He and technical difficulties of polarization and logistic, prompt to employ computer simulation to optimise the acquisition parameters and optimal usage of available gas. However, in such simulations, the whole influence of MRI environment on image acquisition cannot be taken into account. Additionally, due to intellectual property protection, the sophisticated commercial reconstruction algorithms for parallel imaging (e.g. SENSE, GRAPPA) are not exportable to the simulation workstation. To employ the scanner's software computational capabilities and to simulate the complete measurement process without using expensive hyperpolarized gas we developed the dedicated ^{1}H MRI acquisition protocol with using variable flip angle pulse sequence. In the current work this protocol was investigate the effect of different k-space sampling ordering on images acquired with integrated parallel acquisition techniques (iPAT).

Methods:

The phantom used for the MRI acquisition was filled with copper sulfate solution to obtain a respectively T1 and T2* time of 50 ms and 50 ms. The MR-images were acquired on a 1.5T MR-scanner (SIEMENS Sonata, Erlangen, Germany) using a modified GRE sequence. In all the experiment, the repetition time was set to 120 ms to recover all the longitudinal magnetization between two consecutive excitations. To simulate the 3He experiment the flip angle used for the n-th excitation was set to:

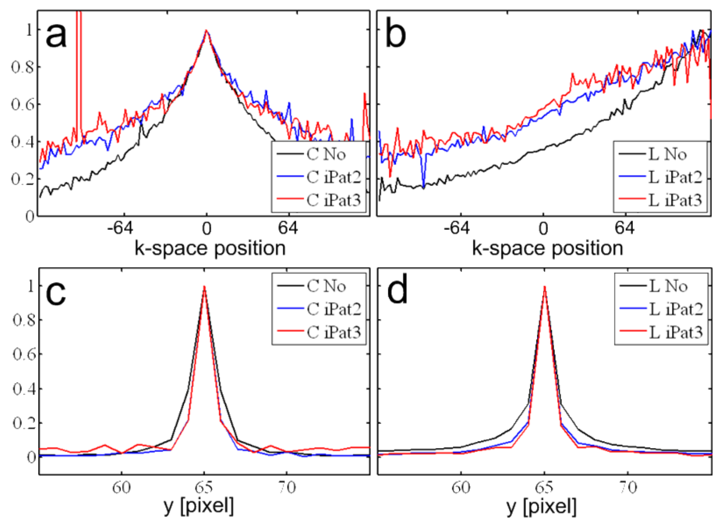
$$\alpha_H(n) = \arcsin\left(e^{-(n-1)\cdot TR_{3He}/T1_{3He}} \cdot \cos\left(\alpha_{3He}\right)^{n-1} \cdot \sin\left(\alpha_{3He}\right) \cdot k\right)$$

with TR_{3He}, α_{3HE} and $T1_{3He}$ respectively the simulated repetition time, flip angle and the longitudinal relaxation. k describes the relation between the flip angle of the proton and helium.

Several experiments were performed with different α_{3HE} from 1° to 10° and one additional without variable flip angle (Reference Image): TE=3.8ms, resolution: 128x128. These acquisitions were repeated with different k-space ordering (centric and linear), with different parallel imaging acceleration factors: no acc., Acc= 2 and 3. The images were reconstructed with spatial-matched-filter (SMF) [1] and Grappa for the accelerated images. For each image, the point-spread-function (PSF) was calculated by deconvolution with the reference image.

Results:

Two dimensional point-spread-functions were obtained but only the center line in phase encoding direction was analysed. (fig. c and d). By calculating the Fourier transform of the PSF the deposed energy in the k-space was obtained. Figure a shows the case of centric reordering with the different acceleration factors and the fig.b the case of linear reordering.



Acquired energy in the k-space (up) and Point Spread Function (down) for centric reordering (left) and linear reordering (right)

Discussion:

The figures show that for accelerated acquisitions, the non-acquired line of the k-space but calculated by GRAPPA algorithm receive the energy that would be obtained by interpolation from the neighbour point. Narrower PSFs were observed for the accelerated acquisitions. They demonstrate that the effective resolution is higher by using parallel image techniques. It can be explain by the fact that the difference of energy between the first and the last acquired k-space line is lower. With simple proton acquisition simulating hyperpolarized condition, reproducible experiments could be performed and then via the PSF, the two trajectories could be directly compared.

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Reference: [1] Walsh.D.O. MRM(2000).43:682–690