Comparison of Different Parallel Imaging Reconstruction Methods for Hyperpolarized 3He MRI

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Introduction:
In the field of lung imaging using hyperpolarized [3]He, the recent involvement of the array coil seems very promising. These techniques allow for a more efficient use of the polarization. The spatial or temporal resolution as well as the comfort of the investigated person directly benefit from this new progress. However, it is a combination of different complicated techniques. The data from multiple coils can be combined using simple approach such as sum-of-square, or more complexes algorithms such as adaptive combination [1]. In addition, the accelerated parallel acquisition schemes were developed in order to reduce amount of phase encodings and therefore the acquisition time. The most common used methods of reconstruction the undersampled parallel imaging datasets on the commercial scanner are mSENSE and GRAPPA. In order to understand the advantages and disadvantages of these algorithms, the raw data from several improved scan protocols (multi-slice 2D, 3D, dynamic, 3D Diffusion) were used to compare the images reconstructed with the different methods.

Methods:
MR-images were acquired on a 1.5T MR-scanner (SIEMENS Avento Tim, Erlangen, Germany) using a in-house built 32 channels phased array. For high resolution morphology imaging the SGRE sequence was used with the following parameters: 256x256 matrix, 5mm slice thickness, TR=7.1ms/TE=2ms/FA=7.5°, 10 slices, FOV=300 mm^2. Accelerator factor of R=1,2 and 4 were used (with 16 reference lines). 3D acquisition was performed using a 2x2, 4x1 and 4x2 accelerated 3D sequence with FOV=300mm^{2}x192mm, 128x256x24 matrix, (8mm effective slice thickness). Further imaging parameters were TR=3.2ms/TE=1.1ms/FA=4°. Dynamic acquisitions during inspiration were performed to acquire series of 150 images using GRE sequence without slice selection: matrix =128x84/TR=2.2ms/TE=0.9ms, bandwidth=1990Hz/pixel FA=4°, R=4. 3D-diffusion acquisition were performed using an accelerated 3D bipolar diffusion encoded GRE: 128x128x24matrix, TR=9,6ms/TE=7,1ms/TD=3ms/FA=3°, R=2x2/4x1.

The raw data of all of these acquisitions were used to reconstruct the images with the different algorithms present on the scanner. For the non accelerated acquisitions, the sum of square (SoS) combination method and the adaptive channel combination (AC) were used to reconstruct the images. The accelerated acquisitions were reconstructed using mSENSE combined with SoS (mSENSE_AC), GRAPPA combined with SoS (GRAPPA_SoS) or Adaptive Combine method (GRAPPA_AC).
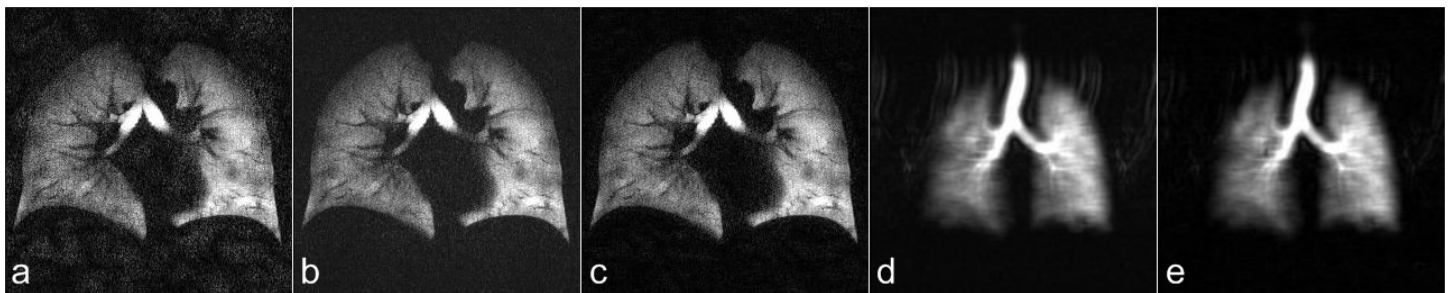

Fig. 1: Morphologic images reconstructed with mSENSE_AC (a), with Grappa_SoS (b), Grappa_AC (c) and Images from Dynamic acquisitions reconstructed with Grappa_SoS (d) and Grappa_AC (e).

Results:
As shown the Fig. 1, the noise in the images reconstructed using GRAPPA_SoS has uniform spatial profile. Using mSENSE or GRAPPA_ AC, the noise level decreases but becomes inhomogeneously distributed over the image which is critical for undersampled data reconstruction in case of a low SNR. This trend is observed for all types of acquisitions mentioned above. The image reconstruction using GRAPPA_AC has the advantage of removing more residual aliasing artifacts in the dynamic acquisition (Fig. 1e) but brings distortions of the contrast on the edges of the objects. The 3D reconstruction using GRAPPA_AC in 3D-morphology and 3D–diffusion images produces significant intensity artifacts, probably caused by problems of coil sensitivity profiles determination.

Conclusion:
The results of the different reconstruction show the complexity of parallel imaging techniques application for hyperpolarized [3]He experiments. Basing on the same raw data the results of the different reconstructions may vary a lot, especially when the SNR is insufficient for reliable use of "parallel" data reconstruction algorithms. In our case, the reconstructions using GRAPPA seems provide better reconstruction than using SENSE. Combined with SoS, GRAPPA has advantage of providing homogeneous noise distribution and combined with AC, it removes more residual aliasing artifacts and increase the "apparent" SNR.

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