Motion Compensation Using Parallel Imaging Without Extra Reference Measurements And With Modified Reordering

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Introduction

Motion artifact reduction using reconstruction methods for parallel acquisition techniques (PAT) on subdivisions of a fully sampled data set have been proposed by various authors. When the individual images were averaged to recover lost signal-to-noise ratio (SNR), the sensitivity information necessary for PAT reconstruction have, to our knowledge, always been acquired with additional measurements, e.g., [1][2]. Sensitivity estimates were derived from the original data only to regenerate individual corrupt k-space lines [3][4]. Here, we present an approach to reduce motion effects by PAT reconstruction without additional measurements, and subsequent averaging of images. A modified reordering scheme is used to minimize motion effects in the partial data sets.

Materials and Methods

T_2-weighted turbo spin-echo (TSE) imaging of a healthy volunteer was performed on a 1.5T system (MAGNETOM Symphony Quantum) with imaging parameters: 20 8mm slices, FOV 375x281mm^2, matrix 256x116, turbo factor 29, TE 101ms, TR 4000ms, refocussing flip angle 150°, bandwidth 260 Hz/pixel. Data were acquired in two breath-holds of 20s each, using two body array and two spine array rf coil elements. The volunteer was asked to hold still in the first exam, and to slightly move the diaphragm in the second exam to simulate involuntary patient motion.

The resulting fully sampled data sets were divided into even and odd phase encoding (PE) lines, corresponding to a virtual acceleration factor (vAF) of 2. The central part of the fully sampled data sets was Hann filtered to varying degrees in order to suppress motion effects, and then used to estimate the coil sensitivities. The partial data sets were reconstructed using the mSENSE algorithm [5], and then combined by complex addition.

Figure 1a) shows the standard TSE reordering within one segment (drawn in black; neighboring segments are also shown in grey): the 4 lines belonging to the 4 echo trains are acquired in a linear fashion. In order to minimize the range of acquisition times (and thus motion effects) in the subdivided data sets, the reordering scheme was modified to that shown in fig. 1b). Now, the first undersampled data set (shaded blocks) consists only of lines from echo trains 1 and 2, whereas the second data set (clear blocks) consists of lines from echo trains 3 and 4. Note that the number of lines per segment has to be an integer multiple of the vAF.

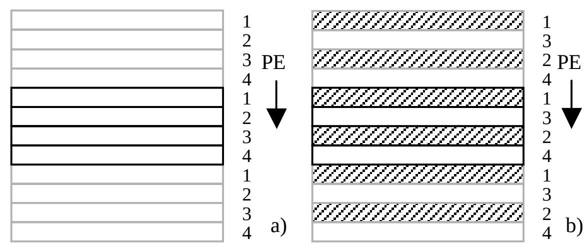

Fig. 1: TSE reordering schemes of 3 consecutive segments (temporal order of k-space lines); standard (a) and modified (b).

Results

Figure 2 shows images reconstructed with root-sum-of-squares (rSOS) combination (a,c), and recombined mSENSE reconstructions using a Hann filter of width 96x96 for sensitivity estimate refinement (b,d), for the volunteer scans with minimal motion (a,b) and some motion (c,d). The motion suppressing effect of the PAT reconstruction in fig. 2b) and d) is evident. There is some noise amplification in the middle of the object (arrows), which can be reduced in exchange for less motion artifact suppression by widening the Hann filter on the reference data. Otherwise, the SNR loss due to the PAT reconstruction appears to have been fully recovered using the subsequent averaging of images.

Image quality of the rSOS reconstruction was found to be equally good for both the modified and the standard reordering (not shown). PAT motion suppression for the latter was also achieved, but only to a lesser extent.

Discussion

Motion artifact suppression for fully sampled data sets using PAT reconstruction on data subsets with subsequent averaging is feasible using the original data for sensitivity estimation. Modified reordering is a key prerequisite for successful application of the method, since it keeps the total acquisition time span short in each subdivided data set. This is supported by the inferior artifact suppression in the standard reordered data set. The amount of Hann filtering should be optimized for sufficient motion artifact suppression with minimal noise amplification. One can envision multiple reconstructions with varying degrees of reference filtering and retrospective choice of the best result based on a suitable measure of the tradeoffs. Also, multiple reconstructions using different vAFs are possible, if the coil arrangement permits it. For maximum impact, the reordering should be compatible with all the vAFs used (e.g. 2/4). The method presented here is less computationally intensive than approaches requiring a model of the motion involved, such as [6]. It should work best when the motion is distributed throughout the whole exam.

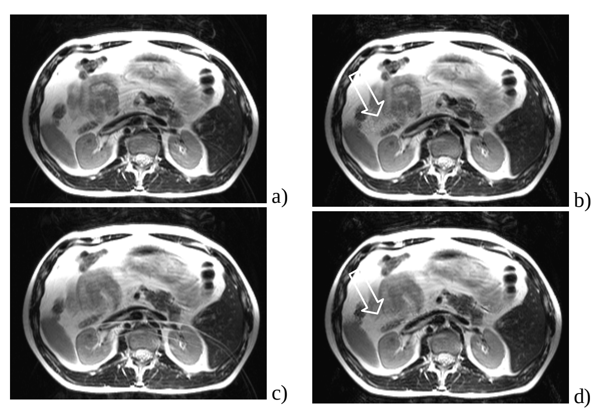

Fig. 2: TSE images (modified reordering) with minimal motion and rSOS (a) vs. PAT (b) reconstruction; with some motion and rSOS (c) vs. PAT (d) reconstruction.

Conclusion

The presented method suppresses motion artifacts using PAT reconstruction without the need of extra coil sensitivity measurements. Successful application to segmented TSE imaging in the abdomen was demonstrated. A special feature of the presented approach is the optimized reordering scheme.

References

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