Improved Image Reconstruction for Multi-Shot Multi-Coil Diffusion Imaging

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Introduction

Image reconstruction for multi-shot diffusion imaging requires accurate phase maps for each individual segment. Existing methods make use of 2D-navigators [1] or self-calibrating trajectories to obtain low resolution phase maps. However, when the phase variations are not smooth enough compared to the resolution of the navigator, the resulting images are affected by phase cancellation artefacts. For this reason, an alternative reconstruction scheme was developed in this work, which allows to estimate high resolution phase maps. The method was applied to a segmented STEAM sequence where large 2D-navigators are not feasible.

Theory

Image reconstruction in multi-shot diffusion weighted imaging has to invert a system of equations similar to parallel imaging. Here, this system is not only determined by the coil sensitivities but also by a spatially varying (nonlinear) phase, which may differ drastically between each segment. To obtain sensitivities as well as phase maps with good accuracy a three step reconstruction technique has been developed: First, a real-valued image without diffusion weighting (and phase problems) is reconstructed from data of all segments making use of the autocalibrated parallel imaging algorithm described in [2] which yields image and coil sensitivities. In a second step, complex-valued images are reconstructed independently for each individual segment by using parallel imaging with the coil sensitivities from step one. The reconstructed images from this second step have a low SNR due to the high acceleration factor, but yield good phase maps with high spatial resolution after moderate filtering. In the last step, the final real-valued images are reconstructed using the coil maps from the first and the phase maps from the second step to combine the data from all coils and segments.

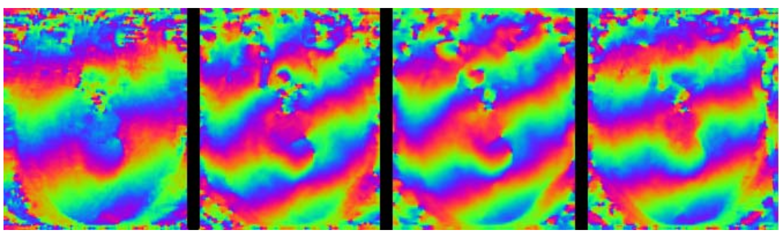

Figure 1: phase maps for all segments

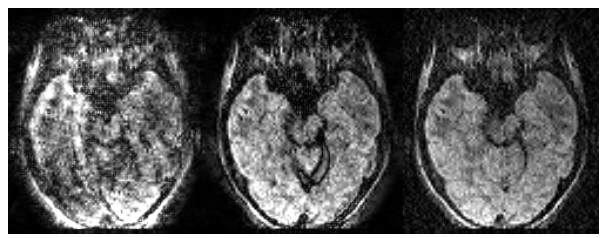

Figure 2: left to right: without correction, navigator-based and proposed technique

Methods and Results

Diffusion-weighted data was acquired with a segmented STEAM sequence at 2.9 T using a 32 channel head coil. A data set at 2 mm isotropic resolution has been acquired in 51 slices (matrix size 96 x 84). For each slice 25 images were measured: 24 different diffusion directions at B = 1000 s mm^{-2} as well as one image with B = 0 s mm^{-2}. k-space was split in 4 segments, each consisting of a fully sampled centre of 8 lines and an undersampled outer part. To further shorten the echo train a partial Fourier factor of 5/8 was used. Figure 1 shows colour-coded phase maps for all segments corresponding to a single selected diffusion weighted image, demonstrating the high amount of phase variations from the pulsation of the brain stem. The final reconstruction can be seen in figure 2. For comparison, the same image is shown with no correction or where only low resolution phase maps from the k-space centre were used.

Conclusion

An image reconstruction technique for multi-shot diffusion imaging was developed and applied to data from a segmented STEAM sequence. The new technique makes use of the redundancy provided by multiple receive coils to obtain high resolution phase maps for each individual segment. In this way, artefact free images can be reconstructed even for data with high frequency phase variations, which - in this example - are caused by the pulsation of the brain stem. The technique allows the reconstruction of affected data without resorting to any data exclusion or weighting scheme and does not need cardiac triggering during the acquisition.

References

[1] Miller et al., MRM 50:343-353 (2003)
[2] Uecker et al., MRM 60:674-682 (2008)