Parallel Diffusion-Weighted Single-Shot STEAM - Less is More

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Introduction: In comparison to EPI-based approaches, diffusion-weighted imaging using single-shot STEAM (DW-SSSTEAM) [1] is not sensitive to susceptibility artifacts but suffers from a longer measurement time. Parallel data acquisition promises to provide a scalable technique to mitigate this situation in a lossless way considering the favorable SNR behavior of DW-SSSTEAM on k-space reduction.

Methods: We applied parallel imaging (PI) with GRAPPA reconstruction [2] and pre-scan reference line determination to diffusion-weighted single-shot STEAM MRI [3]. The distribution of the available magnetization over k-space was controlled by a variable flip angle function for the read-out pulses which was designed to enforce a Lorentz-shaped point spread function (PSF) in phase-encode direction (a generalization of the idea published in [3]). The approach ensures control over the effective resolution and optimal utilization of the longitudinal magnetization. SNR determinations relied on a voxel-wise ensemble measurement to cope with possible inhomogeneous noise amplification. The estimates were checked for consistency with results from methods taking into account intensity distortions in low-signal magnitude images. The MRI system consisted of a 3 T Siemens TRIO and an eight-channel phased array head coil. The present work extends earlier research [4] using constant flip angles and no diffusion weighting.

Results: As previously described [1] for a partial Fourier (PF) version of DW-SSSTEAM, the redistribution of the magnetization for a lower number of read-out pulses theoretically leads to a disproportionately high signal increase compared with the concurrent noise amplification. In comparison with a 5/8 PF version, even PI with an acceleration factor of only 2 omits a higher number of excitations and above all more central k-space lines which bear a greater amount of signal in standard full Fourier mode with Lorentzian PSF. Consequently, an ideal PI acquisition with DW-SSSTEAM is more time- and SNR-efficient. However, experimental evidence suggests that the noise profile of the employed phased array receiver precluded a superior SNR as the quality of PF and PI images was found to be equal. Nevertheless, 17% of the measurement time can be saved in a diffusion tensor experiment compared to PF imaging and 45% compared to non-accelerated full Fourier imaging. Thus, for 50 sections, 24 diffusion directions, b=0 and 1000 s/mm^2, 2×2×2 mm^3 voxel size, and two averages, the method takes a measurement time of ca. 16 minutes. At the expense of imaging time, the image quality can be improved by reducing the receiver bandwidth. Using fiber tractography and data from a PI-accelerated DW-SSSTEAM acquisition it was possible to reconstruct the nerve fibers of the anterior part of the human visual system (optic nerve, optic tract) as well as some of the eye muscles.

Conclusion: Parallel imaging has proven to be a fruitful and quality-preserving method to reduce the time requirements of DW-SSSTEAM. Future developments in receiver coil technology might allow for higher reduction factors and further SNR improvements. In addition, PI and PF data reduction techniques can be combined. In comparison with constant flip angles, read-out pulses with variable flip angles lead to an SNR increase and a better defined PSF.

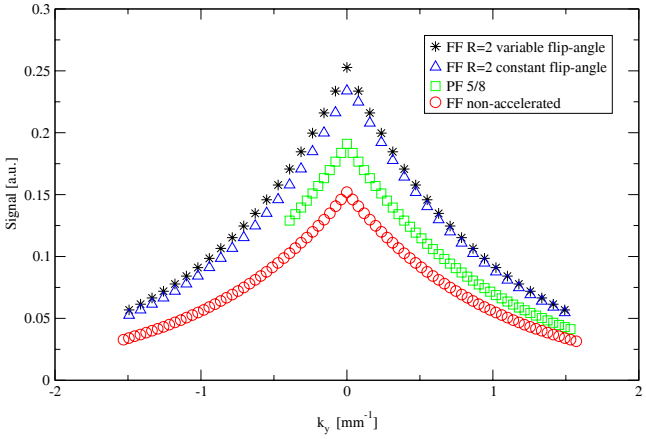

Fig 1: Comparison of the theoretical signal distribution of different acquisition schemes over k-space along the phase-encoding direction

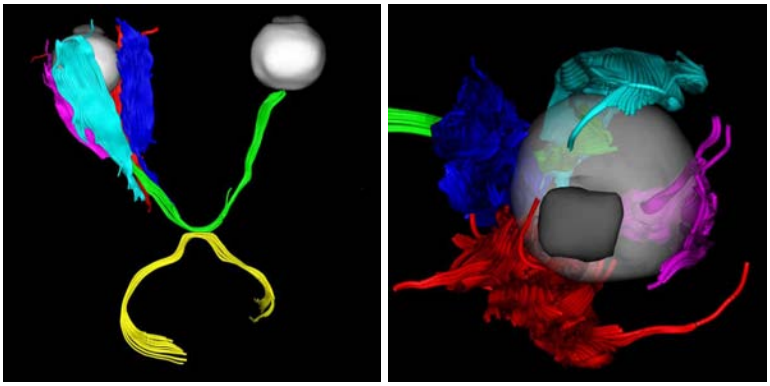

Fig 2: Transversal (left) and coronal (right) views of the optic tract (yellow), the optic nerve (green), the vitreous bodies and some of the surrounding eye muscles: musculus rectus inferior (red), superior (turquoise), medialis (blue) and lateralis (violet).

References:

[1] Rieseberg et al., MRM, 54:486-490 (2005)
[2] Griswold et al., MRM, 47:1202-1210 (2002)
[3] Nolte et al., MRM, 44:731-736 (2000)
[4] Finsterbusch, Koch, Proc. ISMRM, 12:2251 (2004)