Slice-Specific Gradient Compensation of Magnetic Field Inhomogeneities to Improve T2*-Weighted Imaging of the Human Spinal Cord

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Introduction

BOLD-based spinal cord imaging suffers from the magnetic field inhomogeneities induced by the different susceptibilities of the vertebrae and the surrounding tissue (e.g. [1,2]). In T2*-weighted acquisitions, these inhomogeneities cause a signal dephasing that varies between different transverse sections. In this study, it is shown that applying slice-specific gradient compensation moments [3,4] reduces the signal variations and drop outs which could help to improve the detectability and reliability of BOLD-based functional neuroimaging of the spinal cord.

Methods

Measurements were performed on a 3 T whole-body MR system (Siemens Magnetom Trio). Healthy volunteers were investigated from which informed consent was obtained prior to the examination. Single-shot T2*-weighted echo-planar images of 24 slices were acquired with a 128×128 mm^2 field-of-view, parallel imaging (GRAPPA, acceleration factor 2, 24 reference lines), in-plane resolutions of 1.0×1.0 mm^2 and 2.0×2.0 mm^2 (slice thickness 5 mm) yielding echo times of 44 ms and 22 ms and repetition times of 2840 ms and 1860 ms, respectively, using a four-channel receive-only neck coil. Three echoes were acquired after the initial RF excitation to estimate and correct the phase distortion present between echoes acquired with positive and negative readout gradient lobes.

In the slice direction, different, flow-rephased gradient compensation moments (within ±10 mT m^{-1} ms and ±5 mT m^{-1} ms for the long and the short echo time, respectively) were applied after acquiring the signals for the N/2 ghosting correction (see Fig. 1). In each slice, a region-of-interest (ROI) covering the spinal cord was defined and the gradient compensation moment yielding the highest signal intensity in this ROI was chosen for subsequent T2*-weighted acquisitions.

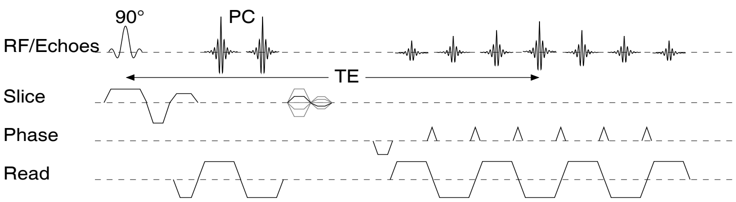

Fig. 1: Basic EPI sequence used involving z-shim gradient pulses and flow rephasing in slice direction. "PC" denote the reference scans acquired to correct N/2 ghosts.

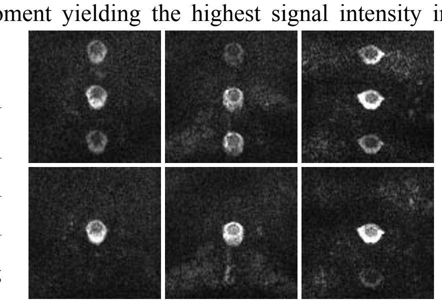

Fig. 2: Three slices acquired with a gradient compensation gradient moment applied prior to (upper) and after (lower) the phase-correction reference scans

Results and Discussion

In Fig. 2, acquisitions with the gradient compensation applied prior to and after the acquisition of the phase-correction scans are compared. For larger compensation moments that may be considered for longer echo times, the dephasing effects on the phase-correction echoes may be significant if the compensation moment is applied before, yielding severe ghosting. These artifacts can be avoided by applying the gradient compensation after the phase correction scans.

The signal intensity within the spinal cord ROIs for several slices and the various compensation moments applied are shown in Fig. 3. The signal curves show a similar shape but different widths and positions of the maximum, i.e. different compensation moments are required to maximize the signal intensity. For longer echo times, the curves are broader and the positions of their maxima cover a larger range which is in accordance with the increase of the dephasing with the echo time.

Figure 4 compares acquisitions without and with an optimized gradient compensation. The, in some slices severe, signal dropouts present without compensation are considerably reduced with compensation yielding a much more homogeneous signal intensity. Minor variations are related to the non-linear, and more importantly, non-homogenous dephasing which in practice may require to optimize the signal intensity in those spinal cord regions under investigation.

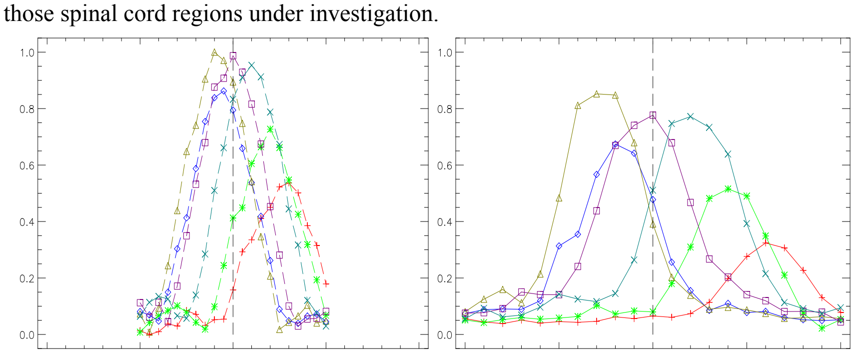

Fig. 3: Plot of the signal intensities within the spinal cord ROIs of different slices vs. the gradient compensation moment in slice direction (in µTs/m) for the short (left) and long echo time (right).

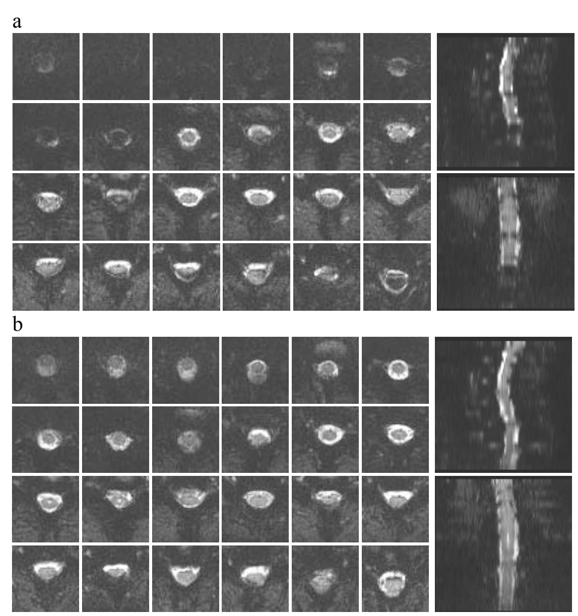

Fig. 4: Spinal cord images acquired (a) without and (b) with gradient compensation. The figures show the transverse sections (left) and sagittal (upper right) and coronal reconstructions (lower right), the latter along a user-defined curve.

References

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