Spectroscopic Imaging with Prospective Motion Correction and Retrospective Phase Correction

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Introduction

Due to their long scan times, spectroscopic imaging (SI) experiments are particularly susceptible to motion-induced artifacts. Unlike in imaging experiments, these artifacts cannot be easily recognized and thus may lead to false diagnoses in clinical scans. Navigator echoes can be used to correct for motion in MRS, but this requires additional RF pulses and gradients, which substantially increase the scan time [1]. A prospective motion correction method employing an external optical motion tracking system has recently been proposed [2] and has already been successfully applied to single voxel spectroscopy (SVS) in the human brain [3]. However, motion correction without a real-time shim update can give rise to considerable frequency drifts in regions with an inhomogeneous susceptibility distribution. This problem can be tackled using the interleaved reference scan (IRS) method, originally proposed by Thiel *et al.* [4] and successfully combined with motion tracking for SVS by Buechert *et al.* [3]. In this work, prospective motion correction in combination with IRS-based retrospective phase correction was implemented, validated and applied for SI in the human brain.

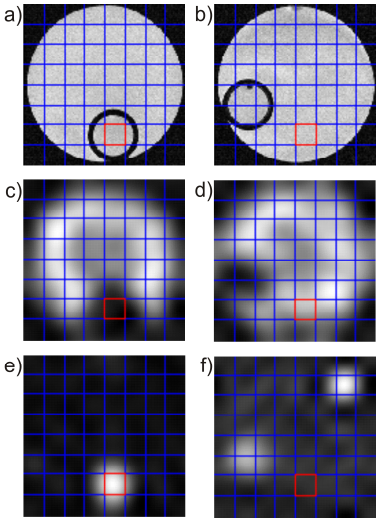

Fig. 1: Spectroscopic imaging results for a phantom experiment with a rotation from a) to b) at the beginning of the scan: with motion correction (left), without motion correction (right). Metabolite maps for Cit (c, d) and Lac (e, f) are shown.

Materials and Methods

Prospective motion correction and retrospective phase correction were implemented with a PRESS-based SI sequence on a Magnetom Trio 3T system (Siemens Healthcare, Germany) equipped with a phased array head coil for signal reception. The stereoscopic tracking system (ARTrack3, Advanced Realtime Tracking GmbH, Germany) reported positions of a mouth piece fitted with four retro-reflective spheres in six degrees of freedom [2]. The PRESS volume, the SI FOV and the outer volume suppression (OVS) slabs were updated after every TR. Retrospective phase correction was achieved with the IRS method [4, 5]. For validation purposes, SI data sets (8×8) were acquired from a large phantom bottle containing citrate (Cit) solution with a small cylindrical phantom containing lactate (Lac) solution attached to its wall (Fig. 1a). The phantom was rotated by approximately 90° after the first phase encoding step of the scan (Figs 1a and 1b). Data sets with and without motion correction were acquired and metabolite maps of Cit and Lac were created by peak integration in the respective chemical shift range as well as subsequent Fourier interpolation. In vivo 2D SI data (FOV = 20 cm, res = 16×16, TR = 2.7 s, TE = 30 ms, OVS with 8 slabs, scan duration ≈ 12 min) were acquired from the brain of a healthy subject (Fig. 2a), once with motion correction and once without. The subject was asked to tilt his head sideways by approximately 10° once per minute, back and forth between two previously defined positions. Acquisitions with motion above a certain threshold (2 mm translation and 3° rotation per TR) were rejected and automatically repeated, which increased the scan duration by about 30 s.

Results

The metabolite maps for Cit (Figs. 1c and 1d) and Lac (Figs 1e and 1f) from the phantom experiment show that phase encoding is correctly updated in the measurement with motion correction, while the uncorrected experiment yields metabolite maps corresponding to the rotated phantom. The bright spot in the upper-right corner of Fig. 1f stems from a baseline artifact. Clippings (2×2) from the in vivo results are presented in Fig. 2. They show huge lipid contamination in the uncorrected spectra (Fig. 2b), while in the motion-corrected spectra the spectral quality is preserved (Fig. 1c). Additional IRS phase deconvolution corrected for line broadening caused by motion-induced frequency drifts and created an SI data set with correctly phased spectra across the whole slice (Fig. 2d).

Discussion

The presented results demonstrate the feasibility of prospective motion correction for SI experiments. Due to the low concentration of brain metabolites compared to fat, and the coarse spatial resolution giving rise to an unfavourable point spread function, OVS plays a pivotal role in SI experiments. Therefore a real-time update of the OVS slabs is crucial, particularly for quantitative studies. The assignment of metabolic features to anatomical structures can also be affected by motion in between the SI measurement and the acquisition of the reference image for data analysis. Thus motion tracking and position locking between scans would be desirable. Motion-induced frequency drifts can be corrected retrospectively, using the IRS method. A correction of higher order field changes would be beneficial, but would require a real-time shim update, which is beyond the capabilities of currently available clinical MR systems. For SVS the shim is very local, giving rise to large field distortions outside the selected voxel, which strongly impair the quality of motion-corrected experiments. For SI experiments, however, the shim volume usually comprises major parts of the SI slice, and therefore the shim is only mildly affected by in-plane subject motion.

Acknowledgements

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References

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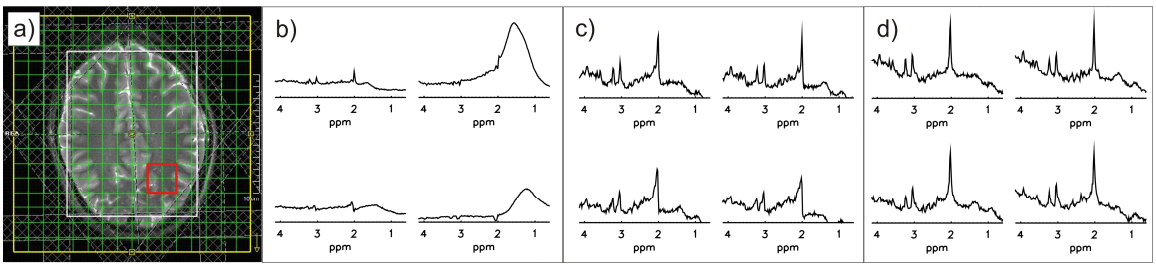

Fig. 2: a) Setup for the SI experiment with the white box representing the PRESS volume and the red box indicating the origin of the presented spectra: b) without any correction, c) with motion correction, d) with motion correction and IRS phase correction.