Real Time Prospective Voxel Position Correction with Interleaved Reference Scan Using an Optical Motion Tracking System

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Introduction

Subject motion during MR investigations is a factor limiting the quality of the results. For MR spectroscopy, the interleaved reference scan (IRS) method[1,2] allows to minimise the spectral quality degradation arising from subject motion. However, it is oft impossible to judge whether the spectra were acquired from the desired location or if the subject has moved during the scan, which may notably decrease the diagnostic value. Additionally, when the voxel is placed close to strong unwanted signal sources, e.g. subcutaneous fat, subject motion during the acquisition may lead to severe lipid contaminations of the spectra. Navigator echoes, such as orbital [3] or spherical [4] navigators, may be used to correct for motion in MRS. This, however, would not only lengthen the measurement, but also require additional RF and gradient pulses to be incorporated into the sequence, disturbing the steady state and introducing additional eddy currents. Here we demonstrate a possibility of interfacing the MR scanner with an external optical motion tracking system, capable of determining object's position with sub-millimetre accuracy at a high update rate. The proposed approach uses the information on the object motion to update in real time the position of the voxel during the acquisition on every repetition. The external motion correction approach presented here is compatible with practically every spectroscopic or imaging sequence and does not compromise the scanning efficiency.

Methods

The prospective motion correction was implemented on the Magnetom Trio 3T system (Siemens Medical Solutions, Germany) equipped with a standard quadrature head coil. Cameras of the optical motion tracking system (ARTrack1, Advanced Realtime Tracking, Germany) were positioned in the magnet room as sketched in Fig. 1a. The tracking system was connected to the internal Ethernet of the MR instrument. Communication with the tracking system was implemented directly on the real time control unit of the scanner. The tracking system was capable of measuring positions of multiple targets fitted with retro-reflective spheres with the accuracy of 0.1mm (RMS) and update rate of 60Hz. For *in vivo* experiments mouthpieces fitted with reflective spheres were used (Fig. 1b). To insure proper contact and reproducible positioning dental casts were applied. 5 volunteers were examined. The experiments were performed in accordance with local IRB regulations.

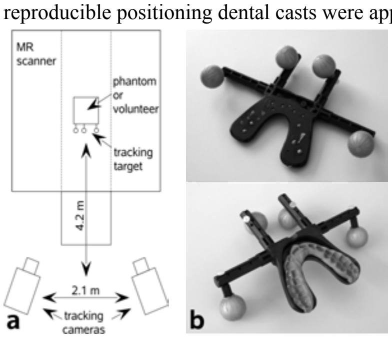

Fig. 1. *(a) Setup of the optical tracking system in the magnet room. (b) Mouthpiece with a dental cast and reflective spheres used in volunteer experiments.*

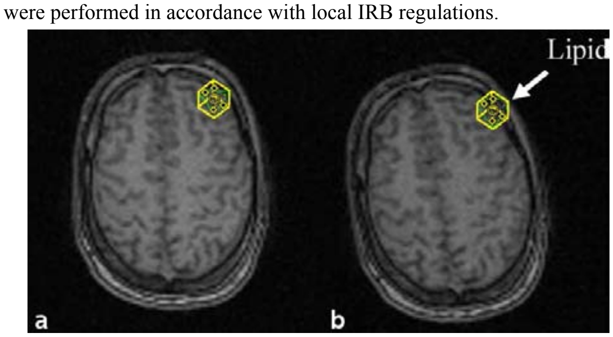

Fig. 2. *(a) For demonstration purposes a voxel location in the temporal cortex near the skull was selected. (b) During subject movement the voxel location is partly outside the brain, covering areas with high lipid concentration.*

The standard PRESS (point-resolved spectroscopy) sequence was used as a template to integrate the IRS scheme and the real-time voxel position update on every TR based on the tracking data. For localization a 3D gradient echo data set was acquired. A typical MRS protocol was used: TE=30ms, TR=3000ms, 96 acquisitions, 15^3mm^3 voxel. Individual averages were saved and processed in Matlab (The MathWorks, USA) as described previously[2]. The voxel was positioned in the temporal cortex (Fig. 2). Examinations consisted of 4 runs: with and without prospective correction, and with and without intended motion. During motion periods volunteers were instructed to perform series of axial head rotations with the amplitude of about 5°. Head motion data were logged to allow for comparison of the subject motion. The LCmodel software package[5] was used to analyse the spectra. The spectral quality was characterized by the SNR and FWHM (full width at half maximum).

Results

The sequence was tested on phantoms to assure proper functionality (data not shown). Results of the *in vivo* examinations are shown in Fig. 3. Subject motion without correction results in severe lipid contamination (Fig. 3b), which is avoided if the correction is activated (Fig 3c). The remaining broadening of the spectral lines due to the varying shim conditions in presence of motion is effectively reduced by the IRS processing (Fig. 3d). The quantitative results are summarised in Table 1.

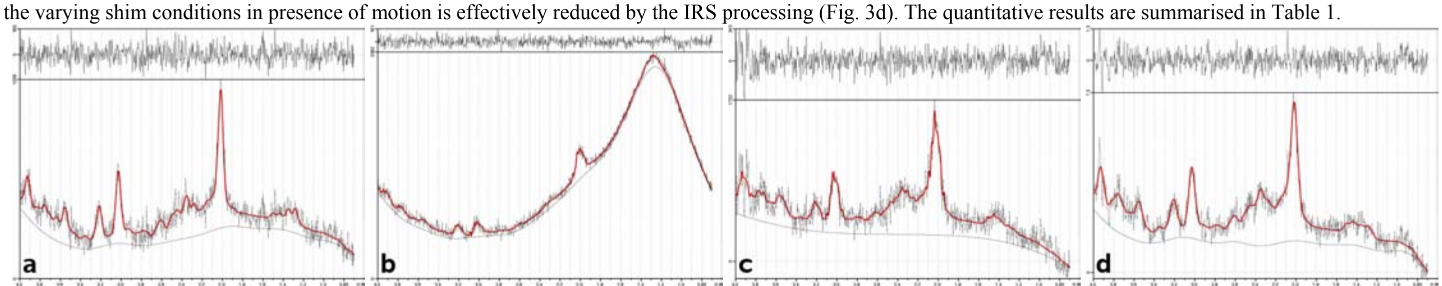

Fig. 3. *Spectra acquired in the volunteer experiment. (a) no motion, no correction; (b) Intended motion, no correction; (c) intended motion with correction. No IRS processing was performed on spectra (a-c). (d) The result of the IRS correction of the spectrum (c).*

Discussion

Subject motion during MRS examinations has various consequences on the acquired data. Firstly, the recorded signals no longer originate from the selected voxel but from the area covered during the movement. This is effectively addressed by the prospective motion correction. Secondly, the high homogeneity of the magnetic field in the selected voxel is disturbed by the motion leading to frequency shifts and intravoxel dephasing. Frequency shifts are effectively corrected by the IRS technique, as demonstrated. The complete field change correction would require real time shim update, which is by far more demanding on hard- and software than nowadays available on clinical MR systems. The results presented demonstrate clearly that using the optical tracking system in combination with IRS improves the spectral quality drastically in the presence of subject motion (Fig. 3b vs. 3d). The approach is particularly advantageous at difficult locations, for prolonged measurements and with uncooperative subjects. The presented principle of online correction is independent of the source of the motion data. Future implementations may utilise simpler and easier to handle motion tracking systems.

Table 1. *Quantitative results given by LCModel*

	Without IRS		With IRS	
Experiment	SNR	FWHM	SNR	FWHM
wo/C, n/M	8	0.048	9	0.055
w/C, n/M	8	0.055	9	0.048
wo/C, w/M	4	0.063	5	0.055
w/C, w/M	6	0.071	8	0.063

References

[1] Thiel T, et al., *MRM* **47**: 1077-1082 (2002) [2] Büchert M, *ISMRM* #**2506**: (2005) [3] Fu ZW, et al., *MRM* **34**: 746-753 (1995). [4] Welch EB, et al., *MRM* **47**: 32-41 (2002) [5] Provencher SW *MRM* **30**: 672-679 (1993)