Real-Time Motion Corrected MRS using EPI Navigators

A. T. Hess[1], M. D. Tisdall[2,3], E. M. Meintjes[1], and A. J. van der Kouwe[2,3]

[1]Human Biology, University of Cape Town, Cape Town, South Africa, [2]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, United States, [3]Department of Radiology, Harvard Medical School, Brookline, MA, United States

Introduction

Motion is an inherent problem in MR imaging introducing artefacts and degrading image quality, this problem is confounded when imaging children. We propose an approach to correct in real time two sources of degradation in single voxel spectroscopy. The first source of signal degradation is that the spectrum will contain averages from different anatomical locations introducing chemical shifts that may not have been present in the original voxel. The second, and most serious, source of signal degradation is changes in the B0 field due to the anatomical relocation resulting in line broadening. This issue is confounded in single voxel spectroscopy (SVS) due to the shim optimisation process causing B0 roll off outside the voxel. Previous methods have been proposed to detect and correct phase induced errors due to motion [1] but have only corrected the zero order shim (Z0) and not corrected the position of the sampled volume. We demonstrate a navigated SVS sequence with real-time motion (position) correction and propose to extend this method to incorporate real-time shim correction.

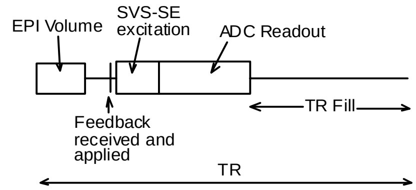

Figure 1: SVS SE with EPI navigator

Method

The core of this technique is to use a low resolution EPI acquisition as a navigator, with a 32^3 matrix size (FOV 256mm) and a low flip angle of 2° to minimise the effect on the spectroscopy FID. A single voxel spin echo (PRESS) spectroscopy sequence from Siemens was adapted to include a complete EPI volume acquisition per TR with the timing demonstrated in Figure 1. As the EPI block is located within the SVS relaxation time it has no effect on the TR and total acquisition time. There is a 100ms separation between the EPI block and the SVS block allowing enough time for the new anatomical position to be calculated and the imaging coordinate system to be updated.

Software was compiled for the scanner's online measurement control and image reconstruction (MCIR) system to collate the SVS data and in parallel reconstruct the EPI volumes as they are acquired and perform motion estimation using the built-in Siemens routines for Prospective Acquisition CorrEction [2] (PACE). PACE performs 3D, six parameter, rigid body motion estimation (rotations and translations) and feeds these parameters back to the sequence in real time. PACE co-registers the first EPI volume with successive volumes, thus negating the need to acquire a navigator map as in other motion navigation techniques [3]. The sequence uses this feedback information to update the imaging parameters and shift the imaged voxel accordingly, this feedback is simultaneously applied to the slab positioning of the EPI volume.

We tested this method on a healthy volunteer, using a Siemens (Erlangen, Germany) 1.5T Avanto scanner. We chose an EPI factor of 32, TE of 6.9ms, TR of 14ms and a bandwidth of 3906 Hz/pixel for which each EPI volume took less than 500ms to acquire. The spectroscopy had a voxel size of $(16mm)^3$, TE 30ms, TR 2300ms, 192 averages, Tacq of 7:22 min:s. We acquired three data sets in a healthy volunteer: one without any motion or EPI navigator excitations, a second with the navigator enabled (no motion), and a third with the navigator enabled and the volunteer performing periodic motion (as depicted in Figure 2). The volunteer provided informed consent and data was acquired according to protocols approved by the Human Investigation Committee at MGH.

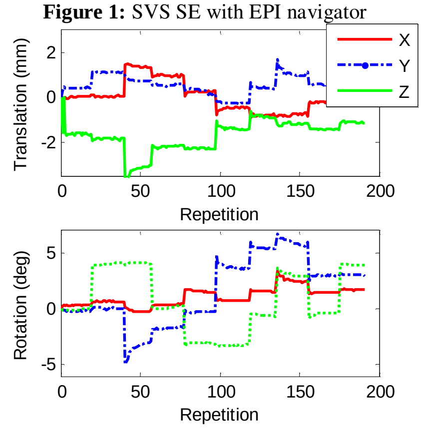

Figure 2: Motion before correction

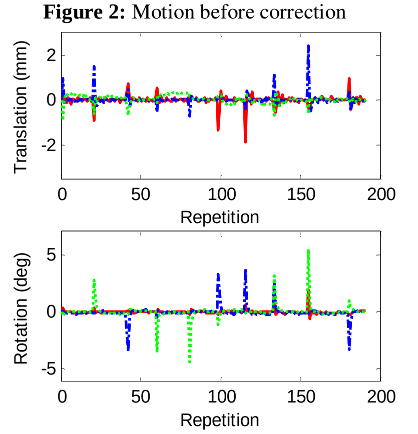

Figure 3: Voxel shifts due to tracking

Results

Table 1: Relative metabolite concentrations.

	NAA/Cr (%SD)	Cho/Cr (%SD)	FWHM	S/N
No Navigator	1.99 (5%)	0.381 (10%)	0.107	7
Navigator	1.888 (5%)	0.349 (8%)	0.107	7
Navigator with Motion	2.102 (5%)	0.361 (10%)	0.123	7

The motion feedback during the third scan (with movement) is demonstrated in Figure 3, noting that the feedback is the change in position between successive navigators and is applied before the SVS block. The residual motion in Figure 3 is less that +/-0.2mm and +/-0.2° demonstrating the accuracy of PACE. The spectra were processed in LCModel [4] and the results of the ratios of the NAA group to Creatine, and Choline group to Creatine, are given along with their relative %SD (closeness of fit from LCModel) in Table 1. There are no significant differences between the metabolite ratios, line widths or signal-to-noise ratios in any of the measurements.

Discussion and Conclusion

These results demonstrate effective real-time tracking of the spectroscopy voxel with no apparent degradation of the spectrum. We propose that this technique can be extended to real-time shim correction by acquiring two EPI navigators back to back with different TEs using the EPI based shimming approach proposed by Reese [5]. The phase difference between these two EPI volumes provides a frequency map which is used to optimise the shim parameters. This is where the greatest benefit of using full volume EPI navigators in spectroscopy lies. The combination of an EPI navigator in spectroscopic imaging can thus mitigate artefacts and loss of data from subject motion.

Acknowledgements

This work was funded by the University of Cape Town, the South African Research Chairs Initiative of the Department of Science and Technology and National Research Foundation of South Africa, NIH grants R21AA017410, R21EB008547, R21DA026104, R01NS055754, P41RR014075, and The Ellison Medical Foundation. We thank Michael Hamm of Siemens for his contribution to this research.

References

[1] T. Thiel, M. Czisch, G. K. Elbel, J Hennig, "Phase Coherent Averaging in Magnetic Resonance Spectroscopy Using Interleaved Navigator Scans: Compensation of Motion Artifacts and Magnetic Field Instabilities" MRM 2002 47:1077-1082.

[2] S. Thesen, O. Heid, E. Mueller, L. R. Schad, "Prospective Acquisition Correction for Head Motion With Image-Based Tracking for Real-Time fMRI" MRM 2000 44:457-465.

[3] A. J. W. van der Kouwe, T. Benner, A. M. Dale, "Real-Time Rigid Body Motion Correction and Shimming Using Cloverleaf Navigators" MRM 2006 56:1019-1032

[4] Provencher S. "Estimation of metabolite concentrations from localized in vivo proton NMR spectra". MRM 1993 30:672-679.

[5] T. G. Reese, T. L. Davis, R. M. Weisskoff, "Automated Shimming at 1.5T Using Echo-Planar Image Frequency Maps". JMRI 1995 5:739-745.