Motion-Induced Frequency and Shim Variations during Localized 1H MR Spectroscopy with Prospective Motion Correction

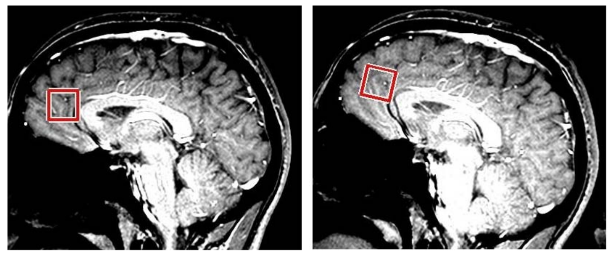
B. Keating[1], and T. Ernst[1]
[1]Department of Medicine, John. A. Burns School of Medicine, University of Hawaii, Honolulu, HI, United States

INTRODUCTION

Localized ^{1}H MR spectroscopy (MRS) of the brain, like all MR techniques, is sensitive to subject motion. Head motion is a particular problem in children and patients who are in pain, ill, confused, or otherwise uncooperative. Prospective motion correction can be used ensure that the voxel remains in the correct brain region during movements [1]. However, even when the voxel perfectly tracks head movements, motion can cause susceptibility-induced changes in the magnetic field (B_0) distribution, which may in turn lead to sub-optimal shims and broadening of spectral lines, as well as frequency changes and possibly poor water suppression. Therefore, we undertook a study to characterize the effects of various types of head motion on shim and center frequency in MRS voxels that dynamically followed head movements.

METHODS

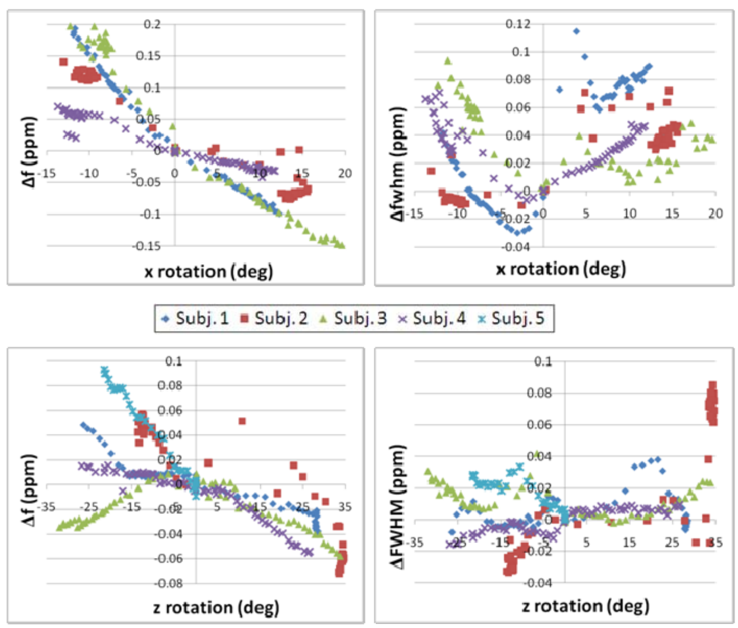
Studies were performed on a 3T Siemens Trio scanner. MRS scans used a point-resolved spectroscopy (PRESS) [2] sequence (TE/TR=30/3000ms, 32 repetitions, 20x20x20mm voxel), modified to include a prospective motion correction module as described in [1]. Five healthy subjects were enrolled, and instructed to perform either a slow left-right head movement (z-rotation) or a slow up-down head nod (x-rotation) during the 2 minute MRS scan. The motion correction module enabled real-time estimation of rigid body motion parameters of the brain (3 rotations and 3 translations), and adjusted the position and orientation of the voxel to ensure that it remained stationary with respect to the moving brain (see Figures on right). Prior to each scan, the voxel was placed in the frontal grey matter and the linear shims were manually adjusted to obtain a water peak full-width half maximum (FWHM) of 0.2 ppm or better (metabolite line-widths of ≤0.06ppm). Water suppression was turned off, and the water peak was used to determine motion-induced changes in line-width (shim) and center frequency.



Before motion **After 13° x-rotation**

RESULTS

Estimated motion parameters confirm that the head movements were dominated by the intended z- or x-rotations, accompanied by small translations of 3-15mm. The graphs show changes in the center frequency (left) and FWHM (right) of the water peak as a function of primary rotation angle for all subjects, both for x-rotations (top) and z-rotations (bottom). The water frequency generally displays a linear dependence on the rotation angle (left). The frequency shifts are much more sensitive to x-rotations (typically 0.01ppm/deg) than to z-rotations (typically 0.002ppm/deg). The FWHM displays a more complicated dependence on the motion. For x-rotations, the line-width is approximately a quadratic function of the rotation angle (Figure, upper right). By contrast, the line-width is fairly insensitive to z-rotations (lower right), with most subjects showing ΔFWHM of <0.03ppm, even at relatively large angles up to 30°.



DISCUSSION

Well-shimmed brain spectra have metabolite line-widths of 0.05ppm or less. Our study demonstrates that shim quality, as reflected in the water FWHM, is a complex function of individual anatomy, linear- and higher-order shims, and the specifics of head motion. X-rotations of as little as 5° can cause noticeable broadening of metabolite peaks, up to 0.06ppm. The center frequency generally shows a linear, but highly variable, dependence on the rotation angle, with frequency changes up to 0.2ppm for 10-15° x-rotations. Therefore, given typical water-suppression pulse bandwidths of ~50Hz (±0.2ppm at 3T), even relatively small x-rotations can render water suppression inefficient. This indicates that effective prospective motion correction for MRS requires real-time shimming and real-time adjustment of center frequency for even moderate head movements.

ACKNOWLEDGEMENTS

This project was supported by NIH grants 1R01 DA021146 (TE), U54 56883 (SNRP), K02-DA16991, and G12 RR003061-21 (RCMI).

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2. Bottomley, P. A. *Spatial Localization in NMR Spectroscopy In Vivo*, Ann. NY Acad. Sci. 508(333), 1987