Real time measurement and correction of motion-induced changes in B0 field for neuro spectroscopic imaging

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Introduction We present real time measurement of the B0 field using an EPI navigator and its application to real time first order shim correction in a chemical shift imaging (CSI) LASER sequence. Breathing [1], frequency drift [2], and subject movement of a couple millimeters can cause local B0 field inhomogeneities resulting in both frequency shifts and line broadening. This abstract focuses on the effects of motion. The effect of a linear B0 gradient of 1 µT/m across a volume of interest (VOI) will give rise to a 0.42 Hz/cm shift. We investigate the linear gradient and frequency changes in B0 due to selected types of motion and use these measurements to correct the frequency and first order shim currents in real time.

Methods All experiments were performed on a 3T Siemens Tim Trio. An EPI navigator [3] was inserted before water suppression in a CSI LASER [4] sequence with constant gradients. The 3D EPI navigator was set to acquire two volumes within each TR, one with TE = 6.9 ms and the other TE = 9.1 ms. EPI parameters were TR = 17 ms, BW = 3906 Hz/pix, EPI factor = 32, matrix = 32x32, slices = 16, ST = 8mm, FOV = 256x256, FA = 2º, total acquisition time (for both EPI volumes) = 600 ms. Interleaved echo times were used to reduce the effect of motion between the two volumes. The volumes were reconstructed online and a B0 field map [5] created from their complex division. PACE [6] was used to track translations and rotations using the first EPI volume, which were used to locate the correct spectroscopy VOI in the field map, correct the CSI localization, and enabled us to investigate the effect of motion on B0. The VOI's linear B0 gradient and frequency shift was estimated using a least squares fit to the 3D field map, calculated in the scanner coordinate system. CSI LASER parameters were as follows: TE = 50 ms, TR = 1500 ms, elliptical phase encoding (16x20 matrix), FOV = 160x200 mm, a Hamming filter = 50, NA = 1, TA = 5min:02s. Offset independent adiabatic pulses (Tp = 4 ms, BW = 6 kHz) based on WURST-8 waveforms [7,8] were used for selection of VOI (80x90x15 mm) due to an improved excitation profile.

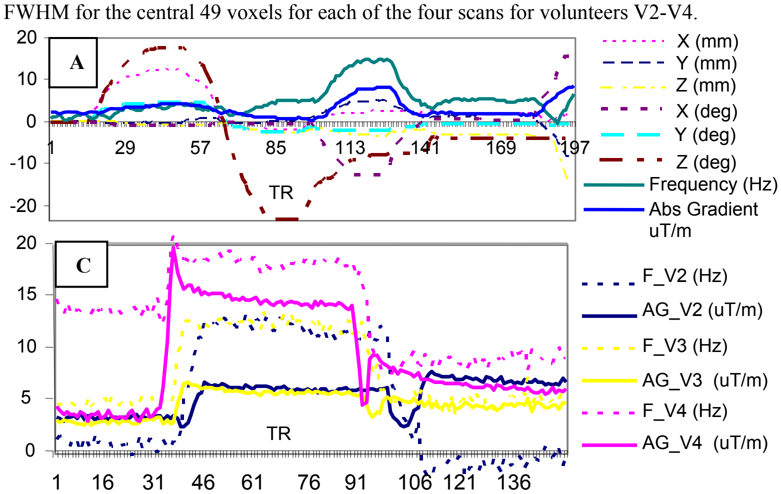
To examine the effects of motion on B0, a volunteer (V1) was imaged using the CSI LASER sequence in an axial slice superior to the ventricles. The volunteer rotated his head slowly from left to right, to chin-up, and finally chin-down (figure A). The magnitude of the first order B0 gradient and frequency shift is superimposed on the curve and demonstrates the significant dependence of the frequency and first order gradients on X rotation (chin-up-down motion). Three further volunteers (V2-V4) were then scanned focusing on the chin-up-down movement. Volunteers lifted their chin 1min into the scan and after a further 1 min lowered their chin below their starting position. Figure B shows this motion for the subject with greatest amplitudes. For all these experiments the shim currents were optimized prior to each CSI acquisition using the scanner's 'Advanced Shim' followed by manual adjustment of the first order shim by the operator.

The estimate of the linear B0 gradient was further incorporated into the sequence to provide a real time update of the shim currents. The shim update was applied 150ms after the execution of the navigator and before the start of the water suppression cycle. This real time feedback was tested in volunteers V3 and V4. For both volunteers, the experiment consisted of two baseline scans without motion, one using the scanner's 'Advanced Shim' plus operator adjustment only, and the other incorporating additional real time first order shim and frequency feedback. A further two scans were acquired with chin-up-down motion (figure B), one again using the scanner's 'Advanced shim' in combination with operator optimization only, and the other the additional real time first order shim and frequency feedback. All the CSI datasets were processed in LCModel [9] and a mean FWHM (given by LCModel) was calculated from a 7x7 voxel region at the center of the data set.

Results Figure C demonstrates how the frequency and absolute linear gradient changes over time with the chin-up-down movement. The frequency shifts are of the order of 10 Hz and linear gradient changes range from 5µT/m to 10µT/m. A change of 5µT/m causes a 17 Hz (0.14 ppm at 3T) frequency difference across a VOI of 80 mm. The table gives the mean FWHM for the central 49 voxels for each of the four scans for volunteers V2-V4.

Table: LCModel mean FWHM (Hz) for chin-up-down (mean of central 49 voxels). Corrected refers to real time first order shim and frequency correction

Volunteer	Stationary	Stationary Corrected	Motion	Motion Corrected
2	3.7	unmeasured	10.4	unmeasured
3	3.8	4.2	10.1	4.7
4	3.6	4.0	9.4	4.6



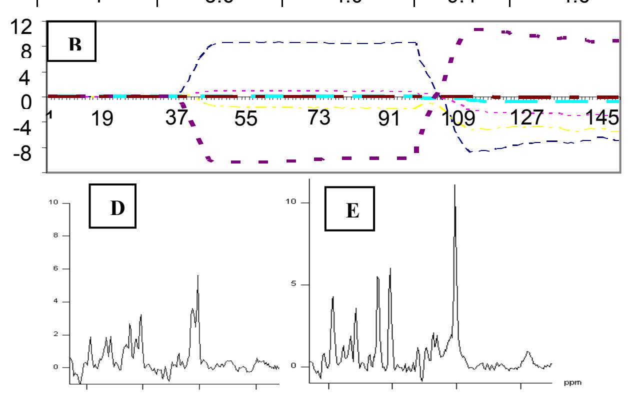


Figure 1 A) Slow left-right to chin-up and ending in chin down rotation with frequency and absolute linear B0 gradient change superimposed (Volunteer 1). Note: X-axis is left-right. **B)** Chin-up-down motion plot for volunteer with largest movement (Volunteer 4), motion for volunteers 2 and 3 were within 3° rotation and 3 mm translation. **C)** Absolute linear B0 gradient and frequency changes over time for volunteers V2-V4 in chin-up-down experiment. **D)** Volunteer 3, voxel 16-16, chin-up-down motion uncorrected. **E)** Volunteer 3, voxel 16-16, chin-up-down motion with shim correction.

Conclusion We have demonstrated linear B0 gradient and frequency changes that occur due to various types of motion. In particular, chin-up-down movements lead to significantly broader signals. We observe that changes in B0 are minimal for left-right rotations. In addition we showed that the use of an EPI navigator can correct these changes in real time without an increase in acquisition time and restore linewidths to the values measured without motion.

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