Examination of gradient-induced frequency drift on GABA-edited MRS

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Target audience: Those performing GABA-edited MRS acquisitions, particularly in combination with fMRI.

Purpose: To examine the effects of frequency drift due to a standard fMRI acquisition on a GABA-edited MRS.

Introduction: The high gradient duty cycles of some MRI acquisitions may cause sufficient heating of scanner components to induce B0 field drift. Difference-edited MRS of GABA relies upon accurate subtraction of Creatine (Cr) to reveal the GABA signal, and GABA measurements might be biased by such drift.

Methods: Data were collected (Philips Achieva) or simulated at 3T. In order to quantify the effects of frequency drift and evaluate retrospective frequency correction, three sequential GABA+ edited MRS acquisitions were acquired in 15 studies of healthy subjects. For ten of these studies, a typical 8.3 min fMRI acquisition preceded the MRS. Drift was estimated using the frequency of the Cr signal during the MRS acquisition. GABA+ edited MRS acquisition parameters included: TR/TE 2s/68 ms; 14 ms sinc-gaussian editing pulses applied at 1.90 ppm and 7.46 ppm; 320 averages with ON and OFF scans interleaved every 16 scans; 2048 data points sampled at a spectral width of 2kHz; 10 min 40s duration; $3\times3\times3$ cm^3 voxel. GABA+ was quantified relative to the unsuppressed water signal.

Simulations to examine the subtraction artifact were performed using a well-aligned *in vivo* dataset, adding linear drift across the acquisition to simulate total drifts of 0, -5, -10, -15 and -20 Hz. Additional simulations to examine the effects of drift on the editing efficiency of GABA and the co-edited macromolecules were performed using the density matrix formalism.[1] In these simulations, 64 ON-OFF pairs were simulated with the first pair at 0 Hz offset and total linear drift of 0, -4, -8, -12, -16 or -20 Hz. The efficacy of retrospective frequency correction was examined in the main *in vivo* data set.

Results: The average frequency drift rates in the three sequential MRS datasets following fMRI were -1.2 ± 0.3 Hz/min, -0.9 ± 0.3 Hz/min and -0.5 ± 0.2 Hz/min, all of which are significantly different from the control condition, 0.03 ± 0.2 Hz/min 0.07 ± 0.2 Hz/min and 0.1 ± 0.02 Hz/min (p <0.001 for each comparison, see Figure A). There is a significant impact of frequency drift on GABA+ measurements, with -10 Hz drift predicting a 16% decrease in measured GABA+, as shown in Figure B. Subtraction artifact simulations predicted an 11% decrease in measured GABA+ with a -10 Hz drift across the acquisition suggesting that subtraction artifacts are the dominant source of decreases in measured GABA+. The editing efficiency simulations showed that while negative drift decreases the editing of GABA, there is an increase in the co-edited macromolecules, resulting in an overall increase in the GABA+ signal. Furthermore, the relative contributions of MM and GABA also change with frequency drift. Retrospective frequency correction largely increases measured GABA+, shown in Figure C, removes the relationship between frequency drift and measured GABA+ and decreased the coefficient of variation of GABA+ by 19%.

Discussion: A typical fMRI acquisition can cause subsequent frequency drift that impacts GABA+ measurements for up to 30 min after the fMRI acquisition. This negative frequency drift likely arises from heating of the gradients and passive shim elements during the fMRI acquisition, which then cool during the lower gradient duty-cycle MRS acquisition.[1,2] While much of the decreased signal can be recovered with retrospective frequency correction, the editing efficiency effects cannot be corrected retrospectively. Therefore, it is recommended that GABA+ edited MRS should be performed before gradient-intensive imaging acquisitions.
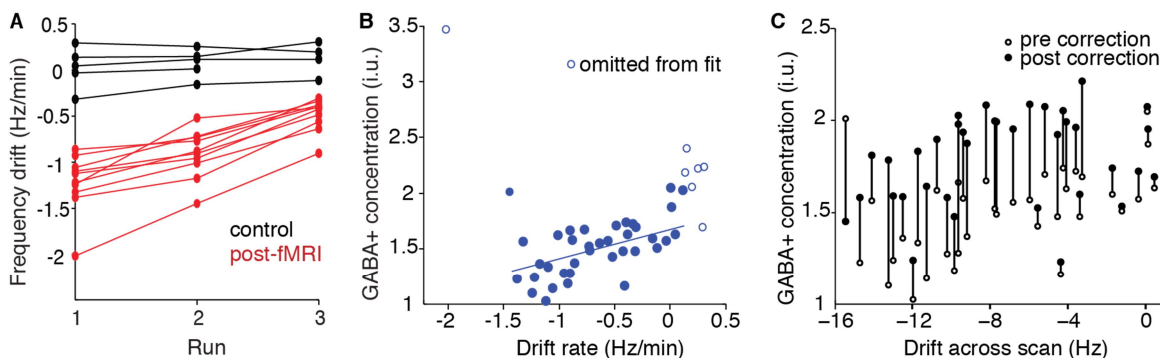

Figure. (A) Frequency drift rate of 3 GABA acquisitions following fMRI (red) or control (black) condition. (B) Measured GABA+ is linearly correlated with frequency drift (R^2 = 0.27, p < 0.001). (C) Frequency correction increases measured GABA+.

References: [1] Near et al. Magn Reson Med; 2012: doi: 10.1002/mrm.24572.
[2] El-Sharkawy et al. MAGMA 2006; 19:223. [3] Lange et al. J Magn Reson Imaging 2011; 33: 748.