Frequency Drift in MR Spectroscopy: An 87-scanner 3T Phantom Study

Introduction

Heating of the gradient coils and thermal dissipation to the passive shims is a common cause of instability in the B0 field, especially when echo-planar imaging (EPI) sequences are used. (1-3) B0 field drift changes the resonance frequency of spins, resulting in line broadening, decreased SNR and changes in editing efficiency for edited MRS experiments which rely on accurately placing frequency-selective pulses. To examine the extent and impact of gradient-induced frequency drift, a standardized protocol was distributed to sites with scanners from three vendors. By collecting data from a large number of sites, we aim to establish ‘typical’ levels of drift for B0 field

Methods

Phantom water samples were acquired with PRESS localization before and after a BOLD-weighted fMRI sequence. Standardized protocols were generated for GE, Philips and Siemens scanners consisting of: minimal preparatory imaging; EPI-MR PRESS (TR/TE 5000/35 ms; 64 transients with data stored separately; no water suppression; voxel size 2 x 2 x 2 cm³, duration = 5.20 min); EPI BOLD sequence based on the ADNI-3 (4) protocol (TR/TE 3000/30 ms; 197 dynamics of one average; EPI factor 31, duration 10 min); and a long post-MRI PRESS sequence (31 transient; other parameters same as pre-MRI PRESS). Sites were instructed to use a water-dominant phantom of spherical or cylindrical shape. Phased-array head or head-neck coils with between 8 and 64 channels were used. Scanning was performed at least 6 hours after the previous scan to avoid any confounds due to heating effects. Phantoms were calibrated in the scan room for the same period, and positioned at the scanner center. Spectral analysis was performed using MATLAB (R2020b, MathWorks, Natick, USA), including eddy-current correction, zero-filling and Fourier transforms. A 3D pre-reconstruction (4.58 mm3), phase maps and FDR-PRESS analysis were also performed. Quality assurance for the fMRI sequences was performed using the ‘psych’ R package (6). ICC calculation was based on a two-way mixed-effects model with average measures of absolute agreement.

Results

Synopsis

This project aimed to examine the relationship between gradient-induced B0 drift and field strength on a typical 5-minute in vivo MRS sequence. A standardized phantom protocol was established, and spectroscopy was performed before and after running 10 minutes of echo-planar imaging (EPI) MRI sequence. The frequency drift was estimated by measuring the water signal in each transient. Drift rates of up to 1.3 Hz/min were seen on a large sample of EPI, and 4 Hz/minute at this rate. This dataset will allow sites to benchmark scanner drift, consider in planning research protocols and examine the need for real-time field-frequency locking.

References

https://index.mirasmart.com/ISMRM2021/PDFfiles/0622.html
Data were received from 71 sites and 87 scanners (GE = 20, Philips = 28, Siemens = 39; 58 scanners submitted repeat data). Figure 1 shows the individual spectra for the highest-drifting scanner, before and after fMRI, with the frequency drift traces. Figure 2 shows the frequency drift traces overlaid for all 87 scanners. Scanners drifted by up to 7 Hz within 5 minutes before fMRI and by up to 26 Hz within 30 minutes after fMRI. Figure 3 shows a box plot of the absolute average frequency offset of each scanner (7). The mean absolute frequency offset across 64 transients (~15 min) was 0.78 ± 0.87 Hz (median = 0.4 Hz) and 1.33 ± 1.42 Hz (median = 0.8 Hz) respectively before and after fMRI. T-tests indicated drifting was significantly increased (p < 0.05) after fMRI, as expected. Simulated spectra that have been convolved with 64-transient water traces (the highest and lowest drift case for each vendor pre- and post-fMRI) are shown in Figure 4. The intensity of the NAA singlet is reduced by up to 26%, 44% and 18% for GE, Philips and Siemens respectively, after fMRI. Since drift does not impact the noise, these peak signal losses represent predicted losses of SNR. Drift behavior was well correlated and reproducible. ICCs were 0.85 and 0.95 for pre- and post-fMRI PRESS repeated datasets, respectively. Pearson correlation coefficients (0.74 and 0.90) also showed good correlation between repeated datasets.

Discussion
Frequency drift data are presented for eighty-seven 3T MRI scanners. Median levels of drift were relatively low (5-minute average under 1 Hz), but the most extreme case suffered from higher levels of drift (up to 3.5 Hz before and 7.2 Hz after fMRI). These levels of drift lead to a measurable loss in SNR for short-TE MRS, as well as changes in editing efficiency and subtraction artefacts in edited MRS. Although the difference between pre- and post-fMRI was significant, it was lower than expected and there appears to be substantial drift associated with running scans ‘from cold’, as indicated by the pre-fMRI traces after only minimal preparatory imaging. Correlation analysis indicated that the drift was highly repeatable between sessions, so one might expect drift associated with previous scans within a protocol to be consistent.

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References

Figures

Figure 1. Individual transients of pre- and post-fMRI PRESS (plotted in blue and red, respectively) from the highest-drifting scanner. The frequency offset derived from modeling the water signals is plotted (middle). 360 averages correspond to 30 minutes total scan duration.

Figure 2. Water offset traces of all 87 scanners. Pre- and post-fMRI traces are plotted in blue and red, respectively. 360 averages correspond to 30 minutes total scan duration.
Figure 3. Box plot for the mean absolute frequency offset for pre- and post-fMRI PRESS data on each scanner.

Figure 4. Comparison of simulated spectra with frequency drift applied between minimum and maximum drift for pre- and post-fMRI PRESS data. The minimum-drift case for each vendor (50% opacity) is overlaid with the maximum-drift case (opaque).