Phase-Rotation for Spectroscopic Motion Correction

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INTRODUCTION

Spectral analysis depends heavily on enhanced peak resolution and narrow line widths. Increased line width due to motion can be a major source of error which contributes to a reduction in spectral quality. Thus, technical improvements obtained at short TE and high Bo fields are at risk in the presence of uncorrected motion artifacts. The increase in Bo field strength also demands a smaller voxel size, which as a result, requires more stringent motion elimination-correction techniques. Longer spectroscopic examinations are more susceptible due to higher chance of involuntary motion. Frequency shifts cause line broadening, whereas phase shifts cause destructive signal addition and degradation of signal to noise ratio (SNR). Thiel et al (1) acquired a water unsuppressed navigator scan after each scan and corrected the acquired data accordingly, while Gabr et al (2) used "constructive averaging" after processing each average individually. Pattany et al (3) proposed a method where brain spectroscopic data is acquired with cardiac gating. Star-Lack et al (4) used RF pulses with asymmetric excitation profiles to correct for motion between scans.

The proposed approach, phase rotation (5,6,7), was first developed to resolve the desired signal from unspoiled and undesired signal in localized spectroscopy. However, the nature of the method (3) makes it suitable for filtering out motion-effected signal in localized spectroscopy experiments.

The acquired signal , *S(t)*, can be described (8) by:

$$S(t) = A\ e^{i\phi}\ e^{(i\omega - 1/T2)t}$$

where A is the signal amplitude, ω is the frequency, $T2$ is the spin-spin relaxation and ϕ is the phase angle between the coil-sample line and an arbitrary fixed reference. It can be seen that as ϕ varies as a result of motion, a corresponding change can be seen in the acquired signal upon Fourier transform (FT) of the acquired signal along the phase domain (7).

MATERIALS AND METHODS

This study was undertaken with Institutional Review Board approval and written informed consent was obtained from all participants. The volunteers were apparently healthy and taking no medication. Data was acquired on a Magnetom Tim Trio system (Siemens AG, Erlangen, Germany), using body coil to transmit and a head-matrix coil (Siemens AG, Erlangen, Germany) to receive. Localizer images were obtained using a gradient-echo imaging sequence. For the localized voxel spectrum, PRESS (9) sequence was used where the spectral width was 2000 Hz, vector size=1024 points, voxel size =20x20x20 mm^3 in the basal ganglia (Fig1A), TE=50ms, TR= 2 s, data acquisition duration=512 ms. The "WET" water suppression method (10) was applied before the acquisition sequence. The 1D spectra were processed using the MestRec(11) program. The voxel was placed in basal ganglia. The first data set was acquired in phase cycling mode (12) with 128 averages. The second data set was acquired in phase-rotation mode, with 128 phase increments where the phase increments for the three RF pulses were 22.5^o, -22.5^o and 22.5^o. The phase of the receiver was kept constant. In both spectra, the subject's starting position was with the brain midline making ~45^o with the vertical axis (Fig1A). Half way through either experiment, the subject was asked to rotate brain, clockwise, so that brain midline was parallel with magnet vertical axis.

RESULTS AND DISCUSSION

The localizer and initial position of the voxel position is shown in Fig1A. The raw data, acquired in phase-rotation mode, is shown in Fig1B. There is a noticeable increase in phase value along the vertical phase domain, even before FT. FT applied in both domains produces the PRESS desired signal along row 24 excluding motion-effected signal (Fig1C). When the same experiment was repeated in phase cycling mode, Fig1D was obtained after FT was applied to the raw data. The quality of water suppression deteriorated as a result of motion and gave rise to a broad residual water peak which was challenging to remove in post processing mode. The sharp lines obtained in phase-rotation are superior to the broad lines obtained in phase-cycling method. Also noteworthy in this result is the larger motion amplitude to illustrate the difference between the two methods. As predicted, motion produced a variation in the phase of the acquired signal, which can be detected as an change in the phase value in raw data, before applying FT (Fig1B).

The size of this phase increase is proportional to the motion amplitude. Random variations of static magnetic field are expected to cause a change in the phase of acquired signal, but this source of error was not evaluated due to the reported low field drift of the magnet. High Bo fields are expected to benefit more from the proposed technique, due to the increased effect on spectral line width as a result of motion and increased magnetic susceptibility.

CONCLUSION

The Phase-rotation technique can be used to filter out signal that has been affected by motion in spectroscopic examinations, to produce narrow-lined spectra. This is an improvement over phase cycling techniques that rely on data averaging in the time domain.

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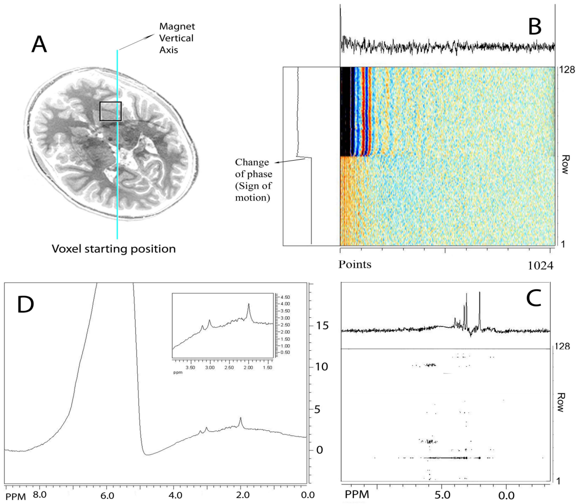

Figure 1. (**A**) Initial position of brain and voxel. (**B**) Raw data collected in phase-rotation mode arranged in a two-dimensional array before FT. Note the jump in phase value at the instant of motion (**C**) Spectrum obtained after two-dimensional FT was applied to raw data in (B). Top horizontal trace is row 24. (**D**) Spectrum obtained by repeating the same experiment as in (B) but using phase-cycling method for data collection.

References

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