Reduction of Aliasing Artifacts in Diffusion-Weighted PROPELLER Imaging

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Introduction Diffusion imaging is typically performed in axial planes. This is largely due to its reliance on single-shot echo-planar imaging (EPI) which suffers from increased image distortion in sagittal and corona planes because of concomitant gradient field 

Materials and Methods A DW PROPELLER sequence was modified to introduce a small “slice-selection” gradient (G_s) in the phase-encoding direction (in our case, the short axis of the blade) during the 90° excitation RF pulse (Figure 1). With this gradient, the slice selected by the 90° pulse is tilted by \( \theta \), which is prescribed slice selection gradient). Due to the tilt, spins excited during the 90° pulse do not overlap completely with those selected by the RF refocusing pulses (Fig. 1a). With an optimally selected tilt angle for a given slice thickness, signal contributions from the regions beyond the FOV can be reduced while the signals within the prescribed FOV are minimally affected. For a given FOV and slice thickness, the tilt angle was chosen such that there was minimal signal contribution from aliasing-prone regions beyond the FOV. The optimal tilt angle under most imaging conditions was rather small (e.g., ~2° for a slice thickness of 5mm).

The loss in signal intensity (\( s \)) due to slice tilting was described by the following function:

\[
s = \begin{cases} 
1 & 0 < d \leq \tan \frac{\theta}{2} \cot \frac{\theta}{2} \\
0 & \cot \frac{\theta}{2} \leq d < 2 \cot \frac{\theta}{2} \\
\end{cases}
\]

where \( \theta \) is the tilt angle, \( d \) is the distance from the center of the FOV, and \( t \) is the applied tilt angle. To compensate for the signal loss, a correction kernel (schematically shown in black in Fig. 1b) was derived from the above equation, and was applied to each slice of the dataset after motion and phase correction [3], before the final gridding reconstruction. To quantitatively evaluate artifact reduction, the strength of the streaking artifacts was calculated as a ratio of the mean intensity of a region of interest (ROI, ~16 pixels) in the background to an ROI in the corpus callosum before and after slice tilting and intensity compensation.

Results Figure 2 illustrates the performance of the proposed technique for sagittal (top row) and coronal (bottom row) DW images. Figures 2a-d are displayed with window and level settings that highlight the streaking artifacts. The strength of the artifacts decreased from 7.3% (Fig. 2a) and 9.2% (Fig. 2b) before the tilt, to 2.5% (Fig. 2c) and 3.8% (Fig. 2d) after the tilt and the signal intensity correction. The images after artifact reduction (Figs. 2c-d) are also displayed with standard window and level settings in Figs. 2e-f.

Discussion We have demonstrated that a small tilt applied to each blade of the PROPELLER sequence, followed by a signal intensity correction, has noticeably reduced the streaking artifacts in non-axial diffusion images. A drawback of using a constant tilt angle in the current implementation is that the signal intensity of all PROPELLER blades is affected irrespective of their relative contributions to the artifacts, which is most likely responsible for the “center brightening” effect observed in Figs. 2c-f. This problem is expected to be reduced by using a variable tilt angle scheme in which the optimal tilt angle is determined based on the blade orientation.

Conclusions A simple slice tilting technique has noticeably decreased streaking artifacts in non-axial DW images using an FSE-based PROPELLER sequence. With further optimizations, this technique is expected to allow high quality DW images to be obtained in arbitrary plane orientations.

References