Suppression of streak artifacts in quantitative susceptibility mapping

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Target audience: Researchers working in Quantitative Susceptibility Mapping.

Introduction: Quantitative Susceptibility Mapping (QSM) offers unique, quantitative information about the magnetic susceptibility of tissues compared to T2* weighted imaging. To characterize and detect microhemorrhages, the imaging hallmark of traumatic brain injury, the accurate representation of susceptibility is essential. A major challenge in quantifying magnetic susceptibility is inverting the acquired phase measurement to estimate the underlying susceptibility. Because the dipole kernel in k-space is zero at angles of ±54.7° with respect to B_0, the solution is ill-posed. Directly inverting the zeros on this cone surface results in inaccurate susceptibility maps, and, for some purposes more importantly, generates significant streak artifacts. One way to overcome this is to scan the subject multiple orientations (≥3) [1,2], whose optimal angles are evenly distributed over π, such that the singular cone surface in k-space can be recovered by data at different orientations. However, this multi-orientation method is both computationally demanding and often impractical because the patient must physically reorient their head or body part multiple times for repeated long scans. Alternatively, single-orientation methods [3-8] alleviate the computation load, scan time, and patient discomfort by employing approximations in inverting the phase. The steak artifacts, however, may still appear in the resultant susceptibility map. In this work, we propose to apply the single-orientation QSM twice, each at different orientation, using fast 3D segmented echo-planar imaging (EPI) [9] to reduce the streak artifacts while maintaining accuracy of the susceptibility measurements.

Materials and Methods:

Patients: SWI was obtained from 6 volunteers, 2 of whom had known microhemorrhage from traumatic brain injury (TBI), on a 3.0 T Biograph mMR (Siemens, release VB18P) after informed consent under an IRB approved protocol.

MRI acquisition: Whole head sagittal isotropic (0.65 mm) 3D segmented EPI with a TE of 25 was obtained in three head positions: neutral, chin-up and chin-down. Each acquisition was 4m45s. The angular differences between chin-up and chin down ranged from 15° to 55°.

QSM processing: Susceptibility was initially computed using the STI suite [10]: (1) Laplacian-based phase unwrapping, (2) SHARP filtering with a varying spherical kernel [11], and (3) finally deconvolution is performed using an orthogonal and right triangular decomposition [8]. To coregister data from different head positions, FLIRT was applied using 6 parameters.

Comparison: QSM maps in neutral position were compared to QSM maps obtained by coregistering and averaging the QSM obtained from the chin-up and chin down positions. Images were qualitatively assessed for streak artifacts. In one case, neutral position was performed twice to demonstrate that reduction in streak artifact was not simply due to interpolation and averaging.

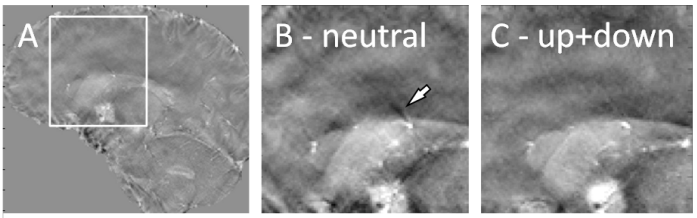

Figure 1. Streak artifacts (*white arrow*) on QSM from average of 2 neutral position datasets (*B*) are nearly eliminated on the average of chin up and down QSM (*C*)

Results: In each case there was a dramatic reduction in streak artifacts. Susceptibility maps from the average of chin-up and chin-down QSM (Figure 1C) show marked decrease in the streak artifacts, as compared to the average of two neutral-position acquisitions (Figure 1B). In Figure 2, streak artifacts adjacent to a TBI induced microhemorrhage are substantially reduced by averaging the chin-up and chin-down orientations (right) as compared to the single orientation (left).

Discussion: Streak artifacts in QSM result from the singularities in the dipole kernel used to recover susceptibility from phase. Here we demonstrate that the simple average of QSM acquired at two head orientations (chin-up and chin-down) markedly reduces such artifacts. Although computational elimination of such artifacts is achievable using 3 orientations with optimal angular separations of 60°, but it is difficult to perform in the confines of a head coil. Because of the rapid acquisition afforded by segmented EPI, the simple averaging of two orientations may be a practical solution to reduce artifacts in QSM. Presumably, a minimal angular separation of the two orientations may be required to achieve satisfactory artifact reduction, but this remains to be investigated.

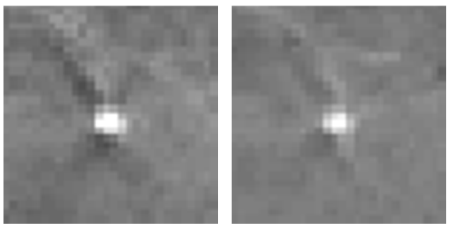

Figure 2: Streak artifacts adjacent to TBI induced microhemorrhage are reduced by averaging two orientations (right) as compared to a single orientation (left)

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