Ultra-Fast Acquisition of High-Resolution Susceptibility-Weighted-Imaging at 3T

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Introduction: Susceptibility-Weighted Imaging (SWI) is an MR technique that utilizes the magnetic susceptibility differences between tissues to highlight small vessels and veins, iron deposition, and calcification in the brain [1]. The standard MR acquisition based on a high-resolution 3D gradient-echo (GRE) sequence with flow compensation provides the high contrast-to-noise images that are necessary for good conspicuity of the brain vasculature. However, acquisition time for 3D GRE is prohibitively long when whole-brain coverage is needed in the clinical setting, indicating a need for image acceleration [2]. Here, we explore an alternative acquisition method based on a segmented (interleaved) echo-planar-imaging (EPI) sequence that significantly shortens scan time for SWI.

Materials and Methods: Brains of 5 subjects were scanned under an IRB-approved protocol on a Philips Achieva 3T (Philips Medical Systems, Best, The Netherlands) MRI system with standard transmit body-coil excitation and an 8-channel head coil. The protocol included localizer, high-order shimming, conventional GRE and segmented-EPI. GRE and segmented-EPI sequences were both 3-dimensional and flow compensated. Both sequences were acquired using the same orientation (transverse plane), same field of view (FOV = 240 x 220 mm^2), same number of slices (40) and same voxel resolution (0.5 x 0.5 x 2 mm^3). Main parameters for GRE sequence were: flip angle = 20º, TR/TE = 50/25 ms, SENSE factor = 2, Water Fat Shift = 5.5 pixels. Main parameters for segmented-EPI sequence were: flip angle = 20º, TR/TE = 58/32 ms, EPI factor = 15, SENSE factor = 2, Water Fat Shift = 25.3 pixels with fat suppression. Acquisition time for GRE sequence was 7min 15sec, whereas acquisition time for segmented-EPI was 53sec only. After data collection, both GRE and segmented-EPI data were SWI-processed in the standard way [1].

Results: Typical image quality of a healthy volunteer brain is illustrated in Figure 1 for GRE (top row) and segmented-EPI (bottom row) using the same voxel resolution (0.5 x 0.5 x 2 mm^3).

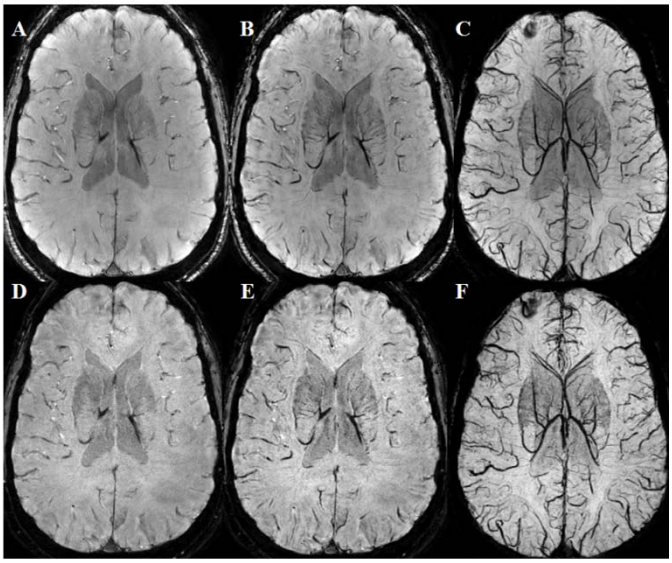

Fig 1: Original magnitude images (A, D), SWI processed magnitude images (B, E) and mIP data over the processed SWI images (E, F). Top row (A, B, C) shows data collected using 3D gradient-echo sequence, and bottom row (D, E, F) shows data collected using segmented-EPI sequence. mIP was carried over 11 sections (representing a 22-mm slab thickness).

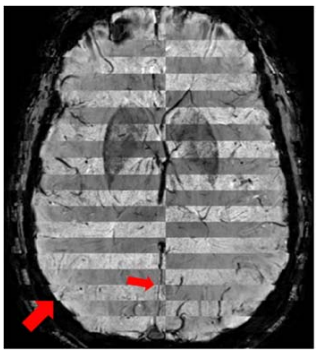

Fig 2: Checkerboard display of two SWI-processed magnitude images from the same brain slice. Brighter intensity slabs are from the slice collected using the GRE sequence. Darker intensity slabs are from the slice collected using the segmented-EPI sequence. Red arrows indicate areas of mismatch between the two images, which reflects small distortions in the segmented-EPI image.

As expected for an EPI-based acquisition, the segmented-EPI magnitude image (Fig 1D) has a lower signal-to-noise ratio than its GRE counterpart (Fig 1A), but conspicuity of blood vessels is similar. Applying SWI processing further enhances the contrast of these vessels on both datasets as shown by the SWI processed images (Figs 1B and 1E). Finally, performing a minimum intensity projection (mIP) over several sections of the SWI data reveals the vessel connectivity for both acquisitions (Figs 1C and 1F). Note that the same vessels are seen in the mIPs from both sequences. Note also that the segmented-EPI images do not appear to suffer from significant T_2^* blurring effects. Although not clearly noticeable in Figure 1, segmented-EPI images were very slightly distorted compared to GRE images (see Figure 2). However, this distortion is much less than what is typically observed with single-shot EPI-based sequences.

Conclusions: We tested a flow-compensated 3D segmented-EPI acquisition for SWI applications. While significantly reducing the acquisition time (53sec for segmented-EPI vs. 7min 15sec for GRE), the segmented-EPI acquisition maintains high resolution and depicts similar brain vasculature as compared to the conventional GRE acquisition. Minimal distortions in the segmented-EPI images do not appear to diminish the usefulness of this ultra-fast imaging technique in a clinical setting.

Reference: [1] Haacke *et al.*, AJNR 2009;**30**:3019-30. [2] Lai S, Lackey J, ISMRM 2010 p4453.