Reconstruction of Multi-Echo High-Resolution T2* and Phase Imaging Data Acquired at 3 Tesla Using a 32 Channel Head Coil

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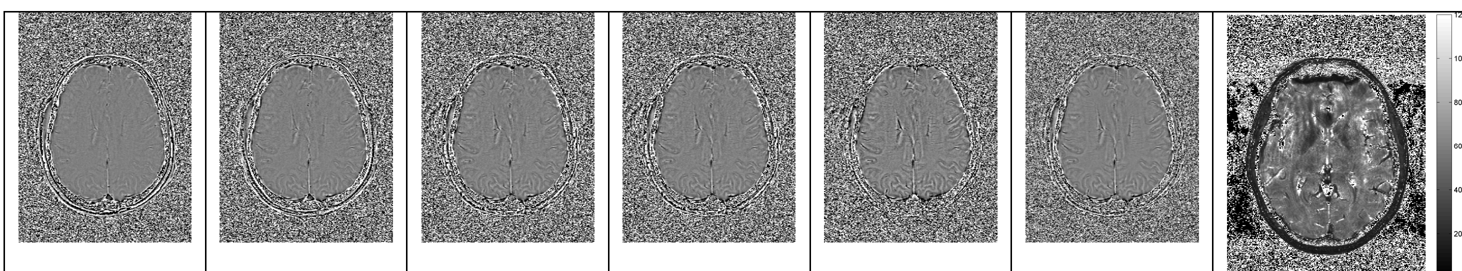
Introduction: Susceptibility weighted imaging (SWI) [1] has been shown, among other things, to be a useful technique for studying a number of neurological diseases. Visualization of small veins, of iron deposits and micro bleeds *in vivo* brain are some of its applications. By using a careful choice of scanning parameters (long TE, etc), combined with a post-processing algorithm that takes advantage of the information found in the phase image, the susceptibility properties of different tissue types can be expressed. Longer echo times will have greater susceptibility weighting but will also be affected by the decay of signal and this lower SNR, while a shorter echo time will show less susceptibility weighting but greater SNR. Because the susceptibility effects present in the image are dependent on the echo time, a multi-echo acquisition like SWAN, even when using just the magnitude information, will be able to provide detailed and complimentary information. A T2* relaxation map could also be calculated. Results for a multi-echo (4 echoes) acquisition at 3T, where the phase information is used in addition to the magnitude were presented recently [2] but the acquisition was done on a standard birdcage coil. We are presenting the challenges, and the way to address them, of reconstructing high-resolution, multi-echo (5 echoes) data on a 32 channel coil at 3T.

Methods: In vivo brain images of a healthy volunteer were collected on a GE 3Tesla MR750 scanner (General Electric, Milwaukee, WI) with a 32 channel head coil, using the multi gradient-echo SWAN pulse sequence, with flow compensation turned on, and the raw k-space data (P-file) was saved for post-processing. Five (5) echos (TE= 13.0/18.8/24.6/30.4/36.2ms and TR=41.1ms) were collected for 64 locations 2mm thick, with a FOV=256mm x 192mm. The acquisition matrix was 512x256, with PhaseFOV=0.75, for a voxel size 0.5x1.0x2.0mm^3, FA=12 and BW=62.5 kHz, for a scan time of ~6.5min. Because of the very large size of the raw-data (4 GBytes for 16 bit integers), and the limited amount of fast workstation memory, the data for each channel is read in and reconstructed individually. Main-field B0 inhomogeneity full resolution maps can be calculated using the phase information at the 5 different echo times, and raw data in each channel can be corrected for this effect. The phase images need to be corrected for the global phase shift in each channel [2]. A high-pass Gauss 24x18 filter was applied in k-space. This larger filter is adequate for vein visualization; a smaller size filter while it would provide more contrast and it would be better for visualizing iron deposits, it would also leave more inhomogeneities in the phase image. When combining the channels, the voxels in the phase images are weighted by the voxel's intensity [2], to minimize noise propagation. Using the N3 [3] intensity correction algorithm, the image inhomogeneity present when using multi-channel coils can be addressed. The magnitude images can be further processed using BET [4], part of FSL tools, for deskulling and to create a binary mask mask (processing only the voxels of interest, found within this mask, further decrease the computational time). Since the signal intensity decreases as $A= A_0 * \exp(-TE/T2^*)$, a T2* map (see Figure, most right) can be computed from the magnitude images, using a linear fitting algorithm once this equation is rewritten as $\log A = \log A_0 - TE/T2^*$. We create phase masks from the phase images as described in [1], and multiply these onto the magnitude images 4 times to create SWI images for each echo time. Minimum intensity projection images (over 13 slice locations) calculated using these SWI images, further help with visualizing the venous structure in the brain.

Results: High pass filtered (HPF) phase images for each echo (see Figure), a T2* relaxation map (see Figure), weighted averages of the 5 echoes HPF phase (see Figure), magnitude and mIP images (not shown) were reconstructed

Discussion and **Conclusions:** Using the information provided by the multi-echo magnitude images combined with the *free* (no extra acquisition time) information found in the phase images, allows for generation of exquisite images containing a wealth of detailed and complimentary information. While there's challenges associated with using reconstructing data acquired with a 32 channel coil at 3T, among which are the need to deal with memory constraints on the reconstruction workstation and correcting for intensity inhomogeneities, the greater SNR that comes with the multi-channel coil compared to the standard birdcage coil, makes this effort worthwhile. This greater available SNR may be used to speed up the acquisition, using parallel imaging, making full brain coverage in less than 4 minutes possible.



Echo 1 HPF phase	*Echo 2 HPF phase*	*Echo 3 HPF phase*	*Echo 4 HPF phase*	*Echo 5 HPF phase*	*Equal-weight average of 5 HPF phase echoes*	*T2* relaxation map (range Displayed 0-120ms) (different slice/location)*

References: [1] Haacke et al, MRM **52**: p612, 2004, [2] Hammond et al, NeuroImage **39**: p1682, 2008 [3] Sled at al, IEEE Trans Med Imag **17** (1): p87, 1998 [4] Smith, Human Brain Mapping **17** (3): p143, 2002