The reproducibility of phase and R_2^* acquired with multi echo susceptibility weighted imaging

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Introduction: Brain iron content is a potential biomarker for several neurological diseases. Due to its high sensitivity to changes in iron content, susceptibility weighted imaging (SWI) [1] [2] has been gaining popularity in the imaging of neurodegenerative diseases, such as multiple sclerosis [3], Parkinson disease [4], or Huntington's disease. However, the metrics obtained with gradient echo imaging not only depend on tissue properties but also on voxel geometry, slice orientation, head orientation or shim. Despite this potential limitation, the reproducibility of these metrics (magnitude, phase, SWI, T2* decay) has not been investigated yet. Therefore, we determined the reproducibility of magnitude, phase, SWI images and R2* maps acquired with multi echo SWI.

Methods: Multi echo SWI data of the brain were acquired twice in 12 healthy subjects (average age 34, range 20 -53 years) on a Philips Achieva 3T system equipped with an 8 channel head coil using a 3D gradient echo sequence. Scan parameters: TE = 13-41ms; ΔTE = 7ms; TR = 45 ms; flip angle = 17°; readout bandwidth = 157Hz/pixel; acquisition voxel size = 0.5 x 0.75 x 1.5 mm^3; reconstruction=0.4 x 0.4 x 0.75mm^3. The time between scans was 1-3 days. No special precautions were made to reproduce the position and orientation of the head within the scanner/coil. The scans were coregistered using FSL (FMRIB, Oxford, UK) by first registering the magnitudes of the first echo and then applying the registration parameters to the real and the imaginary part of all echoes. Phase images and SWI were then reconstructed from the registered complex data. Phase images were corrected using homodyne filters in k-space with the filter behaviour adjusted to the echo time: At TE = 13 ms the size of the filter (a Hamming window) was 0.2 of the k-space dimension. For the subsequent echoes the size was incremented by 0.05 k-space widths. High pass filtered phase images were converted into a negative phase mask and the fourth power of the mask was multiplied with the corresponding magnitude images to obtain the final SWI for each individual echo. Finally, the SWI of the five echoes were averaged. Maps of R2* relaxation rates were computed from the five magnitude images using a Levenberg-Marquardt least squares method for non-linear equations including a correction for signal decay due to background field inhomogeneities [5][6]. Twenty two regions of interest (ROI) in the basal ganglia (red nucleus (RN), substantia nigra (SN; caud = caudal, mid = middle, ros = rostral), subthalamic nucleus (STN), globus pallidus (Gp; post = posterior, ant = anterior), putamen (Pu), caudate nucleus (CN)) and corpus callosum (CC) were drawn in both hemispheres (L and R) for each volunteer. To assess reproducibility in different venous vascular structures, ROIs were drawn in the left and right thalamostriate vein (diameter comparable to voxel size) and a left and right subenpendymal vein (diameter much smaller than the voxel size). To examine intersession reproducibility of phase, magnitude, SWI and R2* maps (in total 19 metrics), the coefficient of variation (COV) between scan A and scan B was calculated.

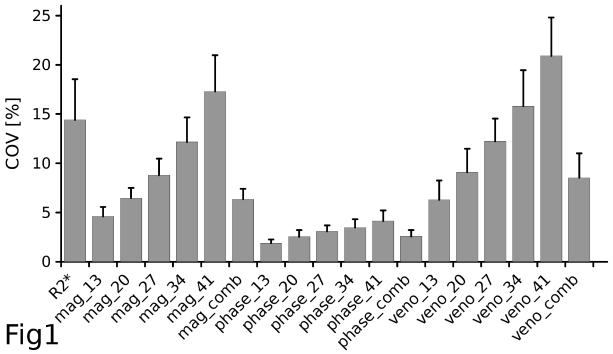

Fig1

Results: Fig. 1 shows the mean COV ± SD of all metrics in the left middle substantia nigra. An increase in echo time leads to an increase of the COV in phase, magnitude and SWI. The combined magnitude, phase and SWI images have COVs similar to the first two echoes. The behaviour shown in Fig. 1 was found to be similar in all ROIs. Fig. 2 shows the COV for the averages of SWI, phase, and magnitude and for the R2* maps. In all ROIs phase had the lowest and R2* the highest COV. All metrics showed a similar trend throughout the ROIs, as indicadet by the lines between the ROIs. The COVs averaged over all ROIs and all subjects were [mean±SD, range] = [2.5 ± 0.9%, 1-4.3%] in phase, [7.6 ± 2.6%, 3.6-12.3%] in magnitude, [9.7 ± 3.5%, 4.2-16%] in SWI and [16.8 ± 3%, 11.8-22.4%] in R2*. In the larger veins the COV was 2 to 3 times higher than in the small veins (not shown).

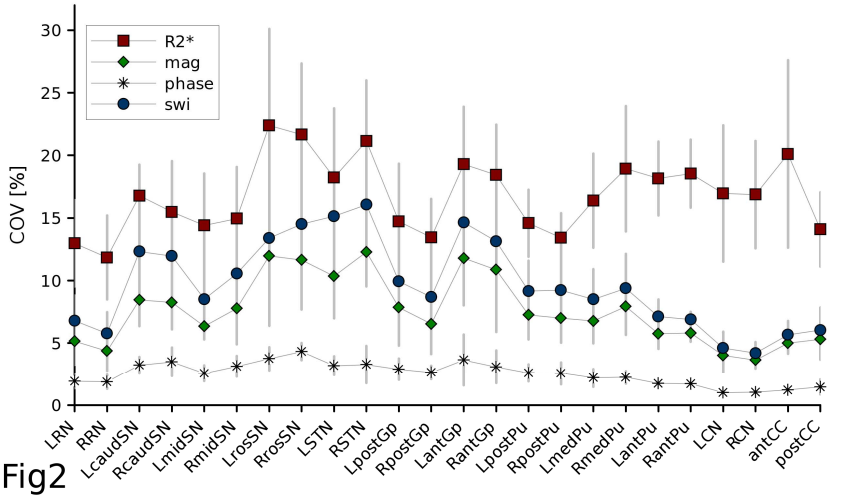

Fig2

Discussion: The low COV values of phase in all metrics indicate high reproducibility. The reproducibility of phase is also higher than that of SWI, and in particular higher than that of R2*. Phase may therefore be better suitable than R2* for the assessment of abnormal cerebral iron content or other sources of changes in the magnetic susceptibility of tissues. The large COV in the large veins may be explained by partial volume effects: The gradient echo signal strongly depends on the location of a vein relative to the voxel [7] and this dependency can be expected to be larger for veins with diametres in the range of voxel dimensions.

References: **[1]** Reichenbach et al. NMR Biomed 2001;14(7-8):453-67 **[2]** Haacke et al. Magn Reson Imaging. 2005;23(1):1-25 **[3]** Martin et al. Neurology. 2008;15;70:1411-7 **[4]** Levine et al. Ann NY Acad Sci. 2004;1012:252-66 **[5]** Fernández-Seara et al. Magn Reson Med 2000;44:358-366. **[6]** Dahnke et al. Magn Reson Med 2005;53:1202-1206. **[7]** Sedlacik et al. Magn Reson Med 2007;58(5):1035-44