Quantitative Susceptibility Mapping of Cerebral Microbleeds

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Introduction: The prevalence of cerebral microbleed (CMB) has been reported as high as 68% in patients with spontaneous intracerebral hemorrhage and 40% in patients with ischemic cerebrovascular disease[1]. Gradient Echo MRI (GRE) is the method of choice for detecting cerebral microbleeds (CMB) due to its sensitivity in detecting the paramagnetic effects of intraparenchymal hemosiderin deposits. However, the hypointensity associated with CMB in a GRE image is highly dependent on echo time (TE), limiting informative cross-study comparisons and reliable longitudinal data collection[2]. In this study we propose to use a novel technique, quantitative susceptibility mapping (QSM) as a more objective measure of CMB. Comparison of the T2* weighted image (T2*w), susceptibility weighted image (SWI) and R2* map showed the total susceptibility of a CMB varies the least with varying TEs.

Theory: Magnetic susceptibility is an intrinsic property of a material. In QSM, the ill-posed magnetic field to susceptibility source inverse problem is overcome by incorporating additional anatomical information derived from the magnitude image. In essence, an edge on the QSM that does not correspond to an edge on the magnitude image is discouraged by solving a non-linear ℓ_1 minimization problem[3]: $\chi^*=\text{argmin}_\chi\|W(D\chi-b)\|_2+|W_G G\chi|_1$, where χ denotes the susceptibility distribution; b is the measured magnetic field, D is a matrix representing the convolution kernel of the dipole; W is a data weighting term to account for the spatially varying noise; G is the gradient operator and W_G is a binary weighting derived from the magnitude images. Edge voxels are assigned zero and non-edges voxels are assigned ones in W_G to penalize variations in χ that do not have a correspondence in the magnitude image.

Materials and Methods: *Data acquisition*. Four patients with CMB were imaged on a GE 3T MR scanner using an 8 channel birdcage head coil and a multiecho spoiled gradient echo sequence with 8 TEs; uniform TE spacing=5ms and TR=51ms; slice thickness=3mm (ZIP2 to effective 1.5mm); in-plane resolution=0.47x0.47mm^2. *Data analysis:* T2*w and SWI were reconstructed at different TEs. R2* and QSM were reconstructed using the first *N* echoes, where *N* was varied between 2 and 8. CMBs were identified by an experienced neuroradiologist on the T2*w image with the 8th echo (TE=40 ms). The maximum diameter of the CMBs were measured on the T2*w, SWI, R2* and QSM images, respectively. In addition, 1x1x1 cm^3 cubes were placed on the CMBs, and the total susceptibility of the CMBs were summed inside the cubes. For a CMB, the diameter measured at the 8th echo was normalized by that measured at the 4th echo (TE=20ms) to calculate the diameter ratio. The susceptibility ratio was also calculated similarly. Diameter ratios were calculated on all the images, and susceptibility ratios were calculated on all the QSM images. One tail t-tests were performed between the susceptibility ratio and one to determine whether there is any statistically significant difference.

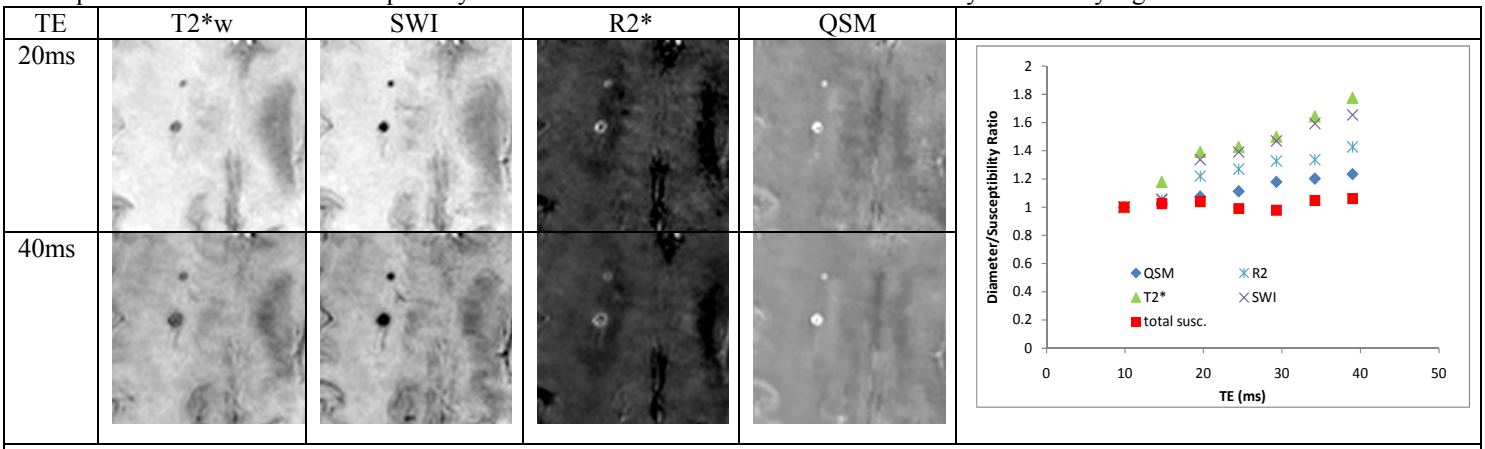
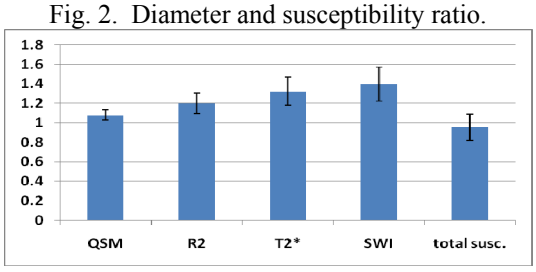


Fig. 1. T2*w, SWI, R2* and QSM images at TE=20ms and TE=40ms show lack of significant blooming effect on QSM compared to other sequences with change in TE.

Results: 13 CMBs were found in these 4 patients. T2*w, SWI, R2* and QSM images of a CMB reconstructed at the 4th and 8th echo are shown. Total susceptibility measured on QSM demonstrated the least dependence on the choice of TE (Fig. 1). The calculated diameter ratio and susceptibility ratio are shown in Fig. 2. The susceptibility ratio measured on QSM (0.96±0.13) did not show a statistically significant difference than one (p=0.13).

Fig. 2. Diameter and susceptibility ratio.



Conclusion: The total magnetic susceptibility, an intrinsic measure of a CMB, is theoretically independent of echo time, which is consistent with the estimated total susceptibility of a CMB on a QSM. This QSM characterization of CMB overcomes the sensitive dependence on TE in T2*w, SWI and R2* images. **Ref:** [1] Koennecke et al. Neurology: 66(2):165-171; [2] Greenberg et al. Lancet: 8(2):165-174; [3] Liu et al. ISMRM Proc 2010: 4996.