Comparisons of QSM Data obtained from a single echo and multiple echoes in patients with cognitive normal, mild cognitive impairment, and Alzheimer′s Disease

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Target Audience: Clinicians and physicists who work for a neurodegenerative diseases.

Background: The susceptibility-weighted imaging (SWI) technique, which is usually used with a single-echo, is able to measure regional iron changes [1]. However, the exact quantification of the iron contents may not be achieved due to its strong dependency on the shape and orientation of the structures. To measure the improved quantification of the iron contents, a multi-echo technique is widely used because the number of echoes is one of the important parameters to acquire a quantitative susceptibility value. Both the single-echo and the multi-echo technique can generate quantitative susceptibility map (QSM). One important characteristic of Alzheimer's disease (AD) is the iron accumulations in the brain [2]. Therefore, QSM may be useful to evaluate the AD brain.

Purpose: The objective of this study, therefore, was to estimate the quantitative susceptibility effect on a number of echoes of SWI and a 3D gradient-echo sequence obtained from subjects with cognitive normal (CN), mild cognitive impairment (MCI) and Alzheimer's diseases (AD).

Materials and Methods: Thirteen CN (mean age = 63.08, 12 females and 1 males), 14 MCI (mean age = 73.36, 12 females and 2 males), and 13 AD subjects (mean age = 75.31, 12 females and 1 males) were participated after informed consent. We run two scans to obtain magnitude and phase images. For the single-echo image, SWI was obtained using a fully first-order flow-compensated three-dimensional (3D) fast field-echo (FFE) gradient echo sequence with a single echo (TE = 33 ms). For the multi-echo image, a 3D gradient-echo (FFE) sequence was run with seven echoes (first TE/△TE/final TE=3.4/5.9/39 ms). For the spatial normalization, sagittal structural 3D T1-weighted (3DT1W) images were acquired with the magnetization-prepared rapid acquisition of gradient echo (MPRAGE) sequence. The MR imaging was performed on 3T MR system (Achieva, Philips Medical system) with a 16 channel neurovascular SENSE coil. QSM data were obtained with the morphology enabled dipole inversion (MEDI) software [3] for the SWI (seQSM) and the FFE (meQSM) data. The Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) toolbox [4] and Statistical Parametric Mapping Version 8 (SPM8) were used to post-processing and to the group comparisons for seQSM and meQSM, respectively using a one-way analysis of variance (ANOVA) test. The gender and age were included as covariates.

Results: Fig.1 demonstrates the differences of QSM values among the three different groups for both seQSM (upper) and meQSM data (low). For the seQSM values (A, B, and C), QSM values in AD subjects were higher in the left superior temporal gyrus and the left inferior frontal gyrus than those of CN subjects, but lower in the left middle frontal gyrus. Compared with MCI patients, QSM values in AD subjects were higher in the left superior temporal gyrus, but lower in the left sub-gyral. QSM values in MCI subjects were higher in the left superior frontal gyrus, but lower in the left middle frontal gyrus than those of CN subjects.

For the meQSM values (D, E, and F), QSM values in AD subjects were higher in the left middle frontal gyrus, sub-gyral, and superior frontal gyrus than those of CN subjects, but lower in the right inferior temporal gyrus. Compared with MCI patients, QSM values in AD subjects were higher in the left inferior parietal loblue and sub-gyral, but lower in the left sub-gyral. QSM values in MCI subjects were higher in the middle frontal gyrus, cingulate gyrus, and superior frontal gyrus, but lower in the left inferior frontal gyrus than those of CN subjects.

Discussions: Quantification of iron concentrations in vivo is instrumental for understanding the role of irons in many neurological diseases. We found higher sensitivity of meQSM data than seQSM data. In particular, more differences between AD and MCI groups and between MCI and CN groups were found in meQSM data compared to seQSM data. Susceptibility values of meQSM increase from CN to MCI and to AD, since iron is a paramagnetic substance and contributes to dephasing of the signals. Because AD is expected to have the most iron plaques, we expected that the AD brains would produce the least signals in comparison to the CN and MCI brains. A multiple echo MRI sequence is preferred for the data acquisition to allow a better edge detection and to be improved the phase correction [5]. The meQSM technique offers more efficiency information of the susceptibility effects for early diagnosis for AD than the seQSM technique.

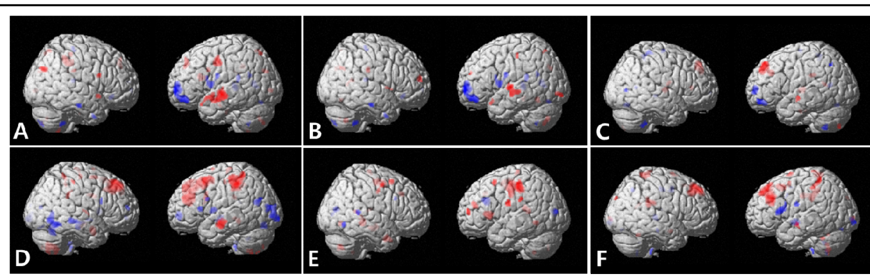

FIG. 1. The results of difference of seQSM(A, B, and C) and meQSM (D, E, and F) data among three subjects. A and D: AD>CN (Red), AD<CN (Blue), B and E: AD>MCI (Red), AD<MCI (Blue), and C and F: MCI>CN (Red), MCI<CN (Blue).

Conclusion: The meQSM technique has been proposed to accurately estimate the amounts of irons compared with seQSM technique. In addition, QSM was useful to investigate susceptibility effects in AD brain with the voxel-based analyses.

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