HIGH RESOLUTION QSM AT 7T : COMPARISON WITH 3T AND 1.5T

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Introduction - Quantitative Susceptibility Mapping is a new way of directly measuring tissue magnetic susceptibility. The method provides a novel contrast for MRI and allows us to visualize different magnetic susceptibility components such as iron, myelin, and calcium (Fig. 1). However, the calculation of magnetic susceptibility from MRI phase images is an ill-conditioned inverse problem and may results in noise amplification. Several methods have been proposed including a k-space thresholding method [1, 2] and a multiple head orientation method [3]. Recently, a regularization-based method [4] have been proposed to solve ill-conditioned inverse problem. The method does not require multiple head orientation and can provide a good image quality when properly regularized. Hence the method is more practical in clinical applications. In this abstract, we applied a regularization method that use magnitude and edge for the regularization factor [4] to calculation magnetic susceptibility at 1.5T, 3T and 7T and compared the susceptibility values across the field strengths.

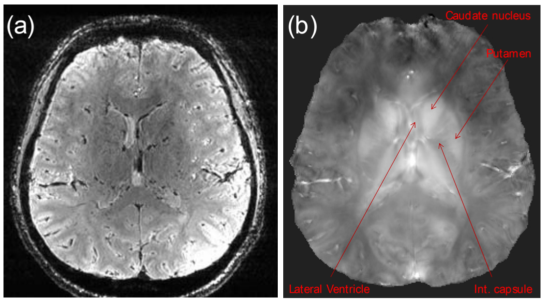

Figure 1. magnitude image(a) and QSM(b) at 7T

Materials & Methods

Data Acquisition: whole brain data were acquired at a 1.5T, 3T and 7T Siemens scanner using a 3D-GRE sequence with 0.6x0.6x0.6mm^3 isotropic resolution. The following parameter was used to acquire the MRI data for each scanner - 1) 1.5T: TE/TR = 40/50ms 2) 3T: TE/TR = 21/40ms 3) 7T: TE/TR = 15/60ms.

Processing: 1) Multichannel phase images were reconstructed from each channel of data [5]. 2) Multichannel phase images were unwrapped using the Prelude tool in FSL [6]. 3) After unwrapping, large scale field inhomogeneity were removed using a dipole filter [7] 4) QSM image was reconstructed using a regularization technique that uses magnitude and edge information for the regularization [4]:

$$\min_x \|W_{mag}(Dx-b)\|_2^2 + \lambda \|W_{edge}Gx\|_2^2 \qquad (1)$$

where x denotes susceptibility distribution; W_{mag} is magnitude image; b is the field shift map; D is a matrix encoding the convolution with the unit dipole field; G is the gradient operator, W_{edge} is an edge information extracted from magnitude image

Image Analysis: QSM images were compared in two different ways: 1) QSM value: the mean of each structure divided by the mean of entire volume image. 2) contrast-to-noise (CNR): mean susceptibility in the globus pallidus divided by the standard deviation of the susceptibility of the corpus callosum [8]. We analyzed iron-rich structures such as caudate nucleus (CN), putamen (PU), globus pallidus (GP), substantia nigra (SN), and red nucleus (RN) using QSM values. CNR were compared in each field strength. For comparison, all the QSM images were co-registered using FLIRT, FSL [9].

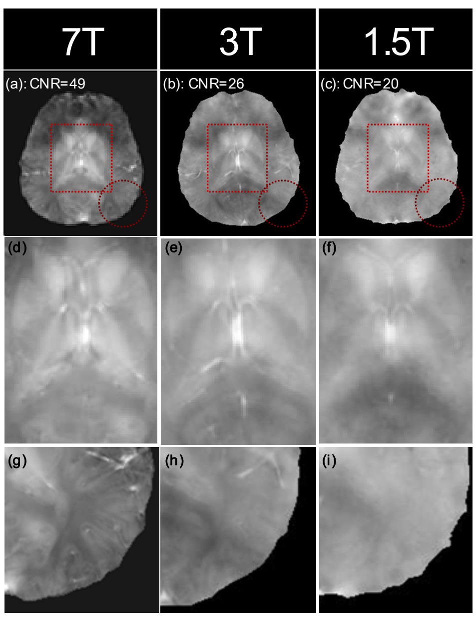

Figure 2.
(a)QSM at 7T (b)QSM at 3T (c)QSM at 1.5T
(d - f): zoom-in of the red box in (a-c)
(g – i): zoom-in of the red circle in (a-c)
;Although it has similar contrast, 7T QSM result revealed detailed anatomical structures which cannot be observed at 3T or 1.5T QSM results.

Result - A representative QSM images and its CNR are shown in Fig. 2, and quantitative QSM values from each scanner are reported in Fig 3. The image contrasts at 1.5T, 3T, and 7T are slightly different, but overall shows similar quantification results (Fig. 3). Although contrasts were similar, 7T QSM result shows CNR superior to 3T and 1.5T QSM as observed in Fig 2a~ c. 7T QSM results revealed detailed anatomical structures which cannot be observed at 3T or 1.5T QSM results. Iron-rich structures including caudate nucleus and putamen were clearly depicted in the 7T QSM image (Fig. 1). Clear boundaries among putamen, internal capsule, caudate nucleus, and lateral ventricle are observed at 7T (Fig. 1, Fig 2d ~ f). Additionally, gray-white matter contrast was improved at 7T (Fig 2g ~ i).

Discussion - Comparing the results produced by different field strength, it is clear that the high field yielded the high quality QSM image using a regularization method [4]. In general, high-field-strength provides a better magnitude image than low-field-strength. In this method, the magnitude image affects two aspects of QSM processing. First, magnitude image is used as a weighting term to compensate for non-uniform noise properties. Thus, high quality magnitude image can produce high quality QSM image. Secondly, this regularization method makes use of edge information extracted from magnitude image as effective priors. Therefore, this method yielded contrast dependent on edge information extracted from magnitude image. Generally, High-field-strength units inherently provide a better SNR and more clear edge information than low-field-strength units. Therefore, 7T QSM image tends to have more accurate anatomical information than lower field-strength images.

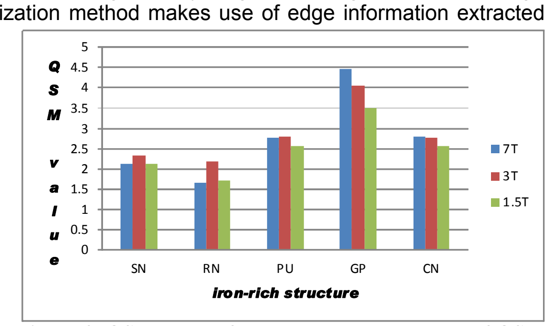

Figure 3. QSM value of each scanner : bar chart of QSM value in several iron-rich tissue (SN: substantia nigra, RN: Red Nucleus, PU: Putamen, GP: Globus Pallidus, CN: Caudate Nucleus)

Conclusion - In this abstract, we have demonstrated that a high-field-strength scanner can generate a high-quality QSM image.

Reference – [1] Karin Shmueli, et al. Mag Reson med, 62(6): 1510-22 [2] Sam Wharton, et al. Mag Reson Med, 63: 1292-1304, 2010. [3] Tian Liu, et al. Mag Reson Med, 61: 196-204, 2009. [4] Ludovic de Rochefort, et al. Mag Reson Med, 63:194-206, 2010. [5] Kathryn E. Hammond, et al NeuroImage, 39: 1682-1692, 2008. [6] Jenkinson, Mark, et al. Mag Reson Med, 49 (1), 193-197, 2003 . [7] Tian Liu, et al. NMR in Biomedicine, 24 [8] Tian Liu, et al. Mag Reson Med, 66: 777-783 [9] Jenkinson, Mark et al. MIA, 5:143-156, 2001

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