Quantitative Susceptibility Mapping by Using the Morphology Enabled Dipole Inversion (MEDI) Approach with a New Prior Information

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INTRODUCTION:

In quantitative susceptibility mapping (QSM), reconstruction methods such as Morphology Enabled Dipole Inversion (MEDI) [1], *a prior* structural information is used to constrain streaking artifacts produced in the field-to-source inversion. It was noticed previously in low spatial resolution imaging, the quantitative accuracy was compromised in subcortical regions where both CNR on the magnitude image and susceptibility values are low [2]. One straightforward solution is to increase the spatial resolution during acquisition, however this comes with a tradeoff of longer scan time. An alternative solution is to provide more accurate prior constraints. In this work, we improve the accuracy of the structural information by incorporating an additional prior information from the local field map, and evaluate its utility at high and low resolution imaging.

METHODS AND MATERIALS :

In the MEDI method [1], the susceptibility reconstruction can be formulated as a minimization problem with a L1 regularization:

$$\min_{\chi} \; E(\chi,\lambda) = \left\| MG\chi \right\|_1 + \lambda \left\| W(C\chi - b) \right\|_2^2, \qquad (1)$$

where χ denotes the vector forms of the spatial susceptibility distribution, the parameter lambda λ was tested with a series of values and the optimal λ was found using discrepancy principle, structural weighting M is derived from the magnitude image and can be chosen as a binary mask that assigns the voxels with large gradient to zero and those with small gradient to one, G denotes the gradient operator, W is a weighting proportional to the magnitude images to compensate for noise inhomogenetiy in the field measurement and control the fidelity of the reconstruction to the data, C is the dipole convolution kernel, b is the vector forms of local field map. It was noticed that in basal ganglia region, the magnitude image has the similar edge information with the underlying susceptibility. But in other regions, particularly the cortical gray matter and white matter, the subtle variation of susceptibility may not have corresponding magnitude edges. However, changes in susceptibility always lead to changes on the local field map. Therefore, we derived a second set of edges from the local field map to reflect subtle susceptibility changes that are not shown in the magnitude image. We used an active contour based method [3] to segment the local field map into an image m_s consisting of only three distinct components (CSF, gray matter, white matter). A gradient operation was applied on m_s to obtain the field edges M_F. This field edges combined with the existing magnitude edges formed a structural weighting that is more sensitive to the change of susceptibility.

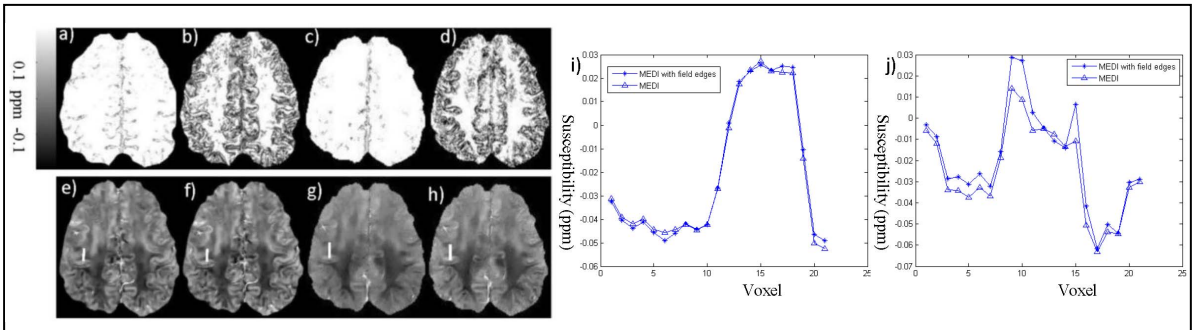

Fig.1 (a) and (c) are the prior information of MEDI, (b) and (d) are the prior information of MEDI with field edges, (e) and (g) are the QSM of MEDI. (f) and (h) are the QSM of MEDI with field edges. (i) MEDI and MEDI with field edges – calculated susceptibility variations along the white line drawn on e and f is shown in i. (j) MEDI and MEDI with field edges–calculated susceptibility variations along the white line drawn on g and h is shown in j.

The utility of the new field edge was evaluated on three healthy volunteers who underwent both high ($0.5\times0.5\times2mm^3$) and low ($1\times1\times3mm^3$) resolution multi-echo gradient echo scans. Other imaging parameters includes 11 echoes evenly spaced between 5 to 50 ms, TR=55ms, BW=±62.5kHz, flip angle=15°.

RESULTS:

Figure 1 shows the axial projections of the 3D binary mask and the corresponding QSM reconstructions for both methods at different spatial resolutions. When the resolution was high, both original MEDI and MEDI with field edge showed virtually identical QSM with clear delineation of gyrus and sulcus. However in the low resolution images, the field edge improved the sharpness of the reconstructed QSM as seen from the 1D signal intensity plot in Fig.1(j).

CONCLUSION AND DISSCUSION:

The phase in a voxel measured in MRI reflects the phase of the averaged spins in that voxels, not the average of the phases of the spins. However, it is the latter one that reflects average field information and is the quantity of interest for accurate QSM. This digitization error naturally increases when the voxel size increases. In this study, we demonstrated that by increasing the spatial resolution, digitization error can be reduced and an image with improved contrast emerged. However, even when the resolution is low, additional *a priori* structural information derived from the local field map is able to enhance the contrast between cortical gray and white matter.

REFERENCES: [1] Liu J, et al, doi:10.1016/j.neuroimage.2011.08.082. [2] Liu T, et al, Magn Reson Med 2009; 61(1):196-204. [3]Tony F. Chan et al, IEEE Transactions on Image Processing , 2001 10(2):266-277.