Quantitative Susceptibility Mapping Using MRI Phase Image

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Introduction

Magnetic susceptibility is the degree to which a material can be magnetized in an external magnetic field. Excellent contrast between gray and white matter in susceptibility maps of the brain makes quantitative susceptibility mapping (QSM) an important tool to investigate brain tissue structure. QSM has many applications in studying neurological disorders related to brain contents. Field inhomogeneities due to magnetic susceptibility distribution can be quantified using phase data from gradient echo MRI. The measured magnetic field is the convolution of magnetic susceptibility and the field produced by a single magnetic dipole [1]. The deconvolution of the measured magnetic field with the magnetic dipole kernel, required to calculate susceptibility maps, is an ill-posed inverse problem due to the zeros on a double-cone surface in the dipole kernel. In this study, we use a regularized single-orientation method [2] to condition the inverse problem. This method uses prior information as a constraint to the original problem and forms a constrained minimization problem. The prior information is incorporated based on the assumption that susceptibility values are approximately constant within tissue compartments.

Experimental

An excised rat brain was imaged at a Bruker 17.6 T magnet. Two gradient echo images were acquired with echo times TE_1=15 ms and TE_2=30. The phase of complex divide of the two data sets was unwrapped and used to calculate the magnetic field map. After removing the global background field produced by external sources, the magnetic field was used as an input to the minimization problem to solve for susceptibility.

Results and Discussion

Fig. 1 shows the local magnetic field perturbations at the top and calculated susceptibility map at the bottom. When solving the constrained minimization, a balance needs to be reached between reducing noise, by putting enough weight on the smoothing constraint, and preserving contrast by avoiding over-regularization of resulting susceptibility map. This balance is reflected by the choice of regularization parameter. The best result still includes minor artifacts from zeros on the conical surface of the dipole kernel (e.g. arrows in Fig. 1)

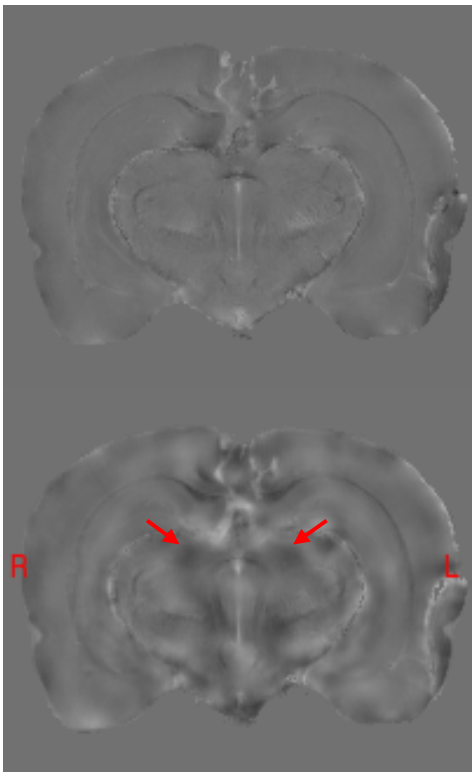

Fig 1. Top: Local magnetic field perturbations calculated from the phase data. Bottom: Susceptibility map.

Conclusions

Excised rat brain susceptibility maps were calculated using a regularized single-orientation method. The resulting maps show contrast between brain contents. Quantitative susceptibility mapping can further be extended to susceptibility tensor imaging (STI) based on susceptibility anisotropy of brain white matter. In our future studies, the method will be applied to characterize the susceptibility of brain *in vivo*.

Acknowledgements

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References

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[2] Bilgic, B., *et al*., NeuroImage, 59, 2625-2635 (2012).