Phase contrast and susceptibility mapping in the mouse at 7T for super-paramagnetic particle visualization

Dávid Z. Balla[1], Jörn Engelmann[1], Sven Gottschalk[1], Klaus Scheffler[1,2], Rolf Pohmann[1]
[1] Max Planck Institute for Biological Cybernetics, Tübingen, Germany; [2] Department of Biomedical Magnetic Resonance, University of Tübingen,Germany

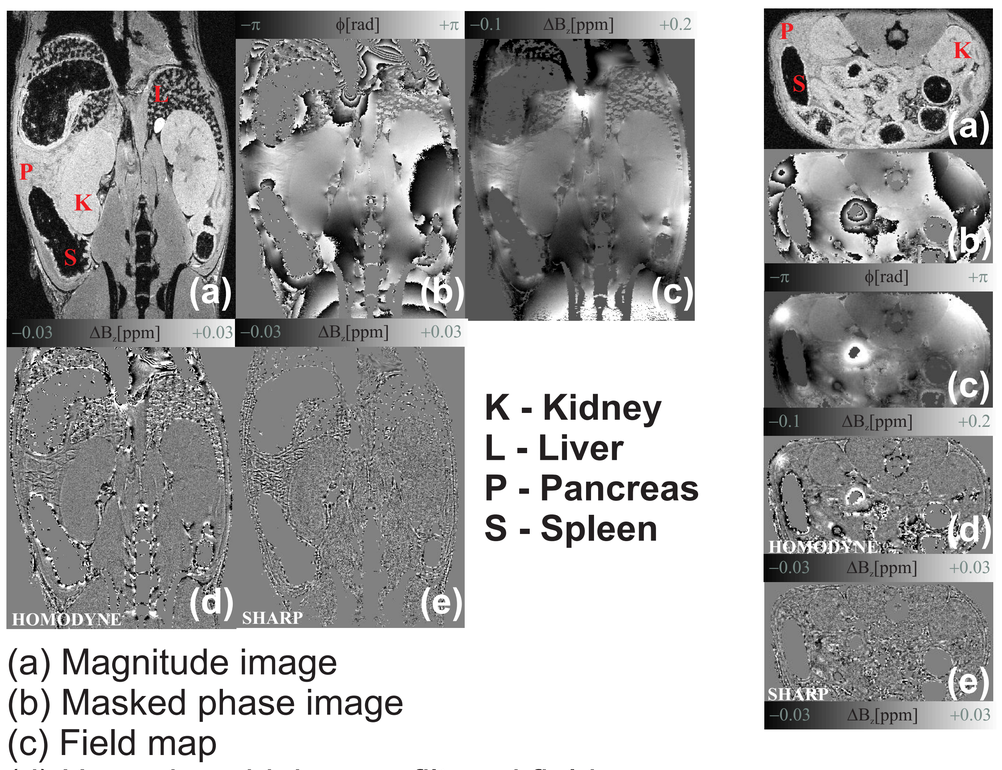
INTRODUCTION

The phase of the MR-signal contains useful information about the local and temporal variations of the magnetic field. Structural phase imaging in the brain reveals a contrast, which is not available in the modulus intensity maps and serves as a complementary source of information to conventional MRI (1). Quantitative susceptibility mapping (QSM) is a reconstruction technique, which deconvolves non-local effects from the phase distribution and unveils a major source of T2* and phase contrast, namely local tissue susceptibility (2,3). Both non-local phase contrast imaging and the QSM method have potential applications in the detection and quantification of super-paramagnetic particles in organs other than the brain. Therefore, we investigated the local phase contrast in the mouse abdomen at 7T with and without contrast agent and applied a QSM-algorithm originally developed for human brain applications on the phase images.

METHODS

- Animal model: healthy adult male C57BL/6J mice
- Treatment: i.v. injection of 1500µg carbon-coated Cobalt nanoparticles in 150µl PBS
- Perfusion: 5h after treatment with PBS
- Fixation: Formalin
- MRI hardware: Bruker 70/30 Biospec and Tx/Rx quadrature birdcage with 40mm i.d.
- MRI acquisition:
  - T2*w 3D-FLASH with (60µm)³ isotropic resolution
  - TR=25ms, TE=10ms, α=20°, NA=22 for the control mouse
  - TR=15ms, TE=5.5ms, α=8°, NA=36 for the treated animal
- MRI reconstruction:
  - High-pass filtering of the phase images with 3D Gaussian convolution (σ=360µm)
  - Or background phase removal with spatial phase unwrapping (4) and SHARP (5)
  - Quantitative susceptibility mapping (QSM) performed with an iterative L2-norm minimization algorithm (6)

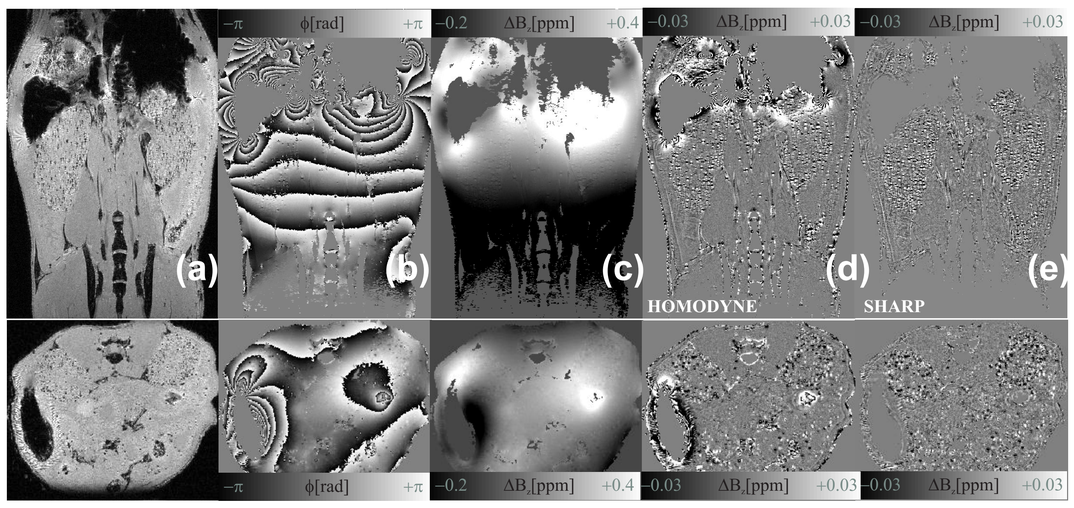
RESULTS: Native contrast



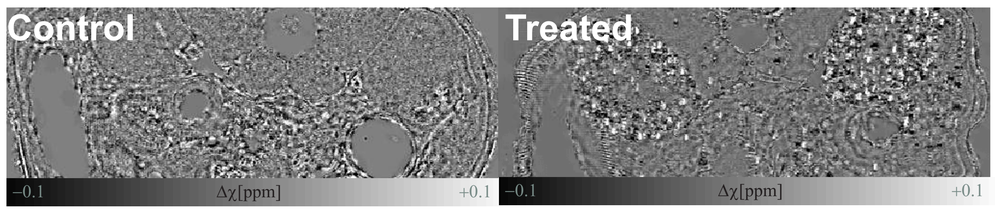
K - Kidney
L - Liver
P - Pancreas
S - Spleen

(a) Magnitude image
(b) Masked phase image
(c) Field map
(d) Homodyne high-pass filtered field map
(e) SHARP filtered field map

RESULTS: Particle contrast



- Background phase modulation from external sources, including massive particle accumulation in some organs, could be removed
- Particle contrast benefits from the reduced native phase contrast
- QSM produced positive punctual susceptibility contrast at sites of local field perturbation tentatively assigned to single or clustered particles



CONCLUSION

- Phase imaging and QSM is feasible in the mouse abdomen after filtering out the dominant non-local phase background
- The native structural phase contrast in the abdomen seems to be less useful as in brain applications for differentiating tissue types
- The homogeneous native contrast, however, allows for the better detection of super-paramagnetic particles
- QSM deconvolves non-local field perturbation caused by different susceptibilty sources and thus allows for a better particle localization
- QSM contrast is quantitative, which makes a differentiation of particles from other local susceptibility source possible and potentially allows for the determination of particle mass in a cluster

REFERENCES

1. Duyn et al. (2007) PNAS 104:11796
2. Schaefer et al. (2008) Proc. ISMRM 641
3. de Rochefort et al. (2008) MRM 60:1003
4. Schofield and Zhu (2003) Optic Lett 28:1194
5. Schweser et al. (2011) Neuroimage 54:2789
6. Wharton and Bowtell (2010) NeuroImage 53:515

ACKNOWLEDGMENTS

This work was supported by the Max Planck Society. Professional technical assistance from Marie-Luise Schwesinger is gratefully acknowledged. The QSM code was provided by S. Wharton.