How do voxel size and shape in whole-brain MRSI affect spectral quality? A simulation study on 1.5T, 3T, 7T and 9.4T

Stanislav Motyka[1]***, Philipp Moser***[1]***, Lukas Hingerl***[1]***, Gilbert Hangel***[1]***, Eva Heckova***[1]***, Petr Bednarik***[1]***, Bernhard Strasser***[2]***, Michal Povazan***[3,4]***, Stephan Gruber***[1]***, Siegfried Trattnig***[1]
Wolfgang Bogner[1]

[1]High Field MR Centre, Department of Biomedical Imaging and Image-guided Therapy, Medical University of Vienna, Vienna, Austria, [3]Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, United States, [3]Russell H. Morgan Department of Radiology and Radiological Science, The Johns Hopkins University School of Medicine, Baltimore, MD, United States, [4]M. Kirby Research Center for Functional Brain Imaging, Kennedy Krieger Institute, Baltimore, MD, United States

Introduction

MRSI of the brain allows detection of spatially dependent concentrations of different brain metabolites. In principle, the spectral separation of different metabolites improves at higher main magnetic field (B0). However, B0 inhomogeneities increase with B0 and cause a spatially dependent decrease in spectral quality. B0 shimming can recover some of the homogeneity by superimposing the magnetic field with spherical harmonics generated by shim coils. Another approach is to increase the spatial resolution which yields more homogenous B0 fields inside voxels.

Methods

MRSI data were simulated based on experimentally measured data of five volunteers on a 1.5T Aera, 3T Prisma, 7T Magnetom and 9.4T Magnetom (all Siemens, Erlangen, Germany) and simulated metabolites and lipids FIDs (jMRUI). B0 maps and MP(2)RAGE were measured on all four scanners using matched gradient echo sequences. Coil combination was performed by ASPIRE[1] and phase unwrapping by UMPIRE[2]. Fat maps (Dixon imaging) were measured at 3T. All data of one volunteer were then coregistered to 3T data. In the simulation model, all brain tissue voxels contained the same spectra including metabolite FIDs of NAA, NAAG, Glu, Gln, PCr, Cr, PCH, GPC and m-Ins. Lipids voxels consisted of amplitude-scaled FIDs of 5 resonances based on Seeger et al.[3] Scaling was based on the intensity of fat maps. MRSI data were simulated with three different spatial resolutions before, fitted by LCModel. FWHM and SNR of every voxel were estimated from its NAA fit. SNR was spatially normalized. Quality of fit was assessed by the mean absolute percentage error (MAPE) of NAA concentration to gold standard (constant concentration, all brain voxels contained same spectra).

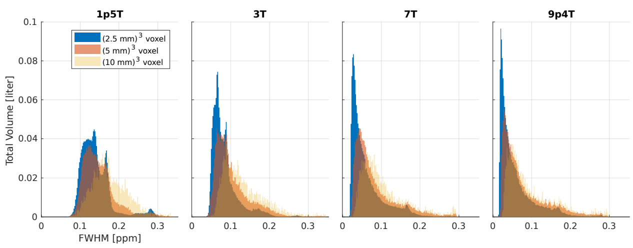

Figure 1 – Histogram of FWHM of all volunteers

Results

Distributions of FWHM (Fig.1) shift to lower FWHM with increasing B0. Increasing spatial resolution shifts the distributions also to lower FWHM; moreover, the shape of the histogram distribution becomes narrower. Spatial dependency is shown in Figure 2. Median values of normalized SNR of all volunteers for three spatial resolution (low/intermediate/high) are: 1.5T: 2.32/3.16/3.5; 3T: 3.93/5.59/6.85; 7T: 5.86/8.62/12.22; 9.4T: 6.97/9.84/13.79. MAPE for same resolutions: 1.5T: 37.31/ 29.07/NaN; 3T: 31.65/21.24/19.44; 7T: 32.46/19.53/14.21; 9.4T: 34.46/21.35/15.58

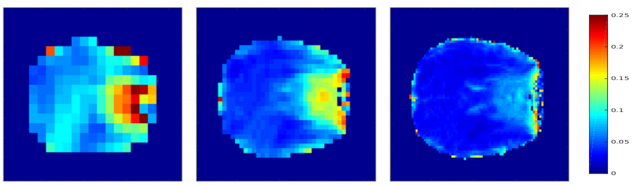

Figure 2 - FWHM maps of one Volunteer on 7T;left: low res.; middle: intermediate res.; right: high res.

Discussion & Conclusion

Spectral quality is changed by increasing spatial resolution of MRSI. With smaller voxels, local B0 inhomogeneities and hence spectral resolution can be significantly improved. This is particularly true for very inhomogeneous regions at B0. These regions benefit particularly from this effect as shown in Figure 2. Of course, SNR is decreased by going to higher spatial resolution, but this is partially counterbalanced by the fact that spectral peaks become narrower, which can translate into a more than 2-fold SNR gain over the whole brain and even more in certain brain regions. The combination of these factors plus the mitigation of the lipids bleeding by improved PSF leads to a substantially improved spectral quality for high spatial resolution MRSI, which is reflected by reduced MAPEs.

References

[1]Eckstein K. et al, doi: 10.1002/mrm.26963; [2]Robinson S. et al. doi: 10.1002/mrm.24897;
[3]Seeger et al, Doi: 10.1002/mrm.10332;