^{1}H-MR Spectroscopy at 7.0 T and intra-individual Comparison to 3.0 T and 1.5 T

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Introduction: Proton MR spectroscopy (^{1}H-MRS) has recently become available in human subjects also at ultra-high magnetic fields of $\geq$ 7 T and clinical applications will soon be investigated. Similar to the progress already obtained when going from 1.5 T to 3 T, additional improvement in SNR (allowing selection of smaller voxels or detection of low-abundant metabolites) and in spectral resolution is anticipated when going to a field strength of 7.0 T . While these items have already been evaluated in examinations of different volunteers at the various field strengths, no intra-individual comparison investigating the same subjects at all 3 field strengths has been performed until now.

Methods: Single-voxel ^{1}H-MR spectra of the brain were obtained at an ultra-highfield whole body MR unit operating at 7.0 T (Achieva 7.0T, Philips Medical Systems, Cleveland OH, USA) and at clinical whole body 3.0 T and 1.5 T MR systems (Achieva 3.0T and Intera 1.5T, Philips Medical Systems). Transmit/receive quadrature head coils were used for cerebral MRS at all field strengths, and the same 3 healthy volunteers were investigated at 7.0 T, 3.0 T, and 1.5 T. PRESS-localized spectra from parietal white matter (WM) were acquired with TR/TE 2000/47 ms and water suppression by dual inversion prepulses, and VOI size and localization were held identical at the three field strengths in each volunteer. Fig. 1 displays a ^{1}H spectrum at 7.0 T obtained with 96 signal averages from a cubic 4 ml voxel (1.6^3 cm^3) in the centrum semiovale. Absolute metabolite concentrations were determined by referencing to the internal water signal in unsuppressed proton spectra. Postprocessing of ^{1}H-MRS acquisitions was done by time-domain analysis using the MRUI software package [1,2]. Spectral resolution, SNR, metabolite ratios and absolute concentrations were analyzed in intra-individual comparisons at the three field strengths.

Results: An intraindividual comparison of ^{1}H-MR spectra obtained at 7.0 T, 3.0 T, and 1.5 T is shown in Fig. 2. The spectra were acquired with 128 signal averages from a 6 ml VOI in the parieto-occipital WM. Although magnetic field inhomogeneity was reduced by higher order shimming at 7.0 T and 3.0 T, the linewidths (LW) of the singlet resonances increased at higher field strength due to susceptibility broadening. Nevertheless, taking into account the more than twofold increase in chemical shift dispersion, a net improvement in the line separation $\Delta\nu$/LW (and thus in spectral resolution) of about 40% was achieved at 7.0 T in comparison to 3.0 T . Line broadening also caused that the SNR, when calculated from peak amplitudes, was only about 20% higher at 7.0 T in relation to 3.0 T, however, when considering spectral line integrals, the increase at 7.0 T was close to the predicted linear field dependence. Measurements of metabolite ratios and concentrations at the different field strengths yielded consistent results for choline and creatine (intra-individual variation <15%) whereas the total signal of N-acetyl amino acids (NAA+NAAG) at 7.0 T was markedly reduced compared to 3.0 T and 1.5 T (Fig. 2), which might be due to bandwidth limitations of the rf excitation pulses at 7.0 T .

Discussion: The results from the initial experience with in-vivo ^{1}H-MRS at 7.0 T show, that the observed gain in spectral resolution and SNR at ultra-high magnetic fields is presently limited by susceptibility-induced line broadening. In our measurements, increased rf bandwidth and pulse duration at 7.0 T allowed a minimum TE of 47 ms in PRESS-localized acquisitions which is sufficient for the singlet resonances, but leads to partially dephased signals of spin-coupled multiplets like myo-inositol (MI) and glutamate/glutamine (Glx). Shorter TE can be used in STEAM acquisitions, however, the inherent signal loss ($\geq$50%) of this localization technique may counterbalance the high field gain in SNR. Inhomogeneity broadening of spectral lines resulting from intra-voxel susceptibility may be reduced by application of 2D and 3D spectroscopic imaging.

References

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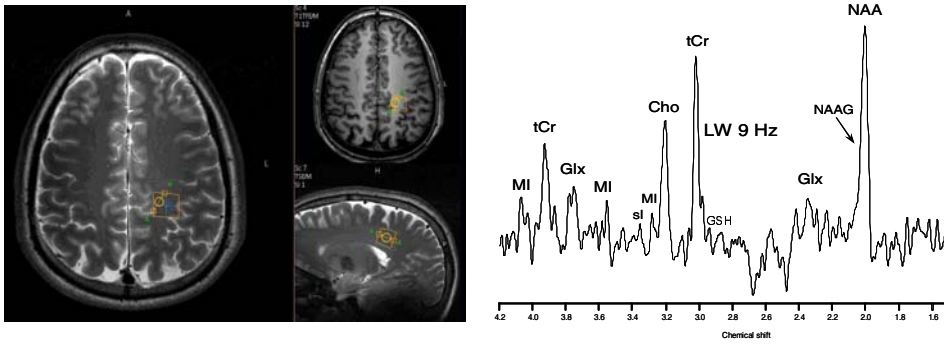

Fig. 1 : ^{1}H-MRS acquisition at 7.0 T of a VOI of 4 ml (16 x 16 x 16 mm) in parietal WM. Selected VOI marked on axial and sagittal MRI. Spectrum obtained with TR/TE 2000/47 ms, BW 4000 Hz, 2048 samples, NSA 96, acquisition time 4 min including H_2O phase reference.

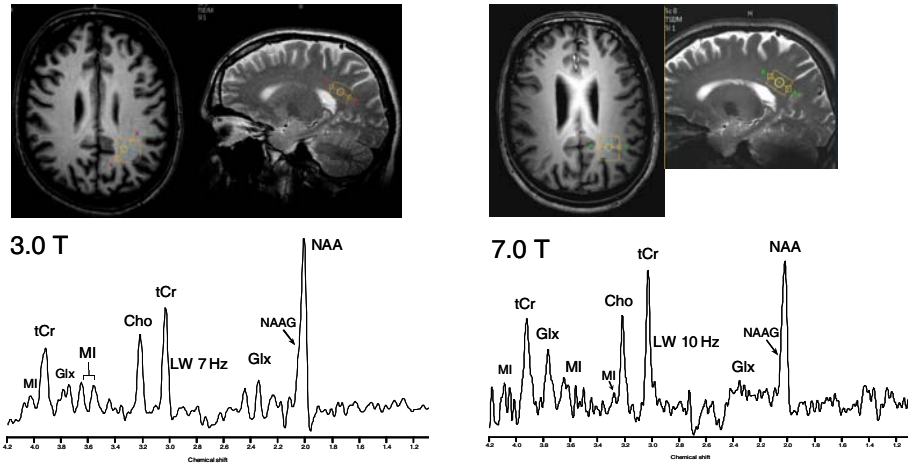

Fig. 2 : Intra-individual comparison of ^{1}H-MR spectra acquired from the parieto-occipital WM of one healthy volunteer at the three different field strengths. Display of VOI (20 x 20 x15 mm) on MRI at 3.0 T and 7.0 T, all spectra with TR/TE 2000/47 ms and NSA 128. Identical frequency resolution (BW/samples) of 2 Hz/pt. at all fields.