HIGH FIELD (7 T) AND SPATIAL RESOLUTION (0.05 ML VOXELS) 3D MRSI IN THE RHESUS MACAQUE BRAIN

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Background

Mechanistic insights of neurological diseases and the development of their novel therapies require pre-clinical trials in non-human primates. Compared to smaller animals, the cost and complexity of such species restrict their number that can be used. Serial studies, therefore, favor non-destructive methods, such as MRI and proton MR spectroscopic imaging (^{1}H-MRSI). The latter modality allows assessment of neuronal cells, cell energetic and membrane turnover, through their respective surrogate markers, NAA, Cr and Cho. The relatively small primate brain require *(i)* proportionally higher spatial resolution than the $1-8$ cm^3 common in humans, to *(ii)* resolve several analogous structures in the same scan; which should *(iii)* be short enough to complete all the tests on an unharmed anesthetized animal. In this study, we report, to our knowledge for the first time, 3D multi-voxel ^{1}H-MRSI at 0.05 cm^3 spatial resolution, over ~25% of the rhesus macaque(RM) brain, in 25 minutes acquisition, at 7 T, to demonstrate that *(i)* $-$*(iii)* above, are addressable with current state-of-the-art hardware, technology and techniques.

Methods

Four healthy 8-10 kg RM monkeys were studied. All experiments were done in a 7 Tesla scanner (Siemens, Erlangen, Germany) using a macaque-size transmit-receive head coil. A 3.5 cm left-right (LR) × 3 cm anterior-posterior (AP) × 1.5 cm inferior-superior (IS) volume of interest (VOI) was graphically prescribed in a 6_{LR} cm ×6_{AP} cm ×1.5_{IS} cm field of view (FOV), as shown in Fig. 1 and shimmed to a ~55 Hz water line width. The VOI was selectively excited using TE/TR=40/1500 ms PRESS. The FOV was partitioned into 16_{LR}×16_{AP} 2D-chemical shift imaging (CSI) and 4th order 1D Hadamard spectroscopic imaging along the inferior-superior direction. To minimize the chemical shift displacement error and increase data acquisition efficiency, a novel multi-slab 3D MRSI approach was developed. We segmented the VOI into two slabs, exciting only one at a time. Consequently, only half the B_1 needed to cover the whole VOI was required, allowing a strong 12mT/m slice select gradient. Furthermore, since each slab excite different parts of the VOI and require less than 750 ms to acquire, both were obtained sequentially every *TR*=1.5 s, halving the 16×16×4 MRSI acquisition time to 12.5 min. (25 min. for two averages) at near-ideal 100% duty cycle.

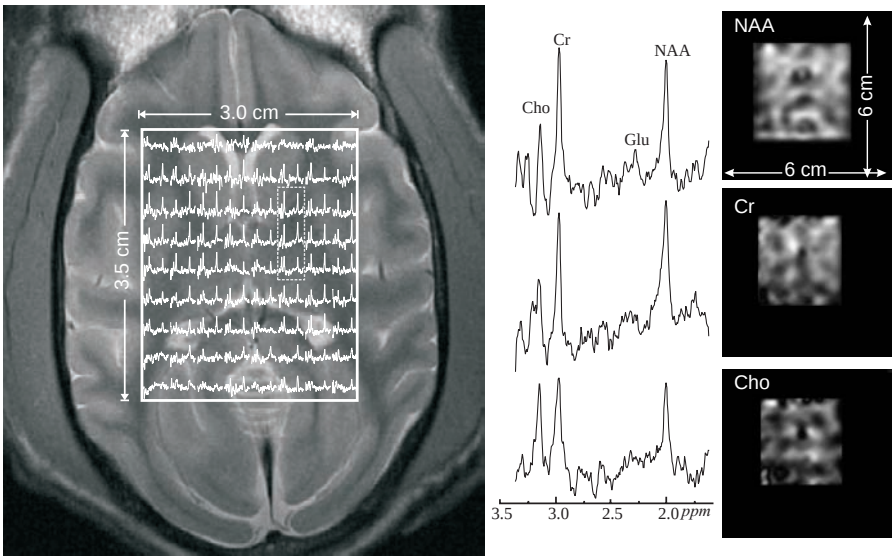

Fig. 1 Axial slice of the RM brain with the 3_{LR}×3.5_{AP} cm PRESS VOI and real part of its 8_{LR}×9_{AP} spectra matrix. Spectra represent (3.75 mm)^3=0.05 cm^3 voxel. Three spectra in the dashed box in the VOI were extracted and expanded for more clarity. Right: the metabolic map of NAA, Cr and Cho. Note the excellent SNR, *spectral* and *spatial* resolutions in this 25 min. acquisition.

Results

The 3D ^{1}H-MRSI data were reconstructed with Fourier and Hadamard transforms, frequency and phase corrected in reference to NAA peak in each voxel and voxel-shifted to align the CSI grid with the NAA VOI. The real part of an 8_{LR}×9_{AP} ^{1}H-MRSI matrix from one (of 4) slices is shown in Fig. 1. Three voxels were extracted from this array to demonstrate the SNR and spectral resolution obtainable at this field. Using Ernst's definition of SNR=peak-height/root-mean-square yield average SNRs of ~30±5, 25±5, 20±5 (mean± standard deviation) for the NAA, Cr and Cho.

Discussion and Conclusion

The combination of very high magnetic field, efficient volume coil, and optimized 3D ^{1}H-MRSI sequence, can yield unprecedented spatial resolution, over extensive brain regions of the non-human primate brain. The sensitivity obtained facilitates the study of these model systems at voxel resolution proportional to the primate/human brain volume ratio, at exam lengths comparable with in vivo human applications, short enough to allow additional MR protocols in a study. Consequently, serial studies of neurological disorders and their treatments in non-human primate model systems can reap the added-value of ^{1}H-MRS's metabolic and physiological data at locale-specific analogy to its human counterpart.

References

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