More for Less? Mapping Cortical Metabolites using Multi-Voxel Magnetic Resonance Spectroscopy

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Introduction:

Concentric ring trajectory-based free induction decay magnetic resonance spectroscopic imaging (MRSI) is a non-invasive technique for generating high-resolution maps of metabolites across the whole brain within reasonable timeframes at both 3T and 7T MRI[1]. Compared to single voxel spectroscopy, MRSI allows for the combination of metabolite maps with segmentations of grey and white matter (GM/WM), allowing for specific metabolite maps of glutamate, glutamine, N-Acetyl-Aspartate (NAA), and creatine

across the cortex and some subcortical regions at 3T and 7T. Previous studies have explored the reproducibility of this technique[2,3], but comparison of MRSI across 3T and 7T in different brain regions have not been performed, which is vital for validation of the technique in GM and WM regions. Considering the improved SNR and spectral resolution at 7T[4], this technique is promising for mapping (sub)cortical metabolite profiles in research settings; while its application in 3T sites lends itself to easy clinical adoption in the future. Here, we show how the upper half of the cortex and white matter can be mapped reliably over time and discuss the implications for future MRS studies.

Methods:

We conducted two scan sessions, 5-9 days apart, on five healthy participants (three female, age: 25-33) using both 7T (Siemens Magnetom 7T+) and 3T (Siemens Prisma) scanners. 3D-FID-MRSI parameters 3T: FOV=220x220x110mm, matrix size=32x32x21 at 6.3 mm^3 iso, TA=4:14 min; 7T: FOV=220x220x110mm, matrix size=64x64x31 at 3.4mm^3 iso, TA=11:30. A T1-w MP2RAGE was acquired for segmentation using FastSurfer[7] and metabolic maps were interpolated onto the Desikan-Killiany-Tourville (DKT) atlas' cortical surface for visualisation and as proof of concept for cortical metabolic mapping. MRSI spectroscopic quantification was performed in LCModel[6]. Maps were overlayed with T1w DKT segmentations (Fig 1). The FOV of MRSI allowed for quantification of 12 bilateral GM and one WM ROI (25 total). We report on three important metabolite ratios relevant for neurodegenerative diseases: NAA/tCr, Glx/tCr, and Glx/tNAA. Mean concentrations at each ROI and field-strength and the intra- and inter-subject Coefficient of Variation (CV) were calculated to assess reproducibility.

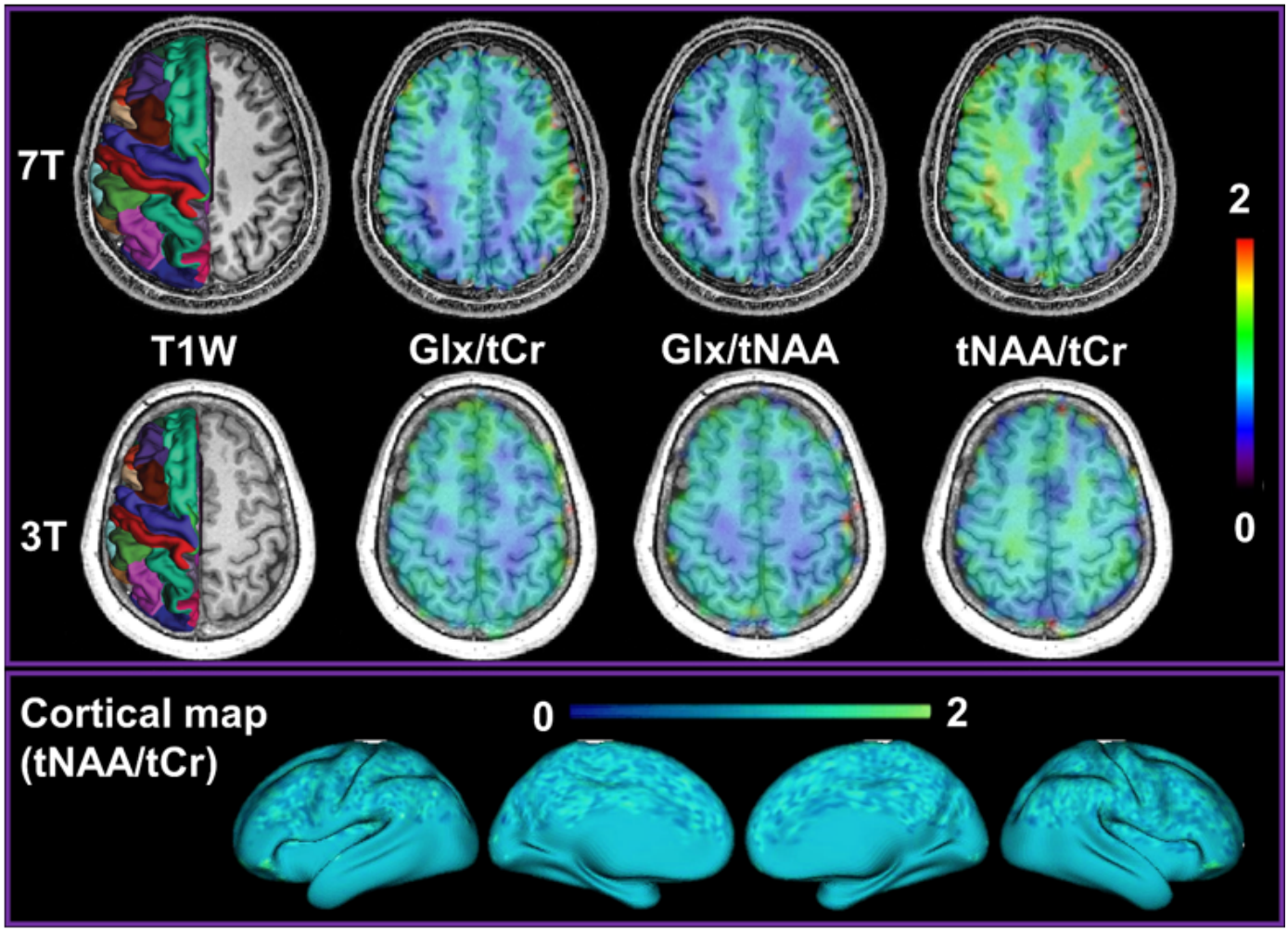

Figure 1: (Top) Metabolic maps of three important metabolites [tNAA = N-acetyl-aspartate (NAA)+ N-acetyl-aspartyl (NAAG); Glx= Glutamate (Glu) + Glutamine (Gln); tCr = Creatine (Cr) + phosphocreatine (PCr) together with anatomical T1-weighted (T1w) images acquired at 7T (top) and 3T (bottom). DKT parcellations are overlayed on the T1w image. (Bottom) The tNAA/tCr map sampled onto the cortical surface. Colour bars indicate relative concentrations.

·Figure 1

Results:

We examined reproducibility for three metabolite ratios across 25 DKT brain regions using test-retest at 3T and 7T. Across ROIs, the metabolite concentration ratio estimates were stable between subjects and within subject at both fields (Fig 2). Mean±SD concentrations were in line with literature[2,3]. The coefficient of variation (CV) for metabolite ratios across most ROIs did not exceed 12% (mean value, 6%; 3T, 7T), which indicated excellent reproducibility for both fields.Metabolic maps were successfully sampled onto FastSurfer cortical surfaces (Fig 1), revealing (for the first time) patterns of metabolic expression over the cortex. We observed higher variability in certain ROIs (e.g., rostral middle frontal) compared to others (e.g., paracentral lobule).

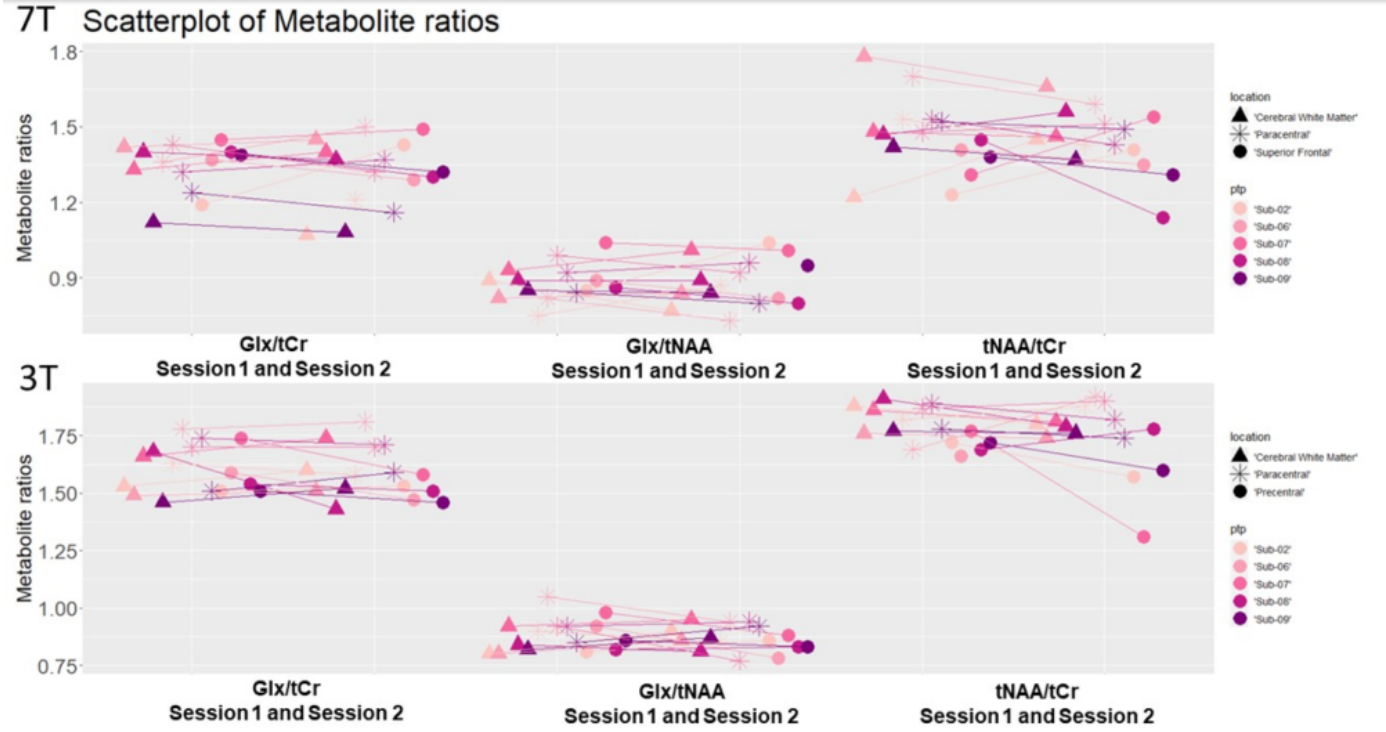

Figure 2: Relative changes of concentration ratios between two sessions with a week apart for three metabolite ratios across select brain regions at both 7T (top) and 3T (bottom). The outlier in the NAA ratios is likely due to a lipid artifact. Points are intentionally jittered.

·Figure 2

Conclusions:

The introduction of a cortical sampling technique for spectroscopy data unlocks the possibility of mapping the metabolic expression of the brain in a reliable, longitudinal manner. Results indicated a high degree of reproducibility for metabolites at both fields, with most ROIs demonstrating higher reproducibility at 3T compared to 7T, likely due to reduced participant movement over the shorter scan time. The variability of NAA/tCr across ROIs was substantial (2.1 CV% to 12 CV%), and besides actual biological variability, this may also be related to lipid contamination in some regions/subjects, warranting further investigation. Our results suggest that ratios of metabolite concentrations can be reproducibly measured with 3D-FID-MRSI at 3T and 7T, and these can be sampled onto the cortex of many brain regions. Scan time is an important factor for variability, and one could test to reduce scan time if lower spatial resolution is not an issue.

Neuroanatomy, Physiology, Metabolism and Neurotransmission:

Cortical Anatomy and Brain Mapping [2]

Novel Imaging Acquisition Methods:

MR Spectroscopy [1]

Keywords:

Cortex
Glutamate
HIGH FIELD MR
Magnetic Resonance Spectroscopy (MRS)
MR SPECTROSCOPY
Neurotransmitter

[1|2]Indicates the priority used for review

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Not applicable

Please indicate which methods were used in your research:

Structural MRI
Other, Please specify - Magnetic Resonance Spectroscopy

For human MRI, what field strength scanner do you use?

3.0T
7T

Which processing packages did you use for your study?

FSL
Free Surfer
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Provide references using author date format

[1] W. Bogner, R. Otazo, and A. Henning, (2021) "Accelerated MR spectroscopic imaging-a review of current and emerging techniques," NMR Biomed, vol. 34, no. 5, p. e4314, doi: 10.1002/nbm.4314.
[2] P. Moser et al., (2020) "Intra-session and inter-subject variability of 3D-FID-MRSI using single-echo volumetric EPI navigators at 3T," Magnetic resonance in medicine, vol. 83, no. 6, pp. 1920-1929.
[3] G. Hangel et al., (2021), "Inter-subject stability and regional concentration estimates of 3D-FID-MRSI in the human brain at 7 T," NMR in Biomedicine, vol. 34, no. 12, pp. e4596.
[4] R. Mekle, V. Mlynárik, G. Gambarota, M. Hergt, G. Krueger, and R. Gruetter. (2009), "MR spectroscopy of the human brain with enhanced signal intensity at ultrashort echo times on a clinical platform at 3T and 7T," Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine, vol. 61, no. 6, pp. 1279-1285.
[5] W. Bogner et al., (2014), "Real-time motion-and B0-correction for LASER-localized spiral-accelerated 3D-MRSI of the brain at 3 T," Neuroimage, vol. 88, pp. 22-31.

[6] L. Hingerl et al., (2018), "Density-weighted concentric circle trajectories for high resolution brain magnetic resonance spectroscopic imaging at 7T," Magnetic resonance in medicine, vol. 79, no. 6, pp. 2874-2885.
[7] L. Henschel, S. Conjeti, S. Estrada, K. Diers, B. Fischl, and M. Reuter, (2020), "Fastsurfer-a fast and accurate deep learning based neuroimaging pipeline," NeuroImage, vol. 219, pp. 117012.

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