Quantitative Susceptibility Mapping of the Squirrel Monkey at 3T and 11.7T: Application to a Model of Parkinson's Disease

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TARGET AUDIENCE: Clinicians and scientists interested in QSM application at ultra-high field in a primate model of Parkinson's disease.

INTRODUCTION: Quantitative Susceptibility Mapping (QSM) is a novel MRI contrast mechanism in MRI. QSM is generated by using information within phase images about variations of local magnetic field induced by magnetic sources. QSM allows discrimination between tissues with different susceptibilities including iron, microbleeds or calcification. QSM has been used in humans to evaluate iron load in brain tissue). Here we investigated the feasibility of brain QSM in the squirrel monkey. Notably, we compared results obtained using conventional MRI (3T) and ultra-high field (11.7T) on control animals. We also investigated the difference obtained in globus pallidus (GP) and substantia nigra (SN) in a monkey during the control state and after treatment with 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP), a neurotoxin that that induces PD-like nigrostriatal pathway injury.

METHODS: These experiments were conducted on three anesthetized squirrel monkeys (female, 7-14 years). One was scanned using 3T Siemens Tim Trio (Siemens, Germany) and the other two were scanned using an 11.7T Bruker Biospec 117/16 (Bruker, Germany). One squirrel monkey was scanned twice on the 3T scanner (i.e. before and 2 weeks after MPTP intoxication). A dedicated 8-channel head coil (LifeServices, USA) was used at 3T. A birdcage transceiver coil was used at 11.7T (MRI.Tools, Germany). QSM images were acquired using 3D Multi Echo Gradient Echo (MGRE) sequence for both 3 and 11.7T.
At 3T, imaging parameters were: FOV= 188*76.4*67.2 mm^3, matrix size=448*182*160 leading to an isotropic resolution of 0.42 mm^3, TR=60ms, 1st TE=6ms last TE=42.96ms with a ΔTE of 5.28ms, spectral width=490 Hz/Pixel. Scan time for the MGRE images was 29min09s. Raw data were saved for offline reconstruction of magnitude and phase images. Combination of the 8 channels was performed with in-house software on Matlab (Mathworks, USA).
At 11.7T, imaging parameters were: FOV= 57.6*51.2*51.2 mm^3, matrix size=288*256*256 leading to an isotropic resolution of 0.20 mm^3, TR=25ms, 1st TE=2.5ms last TE=21.4ms with a ΔTE of 2.1ms, spectral width=694 Hz/Pixel. Two averages were acquired, leading to a scan time of 54min36s. Raw data were saved and reconstructed with in-house software in Matlab.
For QSM images reconstruction, the algorithm used was similar for both 3 and 11.7T. First, unwrapping was performed using the Laplacian operator and then background field removal was performed using the Laplacian Boundary Value (LBV) method. Finally the dipole inversion was performed using the Morphology-Enabled Dipole Inversion (MEDI) method. Regularization parameter λ was set to 500.
ROI were manually defined on the QSM images in the GP and SN. We compared results obtained at 3 and 11.7T and results obtained before and after MPTP intoxication.

RESULTS: Images obtained at 3T and 11.7T are shown in figure 1. The mean QSM values in GP and SN before and after MPTP intoxication was measured at 3T only. We observed that the GP value decreased from 0.065 to 0.034 ppm whereas it increased from 0.019 to 0.30 in the SN. For measurement performed at 11.7T, the mean GP and SN values were 0.090 +/- 0.011 and 0.029 +/- 0.007 ppm, respectively.

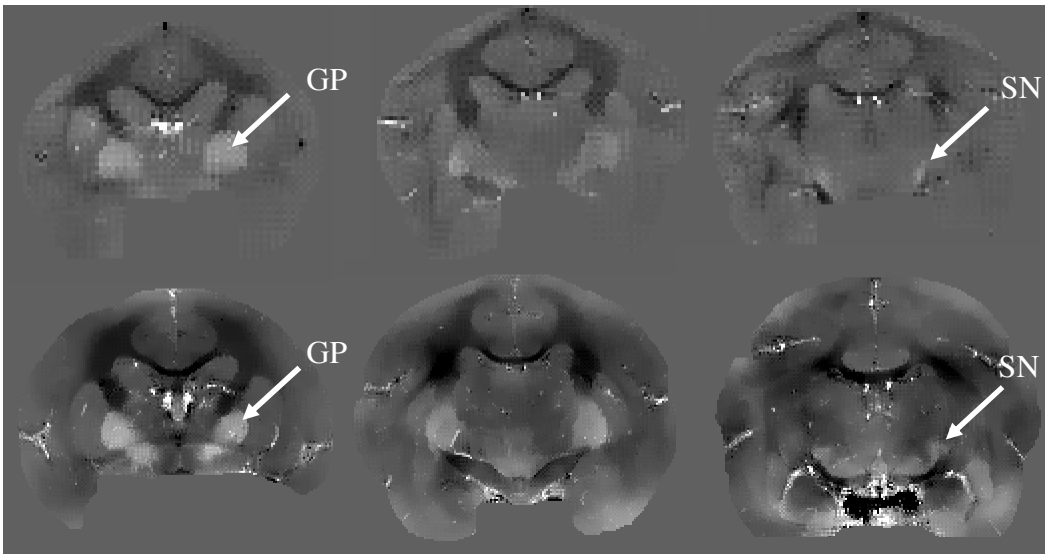

Figure 1: *In Vivo* QSM maps at different levels at 3T (upper row, 420µm isotropic) and 11.7T (bottom row, 200µm isotropic). Scaling -0.120 to 0. 200 ppm

DISCUSSION AND CONCLUSION: Based on these preliminary data, we show here the feasibility of brain QSM measurements at high and ultra-high field in a primate species that is classically used to model Parkinson's disease upon MPTP intoxication. A huge improvement of image quality was obtained at 11.7T as compared to 3T. Further work will be focused on automatic segmentation using a brain atlas under development. Moreover, our results obtained in a single MPTP-intoxicated monkey are encouraging since we were able to show QSM variations in brain regions (GP and SN) known to display iron load modifications (down and up in the GP and SN, respectively) in patients with Parkinson's disease. Additional animals will be processed at 11.7T to confirm and extend this observation.

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