Paramagnetic ions and R2 and R2*map: A preliminary postmortem brain study

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Target Audience: Scientists interested in the relationship between relaxometry rates and paramagnetic ions deposit in the basal ganglia.

Introduction: The basal ganglia show hypointense signals in the T2w and T2*w magnetic resonance images. Several authors suggest that accumulation of diamagnetic and paramagnetic ions in these regions disturb the local magnetic field and decrease resultant signal (1–3). However, the relationship between Al^{+3}, Zn^{+2}, Cu^{+2}, Fe^{+2} and Fe^{+3} paramagnetic ions concentrations in the brain with R2 and R2* values does not have been demonstrated in the literature. In this study we quantify paramagnetic ions in one postmortem brain using Electron Spin Resonance (ESR) and estimate its correlation with R2 and R2* maps.

Methods: Magnetic resonance imaging were performed in one human postmortem brain ex situ (age 29 years) in formaldehyde (10%) using a 3 T scanner. For R2 estimation, a Turbo Spin Echo sequence with 22 equally spaced echoes (10.86-138.92 msec) was used with TR=3000msec and resolution of 0.479x0.479x2.0 mm^3. For R2* estimation a gradient multi-echo sequence was used with 4 equally spaced echoes (TE=7.7, 19.7, 31.7, 43.7 msec) with TR= 48msec and resolution of 0.479x0.479x2.0 mm^3. Several ROIs were drawn in the basal ganglia: substantia nigra (SN), red nucleus (RN), globus pallidus (GP), putamen (PUT), caudate nucleus (CN) and white matter (WM). R2 and R2* were calculate from a mono-exponential decay fit from the averaged signal intensities in each ROI. For each region, a sample of tissue was placed in a glass tube (inner diameter of 3mm) within another tube with liquid nitrogen. ESR spectra was recorded in an X-Band (Jeol JES-FA-200) spectrometer with a central magnetic field of 250mT, scanning field of 150mT, scan time of 4 minutes, modulation amplitude of 1mT, gain of 50 and microwave power of 2mW.

Results: Figure 1(A-B) shows T2w and T2*w acquired from postmortem brain ex situ. R2 and R2* maps processed for all pixels are shown in the Figure 1(C-D). ESR spectrum obtained for basal ganglia had three peaks with specific g values. Figure 3 shows the correlation between paramagnetic ions with R2 and R2* values.

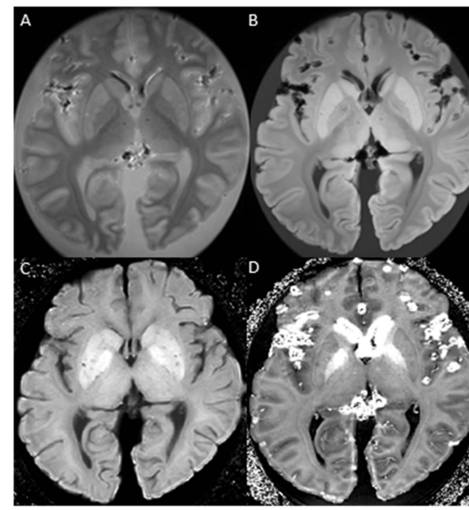

Fig. 1: (A)T2-w;(B)T2*-w;(C)R2 with scale 1-25 s^{-1};(D)R2* with scale 1-55 s^{-1}

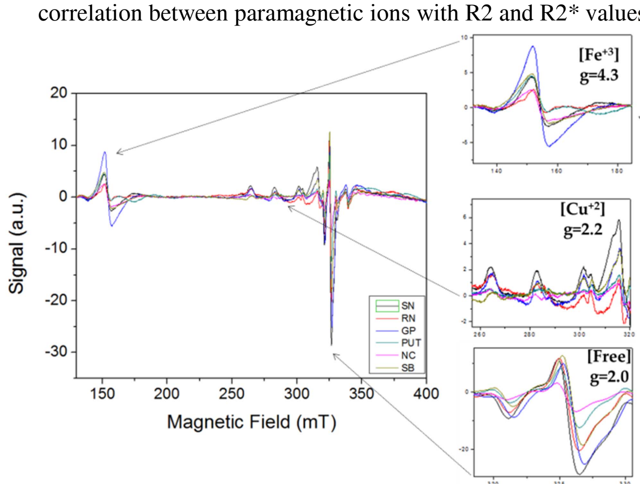

Fig. 2: ESR spectrum of basal ganglia and white matter from healthy.

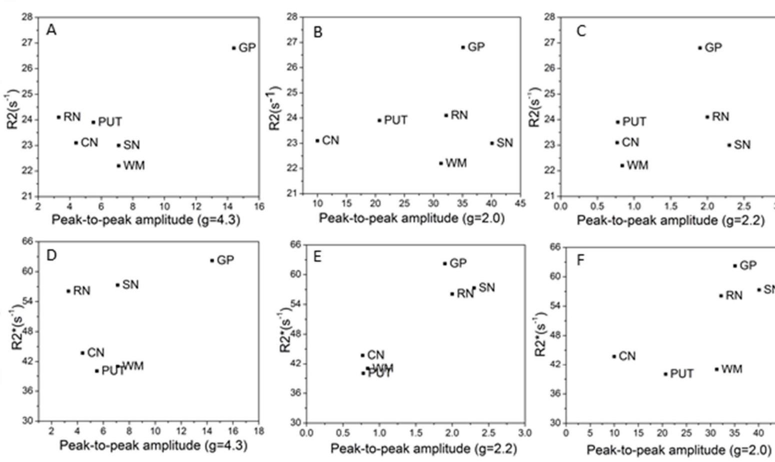

Fig. 3: Correlation between paramagnetic ions with R2 and R2* values.

Discussion: Our results indicate that Fe^{+3} and Cu^{+2} are present in all regions of basal ganglia. The findings of Fe^{+3} are in agreement with some reports (4–6). On the other hand, there are not reports about cooper ion in these regions. The relationship between both ions is not linear, GP has the higher iron concentration and the SN has the higher cooper concentration. Paramagnetic ions disturb local magnetic field and can influence in R2 and R2* values. We observed a strong linear correlation (R^2=0.83) between cooper peak intensity and R2* values. This correlation suggests an important role of cooper in R2*. The magnetic characteristic of the free radical found (g=2.0) needs to be defined to extrapolate possible influences in the R2 and R2* values. At the present, quantitative susceptibility mapping is not possible due to the presence of phase artifacts from the air bubbles. More images from postmortem brain ex situ are been acquiring for future studies.

Conclusion: Fe^{+3} and Cu^{+2} paramagnetic ions were found in regions with considerable increased R2 and R2* values. The determination of the influence from paramagnetic ions can help understanding the origins of changed R2 and R2* values in the basal ganglia.

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