Variations in T2, T2* and T1 between white matter tracts at 7.0 T

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Introduction

T2 and T2* have been shown to vary between white matter tracts[1,2]. The aim of this study is to investigate the relationship between the relaxation times and known features of myelin density and axonal structure, by studying adjacent white matter tracts and comparing known differences in myelin density to the T2, T2* and T1 relaxation times of these tracts.

Method

8 healthy subjects (male/female=4/4, aged 40-49 years) were scanned with local ethics committee approval using the GESE[3] and MP-RAGE[4] sequences on a Philips Achieva 7.0 T MRI scanner. The sequence parameters for GESE were 0.93x0.93x3mm voxel size, TE=40ms, TR=1500ms, gradient echo spacing=1.16ms, number of gradient echoes=31, NSL=18, total time=9mins. For sequence parameters for MP-RAGE were 0.5x0.5x1mm voxel size, TR=11ms, TE=6.7ms, flip angle=8º, shot-to-shot interval=9s, 256 turbo pulses per inversion with 6 inversion times of 0.3, 0.6, 1.5, 2.5, 3.5, 5s and 70 slices. To obtain values for T2, T2* and T1 regions of interest (ROIs) were manually drawn for the internal capsule (IC), corticospinal tract (CST), anterior, middle and posterior regions of the corpus callosum CC (genu, CC_mid and splenium) and the internal and external sagittal stratum (ISS and ESS) (figure 1).

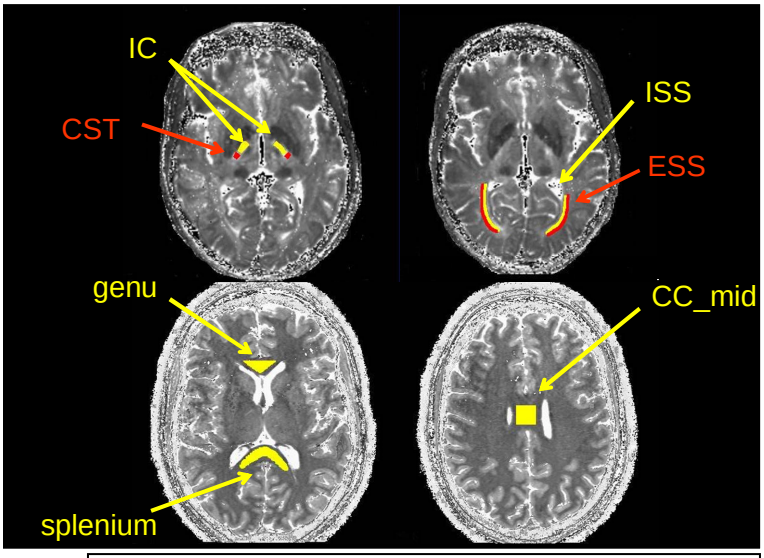

Figure 1: Parametric maps showing the regions of interest drawn to obtain relaxation times (top row=T2, bottom row=T1)

Results

Figure 1 shows the regions of interest in the white matter tracts of interest drawn on T2 or T1 maps. Figure 2 shows the differences in relaxation times between the neighbouring tracts (mean±SEM). The T2 and T2* were found to be longer in the CST compared with the IC, and in the ESS compared with the ISS. The CC was found to have the longest T2 and T2* in the middle and the shortest in the genu. The T1 values did not show any significant differences, and any trends opposed the T2 changes.

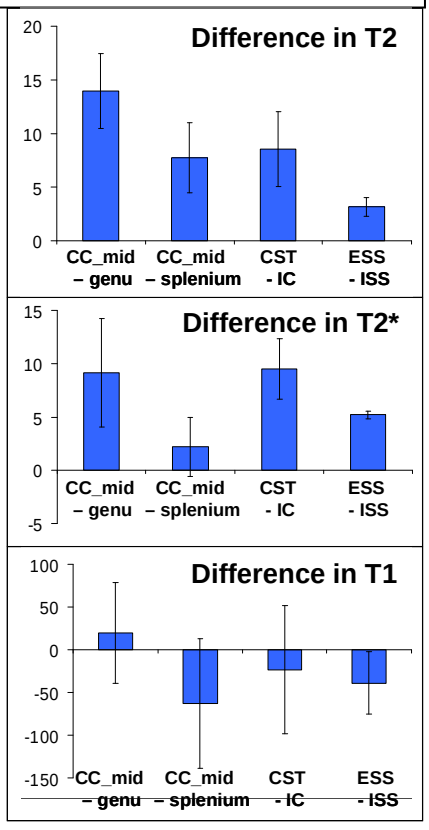

Figure 2: Differences in relaxation times between neighbouring white matter tracts (mean±SEM, in ms).

Discussion

The variation in white matter T2* between tracts that has recently been reported is also visible in T2 data presented here, in agreement with the neuroradiological literature[2]. In fact the T2 maps (in figure 1) and T2* data (not shown) are strikingly similar to myelin stain images[2]. Theoretically, white matter T2 could depend on the degree of myelination, axonal calibre/surface area, and iron content (iron is present in oligodendrocytes as a cofactor to enzymes involved in synthesis and maintainance of myelin). The relationship between myelin density and axonal density is complicated by changes in axonal calibre.

The CST and ESS are heavily myelinated tracts but have long T2s[5,7], suggesting that myelin content may not be the primary determinant of T2 in these particular tracts. Myelin and axonal staining studies demonstrated small axons, thin myelin sheaths and narrow spaces between axons within the ISS (hypointense on T2 –our data and others[1,5,6]), opposed to large axons, thick myelin sheaths and wide spaces between axons (lesser fibre density)[5] within the ESS (hyperintense signal on T2 –our data and others[1,5,6]). The CST is similar to the ESS[5] in terms of both MRI and histological parameters. The differences in the CC relaxation parameters could also relate to known variations in fibre composition of the different regions. The largest fibres are found in the middle and splenium of the CC, while the genu of the CC mostly consists of small diameter fibres. This indicates that T2 could be related to fibre diameter. However the amount of iron within myelin may also differ across tracts, and contribute to these signal variations, which would be consistent with variations between white matter tracts on phase data, although the literature on iron content of white matter is not complete. This could also be consistent with the fact that the T1 changes were not correlated with T2 changes between the tracts.

Conclusion

There is considerable variation in T2 and T2* between white matter tracts at 7T which is not observed on T1 data. Correlation of these difference with histological data may allow the relaxation mechanisms in white matter tracts to be clarified.

References

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