Quantitative parametric mapping and tissue sodium concentration at 3T/4T

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Introduction

Water content and tissue sodium concentration (TSC) are strongly regulated in the human body. Both quantities are therefore potential markers of pathologic conditions such as cerebral oedema [1], neurodegenerative diseases [2] or stroke [3]. MRI allows one to measure these quantities *in vivo* and non-invasively. Combining sodium and proton concentration measurements *in vivo* is of interest since both parameters together may provide additional information concerning the distribution of water inside and outside the cells. In this study, using previously validated quantitative methods [1,4], we computed the proton density (PD) and TSC maps in 4 healthy volunteers. From the computed quantitative maps, PD and TSC were estimated in various automatically selected brain regions, illustrating the feasibility of such an approach for longitudinal monitoring of disease, onset detection, and progression.

Materials and Methods

Four healthy volunteers of average age 28 ± 5 years (two male, two female) were scanned. All measurements were performed in accordance with the local ethics committee and informed consent was obtained prior to measurement. Proton images were acquired on a Siemens (Erlangen, Germany) TIM TRIO using a Siemens 32 channel PA head coil. Sodium images were obtained on a home-assembled Siemens 4T whole-body scanner using a dual $^{1}H/^{23}Na$ birdcage head coil (Rapid Biomed, Germany). PD maps were acquired at 3T using a 2D FLASH acquisition with subsequent correction of the T1 saturation effect, T2* weighting and the transmit and receive non-uniformities, as described in [4]. The corrected map was normalized to the CSF signal, which is assumed to have the same PD as pure water. Imaging parameter of the FLASH acquisition were: TR = 1.8s, FA = 40°, in plane FOV 256x192, in plane resolution 1mm, 60 slices acquired in 2 concatenations with zero gap, slice thickness 2mm.TSC maps were obtained using a TPI sequence to acquire the sodium signal with 4mm nominal resolution in 15 minutes (TR 150ms, 20ms readout). Flip angle variations were corrected using a Bloch-Siegert shift B1 map, images were calibrated using reference standards imaged immediately after the human measurement. Additionally, a 1mm isotropic MP-RAGE acquisition was performed at 4T with the following parameters: TR = 1900ms, TI = 900ms, FA = 9°. All parametric maps were co-registered to the MNI 152 brain atlas. Seven regions (left and right) were selected from Harvard-Oxford Cortical Structural Atlas, nine areas from MNI structural atlas, and two from JHU White-Matter Tractography Atlas. Masks were created from the probabilistic maps using a 25% threshold.

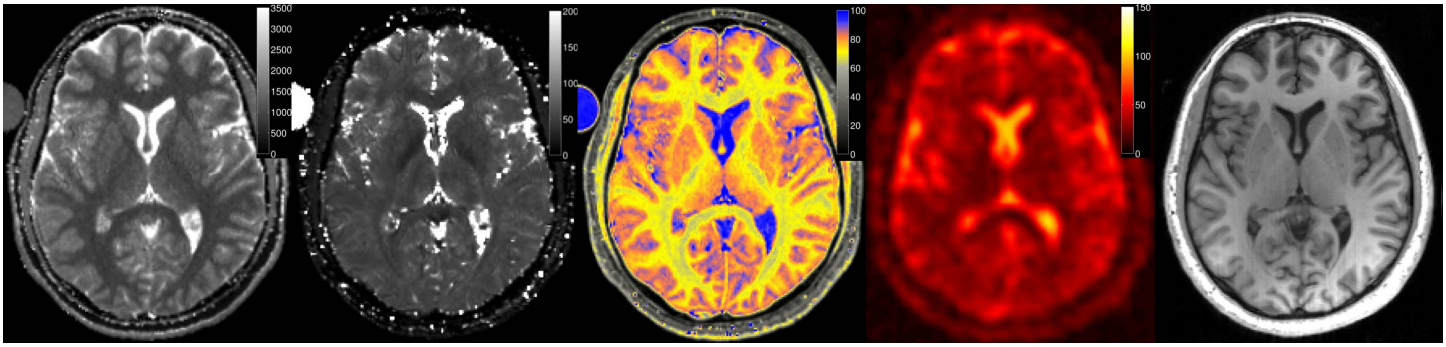

Figure 1: Parameter maps for one volunteer. T1 map (a), T2*(b) map, water content map (c), and TSC map (d) co-registered to the MP-RAGE image (e).

Parameter	Caudate	Cerebellum	Frontal Lobe	Insula	Occipital Lobe	Parietal Lobe	Putamen	Temporal Lobe	Thalamus
T1 (ms)	1637 ± 313	1093 ± 142	1673 ± 91	1580 ±86	1294 ± 65	1555 ± 62	1196± 46	1412 ± 37	1325 ± 131
T2* (ms)	62 ±11	44 ± 7	68 ± 16	72 ± 9	55 ± 3	69 ± 8	48 ± 4	54 ± 4	58 ± 7
PD (%)	83 ± 3	67 ± 7	74 ± 2	83 ± 1	77 ± 6	79 ± 3	80 ± 2	78 ± 4	80 ± 2
TSC(mmol/l)	51 ± 9	41 ± 6	43 ± 5	42 ± 6	39 ± 8	43 ± 8	30 ± 5	40 ± 6	38 ± 6

Table 1.: Mean T1, T2*, PD and TSC across all subjects in brain regions delineated with the help of the MNI atlas.

Parameter	Thalamus		Caudate		Putamen		Pallidum		Hippocampus		Amygdala		Accumbens		Cingulum		Corticospinal Tract	
T1 (ms)	1475 ±151	1356 ±208	1745 ±353	1663 ±669	1197 ± 51	1186 ± 31	1037 ± 43	1057 ± 67	1428 ± 29	1431 ± 91	1519 ± 91	1443 ± 62	1431 ± 79	1430 ± 77	1071 ± 20	1087 ± 83	970 ± 30	991 ± 37
T2* (ms)	65±15	55±3	68±9	48±18	46±3	47±6	38±2	39±3	57±4	62±9	58±7	56±13	53±9	51±9	53±3	53±1	57±4	56±2
PD (%)	82±1	81±4	86±3	83±5	81±2	81±2	77±4	78±3	82±3	84±1	84±2	84±4	89±9	86±4	76±3	76±4	71±2	72±1
TSC(mmol/l)	42±9	43±6	46±9	60±20	29±5	30±6	27±4	27±5	40±5	41±5	39±5	41±4	32±7	40±5	32±8	35±7	26±5	26±5

Table 2.: Mean T1, T2*, PD and TSC across subjects in brain regions delineated with the help of the Harvard-Oxford Cortical Structural atlas and the White Matter Tractography Atlas. Results in the left and right hemisphere are shown separately.

Results and Discussion

Parametric maps of T1, T2*, Water content and TSC obtained in one volunteer are shown in Figure 1. Despite the differences in terms of resolution and contrast, all modalities could be co-registered with high precision to the MP-RAGE scan using an automated procedure. PD and TSC measurements (mean value ± standard deviation) in selected anatomical regions-of-interest are shown in Table 1 and Table 2. Measured standard deviation is relatively low suggesting that image registration and region delineation were of good quality. An exception is found in the caudate nucleus. Proximity of this structure to the lateral ventricles may explain this since signal leakage can occur.

Conclusion

Extended parametric mapping of the healthy human brain is shown to be feasible. Relaxation time mapping, water mapping and TSC mapping were combined to yield an extensive parameter set with very good precision. This set of normal values may serve as a basis for investigation of diseases of the central nervous system.

References

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