Relaxation Times of Human Basal Ganglia Regions at 7 Tesla

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Introduction: The increasing number of clinically oriented studies at 7 T demands a proper knowledge of relaxation times at this field strength. Although there are already a few publications[2, 3] providing information about relaxation times of white and gray matter, CSF, and larger areas such as thalamus and corpus callosum, there is still a need to investigate different brain tissues further and in particular to exactly differentiate between deep brain nuclei. Our study aimed to perform relaxation measurements (T1, T2, and T2*) of the basal ganglia regions which are of great interest in stereotactic surgery and in diagnosing Parkinson's disease, for example.
The basal ganglia regions are two deep brain areas located at the telencephalo-diencephalo-mesencephalic junction. In this study we focused on the superior region, excluding the temporal lobes, and we included the thalamus because of its close relationship with the basal ganglia region.

Methods: This IRB approved study was performed in ten healthy volunteers (five male, five female, mean age 28.2 y). All measurements were performed on a Magnetom 7 T whole-body scanner (Siemens Healthcare, Erlangen, Germany) with an eight-channel transmit/receive head coil (Rapid Biomed, Wurzburg, Germany).
A dual-angle technique based on the 3D-FLASH[4] spoiled gradient echo sequence was used for T1 mapping. Parameters of the 3D-FLASH were chosen as follows: TR 30 ms, TE 2.02 ms, bandwidth 480 Hz/pixel. A slab of 64 mm could be acquired within 5:37 minutes. For an average value of T1 = 1700 ms for brain tissue[2], a set of two optimal angles corresponding to 71% of the Ernst signal were calculated to be 4 and 25 degrees by the vendor supplied software (Siemens syngo MapIt). T2 mapping was based on a multi-echo spin echo sequence with a TR of 4 s, 180° flip angle, and a bandwidth of 482 Hz/pixel. Due to strong SAR (specific absorption rate) limitations, only one slice could be measured within 11:18 minutes. Six echoes were read out at TE = 7.7, 15.4, 23.1, 30.8, 38.5, and 46.2 ms. However, the first echo was ignored in the pixel-wise calculation of the T2 map since it consistently yielded a lower signal than the second echo. A multi-echo gradient echo sequence was used for T2* mapping with TR 800 ms, 25° flip angle, bandwidth 570 Hz/pixel, and a bipolar readout mode to enable short TE. A total of 19 slices could be measured within 5:09 minutes. Twelve echoes were read out between 4.08 ms and 38.76 ms. As for the T2 maps, a log-linear least squares fit algorithm was used for T2*, although in this case the first echo yielded a higher signal and was not excluded from the calculation.
For all mapping sequences a high spatial resolution of 0.5 x 0.5 x 2.0 mm^3 was maintained. A noise threshold of 15 was chosen for the calculation of all parametric maps. Regions of interest were positioned and outlined manually on coronal images; see Fig. 1 and Fig. 2. Because of the long overall MRI acquisition time per subject, the number of sequences allowing for measurement of relaxation times was limited. Thus, the entire set of T2*, T2, and T1 maps was performed only for the posterior (thalamic) region, whereas only T2* maps were realized for all three regions (pre-commissural, retro-commissural, and posterior).

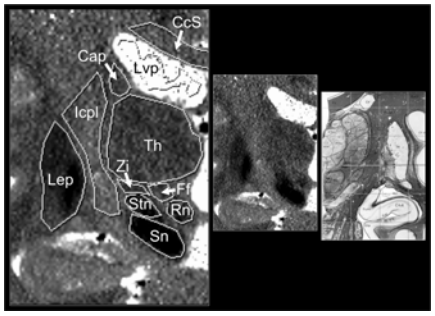

Fig. 1 – Posterior ROIs: ROIs placed on coronal T2 map (left) with the corresponding anatomo-histological section (Schaltenbrand & Bailey atlas[1], right).

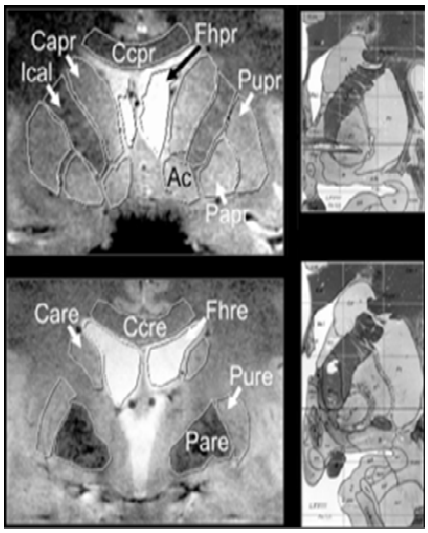

Fig. 2 – Anterior ROIs placed on T2* images (left) with the corresponding anatomo-histological sections (right column): pre-commissural (top) and retro-commissural (bottom) regions.

Results: All anatomic structures were clearly identified in 9 out of 10 datasets. In one dataset the evaluation of the subthalamus could not be performed due to strong artifacts. The relaxation times are summarized in Table 1.

Discussion: High iron levels are present in the pallidum, the substantia nigra, and the red nucleus, and at lower levels in the striatum[5]. Our results corroborate these findings. Based on relaxation time values, T2* weighting seems to offer a better differentiation of the different ROIs than T2 weighting and especially T1 weighting. Although B1 inhomogeneity and flip angle variation introduce a large error on T1, the rather short dual-angle method rendered values which are in agreement with other work[2, 3]. Compared to studies performed at 1.5 T and 3 T[6], the T2 and T2* values found in this study are slightly shorter at 7 T, as expected. Our results also show the inhomogeneity of relaxation times at the different levels (pre and retro-commissural and posterior) of the lateral ventricle, corpus callosum, caudate, putamen, and pallidum. The thalamus was explored in its central region, and our results reflect the average value of the different subcompartments, that is the medial, ventro-lateral and dorsal.
This work may help in optimizing image contrast of deep brain nuclei of the basal ganglia region and may serve as healthy reference values in assessing patients with Parkinson's disease, for example.

Table 1	Abbr	T2		T2*		T1	
[values in msec]		mean	SD	mean	SD	mean	SD
Accumbens	Ac			8.7	2.3		
Lateral ventricle (body, post.)	LvBp	657	157	479	175	3382	318
Lv ant AC Frontal horn	LvFh			190	62		
Lv post AC (body ant.)	LvBa			369	123		
Thalamus	Th	49.4	2.3	22.9	2.1	1666	407
Post. lenticular nucleus	Lep	43.7	5.5	18.6	4.2	1079	177
Putamen pre AC	Pupr			16.1	2.2		
Putamen retro AC	Pure			18.8	2.0		
Pallidum pre AC	Papr			11.4	1.2		
Pallidum retro AC	Pare			10.1	1.2		
Caudate body (post.)	CaBp	50.9	3.0	25.4	3.1	1357	278
Caudate pre AC	CaHpr			20.4	1.8		
Caudate retro AC	CaHre			24.0	2.7		
Corpsus callosum pre AC	CcBpr			23.4	0.8		
Corpsus callosum retro AC	CcBre			25.2	1.7		
Corpsus callosum splenium	CcS	56.8	2.6	26.2	1.4	1037	361
Red nucleus	Rn	40.8	3.5	12.8	1.7	1636	312
Subthlamus nucleus	Stn	47.2	4.1	16.7	2.8	1552	217
Substantia nigra	Sn	37.6	3.0	11.5	1.9	1700	322
Forel's fields	Ff	52.5	3.2	20.5	1.9	1707	175
Zona incerta	Zi	49.5	2.2	21.1	2.3	1540	211
Internal capsule ant. limb	Ical			15.3	2.1		
Internal capsule post. limb	Icpl	61.0	4.2	27.3	3.5	1199	188

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