Evaluation of T1 and T2* Mapping Reproducibility at 3T Using Histogram Analysis

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Introduction

T1 and T2* parameter mapping may provide key measures to monitor degenerative brain diseases such as Parkinson's disease (PD) and Alzheimer's disease (AD). However, reproducibility of these measures needs further evaluation before application to clinical practice. Although numerous studies have evaluated the reliability of relaxation measurements at 1.5T [1], very few have assessed reproducibility at 3T. Histogram analysis of MR measurements provides accurate and sensitive metrics of subtle changes in brain regions of interest (ROIs) [1,2]. This study uses four histogram metrics to evaluate interscan reproducibility of T1 and T2* mapping in healthy subjects for regions relevant to PD and AD studies.

Methods

MR Image Acquisition: Seven healthy volunteers (6 males, 1 female, mean age: 42 yrs, range: 22-60) were scanned twice with an interval of one week. Images were acquired using a 3T scanner (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany). T1 measurements were acquired using a dual flip angle 3D GRE volumetric interpolated breath-hold examination (VIBE) sequence (TR/TE/FA=15 ms/1.68 ms/5° and 26°, bandwidth=420 Hz/px, FOV=240mm, resolution=0.9×0.9×3.0 mm^3, GRAPPA acceleration factor 2). T2* measurements were acquired using a 3D multi-echo spoiled GRE sequence with 12 echoes (TR=100 ms, TE_1=4 ms, ΔTE=5.55 ms, FA=25°, bandwidth =260 Hz/px, resolution=0.9x0.9x3.0 mm^3, GRAPPA acceleration factor 2). Structural MP-RAGE was obtained using ADNI protocol [3].

Image Analysis: T1 and T2* maps were constructed inline at the 3T scanner (MapIt, Siemens Healthcare, Erlangen, Germany) and coregistered to the structural image from the first scan session using FLIRT (FSL, FMRIB, Oxford, UK). Automated segmentation was performed on this structural scan using FreeSurfer (http://www.martinos.org/freesurfer) for ROIs relevant to AD and PD (bilateral thalamus, hippocampus, putamen and caudate) and used to extract T1 and T2* values. Histograms for each ROI were evaluated using four metrics (peak height, peak location, median and mean) from the Gaussian fits of each histogram. Between-time reliability was assessed using intraclass correlation coefficients (ICCs) computed as the ratio of the subject variance to the total variance [4]. Between-time reproducibility was assessed using coefficient of variation (COV) for repeated measures (COV=SD/Mean %) [5].

Table 1: COV for T1 and T2*

ROI	T1 COV (%)				T2* COV (%)			
	Peak Location	Peak Height	Median	Mean	Peak Location	Peak Height	Median	Mean
Left Caudate	**4.8%**	23.2%	**4.8%**	**4.5%**	**7.9%**	31.3%	**9.2%**	**4.5%**
Left Hippocampus	24.2%	21.4%	**8.8%**	**8.4%**	26.6%	26.7%	12.9%	**8.4%**
Left Putamen	12.3%	**6.0%**	**6.7%**	**6.4%**	**6.6%**	25.6%	**4.2%**	**2.9%**
Left Thalamus	8.7%	13.2%	**5.7%**	**6.2%**	**9.3%**	45.3%	**4.1%**	**4.0%**
Right Caudate	5.1%	21.6%	**4.6%**	**4.3%**	10.0%	33.9%	**3.4%**	**4.0%**
Right Hippocampus	27.2%	29.8%	**6.3%**	**5.5%**	16.2%	23.3%	**5.7%**	**4.6%**
Right Putamen	14.0%	23.6%	**8.6%**	12.2%	**4.1%**	23.8%	13.7%	13.5%
Right Thalamus	11.0%	19.2%	**6.3%**	**6.6%**	**8.6%**	19.2%	**9.9%**	**9.2%**
Mean ± S.D.	13.4 ± 8.3%	19.7 ± 7.2%	**6.5 ± 1.6%**	**6.8 ± 2.6%**	11.2 ± 7.1%	28.6 ± 8.2%	**7.9 ± 4.1%**	**6.4 ± 3.6%**

Results

Mean and median histogram metrics showed lower scan-rescan variability than peak height and location (Table 1). Similarly, mean and median ICC (~0.6±0.3 and ~0.5±0.3 for T2* and T1, respectively) reflected fair reliability for most ROIs. On the other hand, ICC for peak location (0.52±0.32 and 0.40±0.42 for T2* and T1, respectively) and peak height (0.19±0.24 and 0.13±0.40 for T2* and T1, respectively) showed lower reliability. Some regions, such as bilateral caudate, were more reproducible than others, such as right putamen (Fig. 1).

Conclusions

T1 and T2* mapping can play a key role in diagnosing and tracking various neurological diseases. This work suggests that in healthy subjects, T1 and T2* scan-rescan reliability is higher for mean and median histogram metrics relative to peak location and height. However, while some regions showed excellent reliability, many regions were only fairly reliable (0.4<ICC<0.75) despite a short interscan interval of one week. Caution should be taken when evaluating these measures in longitudinal studies that will compare measurements over longer periods of time. In addition to measurement instability, inconsistent registration for repeated scan sessions could be a source of error. B1 inhomogeneity can also play a role for inconsistency in bilateral measurements. Low reliability for some regions, such as right putamen, underscores the importance of comprehensive analysis in a static cohort of subjects in parallel with clinical studies before concluding that T1 and T2* changes are related to disease progression instead of measurement instability or registration inconsistencies.

References [1] van Walderveen *et al*. JMRI, 18:656–664 (2003). [2] Bauer *et al*. NeuroImage, 52: 508–514 (2010). [3] Jack *et al*. JMRI 27:685–691 (2008). [4] Shrout and Fless. Psychol Bull 86:420-428 (1979). [5] McLaughlin *et al*. European Heart Journal, 19(2):342-351 (1998).

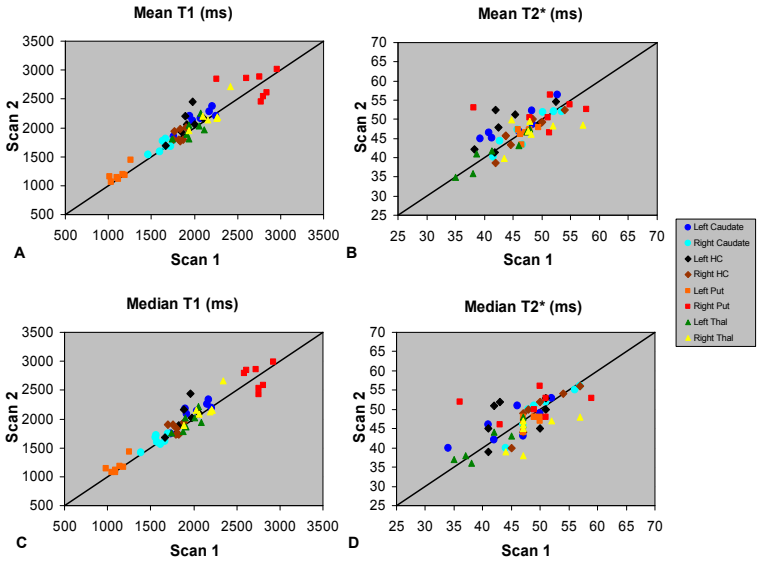

Figure 1: ROI scatter plots show fair reproducibility relative to identity line.