BETWEEN SESSION REPRODUCIBILITY AND BETWEEN SUBJECT VARIABILITY OF ABSOLUTE T1

J. Scholz[1], H. Johansen-Berg[2], and S. Deoni[2]
[1]Clinical Neurology, FMRIB Centre, Oxford, United Kingdom, [2]FMRIB Centre, United Kingdom

Introduction. T1 relaxation times provide quantitative assessment of pathology and have the potential to provide a measure of structural changes due to disease, recovery or learning. Until recently acquisition of T1 maps with high resolution and high SNR was clinically impracticable. The DESPOT1[1] protocol overcomes this limitation. As yet unknown, however, is the longitudinal reproducibility of T1 measurements. In this study we assess the practicability of DESPOT1 for longitudinal studies. Eight healthy subjects were scanned three times on three different days allowing the intra and inter-session reproducibility to be determined.

Methods. *Acquisition.* All data were acquired at 3 Tesla (Siemens Trio; 12-channel headcoil) on eight healthy adult volunteers (5 male, 3 female, 25 to 31 years of age). To account for transmit RF (B1) field inhomogeneties, the DESPOT1-HIFI method[2] was used, which combines DESPOT1 with at least one inversion-prepared (IR-)SPGR image allowing the calculation of B1, T1, and proton spin density. The imaging protocol included two SPGR (flip angles: 4° and 20°, 160 slices, 1x1x1 mm^3, TE/TR = 3.9 ms/9.1 ms) and one IRSPGR image (80 slices, 1x1x1 mm^3, TE/TR/TI = 3.9 ms/9.1 ms/450 ms, inversion time = 450 ms) per T1 map (acquisition time 11 minutes). For each subject three whole-brain T1 maps were acquired per day on three different days. *Analysis.* To account for subject motion and differences in image distortion, raw SPGR and IR-SPGR images were first coregistered before the nine T1 maps per subject were calculated. The resulting T1 maps were then aligned to the first T1 map of the first session to account for within-session movement and between-session differences in positioning of the subject. Both, the raw component images as well as the absolute T1 maps were coregistered using an affine algorithm with 12 degrees of freedom (FLIRT). To segment cortical and subcortical grey matter and white matter structures, synthetic T1-weighted images with high grey matter/white matter contrast were generated from the mean T1 map of each volunteer by substituting the voxel-wise T1 values into the expression $S_{synthetic} = 1000\ (1\text{-}2e^{-1800/T1}\ e^{-800/T1})$. The T1-weighted images were then used in Freesurfer to segment cortical and subcortical structures. We determined the mean and variability of T1 for 31 cortical (caudal anterior cingulate, caudal middle frontal, cuneus, …, transverse temporal) and six subcortical (Amygdala, Caudate, Hippocampus , Pallidum, Putamen, Thalamus) structures for individual subjects within session and across sessions. We repeated the analysis for white matter structures, such as cerebral white matter, cerebellar white matter and the corpus callosum.

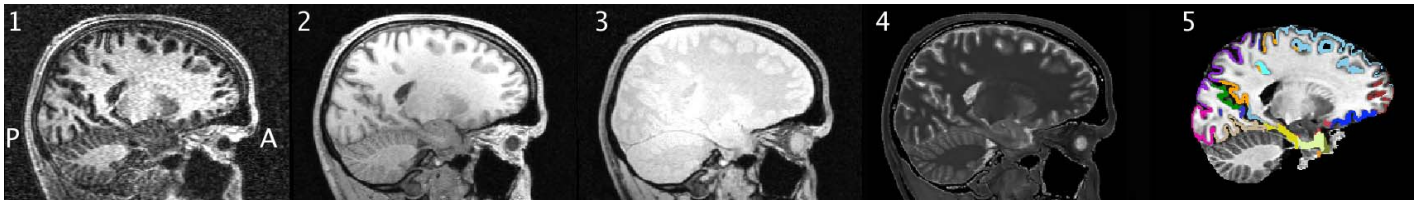

Figure 1: Illustration of the processing steps. From left to right: The IR-SPGR (1) and SPGR images (flip angles: 20° and 4°) (2&3) were used to calculate the T1 map (4). Cortical segmentation superimposed on a synthetic T1-weighted image (5).

Results. Within subjects and across days the coefficient of variation of T1 ranges from 2-4% for subcortical and from 3-5% for cortical structures. Across subjects and days, it ranges from 7-18% for subcortical and from 11-17% for cortical regions. T1 values in white matter structures have comparable variability within subjects (2-3%), but higher variability across subjects (17-24%). The results presented here were obtained using standard image processing steps. It is possible that optimized image processing would reduce this measured variability. In particular, our experience with the analysis of the T1 maps shows that it is essential to account for distortions caused by transmit field inhomogeneities by optimized image registration and that it is critical to remove contaminating cerebrospinal fluid (CSF) influence at a resolution of 1 mm^3. Thus non-linear registration methods might further improve the reproducibility between sessions by removing distortions and partial volume estimate maps may help to remove the contaminating influence of CSF on the tail of the T1 histogram.

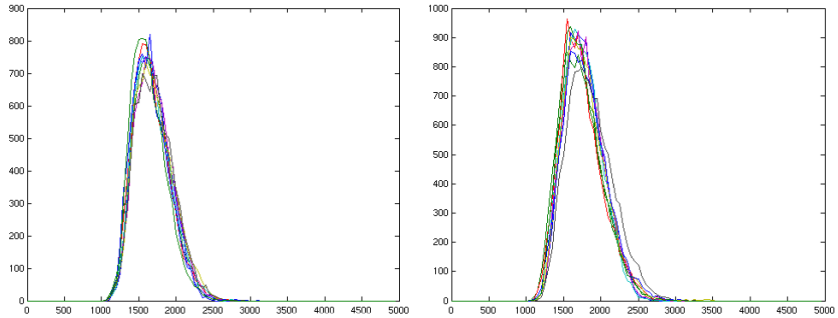

Figure2: Histograms of T1 values for the left superior parietal lobule and the left precentral gyrus for one subject and all nine acquisitions.

Conclusion. We have quantified the reproducibility and variability in T1 measurements over time and across individuals for cortical and sub-cortical grey matter regions as well as cerebral and cerebellar white matter regions. These values will be useful to determine power and sample size required to detect changes in T1 values over time. In combination with other markers of structural properties, such as T2, PD, and MT, these T1-maps might help to elucidate the processes underlying structural changes in the human brain.

References.

[1] Deoni et al. MRM 2003, 49:515-526.
[2] Deoni et al. JMRI 2007, 26(4):1106-11