MAGNETIZATION TRANSFER RATIO OF NORMAL APPEARING SUBCORTICAL BRAIN STRUCTURES IN MS PATIENTS MEASURED WITH BALANCED STEADY STATE FREE PRECESSION IMAGING

Michael Amann[1], Michaela Andelova[2], Athina Papadopoulou[2,3], Yvonne Naegelin[2], Julia Reinhardt[4], Katrin Weier[2], Ernst-Wilhelm Radue[3], Ludwig Kappos[2], Oliver Bieri[5], Christoph Stippich[4], and Till Sprenger[1]

[1]Neurology/Neuroradiology, UniversitÃ¤tsspital Basel, Basel, BS, Switzerland, [2]Neurology, UniversitÃ¤tsspital Basel, Basel, BS, Switzerland, [3]Medical Image Analysis Centre, Basel, BS, Switzerland, [4]Neuroradiology, UniversitÃ¤tsspital Basel, Basel, BS, Switzerland, [5]Medical Physics, UniversitÃ¤tsspital Basel, Basel, BS, Switzerland

Introduction

The magnetisation transfer ratio (MTR) is an MRI surrogate marker for demyelination and axonal loss in multiple sclerosis (MS) [1]. Compared to standard MTR imaging, MT-sensitized balanced steady-state free precession (bSSFP) offers three-dimensional images with high spatial resolution and short acquisition times [2]. This allows the combination of bSSFP MTR with other state-of-the-art 3D MR techniques such as Double Inversion Recovery (DIR) for improved detection of cortical lesions [3] or 3D T1w images for automatic and reliable segmentation of different brain structures. In the study presented here, we combined these three MRI sequences and tested a semi-automatic post-processing pipeline for calculating MTR values for subcortical brain areas on data of a MS patient cohort.

Subjects and Methods

75 MS patients (52 women; 59 RRMS, 12 SPMS, and 4 PPMS) participated in this study. Mean age was 48.0 years (range 23y-70y), mean disease duration was 16.7 years (range 4y-50y), and median EDSS was 3.0 (range 0-7.5). Only patients without an acute relapse in the preceding four weeks were included. All patients underwent a comprehensive MR examination on a 1.5 T MR scanner (Magnetom Avanto, Siemens Medical, Germany) including a 3D DIR sequence (TR/TI/TE = 7.5s/3.0s/307ms; spatial resolution 1.3x1.3x1.5 mm^3), a volumetric 3D-T1w scan (MPRAGE, TR/TI/TE/α = 2080ms/1100ms/3.93ms/15°; 1x1x1 mm^3), and the 3D bSSFP MTR sequence (TR/TE/α = 2.77ms/1.19ms/45°; 1.3x1.3x1.3 mm^3, ipat=2). The RF pulse duration (TRF) of the MT-sensitized acquisition was 0.12 ms; TRF of the non-MT-sensitized acquisition was 2 ms. Scan time for the bSSFP MTR scans (two acquisitions) was 4:14 min. All 3D sequences were acquired in sagittal orientation parallel to the inter-hemispheric fissure.

Post-processing of the image data was performed with AFNI [4] and FSL [5]. First, all data sets were interpolated to the same spatial resolution as the MT images; next, all volumes were realigned to the non-MT-sensitized data set. MTR maps were then calculated according to MTR = $(S_0-S_{MT})/S_0$. The 3D T1w volumes were segmented into grey matter, white matter and CSF with FAST [6], subcortical segmentation was performed using FIRST [7]. The subcortical segmentation masks were visually inspected and falsely classified voxel were corrected manually. MS lesions were outlined on the 3D DIR images using the semi-automatic contour software AMIRA (Visage Imaging Inc., San Diego, CA) and the respective lesion masks were aligned to the MTR maps using the transformation parameters for the DIR data sets. We calculated mean MTR for normal appearing WM, for normal appearing cortical GM (GM with exclusion of the substructures listed below), and for the hippocampus as well as for the following subcortical structures: nucleus accumbens, amygdala, caudate nucleus, pallidum, putamen, and thalamus. CSF and lesions were excluded by applying lesion masks and CSF masks onto the MTR maps. We analysed the mean MTR values by performing a one-way analysis of variance and used Tukey's multiple comparison test to find significant differences between the MTR of the different brain structures.

Results

As an example, subcortical structures are overlaid on a 3D MTR map in Fig.1. The mean MTR and the standard deviations of the different brain structures are shown in Fig. 2 and in Tab.1. As expected, WM had the highest MTR and differed significantly from all other structures. No significant differences were found between the MTR of cortex, hippocampus and pallidum, as well as between caudate nucleus and putamen. The nucleus accumbens had the lowest MTR values and differed significantly from all other brain structures. The MTR of the thalamus was also significantly different from all other structures, and the MTR value was closer to WM MTR than to the MTR of cortex.

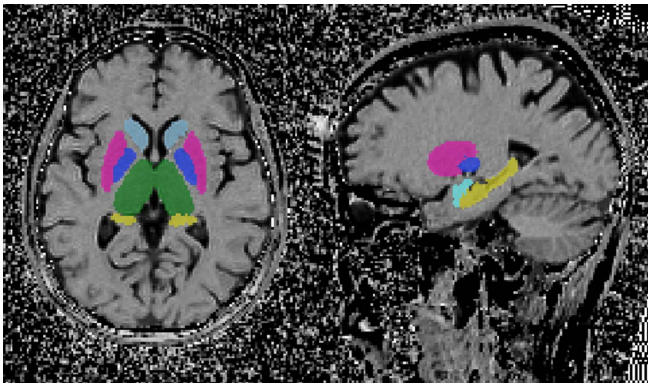

Fig.1: Subcortical segmentation overlaid onto a 3D MTR map. Left: transversal view; right: sagittal view

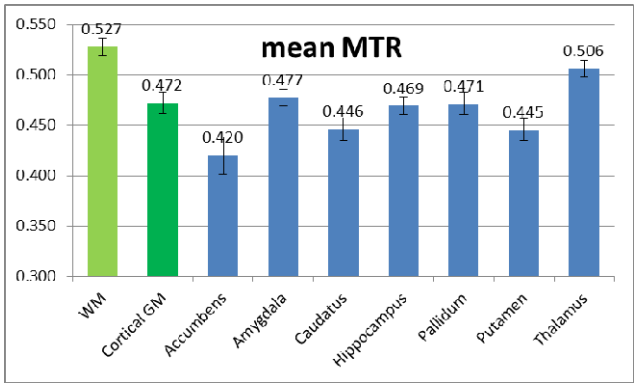

Fig. 2: MTR values for the different brain structures. WM: normal-appearing white matter, GM: normal appearing grey matter

	WM	Cortical GM	Accumbens	Amygdala	Caudatus	Hippocampus	Pallidum	Putamen	Thalamus
Mean	0.527	0.472	0.420	0.477	0.446	0.469	0.471	0.445	0.506
SD	0.008	0.010	0.018	0.008	0.012	0.009	0.011	0.011	0.008

Tab. 1: mean MTR and standard deviation (SD), same structures as in Fig.2.

Discussion

In our study, we were able to demonstrate the feasibility of a semi-automatic post-processing pipeline for calculating MTR values in a relatively large cohort of MS patients. Only little manual correction was necessary by outlining the MS lesions and sparse correction of the subcortical segmentation. Mean MTR of the deep GM structures were in general closer to those of the cortical GM than to those of the WM, with the exception of the thalamus. Similar results were found in a study with 12 healthy subjects using the same bSSFP MTR technique [8]. Next, we plan to correlate individual MTR of the substructures with measures of clinical disability such as the EDSS or MSFC.

References

[1] Grossman RI. Ann Neurol. 36:S97-9; 1994.
[2] Bieri O., Scheffler K. Magn Reson Med. 58(3):511-8; 2007.
[3] Geurts JJ. et al. Radiology 236(1) : 254-269; 2005.
[4] Cox RW. Comput. Biomed. Res. 29:162-173; 1996.
[5] Smith SM. et al. NeuroImage, 23(S1): 208-219; 2004.
[6] Zhang, Y. et al. IEEE Trans Med Imag, 20(1):45-57; 2001.
[7] Patenaude B. et al. NeuroImage 56(3) : 907-922; 2011.
[8] Garcia M. et al. Neuroradiology 53 :159-167; 2011