Correction and Normalization of Magnetization Transfer Ratio Maps for Quantitative Analysis

S. Volz[1], U. Nöth[1], A. Rotarska-Jagiela[2], and R. Deichmann[1]
[1]Brain Imaging Center (BIC), Goethe University Frankfurt, Frankfurt am Main, Germany, [2]Department of Neurophysiology, Max Planck Institute for Brain Research, Frankfurt am Main, Germany

Introduction Magnetization Transfer (MT) imaging is of increasing interest in neuroimaging, yielding important information, e.g. about myelin integrity in the central nervous system [1, 2]. However, a quantitative analysis of the MT ratio (MTR) is affected by several problems, especially at high field strengths: B1 inhomogeneities influence the MT saturation angle, biasing MTR values. High specific absorption rates (SAR) may require a reduction of the saturation angle for individual subjects, impairing comparability of results in longitudinal studies. Purpose of this study was (1) to determine calibration parameters valid at 3 Tesla to correct for B1 bias in MTR maps similar to a method described for 1.5 Tesla [3], and (2) to test if MTR data acquired at 10% and 20% lower MT saturation angles can be normalized to allow for comparison with data acquired at the full angle.

Materials and Methods Measurements were performed on a 3T whole body MR scanner (receive-only 8-channel array head coil, body coil transmission). The following measurements were performed on six healthy volunteers: for B1 mapping a magnetization prepared multislice FLASH sequence with centric phase encoding (PE) and slice selective RF pulses was used [4]. Imaging parameters were: matrix 44x64, FoV 176x256 mm^2, in-plane resolution 4 mm, 44 transverse slices, 3 mm thickness, TR/TE/FA/BW=11ms/5ms/11°/260Hz/Pixel. The acquisition was performed twice, once without and once with a slice selective magnetization preparation pulse (angle 45°), and B1 was obtained from the quotient of image intensities. The total experiment duration for both acquisitions was 46s. MT measurements were performed using a 3D FLASH sequence. Four data sets were acquired per subject: one without MT pulse and three with nominal MT pulse angles of α=[800°, 900°, 1000°]. Imaging parameters were: matrix 176x256, FoV 176x256 mm^2, in-plane resolution 1 mm, 44 transverse slices, 3 mm thickness, TR/TE/FA/BW=25ms/4.08ms/15°/112Hz/Pixel. The duration for each measurement was 4min 6s. For each nominal MT pulse angle α, the respective map MTR_α was calculated in percentual units (pu), yielding for each pixel three MTR values for three different effective MT pulse angles $\alpha_{eff} = \alpha$*B1, where the local B1 followed from the respective map. Linear fitting and extrapolation to a reference angle of α_0=1000° resulted in the map MTR_{ref}, i.e. the MTR map that ideally would have been achieved for this angle in the absence of any B1 inhomogeneities. Relative MTR maps were calculated from $MTR(\alpha_{eff})/MTR_{ref}$ and pooled across all subjects. Assuming a linear dependence [3], relative MTR data were fitted and the average slope value m(AV) was calculated. The B1 maps and m(AV) were subsequently used to calculate normalized maps $MTR_{norm,\alpha}$ according to $MTR_{norm,\alpha} = MTR(\alpha_{eff})/[1\text{-}m(AV)+m(AV)* \alpha_{eff}/ \alpha_0]$ for each subject and MT pulse angle, representing MTR maps that are corrected both for B1 inhomogeneities and deviations of the MT angle from the reference value α_0=1000°.

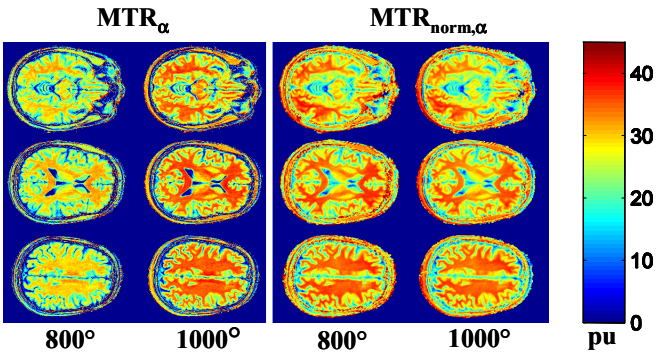

Fig 1: Three different slices for a representative subject from the uncorrected MTR maps acquired with saturation angles of 800° and 1000° (left) and from the respective MTR maps normalized to 1000° (right).

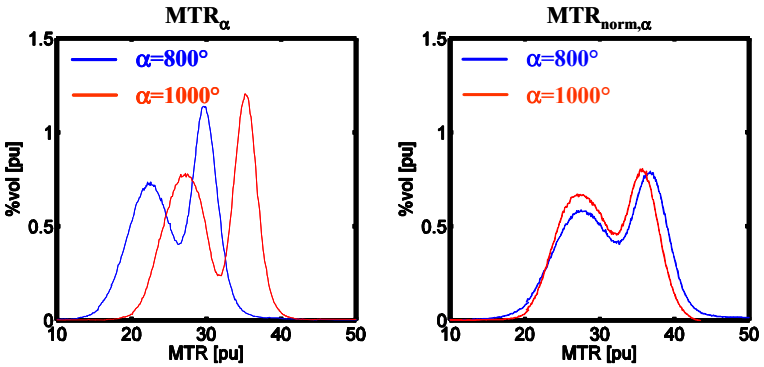

Fig 2: Histograms of MTR values for all voxels containing white matter and grey matter, averaged across all subjects referring to uncorrected (left) and normalized (right) data measured with saturation angles of 800°, and 1000°.

Results A linear dependence of the relative MTR data on the effective MT pulse angle was found and an average slope of m(AV)=0.81 was determined across subjects and tissue types with negligible tissue dependence, in good agreement with results published for 1.5 Tesla [3]. Figure 1 shows different slices of uncorrected (left) and normalized (right) MTR maps for a representative subject, acquired with saturation angles of 800° and 1000°. As can be seen, the uncorrected maps are not directly comparable, but there is good agreement of the normalized maps. For a more quantitative analysis, Fig. 2 shows histograms of MTR values for all voxels containing white matter (WM) and grey matter (GM), averaged across all subjects for saturation angles of 800° and 1000°. In contrast to the histograms of uncorrected data (left), histograms of the normalized data (right) are nearly identical. This can also be seen by calculating mean MTR values (in pu) for different tissue types and saturation angles: without correction, the mean MTR values in WM for 800° and 1000° are 29.60±2.05 and 34.85±1.77, respectively. In GM, the respective values are 22.30±3.67 and 26.68±3.03. For the normalized data sets, values of 35.47±2.67 and 35.04±2.48 were determined in WM and 26.84±4.32 and 26.97±3.22 in GM. The histograms do not show a reduction of the full width at half maximum (FWHM) after B1 correction, an effect which has been reported before [5] and is probably due to anatomical MTR variations [3].

Discussion Results show that the calibration data determined in this study for a field strength of 3 Tesla allow for two types of MTR map correction: (1) Correction for B1 inhomogeneities; (2) Normalization of MTR maps acquired with a reduced preparation pulse angle to allow for direct comparison with maps acquired at the full angle. This normalization is of particular importance for longitudinal studies, allowing for the inclusion of data that had to be acquired with reduced saturation angles due to SAR restrictions.

References [1] Mottershead et al., 2003. Journal of Neurology 250, 1293-1301. [2] Schmierer et al., 2004. Annals of Neurology 56, 407-415. [3] Samson et al., 2006. MRImaging 24, 255-263. [4] Vaughan et al., 2001. MRM 46, 24-30. [5] Ropele et al., 2005. MRM 53, 134-140.