Evolution of Multiple Sclerosis Lesions: Preliminary Results from Quantitative Magnetization Transfer Imaging

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Target Audience. Multiple sclerosis (MS) lesions are commonly assessed by conventional PD-, T2- and T1-weighted (w) images, but this approach provides only limited information about the extent of white matter (WM) damage and repair. In contrast, magnetization transfer (MT) imaging promises increased pathologic specificity for the characterization of MS lesions and could therefore have an essential impact on the diagnosis and management of MS.

Purpose. Lesional MT ratio (MTR) changes have been reported prior to the appearance of MS lesions on contrast enhancing (CE) (1) and T2w imaging (2). However, as conventional MTR is thought to reflect a combination of sequence, relaxation and quantitative magnetization transfer (qMT) parameters, contributions from myelination and inflammation cannot be separated. In contrast, quantitative MT (qMT) imaging provides information about the ratio (F) of the restricted to the free proton pool size, the exchange rate (kf) between the two proton pools, and T1- and T2-relaxation times (3). In this study, whole brain high-resolution qMT is analysed in MS lesions with balanced steady-state free precession (bSSFP) in a clinical setting (4).

Methods. Nine patients with clinically active relapsing MS (m:f = 4:5 m, mean age 42 years) are investigated on a 1.5T MR scanner every other month (months 0, 2, .. 12). We show the preliminary results of the first patient having finished six examinations. Each examination consisted of a standard MS MRI protocol including PDw/T2w, FLAIR and T1w-/+ CE sequences. QMT imaging included a B1 map, two RF spoiled gradient echo sequences with variable flip angles for T1 determination (5), 2 bSSFP sequences with variable flip angles for T2 determination (6), and 9 bSSFP scans using different RF pulse durations (T_{RF} = 120µs - 1500µs) and different flip angles (α = 5° - 35°) respectively, to yield F, kf and MTR (4). QMT imaging was acquired within less 10 minutes with an isotropic resolution of 1.3 mm. Lesions were semi-automatically segmented on whole-brain PDw and T1wCE images. The respective set of lesions was superimposed on the MT images of the various MR examinations. Homologous normal appearing WM (NAWM) regions of interest (ROIs) in the contralateral hemisphere served as a reference.

Results. In the four homologous NAWM ROIs, qMT parameter differences relative to month 0 were 5-16% on average, and MTR varied by 1-4%. MS lesions not visible at months 0-2 on PDw are shown in Fig. 1a and b. Lesion 1 (Fig. 1a) had normal qMT values with up to 10% difference to NAWM, while lesion 2 (Fig. 1b)

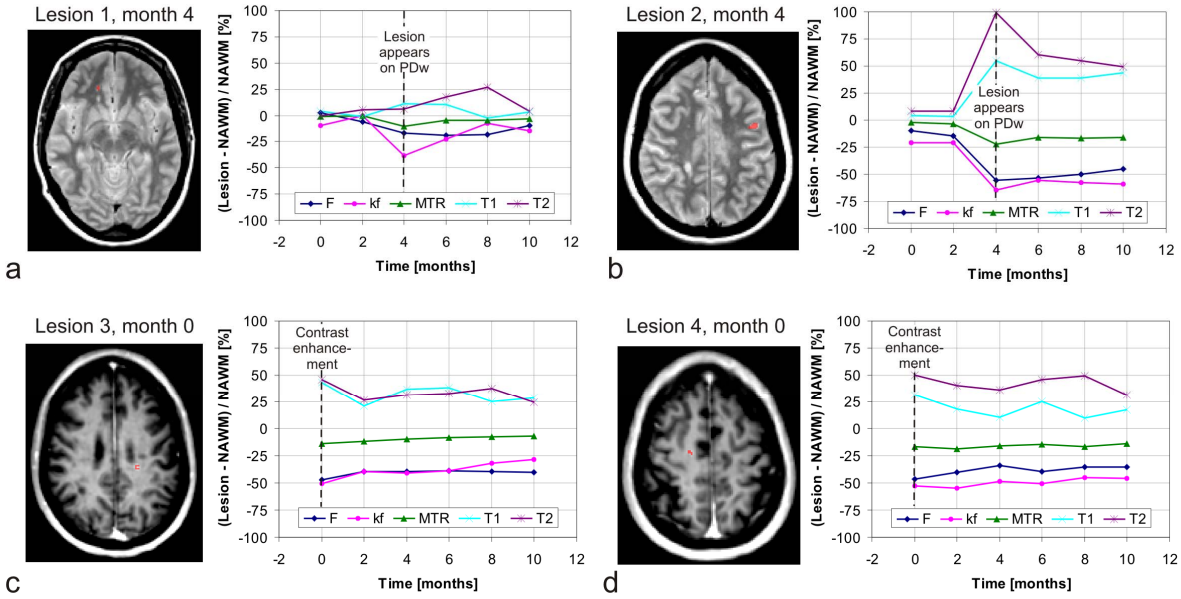

Fig 1. Axial PDw images (a,b) and T1w CE images (c,d) of different MS lesions with the ROI superimposed on the selected MS plaque. Corresponding MT-values at the different time points are shown next to the MR images. The values are given as relative difference to a homologous NAWM region.in the contralateral hemisphere.

showed differences of up to 21%. At the time point of appearance on PDw, F and kf were decreased and relaxation times prolonged. These effects were much more pronounced in lesion 2 (54-99% differences) compared to lesion 1 (6-39% differences). A much smaller change was observed for MTR (reduced by 11% for lesion 1 and 22% for lesion 2). The lesions remained invariably hyperintense on PDw in months 4-10. With qMT, lesion 1 showed a tendency to return to normal values (0-14% differences at month 10), whereas lesion 2 continued demonstrating abnormal values (44-59% differences at month 10). In Fig. 1c and d, two CE lesions at month 0 are studied, showing highly abnormal qMT values at the same time: F and kf were decreased by about 50%, relaxation times were prolonged by 30-50%, whilst only little change was observed for MTR (~ 15%). Although the CE was no longer visible in the follow-up examinations, qMT indicated persistent lesion activity, reflected by sustained pathological qMT values, only showing a slight tendency towards normalization at month 8 and 10 (24-40% differences for lesion 3 and 17-46% for lesion 4).

Discussion. Despite its lower stability, qMT provides more detailed information about myelination and water properties of the individual lesion than MTR (1-3). In contrast to previous studies (6-8), fast qMT-bSSFP provides information on the whole brain within 10 minutes. Once a lesion is detected, qMT enables the tracing of the evolution and estimation of the contribution of the macromolecular content of MS lesion, which appear unchanged on PDw images. In addition, lesions losing CE properties may still possess a significant degree of inflammation and thus be considered highly active over time, as shown by the persisting abnormalities on qMT imaging.

Conclusion. Fast high-resolution whole brain qMT imaging with bSSFP provides clinically useful information, complementary to conventional MTR. It provides a mean to track the microstructural evolution of individual MS lesions. Such changes, not discernible with conventional MRI, emphasize the diagnostic potential of qMT imaging. As a result and in the light of the short acquisition time, qMT might be a useful addition for the diagnostic assessment and treatment monitoring in MS.

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