In-vivo 3D Multi-component T2-Relaxation Measurements for Quantitative Myelin Imaging at 3T

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Introduction: Over the last few years, a variety of MR-techniques have been proposed to separate the short T2-component attributed to myelin water (<40ms) in human brain tissue from intra/extra cellular water (T2>50ms) as well as other long T2-components (>200ms) [1-3]. However, the single slice CPMG-multi-echo sequence is still the "gold standard" [4]. The disadvantage of this method is its very long acquisition time (20-30min) to avoid T1-weighting and its limitation to only acquire one slice at a time. Faster multi-slice techniques are susceptible to magnetization transfer effects and often don't provide the necessary signal-to-noise (SNR) or do not separate the small contribution of the myelin-water signal (<15%) sufficiently well from the other dominating T2-components.

Methods: The reference single slice 32-echo CPMG sequence [4] was modified in two distinct ways:

a) phase encoding lobes along Gz were added to encode the data in 3D k-space. The initial slice selective 90°- pulse was replaced with a 90°-slab selective pulse and large alternating-descending crusher gradients Gz were applied before and after each refocusing radiofrequency pulse to remove unwanted signal from outside the selected slab.

b) the composite rectangular refocusing pulses were replaced by slice selective pulses, to allow for better signal cancellation from out of slab signal and to substantially reduce SAR. Because the slice selective refocusing-pulses were longer, the Gz crushers were shortened to maintain the same echo spacing. The refocusing pulse angle was optimized on a large spherical phantom prior to the in-vivo measurements.

Imaging parameters, except TR (due to SAR limitations), were kept the same for both sequences: acquisition matrix 256x128, 32 echoes at ΔTE=10ms, TR=1600ms (a)/ 1200ms (b), receiver bandwidth=100 kHz, NSA=1, k-space undersampling=0.75, 12 slices at 3mm (overcontiguous). All measurements were performed on a Philips Intera 3T whole body system operating at release level 10.4.3 with an eight-channel phased array head coil (6 receive channels) in quadrature mode. The total acquisition time for the sequences was 16 min (a) and 12 min (b), respectively.
The 32-echo T2-decay curves were analyzed on a per pixel basis with a regularized non-negative least square algorithm (NNLS) such that the range of chi^2 misfit was between 1.02 and 1.025. The sequences were tested on 6 healthy volunteers.

Results: Both sequences gave a reasonable performance in their ability to produce T2-echo decay curves without significant off-resonance effects or stimulated echo contamination, although the first echo point in sequence (b) was sometimes lower than that in sequence (a) for specific brain regions, indicating B1 inhomogeneities and consequently leading to a slightly smaller myelin water fraction (MWF). Myelin water fractions based on individual ROI's were in agreement with reported literature values at 3T [3] but slightly larger than at 1.5T [4], especially in grey matter structures.

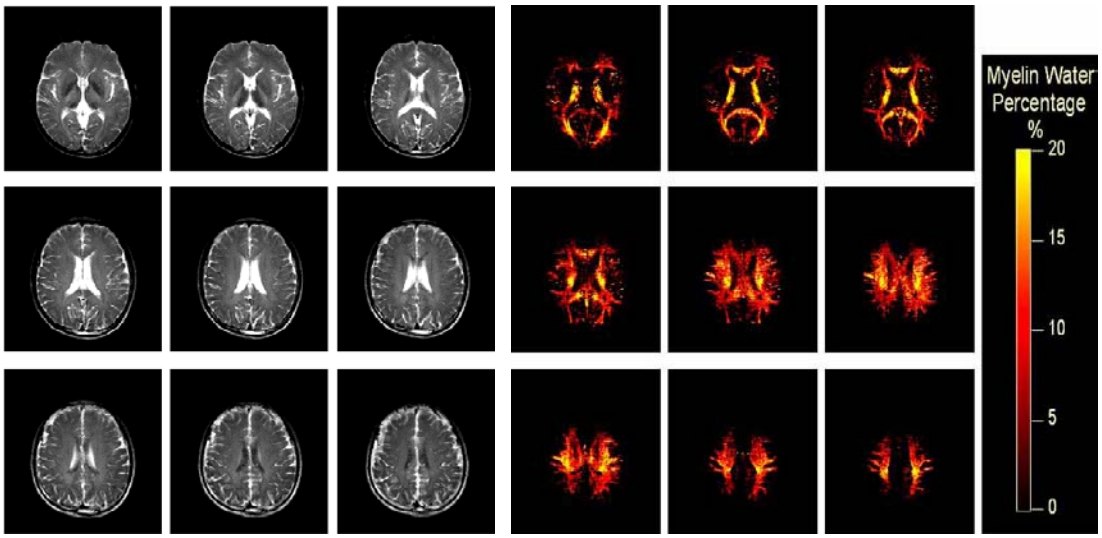

Fig.1: a) T2W images at TE=80ms (only 9 out of 12 slices shown)

b) MWF-maps based on integration of the T2-distribution amplitudes between 12-35ms (fat signal was eliminated from the myelin maps by post-processing segmentation)

	MWF ± sdev
min. forceps	6.9 ± 3.4
maj. forceps	10.8 ± 2.3
genu	9.0 ± 1.2
splenium	14.7 ± 1.5
inter. capsules	14.8 ± 2.0
parietal WM	12.1 ± 0.5
occipital WM	10.3 ± 2.3
caudate	4.9 ± 1.2
putamen	3.5 ± 2.2
thalamus	6.8 ± 2.8
ins. cortex	2.9 ± 1.7
cingulate gyrus	0.5 ± 0.6

Tab.1: Mean Myelin Water Fractions (MWF) and SD from 6 healthy controls

Conclusion: 3D acquisition techniques provide an accurate and reliable way to carry out multi-component T2 measurements over most of the brain volume in a clinical acceptable time (<20min). RF deposition for multi-spin echo sequences is a concern, especially at higher field strength. We have shown that, by replacing composite hard-pulses with less SAR sensitive slab selective pulses, high quality multi-echo decay curves can still be obtained when a body coil with uniform B1 homogeneity over the brain volume is used. Geometric mean T2 measurements were in agreement with previously published mono-exponential T2 data [5-7]. MWF were on average slightly higher than reported values at 1.5T but were in agreement with published data at 3T [3].

References: [1] Vidarsson et al. Proc. ISMRM 11 (2004); [2] Jones et al., MRM 51:495-502 (2004); [3] Oh et al., Proc. Intl. Soc. Mag. Reson. Med. 13: 759 (2005); [4] Whittall et al., MRM 37: 34-43 (1997); [5] Gelman et al., Radiology 210: 759-767 (1999); [6] Wansapura et al., JMRI 9: 531-538 (1999); [7] Hanzhang et al., JMRI 22: 13-22 (2005)