IN VIVO MYELIN WATER IMAGING USING Z-SHIMMED MULTI-GRADIENT-ECHO PULSE SEQUENCES AT 3T

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Introduction. Quantitative imaging of the myelin water fraction (MWF) is able to show demyelinating processes and therefore provides insight into the pathology of white matter (WM) diseases such as multiple sclerosis. So far, mapping of the MWF most often was performed using a multi-echo spin-echo sequence and fitting the biexponential T_2 decay with a non-negative least-squares algorithm (1). In this work, a different approach is presented using multi-gradient-echo pulse sequences. This method has been introduced by one study measuring formalin-fixed brains (2). We present a solution for in vivo measurements using z-shimming as a correction for magnetic field inhomogeneities.

Methods. Experiments were performed on a 3T system on healthy volunteers based on a single slice 192x144 matrix with $1.5\text{x}1.5\text{mm}^2$ resolution and 4mm slice thickness. The multi-gradient-echo sequence had alternating readout gradient polarities and consisted of 96 different echo times with a first echo time of 2.19ms and an echo spacing of 1.54ms. Moreover, TR was 350ms, the flip angle was chosen to be 46° and 2 averages were recorded per image. This measurement was repeated 12 times with different z-shim acquisitions having nominal z-gradient refocus lobes varying between 40 and 150% (3). Adjacent acquisitions were then combined offline using the maximum intensity projection (MIP) method (4), where $I_{c(1\text{-}N)}$ are the N compensated gradient-echo images (Eq. [1]). Additionally, an inversion-recovery turbo-spin-echo (IR-TSE) sequence was used for segmentation of white matter. Total scan time was 20min. The T_2^* decay was fitted pixelwise using a two pool WM model consisting of a short pool (myelin water, T_2^*<40ms) and a long pool (intra- and extracellular water, T_2^*>40ms), and with the help of a non-linear least-squares algorithm. The fit equation can then be described as proposed in Eq. [2], where c is a residual baseline signal. The MWF is calculated according to Eq. [3].

$$S_{MIP} = \max[I_{c1}, I_{c2}, \ldots, I_{cN}] \quad [1]$$

$$S(TE) = A_S\, e^{-TE/T_{2,s}^*} + A_l\, e^{-TE/T_{2,l}^*} + c \quad [2]$$

$$MWF[\%] = \left[A_s / (A_s + A_l)\right] \cdot 100 \quad [3]$$

Results & Discussion. Fig. 1B shows T_2^* decay curves for 3 ROIs. Especially in midbrain regions (1. ROI) the z-shim correction seems not to be important, whereas in fronterior and posterior WM an essential difference between uncorrected and corrected signal curves is observed. The pixelwise fit results of one volunteer are presented in Fig. 2. In Fig. 2A, the T_2^* time series was corrected with the z-shim method. Averaged fit results over all WM pixels and corresponding standard deviations are: 12.2±2.7ms for the short T_2^* component, 63.9±12.0ms for the long T_2^* component and 10.1±2.6% for the MWF. The results for the myelin water fraction correspond well with literature values (5<MWF<25%) and agree as well with the results from (2). Fig. 2B shows the pixelwise fit results for the uncorrected time series. One might notice that the fit is not conducted in many regions because of too high standard errors. Therefore, the z-shim correction becomes necessary in order to get reliable fit results.

Conclusion. We present a new solution to in vivo imaging of the myelin water fraction based on T_2^* mapping and z-shimming. Our results show that correcting field inhomogeneities is essential for two pool T_2^* evaluations. Despite long acquisition times, z-shim corrected T_2^* mapping has the advantages of a short first echo time and short echo spacing and might provide an alternative to conventional multi-echo spin-echo sequences.

References. 1. MacKay et al., *MRM* **31** (1994) 2. Du et al., *MRM* **58** (2007) 3. Frahm et al., *MRM* **6** (1988) 4. Constable et al., *MRM* **42** (1999)

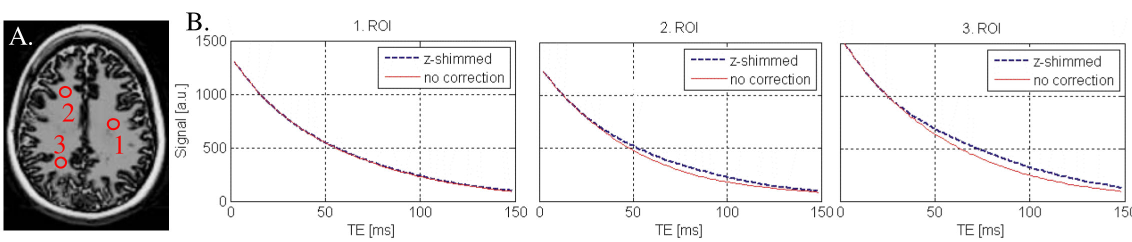

***Fig.1: A:** T_1-weighted IR-TSE transversal image, which was used for WM segmentation. The red circles represent the positions of the 3 ROIs. **B:** T_2^* decay curves of the 3 ROIs with z-shim correction (blue) and without correction (red).*

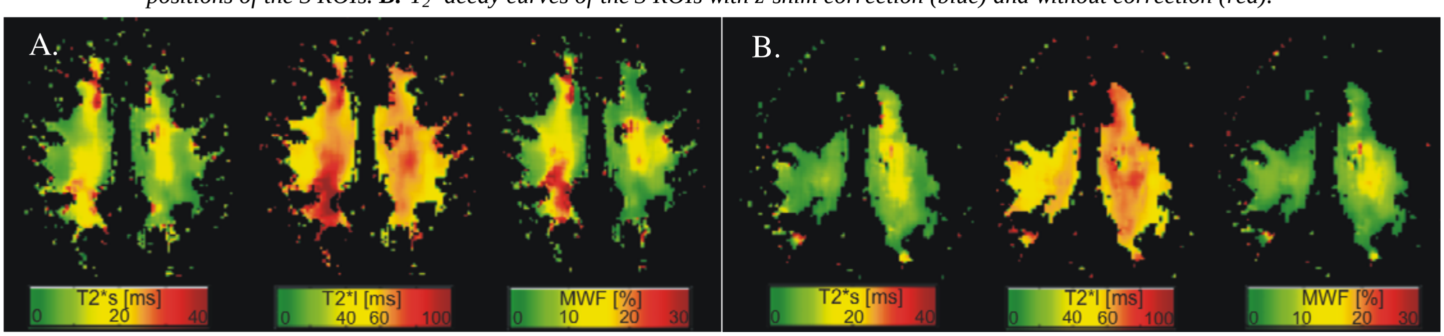

***Fig.2: A:** Pixelwise fit results from one volunteer (with z-shim correction) showing transversal maps of the two T_2^* components and the MWF.*
***B:** Pixelwise fit results without correction for magnetic field inhomogeneities.*