Fast proton density mapping using bias field correction

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Introduction: Mapping of the proton density (PD) in human brain tissue allows for the determination of local water content, for example in human acute stroke [1] and in tumour patients [2]. In general, PD is derived from relaxometry data in the following way: the dependence of image intensities on tissue parameters is described by MF·f(T1,T2*) where f depends on the relaxation times and MF is a multiplication factor. Fitting yields maps of the relaxation times and MF, the latter parameter being directly proportional to PD. However, MF is biased by several other parameters requiring correction [3], such as the sensitivity profiles of the transmit coil (B1) and of the receive coil (S_{Rec}). The determination of S_{Rec} can pose problems, and is either based on phantom data [2] or on the reciprocity principle [4], assuming that B1 and S_{Rec} are identical [3, 5]. As shown recently, B1 mapping is possible by creating synthetic anatomical data sets with a B1 bias and determining the bias field during tissue segmentation [6]. The purpose of the study presented here was to apply this concept to the determination of S_{Rec} and to base quantitative PD mapping on a T1 mapping sequence presented recently [7] with whole brain coverage and an isotropic resolution of 1 mm.

Materials and Methods: Measurements were performed on four healthy volunteers, using a 3T whole body MR scanner (body coil transmission, 8-channel phased-array head receive coil). T1 mapping with whole brain coverage and 1 mm isotropic resolution was based on the variable flip angle technique with a spoiled FLASH-EPI hybrid readout for increasing the SNR [7]. Parameters were: TR/TE/FA1/FA2 = 16.4ms/6.7ms/4°/24°, matrix size 256x224x160, 1 mm isotropic resolution, BW=222Hz/pixel. B1 mapping was based on the technique proposed in [8]. For T2*-mapping, two FLASH scans with different TE (4.3ms/11ms) were performed (matrix size 112x128, FoV 224x256 mm^2, in-plane resolution 2 mm, 80 transverse slices, 2 mm thickness, TR/FA/BW=16.7ms/50°/292Hz/pixel). The total acquisition time for all scans was 15min 40sec. PD was calculated according to the following four steps. **Step 1:** T1 maps with corrections for B1 inhomogeneities and insufficient RF spoiling were calculated according to [7]. T2* maps were obtained from the FLASH images. **Step 2:** The function $f(T1,T2^*)=\sin\alpha\cdot(1-\varepsilon1)/(1-\varepsilon1\cdot\cos\alpha)\cdot\varepsilon2$ with $\varepsilon1=\exp(-TR/T1)$, $\varepsilon2=\exp(-TE/T2^*)$ was calculated for the data set acquired with FA=4°. Pixelwise division of the image intensities in this data set by the calculated f-values yielded maps of $MF=C\cdot PD\cdot S_{Rec}$, C being a scaling constant. **Step 3:** A synthetic T1-weighted anatomical data set was calculated by multiplying the MF map with a function of T1. This data set was segmented using SPM8 and the bias field was determined. Since S_{Rec} is the only residual bias in the synthetic anatomical scan, it can be expected that the bias field represents the coil inhomogeneity, as described in [6]. **Step 4:** The MF map was corrected on the basis of the bias field and converted into a PD map by normalization, setting the mean value inside a ROI containing the ventricles to 1. PD values were evaluated in different ROIs. The PD evaluation was repeated without the bias field correction and the results with and without correction were compared histographically for a brain mask containing white and grey matter only.

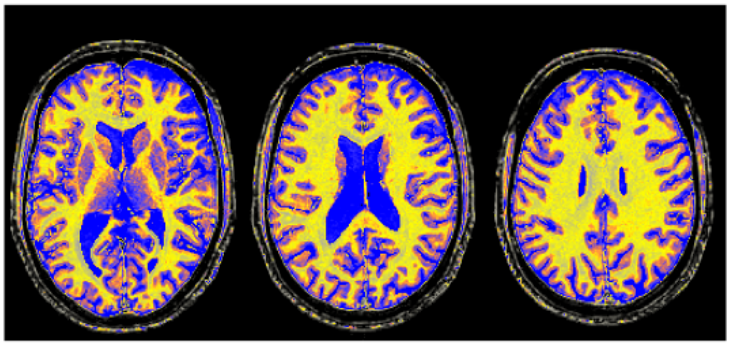

Fig 1: Three different slices from the PD map with correction for coil inhomogeneities for a representative subject.

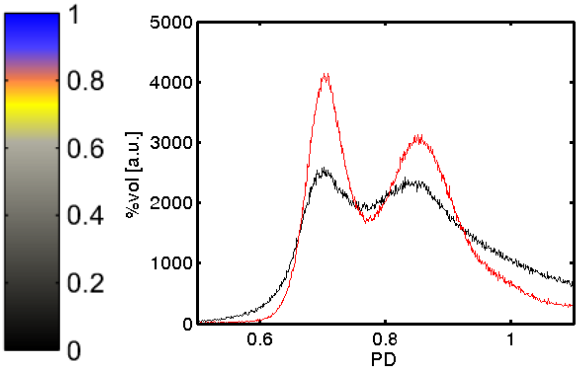

Fig 2: Histograms of PD values for all voxels containing white matter and grey matter, for uncorrected (black) and corrected (red) data.

Results Figure 1 shows for a representative subject three different slices of the PD map with correction for coil inhomogeneities. The ROI analysis yielded the following values (mean ± SD across all subjects): Occipital white matter: 0.653±0.003, Frontal white matter: 0.703±0.010, Caudate Nucleus: 0.832±0.022. These values are in very good agreement with the literature [5]. Figure 2 shows histograms of PD values in white and grey matter for data corrected for coil inhomogeneities (red) and for uncorrected data (black). Without correction, the width is increased and there is a stronger overlap between white matter and grey matter values.

Discussion The results show that reliable PD maps can be calculated from quantitative T1 mapping data based on the variable flip angle approach. In particular, the correction for the receive coil inhomogeneity does not require additional measurements, but can be based on bias field correction of a synthetic data set. The total scan time for whole brain coverage and an isotropic resolution of 1 mm was 15min 40sec.

References [1] Gideon et al., 1999, MRI 17: 301-304. **[2]** Neeb et al., 2006, NeuroImage 31:1156-1168. **[3]** Warntjes et al., 2007, MRM57: 528-537. **[4]** Hoult, 2000, ConcMagnReson 12: 173-183. **[5]** Neeb et al., 2008, NeuroImage 42: 1094-1109. **[6]** Weiskopf et al, 2010. Proceedings of ISMRM, 1914. **[7]** Preibisch et al., 2009. MRM 62, 240-246. **[8]** Volz et al, 2010. NeuroImage 49, 3015-3026.