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 (SR). The determination of SR can pose problems, and is either based on phantom data [2] or on the reciprocity principle [4], assuming that B1 and SR 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 SR 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°/22°, 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 mm², 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(1-e1)/(1-e1-cos⁡(ε2) with e1=exp(-TR/T1), e2=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 PD SR, 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 SR 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.

Results Figure 1 shows for a representative subject three different slices of the PD map with correction for coil inhomogeneities for a representative subject.

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

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.