High-Resolution T1 Mapping with Incorporated Transmit Radio Frequency Field Inhomogeneity Correction

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Introduction: T_1 determination via DESPOT1[1] involves acquisition of at least two spoiled gradient recalled echo (SPGR) images with varied transmit flip angle (α_T) and constant repetition time (TR). From these data, T_1 and proton density (〉) may be calculated from the slope and intercept of the linear S_{SPGR} / tanα_T vs. S_{SPGR} / sinα_T curve, where

$$S_{SPGR} = \rho\ [1-\exp(-TR/T_1)]\sin\langle_T\ /\ 1-\exp(-TR/T_1)\cos\alpha_T, \qquad [1]$$

as T_1 = -TR / log(slope) and ρ = intercept / (1-slope).

As T_1 is calculated directly from the S_{SPGR} / tanα_T vs. S_{SPGR} / sinα_T line, the derived value depends critically on correct knowledge of α_T - generally assumed to be spatially uniform and equal to the prescribed value, α_P. At high field strengths (i.e. 3T and above), or with non-symmetric RF coils, the uniformity of α_T cannot be guaranteed and α_T calibration becomes necessary. Unfortunately, existing α_T mapping methods[2,3,4] suffer lengthy scan times or geometric distortions, reducing their clinical appeal. Here we present an alternative approach (DESPOT1-HIFI - *DESPOT1* with *H*igh-speed *I*ncorporation of transmit *F*ield *I*nhomogeneity), involving the acquisition of an inversion-prepared SPGR (IR-SPGR) image alongside the conventional multi-angle DESPOT1 data. From these combined data, α_T and T_1 can be determined with high accuracy and precision.

Methods: IR-SPGR involves application of a π inversion pulse, a delay of TI, and a train of low angle RF pulses, separated by TR, which sample successive *k*-space lines. If the centre of *k*-space is acquired immediately following each π pulse, the IR-SPGR signal can be approximated as

$$S_{IR\text{-}SPGR} = \rho[1-(1-\cos\kappa\pi)\exp(-TI/T_1) + \exp(-Tr/T_1)]\sin\kappa\alpha_P \qquad [2]$$

where Tr is the time between π pulses and κ denotes the spatially varying α_T profile ($\alpha_T = \kappa\alpha_P$). A unique solution for T_1, ρ and κ can be determined via least-squares minimization of Eqns. [1] and [2] with the measured data.

To demonstrate the DESPOT1-HIFI method, whole-brain T_1 maps were calculated from data acquired of two healthy volunteers (aged 25 and 29) with a 22cm^2 x 13cm FOV, 256x256x142 matrix, ±18kHz bandwidth, and the following specific parameters, *SPGR:* TE/TR = 1.8ms/6.98ms, α_P = 4° and 18°, *IR-SPGR:* TE/TR/TI = 1.8ms/6.98ms/450ms, α_P = 5°. Since κ was not expected to rapidly vary, the IR-SPGR data were acquired with a 256x128x76 matrix and zero-padded to full size prior to Fourier reconstruction. Total time for the DESPOT1-HIFI collection was 10:40. For reference, T_1 maps were also calculated from multiple TI inversion recovery (IR) data acquired with a 25cm^2 x 5mm FOV, 128x128 matrix, TE=9ms, TR=10,000ms and TI={50,100,150,200,400,600,800,1600,3200}ms. Average DESPOT1-HIFI and IR T_1 values were obtained for several brain regions and compared.

Results: Figure 1 contains representative coronal images through the uncorrected T_1, calculated κ (α_T) field, and corrected T_1 maps of each volunteer. The corrected maps show obvious improvement in uniformity and do not suffer the fall-off in periphery values as seen in the uncorrected maps. Strong agreement is also noted between the regional DESPOT1-HIFI and IR T_1 values (Table 1).

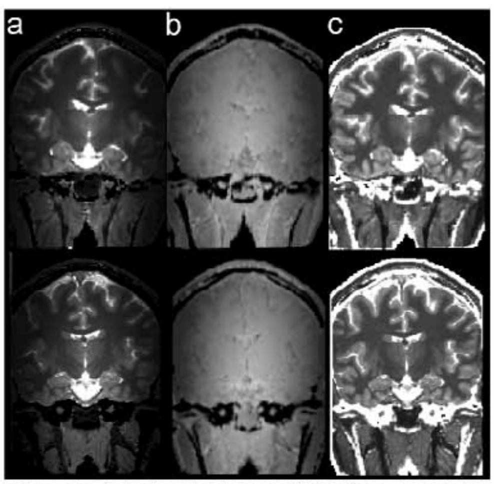

Figure 1: (**a**) Uncorrected DESPOT1 T_1 maps and corrected DESPOT1-HIFI κ (**b**) and T_1 maps (**c**).

	IR		*DESPOT1-HIFI*	
Tissue / Region	*Vol. #1*	*Vol. #2*	*Vol. #1*	*Vol. #2*
White Matter	843 (33)	860 (36)	827 (33)	846 (37)
Caudate Nucleus	1318 (57)	1368 (34)	1298 (72)	1325 (83)
Thalamus	1180 (91)	1115 (41)	1156 (99)	1073 (87)
Globus Pallidus	982 (37)	952 (32)	990 (45)	934 (54)
Putamen	1300 (36)	1269 (36)	1323 (54)	1298 (49)

Table 1: Comparison of IR and DESPOT1-HIFI T_1 values from various brain tissues from each volunteer.

Discussion / Conclusion: DESPOT1-HIFI is a quick and unencumbered approach for robust T_1 mapping in the presence of transmit RF field inhomogeneity. The described approach permits rapid whole-brain T_1 mapping with near perfect correction for α_T variations while requiring minimal additional scan time (the presented 0.73mm^3 maps were acquired is less than 11 minutes with the IR-SPGR data acquired in approximately 2 minutes) and without requiring additional distortion correction, as alternative EPI-based approaches[4] do. The provided κ field may also be useful for correction of subsequently acquired data, or when DESPOT1 is used in combination with the DESPOT2 T_2 mapping approach[5], which also requires correct knowledge of α_T.

References: [1] Christensen et al. J Phys Chem 1974;78:1971-1977, [2] Insko et al. MR 1993;103:82-85, [3] Stollberger et al. MRM 1996;35:246-251, [4] Cheng et al. MRM 2006;55:566-574, [5] Deoni et al. MRM 2003;46:515-526.