Impact of B1 field inhomogeneity on DESPOT-based T1 and T2 mapping at 1.5T

Yulia Shcherbakova[1], Cornelis A.T. van den Berg[1], Jan J.W. Lagendijk[2], Chrit T.W. Moonen[2], and Lambertus W. Bartels[1]
[1]*Imaging Division, University Medical Center, Utrecht, Utrecht, Netherlands,* [2]*Imaging Division, University Medical Center, Utrecht, Netherlands*

Target audience: Scientists who are interested in fast quantitative abdominal MRI.

Purpose: Accurate tumor depiction is important for planning and guidance of MRI-guided oncological therapy, like MRI-guided High Intensity Focused Ultrasound ablation of lesions in the liver [1]. Rapid quantitative imaging has been proposed for these purposes, and also to assess the therapeutic response [2-3]. T_1 and T_2 relaxation times and their ratio T_1/T_2 are different for normal liver tissue and metastases [4], which makes these parameters relevant quantitative imaging biomarkers. Conventional T_1 and T_2 mapping techniques are relatively time-consuming, which has led to the development of promising rapid techniques, such as DESPOT1 and DESPOT2 [5]. However, in practice, even at 1.5T, electromagnetic fields are imperfect, which may influence the accuracy and precision of quantitative imaging techniques. The goal of this study was to investigate the impact of B_1 field inhomogeneity on the performance of 3D DESPOT1 and 3D DESPOT2 methods, and to estimate the errors that can be expected when used in the abdomen in human subjects.

Methods: First, signal behavior was simulated for a range of B_1 field deviations using Spoiled Gradient Echo (SPGR) and balanced SSFP (bSSFP) signal equations [6]. The nominal angles were chosen based on optimal flip angle values [5]. From the simulated signal intensities, T_1 and T_2 values were estimated using the DESPOT1&2 methods for a range of B_1 deviations (λ=B1/B1$_{nom}$) for intrinsic T_1 and T_2 values combinations relevant for tissues in the abdomen (liver, adipose tissue, kidney). The errors with respect to the intrinsic values were determined.

$$S_{SPGR} = f_1(M_0, TR, FA, T_1)$$
$$S_{bSSFP} = f_2(M_0, TR, FA, T_2, T_1)$$
$$T_1 = T_1MAP(S_{SPGR1}, S_{SPGR2}, FA_1, FA_2, TR_1)$$
$$T_2 = T_2MAP(S_{bSSFP3}, S_{bSSFP4}, FA_3, FA_4, TR_2, T_1)$$

Next, *in vitro* MRI experiments were performed on a clinical 1.5-T MR scanner (Philips Achieva, Best, The Netherlands) using a special phantom consisting of gel tubes with calibrated T_1 and T_2 values (TO5, Eurospin II test system, Scotland). For receive an 8-channel head coil was used. The mean T_1 and T_2 values of gel tubes were calculated by taking the spatial average over an ROI inside the tubes on the T_1 and T_2 maps, calculated using DESPOT1 and DESPOT2 reconstruction methods (figure 2), with and without correction for spatial FA variations using a separately acquired B_1 map.

To demonstrate the impact of typical abdominal B_1 field inhomogeneity *in vivo*, an experiment in the liver on a healthy volunteer was performed using a 16-channel Torso-XL receive coil. Sequences parameters for the volunteer scan were: DESPOT1: 3D SPGR, FOV 350x240x200mm^3, voxel size 4x4x4mm^3, TR 6.2 ms, TE 1.64 ms, 1 NSA, FA 4 and 18 degrees, one 9 sec breath hold (BH) scan. DESPOT2: 3D bSSFP, FOV 350x240x200mm^3, voxel size 4x4x4mm^3, TR 4.5 ms, TE 1.4 ms, 1 NSA, FA 15 and 65 degrees, one 7 sec BH scan. The mean T_1 and T_2 values of the liver tissue were calculated using DESPOT1&2 methods and B_1 field correction.

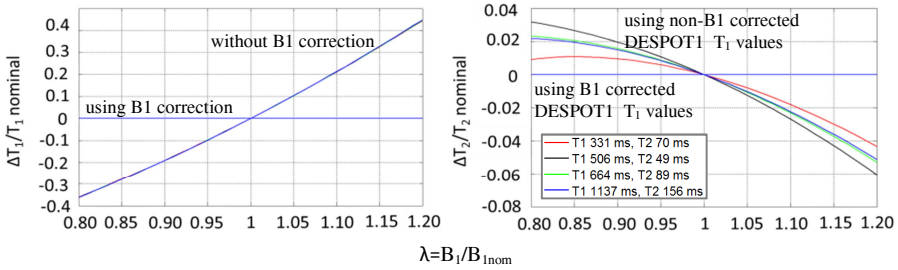

Figure 1. Simulation of T_1 and T_2 errors for different λ

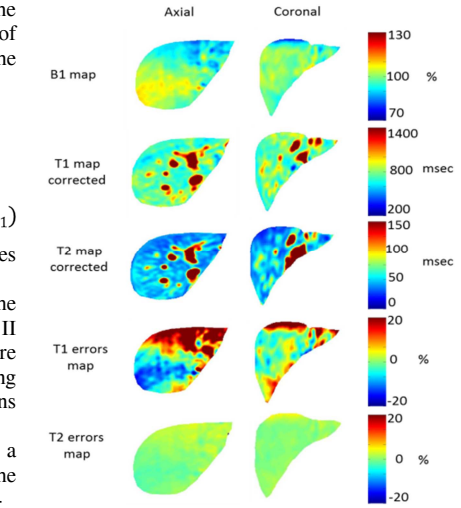

Figure 4. Quantitative maps of the liver

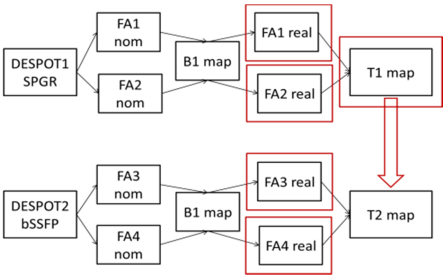

Figure 2. Scheme of impact of B_1 field on T_1 and T_2 maps

Results: Figure 1 illustrates results of simulated T_1 and T_2 errors for a range of B_1/B_{1nom}. The relative errors in T_1 and T_2 depend on the flip angle deviation and on the nominal T_1 and T_2 values. Note, if we let the non-B_1 corrected DESPOT1 T_1 estimates enter in the DESPOT2 calculation, the bias on the T_2 maps is very modest. Figure 2 shows the scheme of impact of B_1 field on T_1 and T_2 mapping methods. Figure 3 shows a comparison between tabulated, calculated and corrected T_1 and T_2 values for 4 different phantom tubes. Figure 4 presents B_1, T_1, T_2 maps and T_1 and T_2 errors maps for the liver (before and after B_1 correction). A maximum of 6% change in B_1 field (λ:0.94-0.98) was measured in the phantom and 10% change (λ:0.9-1.1) in the liver tissue. According to the simulations the B_1 deviations resulted in a maximum 12% error in T_1 values in the phantom and 21% error in T_1 values in the liver tissue.

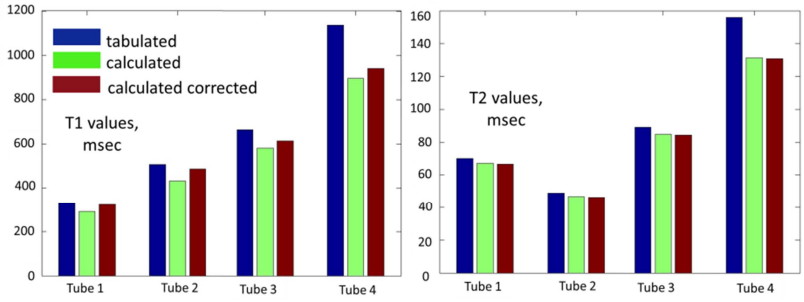

Figure 3. Tabulated, calculated and corrected T_1 and T_2 values for the phantom tubes

Discussion and Conclusion: We have demonstrated that DESPOT1 method is sensitive to B_1 field inhomogeneity, even at 1.5T. A 5% error in nominal flip angle significantly influences the calculated T_1 value and leads to a 10% error in the observed T_1 value. However, the T_2 estimates are minimally affected, when T_2 is calculated using non-B_1 corrected T_1 values. Thus, the influence of B_1 deviations on T2 mapping is negligible, so, B_1 field correction for T_2 mapping based on DESPOT2 method, is not required.

References: [1] Jolesz FA, Annu. Rev. Med. 60 (2009); [2] Leslie TA, et al. Br J Radiol. (2008); [3] Chandarana H, et al., US Radiology, Touch Briefings, (2008); [4] Bartolozzi C, et al. Liver Malignancies. (1999); [5] Deoni SCL, et al. MRM 49 (2003); [6] Haacke EM, et al. Magnetic Resonance Imaging. Physical Principles and Sequence Design. Chapter 18, (1999).