Clinical Assessment of B1+ Inhomogeneity Effects on Quantitative Prostate MRI at 3.0 T

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Target Audience: Clinicians and physicists interested in quantitative multi-parametric MRI for prostate cancer.

Purpose: Dynamic contrast-enhanced MRI (DCE-MRI) has an important role in multi-parametric MRI for prostate cancer detection and characterization. A primary step in the pharmacokinetic modeling analysis includes conversion of signal intensity curves into contrast agent concentration curves, which requires knowledge of the pre-contrast T_1 (T_{10}) values. Variable flip angle (VFA) imaging is commonly used for T_{10} measurements since it can provide fast volumetric T_1 mapping [1], however, it heavily depends on the set of flip angles used, and therefore is sensitive to any flip angle variation. Transmit RF (B_1^+) field inhomogeneity creates the flip angle variation, which tends to be 30 - 50% across the abdomen at 3T [2]. In this work, we measure B_1^+ variation in the pelvis using the reference region VFA method [3] and evaluate the impact on the estimated T_1 values in prostate and pelvic muscle with and without compensating for B_1^+ variation in a total of 108 prostate patients at 3T.

Methods: Experiments were performed on two 3.0T systems (TIM Trio and Skyra, Siemens) in a total of 108 men undergoing clinically indicated prostate MRI, ranging in age between 48 and 87 years (age = 65.4 ± 7.8 years and mass = 82.0 ± 13.5 kg). Local IRB and informed consent was obtained. All MRI scans were feet first. A body coil was used for RF transmission, and the automatic pre-scan was used to calibrate RF transmission. A circular polarization (CP) mode was used for Trio (n = 18), and an elliptical polarization (EP) mode was used for Skyra (n = 90).

A 3D SPGR sequence with a dual-echo bipolar readout was used and TEs were chosen to be in- and out-of-phase (TE1 = 1.23ms and TE2 = 2.46ms) at 3T. A 2-point Dixon fat-water separation algorithm was used to generate fat- and water-only images [4], and B1+ maps were further calculated using RR-VFA [3] in prostate and in-house software (Matlab R2013, Osirix 5.9, Pixmeo SARL).

Maps of relative flip angle (rFA) as a percentage were calculated by dividing the actual flip angle by the nominal flip angle, and T_1 maps were calculated with and without FA correction. Regions of Interest (ROI) were manually drawn on the prostate, left and right muscle in the pelvis, and we computed rFA and T_1 before and after FA correction, averaged over these ROIs (Fig 1). Paired t-tests and f-tests were performed to compare the means and standard deviations of rFA and T1.

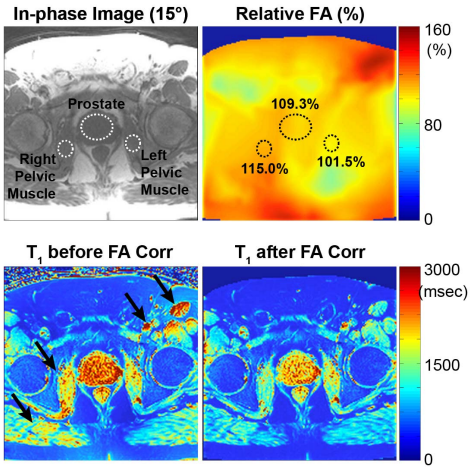

Fig 1: *A representative example of inaccuracies of T_1 measurements due to B_1^+ inhomogeneity.*

Results and Discussion: Qualitative assessment (Fig 1) showed that T1 estimation was improved following FA correction.

Statistical results in different tissues from 108 prostate patients are shown in Table 1. The average rFA was 104.5 ± 8.0% in the prostate, ranging from 70.2% to 121.6%, which indicated that the FA correction is crucial to achieve more accurate quantitative results**.** The difference of mean T_1 between the left and right pelvic muscle was 143ms before FA correction and was reduced to 27ms after the FA correction; the standard deviations of all T1 estimates were reduced by half after FA correction, resulting in a more uniform T_1 value for each tissue ($p = 9.77\times10^{-9}$). The reduction in these values gives more confidence in T_1 correction results.

Table 1: *relative FA values and T_1 values obtained from prostate and both pelvic muscles*

	rFA (%)	T_1 before FA corr (msec)	T_1 after FA corr (msec)
Prostate	104.5 ± 8.1	2421.9 ± 411.3	2209.3 ± 232.6
Left Pelvic Muscle	106.3 ± 6.7	1701.1 ± 206.6	1506.2 ± 103.7
Right Pelvic Muscle	110.7 ± 7.2	1834.5 ± 267.2	1479.2 ± 105.2

The average estimated T_1 value in prostate is reduced from 2422ms to 2209ms with FA correction, which may be a more accurate estimation in prostate T_1.

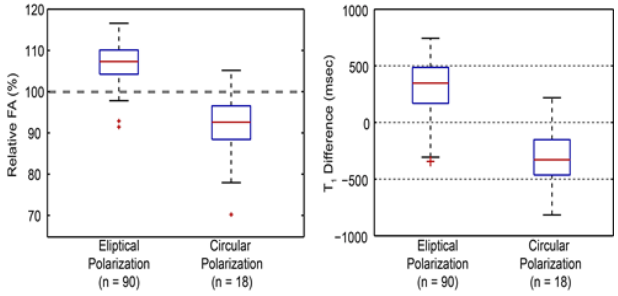

Fig 2: *Comparison of relative FA (a) and difference of prostate T_1 (b) between two types of RF transmission.*

The rFA and T1 values were also compared between two RF transmission modes: EP mode - Skyra and CP mode - Trio (Fig 2). From the box plots, a significant difference of B_1^+ characteristics can be clearly seen. Skyra has relatively higher rFA while Trio has lower rFA, which leads to inconsistency between scanners in estimating T_1 values. The average value of prostate T_1 between scanners differed by 601ms, and the difference was significantly reduced to 65ms after FA correction. Paired t-tests were applied to data between different scanners, and the p value decreased from 1.22×10^{-5} to 2.78×10^{-1} after correction, showing a more uniform prostate T1 value after FA correction. Since an important application for quantitative imaging is to compare results from different scanners during follow-up studies, FA correction is necessary for accurate T_1 estimation.

Conclusion: We have measured B_1^+ inhomogeneity and the T_1 value in 108 prostate MRI exams and have shown improved T_1 measurements in both prostate and pelvic muscles. The FA correction provides a more uniform T_1 value for each tissue and significantly reduces the inconsistency between different scanners. Since the RR-VFA method does not require additional scan time, it is recommended to use RR-VFA to correct T_1 mapping for 3T prostate MRI.

References: [1] Deoni et al., MRM 2003. [2] Azian et al., JMRI 2010. [3] Sung, et al., MRM 2013. [4] Ma et al. MRM. 2004.