Transmit B1 Field Inhomogeneity and T1 Estimation Errors in Breast DCE MRI at 3T

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Introduction: A measurement of T_1 is important to monitor contrast agent concentration using signal intensity in quantitative dynamic contrast enhanced (DCE) MRI [1]. Variable flip angle spoiled gradient echo (SPGR) acquisitions, called DESPOT1, are a common choice to measure T_1 since they can provide a fast 3D volumetric T_1 mapping [2]. DESPOT1, however, heavily depends on the set of flip angles used, and therefore is sensitive to any flip angle variation. Transmit B_1 field (B_1) inhomogeneity creates flip angle variation and the variation tends to be 30 - 50% across the breast at 3T [3]. In this work, we include B_1 mapping in our breast DCE imaging protocol, and compensate T_1 maps by including B_1 variation in the DESPOT1 calculation [4,5]. We then compare T_1 relaxation in fat (as a validation) with and without compensating B_1 variation in a total of 25 patients at 3T.

Methods and Materials: Although faster methods exist, B_1 maps were measured by using a 2D multi-slice SPGR sequence with prescribed flip angles of α and 2α (α = 60°), the well-known double angle method (DAM) [6]. B_1 mapping was placed after post contrast sequences to ensure greater T_1 relaxation recovery of all tissue after a repetition time (TR) of 5 seconds. The 2D imaging slice profile was simulated and the error due to the slice profile was corrected in the DAM calculation [7]. We then divided the actual flip angle by the prescribed flip angle (60°) to compute a relative B_1 variation map in %. Other imaging parameters were as follows: TE=2.5ms, acquisition matrix=64×64, FOV=44cm, and total scan time=9min.

T_1 maps were measured by using a 3D SPGR sequence with a dual-echo bipolar readout. A 2-point Dixon fat-water separation algorithm was used to generate fat and water only images [8]. Prescribed flip angles of 5° and 10° were used and the flip angle set was computed to symmetrically sample the signal curve of fat (T_1 is assumed to be around 400 ms and TR = 4 ms). Other imaging parameters were as follows: TR=4ms, TE=1.2/2.4ms, acquisition matrix size=256×128, and FOV=32cm.

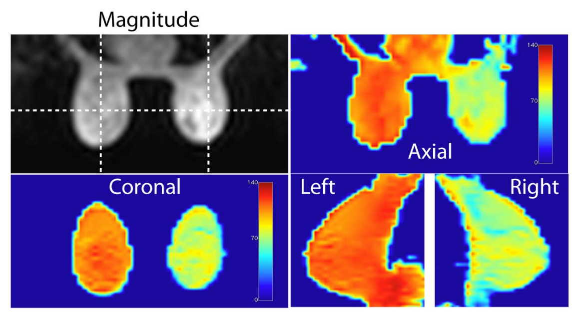

Fig 1: *An example of relative B_1 variation in percentage on a subject at 3T.*

Imaging experiments were performed on 3.0T GE MR750 scanners. The automatic pre-scan provided by the scanner was used to calibrate RF transmission. All image analysis was performed on OsiriX, an open source image viewer. We have developed a freely-available OsiriX plug-in to compute T_1 and B_1 maps. A region of interest (ROI) was drawn for each side of both breasts (see red arrows in Fig 2) and an average T_1 was computed over an ROI.

Results and Discussion: Fig. 1 shows an example of relative B_1 distribution. The left breast has an average 113% (± 4.3%) higher flip angle than the prescribed flip angle whereas the right has an average 80% (± 5%) lower flip angle than the prescribed flip angle.

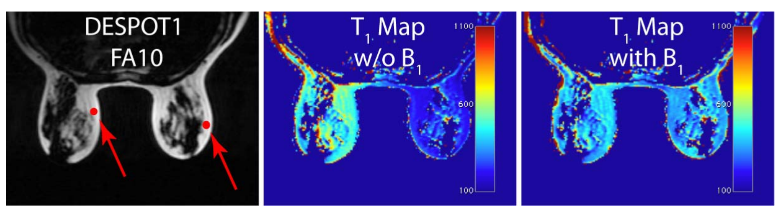

Fig 2: *Comparison of T_1 estimation without and with B_1 inhomogeneity consideration.*

Fig. 2 shows T_1 maps with and without compensating for B_1 inhomogeneity in one subject. The fat only image is displayed for anatomical reference. The T_1 map generated by the prescribed flip angle of 5° and 10° has a huge T_1 difference between the left and right breast while the compensated one shows more uniform T_1 across the whole breast. Table 1 contains a comparison of T_1 estimation with and without B_1 maps in 25 patients (mean ± SD across the patients). The average B_1 variations are 115.4% (on the left ROI) and 82.4% (on the right ROI). The B_1 field difference of the left and right breast conforms to the literature [3]. The T_1 difference between the left and right ROIs is 52% and this is reduced to 7% by including B_1 variation. More importantly, the estimated T_1 values (374.4 ms and 346.5 ms) are close to the literature-reported values (T_1 = 366 ms) [9].

	Left ROI	Right ROI
Relative B_1 Variation	115.4 ± 9.3 %	82.4 ± 6.9 %
Fat T_1 without B_1	497.9 ± 112.1 ms	239.0 ± 44.4 ms
Fat T_1 with B_1	374.4 ± 44.8 ms	346.5 ± 35.1 ms

Table 1: *Relative B_1 variation, T_1 without and with B_1 over the left and right ROIs in 25 patients.*

In this work, we have validated the T_1 estimation correction in fat since T_1 of fat is uniform and consistent across patients. For future studies, we will focus on correcting quantitative DCE analysis, and this includes fibrogladular tissue T_1 where the tissue structure is more complex and T_1 is less consistent across patients. A different set of flip angles in DESPOT1 can be used to better optimize for fibroglandular tissue T_1, and two different sets of flip angles (one for left and the other for right) also could be applied by using the expected relative B_1 variation observed here.

Conclusion: We have shown that severe B_1 variations over the breast can cause a substantial error in T_1 estimation using DESPOT1. We then compensated the error by measuring the actual B_1 variation, and showed a good improvement in T_1 calculation. This correction can benefit quantitative breast DCE MRI.

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References: [1] Larsson et al., MRM 1990;16:117, [2] Deoni et al., MRM 2003;49:515, [3] Azian et al., JMRI 2010;31-234, [4] Treier et al., MRM 2007;57:568, [5] Andreisek et al., Radiology 2010;257:441. [6] Insko et al., JMR Ser A 1993;103:82, [7] Schar et al., MRM 2010;63:419, [8] Ma et al. MRM. 2004:52;415, [9] Rakow-Penner et al., JMRI 2006;23:87.