Simultaneous T1 and B1 mapping using Variable Flip Angle Imaging on Fatty Tissue

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Introduction: Variable flip angle (VFA) imaging, also known as DESPOT1 [1], is a common choice to measure T_1 since it can provide fast volumetric T_1 mapping, but is highly sensitive to flip angle variation. Transmit B_1 field (B_1) inhomogeneity can create the flip angle variation, and the variation tends to be 30 - 50% across the breast at 3T [2]. Here, we describe a novel way to simultaneously measure T_1 and B_1 maps using fat-only VFA images. We assume the T_1 relaxation times in fat to be globally uniform [3], and the B_1 inhomogeneity is smoothly varying across the object. We first compare our B_1 maps with those using double angle method (DAM) in a total of 25 breast patients at 3T. We then show an improvement in T_1 calculation by compensating the actual B_1 variation.

Methods: Fig. 1a shows a signal behavior of fat as a function of relative flip angle variation B_1 (1 means no flip angle variation). Provided fat T_1 is known (T_1 = 366 msec [3]), a signal ratio ($S_{\alpha 2}/S_{\alpha 1}$) between images with two flip angles (α_1 and α_2) becomes:

$$\frac{S_{\alpha 2}}{S_{\alpha 1}} = \frac{\sin(B_1\alpha_2)\cdot(1-E_1\cos(B_1\alpha_1)}{\sin(B_1\alpha_1)\cdot(1-E_1\cos(B_1\alpha_2)}$$

where E_1 is $e^{-TR/T1}$. With two flip angles (α_1 = 6°, α_2 = 13°), Fig. 1 shows the signal ratio has a good sensitivity to measure the relative flip angle variation (0.4 – 1.6).

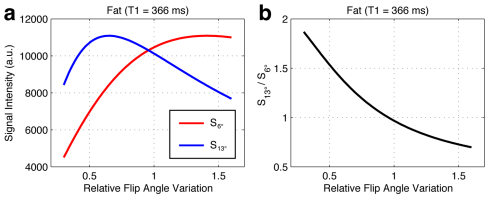

Fig 1: *(a) a signal behavior of fat and (b) its ratio as a function of relative flip angle variation.*

Fig. 2 illustrates several steps to generate a final B_1 map using VFA fat images. After computing the signal ratio between two fat-only images, we generate a fat-only B_1 map using the simulated signal ratio and apply the 2D interpolation method (gridfit.m in MATLAB) to construct the complete B_1 map by assuming the B_1 inhomogeneity varies smoothly across the object.

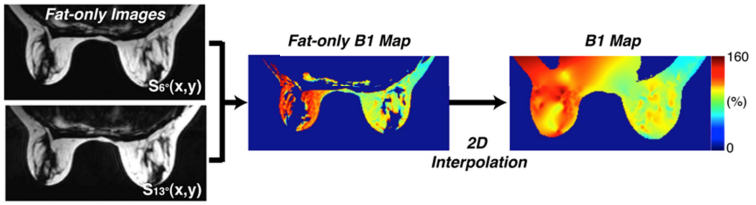

Fig 2: *A diagram of the proposed B_1 mapping using VFA fat images.*

Experiments were performed on 3.0T GE MR 750 systems in a total of 25 women undergoing clinically indicated breast MRI for a history of known or suspected breast disease, ranging in age between 26 and 73 years (age = 50.1 ± 11.4 years and mass = 62.4 ± 10.8 kg). A body coil was used for B_1 transmission, and the automatic pre-scan provided by the scanner was used to calibrate B_1 transmission. We used a 3D SPGR sequence with a dual-echo bipolar readout, where TEs were chosen to be in- and out-of-phase images, and a 2-point Dixon fat-water separation algorithm was used to generate fat- and water-only images [4]. Water-only T_1 maps were generated by using the conventional VFA method [1]. As a comparison, we also measured B_1 maps using DAM [5] with prescribed flip angles of α and 2α (α = 60°) and TR of 5 sec.

Results Discussion: Fig. 3 shows an example of relative flip angle distribution (%) in three orthogonal planes (axial, coronal and sagittal) using the VFA fat images (left) and DAM (right). B_1 maps using two different mapping methods are qualitatively well matched each other in all three planes. In this subject, the left breast has an average 21% higher flip angle than the prescribed flip angle, while the right breast has an average 22% lower flip angle than the prescribed flip angle.

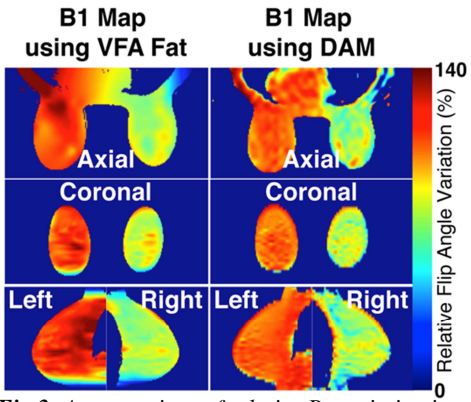

Fig 3: *A comparison of relative B_1 variation in percentage on a subject at 3T.*

Fig. 4 shows fibroglandular tissue T_1 maps with and without compensating for B_1 inhomogeneity in one subject using the B_1 map generated by the VFA fat images. The water only T_1 map generated by the prescribed flip angle of 6° and 13° 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. We expect a different set of flip angles (more than two) can be used to better optimize for fibroglandular tissue T_1.

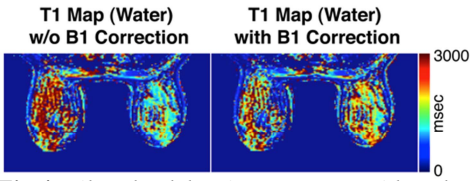

Fig 4: *Fibroglandular tissue T_1 maps with and without compensating for B_1 inhomogeneity*

In all 25 cases, the proposed method can robustly generate fat-only B1 maps, qualitatively well matched with DAM, but in a few cases, the 2D interpolation process was unstable due to fat-water boundary regions. We believe the 2D interpolation can become better if the process can smartly exclude those problematic areas. The VFA imaging is commonly used in routine clinics to calculate T_1, especially for quantitative dynamic contrast-enhanced (DCE) MRI. One advantage is that the proposed technique allows generating B_1 maps in addition to T_1 maps without additional scanning.

Conclusion: We have described a new method to simultaneously measure both T_1 and B_1 maps. The proposed method is based on two major assumptions: T_1 of fat is uniform and consistent across patients, and the B_1 inhomogeneity is smoothly varying across the object at 3T. We showed B_1 maps using the proposed method are similar those using the conventional DAM method. Additionally, we demonstrated we can reduce a T_1 estimation error due to B_1 variations by using our simultaneous T_1 and B_1 mapping method.

References: [1] Deoni et al., MRM 2003;49:515, [2] Azian et al., JMRI 2010;31-234, [3] Rakow-Penner et al., JMRI 2006;23:87, [4] Ma et al. MRM. 2004:52;415, [5] Insko et al., JMR Ser A 1993;103:82