B_1^+ Field Mapping Improves Accuracy of T_1 Measurements in Phantoms and Normal Breast at 3.0 T

Jennifer G. Whisenant[1], Lori R. Arlinghaus[1], Richard D. Dortch[1], William A. Grissom[1], Gregory S. Karczmar[2], and Thomas E. Yankeelov[1]
[1]*Vanderbilt University, Nashville, TN, United States,* [2]*University of Chicago, Chicago, IL, United States*

Target audience: Clinical researchers performing quantitative DCE-MRI in the breast at 3.0 Tesla

Purpose: To evaluate the effect of B_1^+ mapping on the accuracy of T_1 estimates in the breast, which are required for a quantitative evaluation of dynamic contrast enhanced (DCE) MRI data. Indeed, previous simulation results calculated percent errors >15% in K^{trans} and v_e when T_1 was ≥14% of the nominal value [1]. The variable flip angle (VFA) technique yields rapid, high-resolution T_1 maps [2], thus it is often used in quantitative analyses of DCE-MRI data of the breast [3]. Unfortunately, the accuracy of the VFA-derived T_1 values are affected by B_1^+ inhomogeneities [2], which can be substantial in breast imaging at 3.0 T [4]. As a result, we investigated a B_1^+ mapping technique using the Bloch-Siegert shift [5] in gel phantoms with varying T_1 values and *in vivo* of normal breast tissue. To evaluate accuracy, VFA T_1 measurements (with and without B_1^+ correction) were compared to measurements of T_1 from inversion recovery (IR) data.

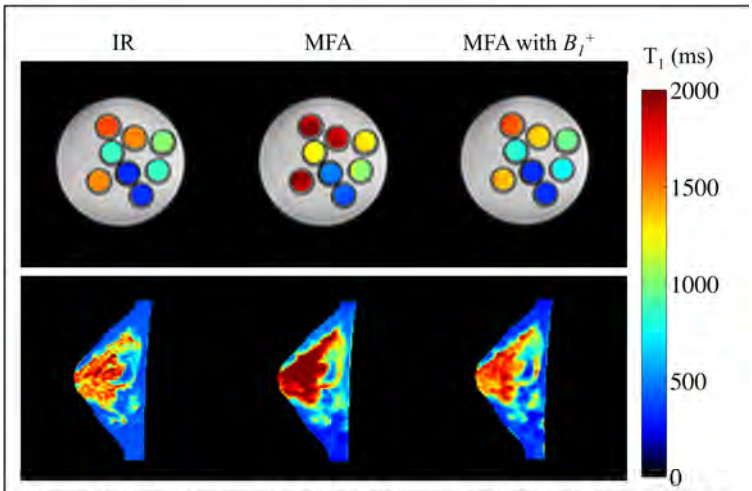

Figure 1. T_1 (ms) maps of eight gel phantoms and the right breast from a healthy volunteer. T_1 maps acquired using the gold-standard IR sequence were compared to the VFA maps with and without B_1^+ correction.

Methods: Eight gel phantoms (The Eurospin II Test System, Diagnostic Sonar, Livingston, Scotland, United Kingdom) and a healthy volunteer (female, age = 30) were imaged with a 3.0 T Philips Achieva MR scanner equipped with a two-channel body coil and a 16-channel receive double-breast coil (MammoTrak, Philips Healthcare, Best, The Netherlands). T_1 was measured from 3D spoiled gradient echo images with multiple flip angles (20 flip angles = 1,2,3…20°; matrix = 192×192; FOV = 256×256×60 mm^3; 15 slices, TR/TE = 7.9/4.9 ms). B_1^+ field variations were measured using the Bloch-Siegert method with a 2 ms frequency-swept B_1^+ phase encoding pulse [6] with matched slices (RMS B_1 = 2.29 μT; matrix = 128×128; TR/TE = 657/6.4 ms). As a gold standard, T_1 was also measured using a single slice IR sequence (12 inversion times logarithmically spaced from 25-10,000 ms; matrix = 128×91; FOV = 256×256 mm^2). The mean and standard deviation (SD) in T_1 were calculated from circular regions of interest (ROIs) drawn within each gel phantom, as well as fibroglandular tissue and fat *in vivo*. The effect of B_1^+ correction on VFA T_1 measurements was evaluated by comparing the percent errors between IR- and VFA-derived T_1 values.

Results: Figure 1 presents T_1 maps (in ms) of the gel phantoms and in the breast of a healthy volunteer generated from IR and VFA data (with and without B_1^+ correction). Large differences in T_1 are observed between the IR and uncorrected VFA maps, which are minimized after B_1^+ correction. Prior to B_1^+ correction, the average percent error between IR- and VFA-derived T_1 measurements was 31% (range: 20%-54%) in gel phantoms and *in vivo*. The percent error was significantly (Wilcoxon signed-rank test, P<0.001) reduced to 6% (range: 0.2%-14%) after B_1^+ correction (Table 1).

Discussion: The Bloch-Siegert method of B_1^+ mapping improves the accuracy of T_1 measurements from VFA data in both phantom and *in vivo* breast data. With the exception of the T_1 comparison in fat, the percent errors after B_1^+ correction were ≤ 10%. We hypothesize the higher percent error in fat was due to respiratory motion since the ROI within fat was drawn adjacent to the chest wall (to eliminate partial voluming with fibroglandular tissue).

Table 1. Mean (±SD) in T_1 and Percent Error from IR

	IR	MFA	% Err	MFA with B_1^+	% Err
P1	311 ± 31	478 ± 12	54%	326 ± 6	5%
P2	318 ± 24	399 ± 23	26%	318 ± 5	0%
P3	846 ± 40	1221 ± 38	44%	813 ± 24	4%
P4	840 ± 37	1037 ± 53	24%	757 ± 33	10%
P5	1006 ± 45	1259 ± 58	25%	957 ± 26	5%
P6	1467 ± 32	1863 ± 54	27%	1322 ± 33	10%
P7	1463 ± 35	1909 ± 62	31%	1371 ± 43	6%
P8	1584 ± 41	1974 ± 125	25%	1567 ± 47	1%
FGT	1663 ± 198	2213 ± 202	33%	1652 ± 143	1%
Fat	390 ± 7	469 ± 43	20%	337 ± 32	14%

% Err: percent error; P#: gel phantom number; FGT: fibroglandular tissue

Conclusion: These data, combined with other preliminary reports [7], indicate that B_1^+ mapping using the Bloch-Siegert method is an attractive option for accurate T_1 mapping of the breast. Future work includes evaluating the reproducibility of the T_1 measurement protocol described herein.

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