T1 mapping in the breast, with a Bloch-Siegert correction for variation in transmitted B1.

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Target Audience: Clinical researchers in breast cancer

Purpose: To establish B_1-corrected T_1 measurements in the breast, including compensation for cardiac motion artifact. Accurate and robust estimation of T_1 is a prerequisite for modelling of dynamic contrast enhancement MRI data. At 3T, estimates can be badly affected by variations in the transmitted B_1 field. The Bloch-Siegert method[1] has been shown to give a robust estimate of B_1 in tissues with a wide range of T_1 values. We have investigated the application of this to a study of breast cancer. A simple solution is proposed for reducing the effect of cardiac motion which is applicable to the thoracic region.

Methods: Four healthy volunteers and 3 patients with confirmed breast cancer were studied using a 3.0T MRI scanner (MR750, GE Healthcare, Waukesha, WI). T_1 was measured from 3D spoiled gradient echo images with variable flip-angles (VFA: flip = 2,3,5,10, & 15°; 34cm FOV, 7mm slices, TE 2.1ms, TR 4.6ms) and was subsequently calculated in MATLAB using the DESPOT1 method (2), with and without correcting for B_1 variation, determined from a Bloch-Siegert sequence with matched slices (2D gradient echo, matrix 128x128, TE/TR = 13.5/28 ms). Since artifacts extend in the phase direction as a result of cardiac motion, a second B_1 map was acquired with the phase encoding in the orthogonal direction (A/P). B_1 maps were calculated in MATLAB and spatial convolution was performed with a median filter (7×7 kernal size) to smooth the noise. A rectangular region was defined to encompass the heart, and the B_1 map generated with A/P phase encoding was used to determine the sides of the region, while the L/R phase encoded B_1 map was used to determine the remaining areas. The effect of B_1 correction on T_1 was evaluated visually and statistically by comparing the median and interquartile range of T_1 values over all the segmented fat pixels of the left and right breasts, using a mask determined after manually thresholding the 5° VFA images.

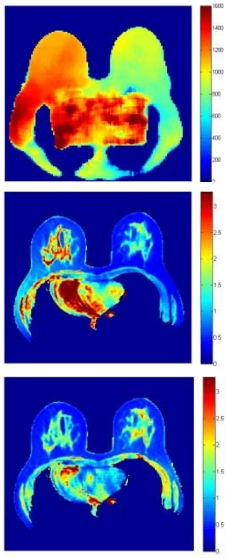

Figure 1: Maps of B_1 (top), uncorrected T_1 (middle), and B_1-corrected T_1 (bottom) in a healthy volunteer.

Results: A B_1 map derived from a healthy volunteer (normalized such that intensity/1000 is the ratio of actual to nominal flip angle) and T_1 maps (in seconds) with and without correction for B_1 are presented in Figure 1. As commonly observed (3), the B_1 is higher than desired on the left and lower on the right. This causes artifactual elevation in T_1 in the left breast, observed as hot spots in the parenchyma with T_1 >> 2s. Following the correction there is greater uniformity between left and right breasts. This is demonstrated further by analysis of segmented fat pixels (Fig. 2). An arbitrary intensity threshold was applied to the 5° VFA images to create a fat mask, which was applied to the T_1 maps; two rectangular regions were selected to analyse the distribution of T_1 in the fat over the entire 3D volume of both breasts (Fig. 2). Following B_1 correction the average T_1 was 458 ± 39 ms. An inverse of the fat mask was applied to investigate parenchymal T_1 in a ROI in the central slice of each breast in the healthy volunteers only, since patients had little normal-appearing parenchyma. B_1 correction again improved homogeneity: the asymmetry $|(L-R)/R|$ was reduced from 73 ± 28% to 5 ± 2% in parenchyma, and from 70 ± 21% to 5 ± 3% in fat. The B_1-corrected overall mean was 1368 ± 276 ms, consistent with previous estimates of 1284ms (3) and 1680ms (5). Figure 3 demonstrates that cardiac motion artifact in the axilla can be eliminated by combining B_1 maps derived from orthogonal phase directions.

Discussion: A large and consistent difference between the breasts was observed in the raw T_1 maps, which was diminished by applying B_1 correction. Our estimate of fat T_1 (457ms) is somewhat higher than literature estimates at 3T (382ms in ref 4; 423ms in ref 5), probably due to the imperfect segmentation in the current approach. Also, previous estimates have been based on smaller ROIs or single slices rather than whole-breast values. However, the improvement in uniformity following B_1 correction here is notable and should provide adequate robustness for modelling of DCE timecourses. One disadvantage of the Bloch-Siegert method is the sensitivity to cardiac motion (Fig 1, 3). At the penalty of doubling the scan time, images can be acquired with the phase encoding direction along both axes, allowing the recovery of signal along the sides of the abdomen (Fig. 3). This can be helpful in cases of axillary metastasis, as shown. Additionally, the left side of the chest, normally obscured by cardiac artifact, can be seen to be a particular hot spot for RF power deposition, which may be of interest in safety checking during pulse sequence development.

Conclusion: Variable flip angle measurement in combination with B_1 correction using the Bloch-Siegert method gives a robust estimate of T_1 over the breasts. Cardiac motion artifact obscures the axilla in the B_1 maps, but it is possible to recover the signal through combination of 2 datasets.

References: [1] Sacolick LI, Wiesinger F, Hancu I, Vogel MW. Magn Reson Med 2010; 63:1315-1322. [2] Deoni SCL, Rutt BK, Peters TM. Magn Reson Med 2003; 49:15-26. [3] Sung K, Saranathan M, Daniel BL, Hargreaves BA. Magn Reson Med 2013; 70: 954-961.
[4] De Bazelaire CM, Duhamel GD, Rofsky NM, Alsop DC. Radiology 2004; 230:652-659. [5] Edden RA, Smith SA, Barker PB. JMRI 2010; 32:982-987.

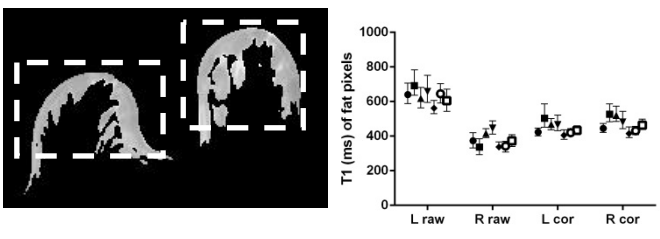

Figure 2: (Left) T_1 map after application of mask to null non-fat tissue. (Right) Median and interquartile range of T_1 values over all fat pixels of the left and right breast, before (raw) and after (cor) applying a B_1 correction, for each subject.

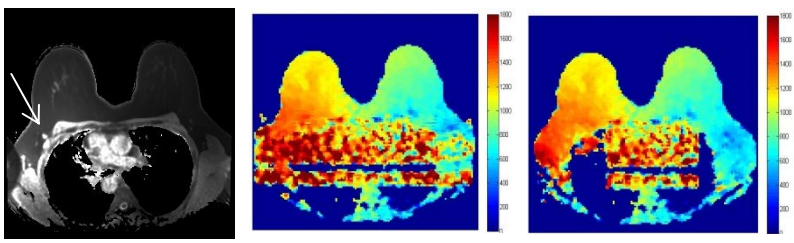

Figure 3: (Left) T_1 map in a cancer patient indicating an involved node in the chest wall. (Middle) B_1 map obscured in this region by cardiac motion. (Right) Addition of data acquired with phase direction A/P can recover B_1 information in the axilla.