Breast DCE with Fat Suppression: Enabling Quantitative Measurements

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Target Audience: Radiologists and physicists interested in quantitative measurements in breast DCE.

Purpose: Breast Dynamic Contrast-Enhanced (DCE) examinations are usually performed with fat suppression, providing qualitative enhancement curves. In contrast, pharmacokinetic modelling often uses spoiled gradient-echo images and a proton density weighted image as a reference to calculate T1 values. It would be desirable to calculate T1 values from fat suppressed clinical DCE examinations to quantify contrast-agent uptake in longitudinal studies and to assess parenchymal enhancement. In this work we introduce a reference image of low flip angle (thus approximately proton density weighted) and a calibration process, and evaluate the accuracy of T1 values thus obtained.

Methods: This work was undertaken at 3.0T (Siemens Skyra), with a 18-channel breast receiver coil, and was approved by the Ethics Committee.
Data Acquisition: The standard clinical breast DCE protocol includes a dynamic series of 7 fat suppressed T1-weighted gradient-echo images, acquired in under 1 minute each, in agreement with current guidelines (TE/TR = 1.68/5.07ms, FA = 18º). For 10 patients (histologically verified untreated breast tumours), a separate dataset was obtained post-contrast with identical parameters but flip angle 5 º, also fat suppressed, and both sequences were employed jointly to calculate T1. In addition 3 volunteers were scanned with test objects of known T1 within the breast coil, below the breasts, to validate the method. A set of solutions of known T1 values (from 25ms to 3000ms) was scanned with same sequences, on different occasions, to calibrate the T1 measurement and to evaluate the stability of the calibration curves. This test object was also scanned by changing the central frequency in steps of 25 Hz in order to investigate off-resonance effects (in case of field inhomogeneity).
Data Processing: The test object data were used to produce a curve representing the ratio between the image intensity obtained with the high flip angle (HFA, DCE) and low flip angle images (LFA), now referred to as image ratio, as a function of R1 = 1/T1. A separate curve was calculated to provide calibrated image intensity values for the imaging sequences also as a function of 1/T1. These curves were used to calculate R1 values pre-contrast, post-contrast and at peak contrast concentration (R1pre, R1peak, R1post, respectively). All calculations were undertaken with in-house software (IDL 9.3 Boulder, Colorado, USA); line fitting was performed using R.

Results: Figure 1a-b shows image ratio as a function of 1/T1, and image intensity as a function of 1/T1 for the HFA images, as measured with test objects in two separate occasions, and the least-square spline fitted to the data. These curves which characterise the pulse sequences were used in clinical T1 calculations, and proved to be reproducible (4 measurements in 9 months). Fat suppressed T1 measurements agree with inversion recovery (IR) measurements for test objects (Fig 1c). The curves in Fig 1ab are affected by off-resonance effects if field inhomogeneity causes the fat suppression pulse to suppress water, but frequency variations under 150 kHz introduced only small changes (up to 3%) to the image ratio for the range 100ms < T1< 1500ms.

Figure 2a-b shows two subjects scanned with known test objects within the breast coil (Left: low FA reference image, Right: calculated R1 image). The presence of the test tubes within the breast coil makes shimming more difficult. Median T1 values obtained for breast parenchyma on pixels above the threshold in the low FA images are in agreement with the literature [1]. For the range of T1 values of interest (100ms < T1< 1500ms, gray area in Figure 2c) the average absolute difference between fat suppressed R1 measurements and IR measurements of the test tube solutions is 13% (the average difference is 4%); the maximum difference reached 20% for the bottle with T1 = 100ms. Figure 3a-d shows the pre, peak and last post-contrast frame of a given breast examination, followed by the image with low flip angle. Using the calibration curves obtained with test objects, R1 maps were calculated (3e-g). Figure 3h shows the difference R1peak – R1pre, directly proportional to contrast agent concentration, showing uptake on lesion and breast parenchyma. For the 10 patient group R1peak was 0.003±0.001 ms^{-1} (mean±standard deviation).

Discussion: In our measurements significant discrepancy between IR and fat suppressed measurements occurred only for very long T1s (distilled water, poor SNR), and for T1s below 100ms (IR measurement less accurate). Field inhomogeneity is expected to be the main source of error in fat suppressed T1 measurements. Fat suppressed DCE images may have fat and water out of phase; in case of fat suppression failure no quantitative measurements are possible for voxels containing both fat and water. Measurements of T1 on breast parenchyma are likely to be more affected by fat suppression failure than measurements on breast lesions, as the latter are not expected to have a significant fat content. T1 measurements were shown to be less accurate if the water is suppressed by the fat suppression pulse, as expected, but unintentional water suppression is relatively rare [2]. Recent developments in shimming are encouraging [3], and will in general lead to improved performance in commercial systems. Fat suppressed T1 measurements are viable, and can make fat suppressed DCE MRI quantitative: a valuable tool for longitudinal studies.

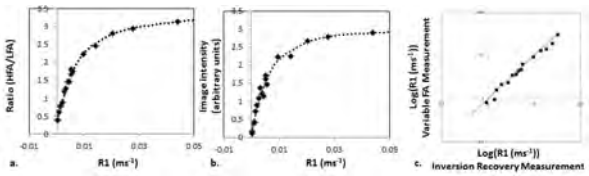

Figure 1 –Calibration Curves

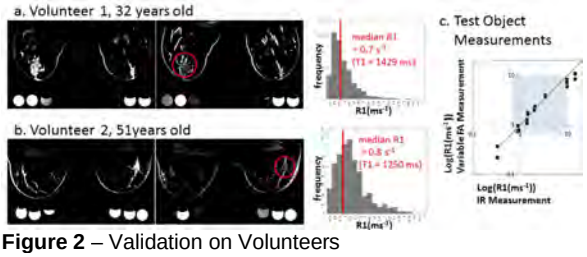

Figure 2 – Validation on Volunteers

References: 1. Rakow-Penner et al. JMRI 2006; 23:87-91. **2.** Schmidt et al. Eur Radiol. 2013; 23(6):1537-45 **3.** Hancu et al. MRM 2013; 69:862–867.

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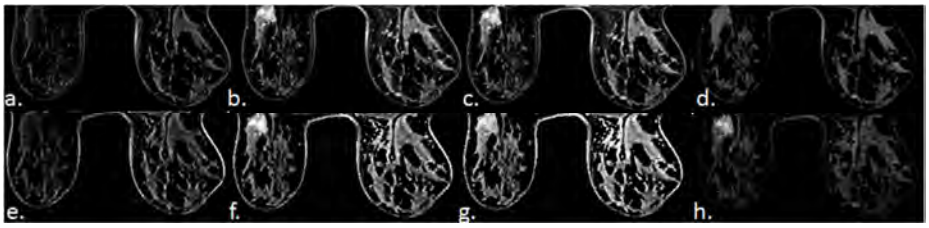

Figure 3-a-c. FA18º pre CA, at peak [CA], and post CA, **d.** FA5º post CA (acquired images) **e-g.** calculated R1 pre CA, at peak [CA] and post CA, respectively, **h.** peak CA concentration (R1peak –R1pre)