# A breast phantom for quality assurance in a multi-centre screening trial

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## Aims

To design and evaluate a breast coil phantom for use in fifteen MR centres participating in a five year screening trial using MRI. The phantom should allow (1) accurate monitoring of system performance and identification of instrumental problems which could lead to a deterioration in image quality, (2) calibration of the instruments to allow absolute $T_1$ values to be measured in contrast-enhanced dynamic imaging of the breast. The phantom should fit a variety of breast coils and should fill as much of the coil as possible. The test materials should be stable, their constituents well defined and they should be available in large quantities at a reasonable price.

## Introduction

A multi-centre trial involving the participation of a range of MR systems must include a quality assurance protocol to monitor system performance and to allow comparison between images acquired on different systems. The UK trial of MRI for screening pre-menopausal women at genetic risk of breast cancer involves the use of 15 MR systems (8 Siemens, 6 IGE, and 1 Philips). The trial MR imaging procedure[1] includes a 3D examination of both breasts using contrast agent. In women presenting equivocal results, this is followed-up two weeks later by a localised examination of the equivocal area using contrast-enhanced dynamic 2D FLASH sequences. Data analysis will be carried out using standard techniques for assessing morphology and pattern of contrast enhancement, manual quantitation of signal-time curves, measurement of maximum concentration of contrast agent achieved and pharmacokinetic analysis of concentration-time curves. The phantom should therefore provide a means of verifying the accuracy with which quantitative measurements are made.

## Design of the breast phantom

A number of factors were considered in the design of the phantom: (1) dimensions, shape and type of container, (2) availability, stability, cost and NMR properties of the test liquids, (3) loading device, (4) ease of usage in routine tests.

## Methods

A number of container types and shapes were studied. These were made of Perspex or glass. MR images were acquired with the containers filled with either Gd-doped aqueous solutions or oils. The former were studied because of their better approximation to biological tissue, the latter because of their low dielectric constants and thus lower tendency to generate RF standing waves. A number of experiments were also performed to try to simulate the loading of the receiver coil normal in clinical use. The imaging sequences employed were 3D and 2D FLASH sequences and the image acquisition parameters were identical to those chosen for the screening trial[1]. The test measurements were all performed at 1.5 Tesla. The following evaluations of the images were made: (1) the signal-to-noise ratio (SNR), (2) the percentage uniformity, (3) the ratio of the signal intensity in a ROI for a $T_1$-weighted acquisition to the signal intensity in the same ROI for a proton density weighted acquisition, (4) a visual examination for distortion and artefacts. These evaluations were made for each slice position.

## Results and Discussion

*Phantom design:* For the container, a Perspex cylinder ($\phi = 110$ mm) was finally chosen to which a rounded base and a tight-fitting lid were fixed. Two identical containers were produced to fill each cup of the breast coil. A Perspex frame was also made to support the containers and to ensure accurate and easy phantom positioning. This customised design was chosen because it best fulfilled our criteria and was convenient to produce. The containers were filled with Bayol 82 oil, which provides appropriate dielectric and relaxation properties [2].

Tests of a variety of loading devices on a Siemens Vision system showed that there was no change in neither the SNR, the percentage uniformity nor the ratio of the signal intensity of a T1-weighted acquisition to that of a proton density weighted acquisition, once these parameters had been normalised. Furthermore, the presence or absence of a loading device did not generate any artefacts. Given that the receiver loading also varies considerably in clinical use, it was decided not to employ a loading device in the quality assurance protocol.

*Tests of system performance:* Measurements of the SNR of a Siemens Vision breast coil showed a 35 % variation along the coil's Y axis (bottom to top). The signal uniformity varied by 15 % along the same axis. The average uniformity in the XZ plane was 80 %. The ratio of the signal intensity of a $T_1$-weighted acquisition to that of a proton density weighted acquisition varied by 3 % along the Y axis for a 3D FLASH sequence. However, these values varied by as much as 10 % for 2D FLASH sequences. These variations arise from factors such as inhomogeneities in the $B_1$ field and the coil sensitivity and for the 2D FLASH sequences, from imperfections in the slice profile. The dependence of the signal intensity ratio on slice position has implications for localised quantitative analysis, especially for pharmacokinetic analysis. In order to overcome these variations, each coil used in the trial will be calibrated using the same phantom. The signal intensity ratio, determined using both 3D and 2D FLASH sequences, will be mapped as a function of slice position. These signal intensity ratios may then be converted to $T_1$ values using a calibration curve constructed, using reference gels, for each MR system[3]. The calibration will be incorporated in all software used to analyse quantitative contrast agent uptake.

## References

1. http://www.thelancet.com/lancet/writing/writing4.html
2. Tofts, P.S. et. al., Mag. Res. Imag., 15, 69-75, (1997)
3. Parker, G.J.M., et. al., J. Magn. Res. Imag., 7, 564, (1997)