Universal Breast Phantom for Quantitative MRI

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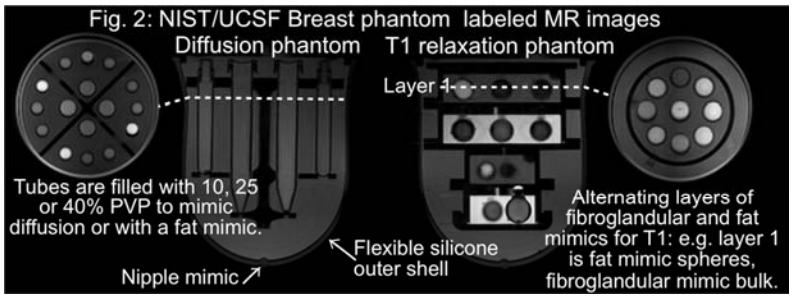
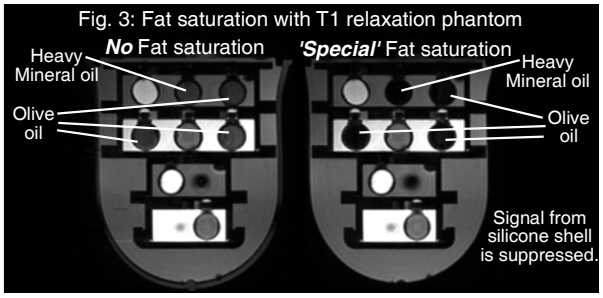
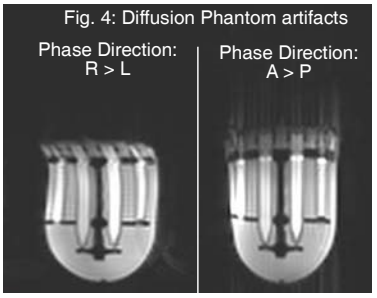
Purpose: The breast imaging community needs a universal phantom for quantitative MRI to enable standardization of protocols and implementation of quality control measures for clinical trials. Breast phantoms are challenging to create because they must mimic the well-distributed mix of fat and fibroglandular tissue, and they must fit into all coil styles. For example, we evaluated the phantom used by Tuong and Gardiner [1], but it does not fit in all coil styles and thus could not be used universally. Freed et al. created an anthropomorphic breast phantom with a mix of fat and fibroglandular tissue mimic including a lesion [2], but their design does not address diffusion MRI. This project aims to create a breast phantom for quantitative MRI measurements, including T1 relaxation and apparent diffusion coefficient (ADC), on a variety of coils.







Methods: The breast phantom was created using two distinct phantoms for diffusion and T1 relaxation mimics (Fig. 1). Both phantoms consisted of a flexible outer silicone shell (durometer 10A), rigid internal components made of polycarbonate, and a bulk solution of 35% corn syrup w/w in water to mimic the T1 relaxation time of fibroglandular tissue (Fig. 2). The diffusion phantom contained plastic tubes with their long axis in the anterior-posterior direction; the tubes are filled with varying concentrations of polyvinylpyrrolidone (PVP) in aqueous solution to control the ADC of water [3], or a fat mimic of either oil or doped water containing 2.26 mM $NiCl_2$ and 0.25 mM $MnCl_2$. The T1 relaxation phantom consisted of four layers alternately filled with fat or fibroglandular mimic. Additionally, each layer contained several plastic spheres filled with fibroglandular or fat tissue mimics. The fat and fibroglandular mimic relaxation times were selected based on the work of Rakow-Penner et al. [4].

Results: The phantom was imaged on a 1.5 T pre-clinical MRI system to determine T1, T2 and ADC values of all components at bore temperature, ~16.5 °C (Table 1). Quantitative analysis was performed using in-house software (PhantomViewer). The phantom was also imaged on clinical MRI systems to assess performance (Fig. 2). The phantom fit in several coil designs, enabled fat-suppression tests (Fig. 3), and allowed assessment of diffusion artifacts with respect to phase encoding direction (Fig. 4).

Table 1	T1 relaxation time (ms)	T2 relaxation time (ms)	ADC (10^{-3} mm^2/s)
PVP 10%	2021 ± 63.5	1120 ± 449.1	1.42 ± 0.06
PVP 25%	1033 ± 12.1	471 ± 138.1	0.81 ± 0.03
PVP 40%	625 ± 10.5	465 ± 209.1	0.54 ± 0.05
Olive oil	187 ± 7.1	40 ± 0.4	0.08 ± 0.02
Heavy Mineral oil	103 ± 2.6	33 ± 0.5	0.05 ± 0.01
Fat T1 mimic	308 ± 13.1	54.1 ± 3.7	1.85 ± 0.12
Fibroglandular T1 mimic	1116 ± 17.8	261 ± 45.0	0.92 ± 0.03

Discussion: The novel breast phantom design with flexible outer shell easily fit into different coils and was useful for clinical breast imaging techniques. For the next design, we will revise the phantom to better mimic fibroglandular T2, incorporate findings from initial imaging, and address other interests of the breast MRI community, such as microcalcifications.

Conclusion: We successfully designed a breast phantom that can be used by the breast imaging community to validate MRI clinical trial sites and implement quality control measures. Please visit our website for additional information: http://collaborate.nist.gov/mriphantoms/bin/view/MriPhantoms/BreastPhantom.

References: [1] Tuong & Gardiner, AJR 201(3):W511-W515, 2013. [2] Freed et al., Medical Physics 38(2):743-753, 2011. [3] Pierpaoli et al., 17th ISMRM 2009, p.1414. [4] Rakow-Penner et al., JMRI 23:87-91, 2006.