Standardized Phantoms for Quantitative MRI

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Quantitative Magnetic Resonance Imaging (MRI) is increasingly used as an outcome measure to diagnose and assess cancer and for quantitative mapping of tissue properties during therapies. For example, MRI can be used to measure tumor volume or to distinguish between healthy and diseased tissue using diffusion, perfusion or contrast-based MRI techniques. MRI can also be used to map temperature rise during radio frequency (RF) or focused ultrasonic ablation of tumors.

The ability of MRI to measure real, physical parameters of interest requires reference standards to ensure accuracy and reproducibility of data. Currently, variability exists across MRI systems, manufacturers, models, software version, and analysis packages, which impedes comparison of data across centers. (And can lead to publication of incorrect results, see the recent PNAS article "Cluster failure: Why fMRI inferences for spatial extent have inflated false-positive rates" by Eklund et al.)

The National Institute of Standards and Technology (NIST) Bioimaging project, in conjunction with professional societies, has developed a suite of physical reference objects, known as phantoms, to serve as standards. These phantoms provide valuable information regarding biomarker measurement reproducibility, as well as allowing for calibration and validation of specific techniques in MRI. NIST, along with the International Society for Magnetic Resonance in Medicine (ISMRM), developed a phantom to assess MRI system performance. Round-robin results show significant variation in the measurement of fundamental magnetic resonance parameters such as the longitudinal relaxation time (T1) of water molecules. The variation in measured T1 is due in some part to spatial inhomogeneity of the RF excitation of the sample. The factors contributing to these errors are complicated, since clinical scan protocols are often optimized for speed, not accuracy.

Phantoms used in regular quality assurance protocols can reveal system failures and abnormalities that are not observed in patient imaging due to a) the complex and multiple components of a system and b) the variability inherent in patients. Standardized phantoms for quantitative MRI, which are supported by a national metrology institute, enable data to be compared across MRI systems, manufacturers, and time.