Development of materials for use in nuclear magnetic resonance imaging contrast-resolution phantoms

Joseph Chester Blechinger

The early detection of cancer relies on the ability to detect small lesions that have properties close to those of the surrounding normal tissue. The measure of the smallest size object visible with a given contrast is called the resolution of the imaging system. Contrast resolution and other performance tests of a medical imaging system are performed with objects called phantoms. A phantom with low contrast, like that of tissues, is required for the evaluation of the contrast resolution of the system. Such phantoms are available for use with X-ray computed tomography and ultrasound imaging systems but, previous to this work, none were available for a magnetic resonance imaging system. The purpose of this work has been to develop tissue-mimicking phantoms suitable for evaluation of contrast resolution in an $\sp1$H magnetic resonance imager.

The project started with the establishment of a system for measurement of $\sp1$H nuclear magnetic resonance relaxation times at 10 and 40 MHz for phantom materials as well as breast tissue. Materials were developed which can mimic the hydrogen density and relaxation times of a range of tissue types. The relaxation times of the material were characterized for the temperature dependence and the measurements at two frequencies allowed for an estimate of the frequency dependence. The materials were measured periodically over several months to establish long-term stability of the relaxation times; a phantom must not change if it is to measure the reproducibility of an imaging system.

Materials were formed into configurations that were representative of the clinical situation. Clump-like tumors were mimicked using spheres made of material with higher relaxation times than those of the background simulated normal tissue. The sphere sizes, relaxation times, and $\sp1$H density were varied. The phantoms developed have two rows of spheres, each row contained seven spheres ranging in diameter from 9.5 mm down to 2 mm.

This work paves the way for development of commercial contrast-resolution phantoms for use in MRI as well as the development of anthropomorphic phantoms which will challenge MR imagers with "constant" patients having known representative geometries and associated NMR properties.