QIBA DCE-MRI Technical Committee Update: Phantom Studies and First DCE-MRI Profile

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INTRODUCTION

The QIBA initiative seeks to advance quantitative imaging and the use of imaging biomarkers in clinical trials and clinical practice by: 1) collaborating to identify needs and solutions to develop and test consistent, reliable, valid, and achievable quantitative imaging biomarker results across imaging platforms, clinical sites, and time, and 2) accelerating the development and adoption of hardware and software standards needed to achieve accurate and reproducible quantitative results from imaging methods [1]. The QIBA DCE-MRI technical committee initially focused on item 1) by initiating multivendor, multicenter, test-retest phantom assessments. More recently, efforts have focused on development of the first DCE-MRI profile and associated claim. This poster provides an update on each of these efforts.

DCE-MRI Phantom (version 1)

Phantom: Two matched 20-cm internal diameter spherical phantoms were purchased from The Phantom Laboratory (funded by National Cancer Institute contract 27XS112). For this particular application, the key component of the phantom design was the inclusion of eight 3-cm diameter spheres filled with $CuSO_4$-doped H_2O to yield T_1 relaxation times ranging from ~300-960 ms (R_1: ~1.0-3.3 s^{-1}). The remainder of the phantom was identical to the ADNI Magphan phantom [2, 3], including a 6-cm diameter central sphere filled with pure water. A 17-cm by 11-cm "cuboid", filled with 30 mM NaCl water (same solution as used for the flood fill component of the phantom), was used to appropriately load the radiofrequency coil.

Scanners and Sites: The phantom studies are initially being performed at five sites utilizing 1.5T scanners from GE, Philips, and Siemens.

Scan Protocol: Initial phantom characterization (inversion recovery T_1 measurements, phantom cross-comparison scans, initial QIBA protocol scans) were performed at M.D. Anderson Cancer Center. At each subsequent site, the phantom was scanned twice, with one week between the scans. During each scanning session, the phantom was rotated by 90° four times and rescanned at each position. This provides data necessary for a "coffee break" test–retest analysis as well as a one-week interval test-retest analysis. The phantom and cuboid were positioned in a phased-array receive coil. The phantom position at each of the five rotations was identified as A, B, C, D, and A'. Table 1 summarizes the data obtained at each rotation. All data were acquired using a 3D fast spoiled gradient echo sequence with acquisition parameters harmonized, vendor-to-vendor, as closely as possible. The same protocol was used to obtain data one week later. Inversion recovery (IR) based T_1 measurements were performed at one site; the results were used as "ground truth" for subsequent variable flip angle (VFA) T_1 measurements.

Data Analysis: The raw data analysis was carried out using software developed by VirtualScopics, Inc. From the DCE-MRI acquisition data, signal intensity, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR) measures were computed from each of the eight contrast spheres. T_1 measures were computed from the variable flip angle data from each sphere. These measures were obtained both before and after correction of the phased array coil data for spatial variations in coil sensitivity. This correction was carried out as follows:

1. Import the body coil and phased array ratio images
2. Normalize the range of the two images
3. Calculate signal intensity ratios (body coil:phased array) for each pixel
4. Apply 21x21 pixel kernel median filter
5. Multiply each pixel in the source image by the ratio map pixel data

Analysis of the signal characteristics in the DCE scans was accomplished by placing a uniform spherical 2-cm diameter region of interest (ROI) in the center of each phantom compartment. Mean and median pixel values within each ROI were calculated, along with SNR and CNR values. Noise in each compartment was defined as the standard deviation of the differences at each pixel between one phase and the next, divided by √2. Signal was defined as the mean signal value within each ROI. Contrast was defined as the absolute difference between the mean signal in an ROI and that of the central 6-cm sphere (water).

Preliminary data from two sites (systems from two vendors) were obtained and analyzed as described above. All relaxometry and DCE-MRI signal intensity *vs.* R_1 data are publically available on the QIBA DCE-MRI technical committee website (http://qibawiki.rsna.org/index.php?title=DCE-MRI_subctte). The results indicate that 1) IR-based and VFA-based R_1 measures compare favorably over the R_1 range assessed by this phantom (correlation coefficients of 0.997 and 0.991 for Site 1/Vendor A and Site 2/Vendor B, respectively), and 2) with intensity corrections as described above, the DCE-MRI signal intensity change *vs.* R_1 mean correlation coefficients (across all phantom rotation positions and scan dates) increased from 0.983±0.009 to 0.994±0.002 for Site 1/Vendor A and 0.917±0.026 to 0.993±0.002 for Site 2/Vendor B, indicating successful phased array coil intensity correction.

Series	Acquisition Details	Time (min)
Scout scan		5
Ratio images	Body coil; 15° flip angle, 8 averages	2
Ratio images	Phased array coil; 15° flip angle, 8 averages	2
SNR images	15° flip angle; 8 sequential acquisitions	8
Variable flip angle	2, 5, 10, 15, 20, 25, 30° flip angles; 4 averages	6
DCE-MRI images	40 phases for Rotations A & A', 6 phases for other rotations; 30° flip angle; ≤10 s temporal resolution	6 (40 phases) or 1 (6 phases)

Table 1: Data acquired at each rotation of the phantom.

DCE-MRI Phantom (version 2)

The version 1 phantom produced highly useful data for evaluation of contrast response and corrections for phased array response characteristics. However, the goal of routine use of such a phantom for site qualification and ongoing quality control led to a new proposed phantom design that was 1) less expensive, 2) more robust to shipment and routine use, 3) more time efficient in evaluating the same characteristics as the version 1 phantom design, and 4) allowed the assessment of contrast response over a broader R_1 range (representative of vascular input function relaxation rates). The new design consists of three "pseudo rotations" of 8 R_1 samples representative of tissue response in a DCE-MRI experiment (R_1: 0.7 - 11.4 s^{-1}). An inner set of 8 R_1 samples is representative of the vascular input function (R_1: 0.6 - 44.0 s^{-1}).

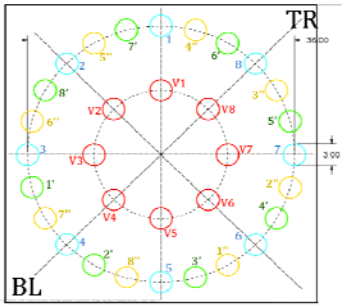

Figure 1: QIBA DCE-MRI Phantom version 2. Outer ring: 3 "pseudo rotations" (blue, green, yellow) of 8 R_1 samples representative of tissue response. (R_1: 0.7-11.4s^{-1}) Inner ring: 8 R_1 samples representative of vascular response (R_1: 0.6-44.0 s^{-1}). TR and BL are etched fiducials in the top and bottom plates of the phantom. Flood fill solution is 30 mM NaCl. R_1 doping material is $NiCl_2$. Phantom thickness is 12.5 cm.

The same data acquisition protocol described for the version 1 phantom was used to acquire preliminary data from a prototype version 2 phantom at a single site using a single vendor's system. For the QIBA protocol acquisition parameters, R_1 relaxometry data (Figure 2) demonstrate good agreement between IR-based R_1 measures and theoretical R_1 predictions for both the "tissue" and "vascular" samples. VFA R_1 measures agree well for the "tissue" samples, but demonstrate a marked departure for the "vascular" samples, *i.e.*, for R_1≥20 s^{-1}. DCE-MRI signal intensity (with phased-array coil intensity corrections) *vs.* R_1 results are similar (linear dependence over the "tissue" R_1 range, non-linearity becoming apparent, even with a 30° flip angle, for the "vascular" R_1 range, particularly for R_1≥12 s^{-1}).

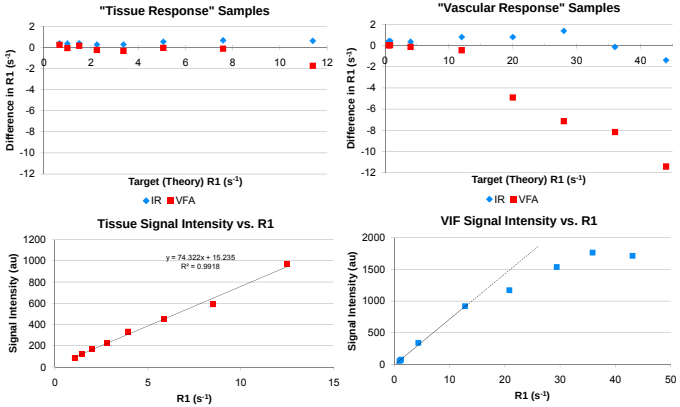

Figure 2: Top: R_1 difference (measured – target) for IR and VFA techniques for tissue (left) and vascular (right) R_1 ranges. Bottom: DCE-MRI signal intensity *vs.* R_1 for tissue (left) and vascular (right) R_1 ranges.

With initial assessment of the prototype QIBA DCE-MRI phantom complete, two commercial versions of the phantom will be manufactured and tested on scanners from three vendors at a minimum of four sites. Upon successful completion of field testing, the phantom will be made commercially available. (All design information is publically available on the RSNA QIBA wiki site.)

First QIBA DCE-MRI Profile and Associated Claim

A QIBA profile is a document that 1) tells the user what can be accomplished by following the profile requirements (the "Profile Claims"), 2) tells the vendor what they must implement in their product to state compliance with the Profile ("Profile Details"), and 3) tells the user staff what they must do for the Profile Claims to be realized ("Profile Details").

The first DCE-MRI Profile is currently under development and specifically addresses the following claim: "*Quantitative microvascular properties, specifically K^{trans} (endothelial transfer constant) and blood normalized initial area under the gadolinium concentration curve ($IAUGC_{BN}$), can be measured from DCE-MRI data obtained at 1.5T using low molecular weight gadolinium-based contrast agents within a 20% test-retest coefficient of variation for solid tumors at least 2 cm in diameter.*"

This profile is scheduled for completion in early 2011. Drafts can be obtained at http://qibawiki.rsna.org/index.php?title=DCE-MRI_subctte.

References

[1] http://qibawiki.rsna.org
[2] http://www.loni.ucla.eduADNI/
[3] http://www.phantomlab.com/magphan_adni.html