Simple, universal phantom for multi-center apparent diffusion coefficient (ADC) measurement

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Introduction

Quantitative biomarkers are being developed for tumor therapy response assessment where timely assessment of therapy response is extremely important. Diffusion-weighted MR imaging provides such a biomarker, the apparent diffusion coefficient (ADC), and there from derived functional diffusion maps (fDM) [1] in a noninvasive manner. In order to estimate the accuracy of ADC as a biomarker and provide uniform quality assurance across multiple MR systems a reproducible phantom is needed [2]. In this study ADC was measured in an ice-water phantom on multiple field strength MR scanners.

Methods

A phantom was built by immersing a vial of water into a larger container filled with iced water (figure 1). Thus the temperature drift of the diffusion measurement was avoided, as well as dependence on b-values range since the phantom is monoexponential. Apparent diffusion coefficients were measured on diffusion weighted images on 7 MR scanners from multiple manufacturers (GE, Philips, Varian) and multiple field strengths (1.5T, 3.0T, 9.4T). Diffusion weighted images were acquired with a single-shot sequence using multiple b-factors (0, 500, 800, 1000 s/mm^2) on the clinical scanners. The measurement was performed using 3 types of breast coils (4, 7, and 8-channel), or an 8-channel head coil, using a wide range of parameters from brain, breast and body protocols. The apparent diffusion coefficients were measured from 3 pairs of b values: 0 – 500, 0 – 800 and 0 – 1000 s/mm^2. On the animal system (9.4T) an isotropic diffusion-weighted spin-echo sequence was used [3] with a birdcage head coil. The b-factors were: 120, 1200, 2000 and 4000 s/mm^2.

Results

The ADC measurements are presented in figure 2. Eleven sets of mean ADC value ± s.d. calculated from 3 pairs of b-factors each were measured in a phantom ROI. Across all scanners, field strengths (1.5T, 3T, 9.4T) and sequence parameters there was no significant difference among the measured values (p=0.945).

Conclusion

This study shows the inter- and intra-system reproducibility of ADC measurements, as well as the independence of ADC on MR hardware, field strength, sequence parameters, and diffusion b-factors in a simple water phantom. Therefore, ADC presents good technical properties as a biomarker for therapy response evaluation. The ice water ADC phantom is simple, inexpensive and offers a highly reproducible material to test proper calibration and stability of an MRI system in performing serial ADC measurements as required for treatment response studies. Compared to other potential biomarkers (eg. blood volume/flow, K$_{trans}$, metabolite concentrations), ADC is relatively immune to specifics related to vendor, software level, field strength, and acquisition sequence conditions. Note, the ice water ADC phantom is not intended to mimic water diffusion tissue. It does, however, provide a reliable quality assurance system well suited for multi-center, multi-vendor DWI-based studies.

References:[1] Moffat BA et al, Proc Natl.Acad.Sci. USA. 2005, Apr 12;102(15):5524-9, [2] Tofts PS, et al. Magn Reson Med. 2000 Mar;43(3):368-74, [3] Moffat BA, et al. MAGMA 2004; 17:249-259.
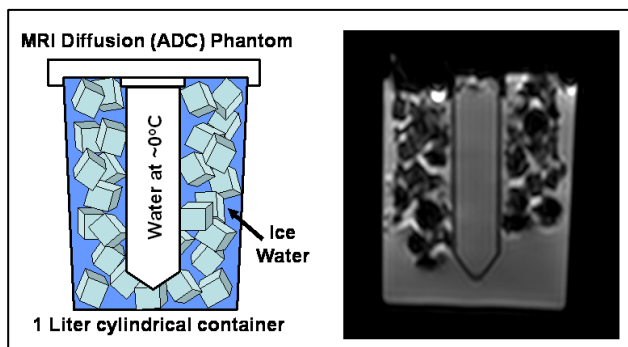
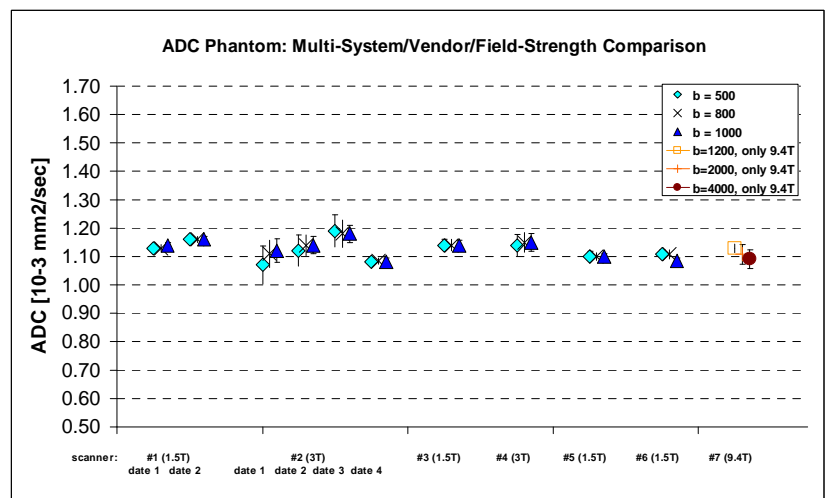**Figure 1.** The iced water phantom description, and a diffusion-weighted image of the phantom.

Figure 2. Thirty three ADC measurements (±σ) on the proposed ADC phantom across 3 vendors, 3 two field strengths and 7 different magnets. ADC calculated using b values 0-500, 0-800, & 0-1000 s/mm^2 at 1.5T and 3T, and 120-1200, 120-2000, 120-4000 s/mm^2 at 9.4T.