Quality Assurance of Diffusion-Weighted MRI for Multicentre Clinical Trials

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Purpose: Recent consensus reviews have advocated multi-centre validation of quantitative imaging bio-markers such as the Apparent Diffusion Coefficient (ADC)[1]. Previous phantom designs have demonstrated the utility of ice/water for thermal control[2] and sucrose for manipulation of diffusion properties[3]. This study aimed to establish multi-centre reproducibility of phantom ADC measurements and identify primary sources of variability. A programme of quality assurance for DW-MRI at 1.5 T was carried out in 5 European imaging centres with different scanner manufacturers.

Methods: DW-MR images were acquired using a purpose-built temperature-controlled phantom containing five samples of varying sucrose concentrations (ICR, UK; submitted ISMRM abstract #1868); repeat measurements were carried out over a 6 month period (6 – 12 data points per site). Sequence parameters were as follows: b = 100, 500 and 900 s mm^{-2}; parallel imaging with acceleration factor 2; TR ≥ 7000 ms; minimum available TE (range 100 – 127 ms); 128 matrix; pixel size = 2.5 x 2.5 mm; slice thickness = 5 mm, no slice gap. All acquisitions used surface body coils and a reproducible position and orientation of the phantom. A one-off measurement with 10 b-values (b_{max} = 2000 s mm^{-2}) and three separate, orthogonal direction, diffusion-weighted images was also acquired at each site.

Results: Differences were observed in scanner accuracy, precision and stability, Figure 1 shows mean and standard deviation of reported ADCs. Measurements revealed a mean inter-site coefficient of variation of 2.2% averaged across all five samples (single site range = 1.1 – 4.8%), Table 1. Image artefacts were identified at sites B and D. The 95% interval of ADC measurements of 0, 10 and 20% w/v sucrose solutions at 0°C were (105 – 120), (86 – 102) and (69 – 80) x 10^{-5} mm^2 s^{-1}, respectively.

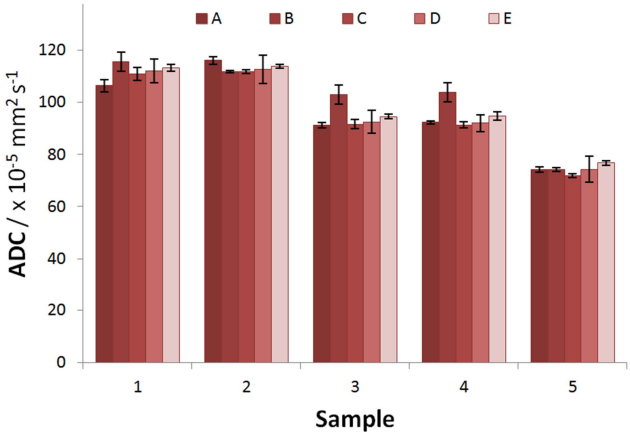

Figure 1: ADC values of 5 samples (0, 0, 10, 10 and 20% sucrose) measured on 5 independent scanners (sites A – E)

Site	Sample CoV / %					Single site mean CoV
	1	2	3	4	5	
A	2.1	1.3	1.1	0.5	1.4	1.3
B	3.1	0.4	3.6	3.6	1.0	2.3
C	2.3	0.5	1.9	1.3	1.1	1.4
D	4.0	4.9	4.8	3.5	6.8	4.8
E	1.1	0.7	0.8	1.6	1.1	1.1
Single sample mean CoV	3.0	1.6	5.1	5.4	2.3	

Table 2: Coefficient of variation of phantom ADC values of 5 samples measured on 5 independent scanners

Discussion: At site B, elevated ADC observed for samples 3 and 4 prompted further investigations which revealed spatial variation in ADC within a uniform test object. At site D, comparison between separate, orthogonal direction, diffusion-weighted images showed unexpected asymmetric signal attenuation; this effect was reduced when partial Fourier techniques were not applied. Assessment of the 10 b-value acquisition at all sites showed no evidence of noise bias at high b-value affecting ADC accuracy.

Conclusion: Quality assurance carried out in five imaging centres with five structural phantoms engineered to a high standard has identified site-specific systematic errors in ADC calculation. Prior to quantitative testing of ADC, spatial uniformity should be assessed with a large uniform test object. For optimal precision in repeat measurements of ADC, reproducible subject positioning within the bore of the magnet is critical. Results from systems without identifiable artefact suggest that an ADC CoV of less than 2% is achievable with well controlled scanner set-up.

References: (1) Waterton JC, Pylkkanen L. *Eur. J Cancer.* 2012; 48: 409 – 15. **(2)** Chenevert TL, Glaban CJ, Ivancevic MK, *et al. J. Magn. Reson. Imaging.* 2011; 34(4): 983-7. **(3)** Delakis I, Moore EM, Leach MO, De Wilde JP. *Phys. Med. Biol.* 2004; 49: 1409.

Acknowledgements: We acknowledge the support of QuIC-ConCePT (a project of the Innovative Medicines Initiative), CRUK and ESPRC Cancer Imaging Centre in association with the MRC and Department of Health (England) grant C1060/A10334 and also NHS funding to the NIHR Biomedical Research Centre.