Development of a Phantom for Quality Assurance in Multi-Centre Clinical Trials with Diffusion-Weighted MRI

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Purpose: Diffusion-Weighted (DW) MRI has gained prominence in oncology as a technique which may allow quantitative assessment of tumour status and progression of disease. For widespread application in multi-centre trials, these techniques require assessment of the sensitivity and reproducibility of the technique; comparison between scanner platforms[1] and performance assessment of common protocols should be carried out. The purpose of this study was to develop a phantom for quality assurance in multi-centre clinical trials which apply DW-MRI.

Methods: A modular Perspex phantom was designed and built to facilitate temperature controlled measurements of the Apparent Diffusion Coefficient (ADC). The phantom has capacity for five sample tubes within a 10 litre cylindrical vessel, an example image is shown in Figure 1; the samples may be removed and altered as required. The phantom is compatible with both head and body coils from major manufacturers and may be moved within the magnet bore to assess performance as a function of position.

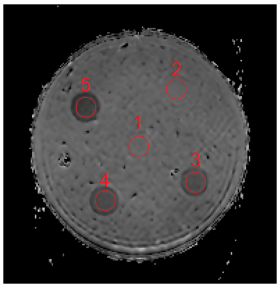

Figure 1: Example ADC map with ROIs

Temperature control was achieved with the use of an ice/water mixture in the main vessel of the phantom[2]. Temperature stability was monitored with a thermocouple. Control over the ADC of the sample was achieved with the addition of sucrose[3]. The sample ADC, T1 and T2 were measured as a function of sucrose concentration (0 – 50% w/v) at 0 and 22°C. Sample T1 and T2 were altered with the addition of manganese chloride ($MnCl_2$). The relaxivity properties of $MnCl_2$ were assessed at 0 and 22°C as a function of $MnCl_2$ concentration (0 – 0.04 mM). T1 mapping was achieved using a variable flip angle method. T2 mapping was achieved from a multi-echo spin echo sequence with 32 echo times ranging from 13.1 – 419.6 ms. ADC maps were acquired using a diffusion weighted SS-EPI acquisition with 10 b-values in the range 0 – 2730 $mm^2\ s^{-1}$. Sodium azide (0.02% w/v) was added to each of the solutions as a bactericidal agent.

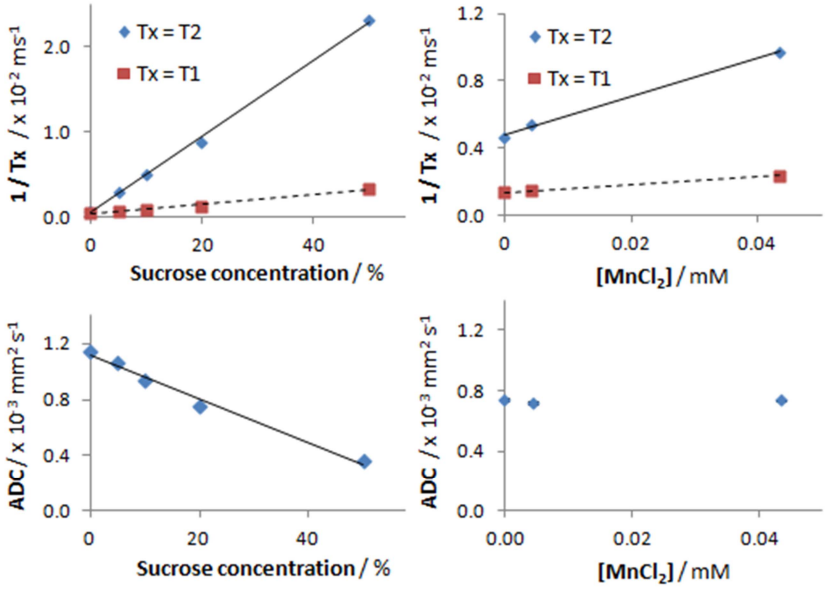

Figure 2: Sample T1, T2 and ADC as a function of dopant concentrations

Results and discussion: Stable temperature control is achieved over a 2 hour period. Linear relationships were observed between sucrose concentration and measured ADC, T1 and T2. Linear relationships were observed between $MnCl_2$ concentration and relaxation parameters, but not with sample ADC, see Figure 2. For the final design, concentrations of sucrose and $MnCl_2$ were selected to provide physiologically relevant ranges of T1, T2 and ADC at 0°C; these are shown in Table 1.

#	Sucrose / %	$MnCl_2$ / mM	T_1 / ms	T_2 / ms	ADC / x 10^{-3} $mm^2\ s^{-1}$
1	0	0.13	400	80	1.1
2	0	n/a	1900	1400	1.1
3	10	0.09	400	80	0.95
4	10	n/a	1300	200	0.95
5	20	0.07	400	80	0.75

Table 1: Phantom sample contents and properties at 0°C

Conclusion: A phantom suitable for inter-scanner comparison of ADC measurements has been developed based on previous work by Chenevert *et al*[2]. This test object is being used to aid the validation of ADC as a biomarker for treatment response of tumours in multi-centre clinical trials.

References: **(1)** Padhani AR, Liu G, Koh DM et al. *Neoplasia*. 2009; 11(2): 102-25. **(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.

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