In-Vivo Measurement of ADC change due to Intravascular Susceptibility Variation

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INTRODUCTION

It has been known for some time that background gradients can distort diffusion measurements (1). More recently, it was shown that when the background gradient is not constant over the volume, but distributed in a gaussian manner, the apparent diffusion coefficient (ADC) is *reduced* (2). Demonstrations of this phenomenon were made with computer simulations, microsphere phantoms, and in *ex-vivo* rat livers containing a superparamagnetic contrast agent (AMI-125) (2).

This abstract presents *in-vivo* measurements of ADC reduction due to a distribution of background gradients resulting from induced intravascular susceptibility variations. The ADC reduction is found to correlate approximately linearly with both intravascular susceptibility ($\Delta\chi$) and R_2^*. Interpolation indicates that for the pulse-sequence parameters employed in these measurements, an ADC change of up to ≈5% can result from blood-oxygenation changing from fully oxygenated to fully deoxygenated.

METHODS

Imaging was performed at 2.0 Tesla on a small-bore, GE Omega CSI system, using a 50 mm diameter home-built birdcage coil, and Acustar imaging gradients. Rat brain images were generated using a 40 mm FOV, 64 samples x 32 phase-encode steps, 2 NEX, TR = 2 s. ADC and R_2^* were measured using a series of four images: two gradient-echo images—TE = 7 ms and 30 ms—and two spin-echo images—TE = 42 ms, Δ = 23 ms, δ = 8 ms, with read-direction, half-sine diffusion-sensitising gradients of 0.1 G/cm and 18 G/cm. Intravascular susceptibility was varied using 0.3 mL injections of superparamagnetic contrast agent AMI-227, with an iron concentration of 2 mg/mL. Two sets of images were generated before the first and following each injection. Corresponding to each set of images, ≈ 0.3 mL of blood was sampled and later used to measure the susceptibility change resulting from the contrast agent. Experiments were repeated on five different female Sprague-Dawley rats, weighing approximately 200g each.

RESULTS AND DISCUSSION

R_2^*, ADC, and $\Delta\chi$ were all found to change approximately linearly with increasing AMI-227 injections. For all three measures, mean data were fit to a linear dependence on iron dose. The ADC data was also normalised to 1 for the baseline case of no contrast agent. Susceptibility was found to change by ≈ 0.25 ppm/mg, R_2^* increased by ≈ 16 s^{-1}/mg, and ADC decreased by ≈ 7%/mg. Reworking these relationships gives ADC decreasing by ≈ 27% per ppm of susceptibility shift and by ≈ 0.4% per s^{-1} R_2^* rate increase. Fig. 1 shows the mean ADC data as a function of AMI-227 dose—errorbars indicate standard deviations over the five rats.

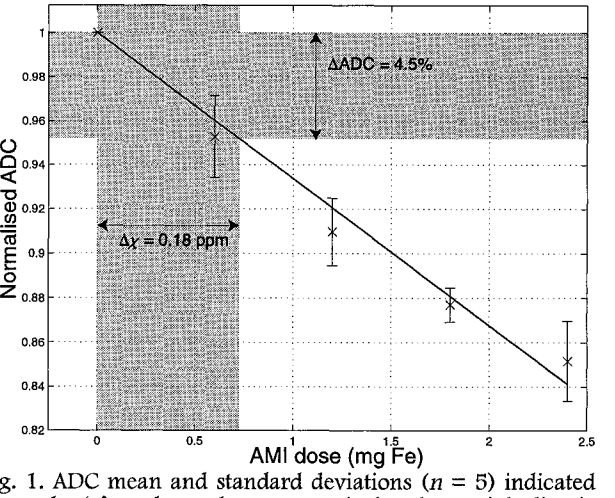

Fig. 1. ADC mean and standard deviations (n = 5) indicated by 'x's and errorbars, respectively. The straight line is a least-squares fit of the mean data to a linear reduction of ADC with iron dosage.

Also shown in Fig. 1 is the range over which blood oxygenation levels could alter ADC. Vertical grey bar corresponds to the range of susceptibility from fully oxygenated to fully deoxygenated blood (3), and the horizontal grey bar shows the resulting ADC reductions over that range of intravascular susceptibility.

Note that the observed ADC changes are dependent upon various pulse-sequence parameters and, therefore, may vary significantly from one ADC measurement protocol to another.

CONCLUSION

Intravascular susceptibility changes induce microscopic background gradients in rat brain tissue, which, in-turn, result in a decrease in the ADC. For a PGSE sequence, with the aforementioned timings, this ADC reduction is approximately 7% per mg of iron, which corresponds to an expected ADC reduction of up to 5% due to maximum blood-oxygenation level changes.

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