Errors in DCE MRI Measurements Due to Errors in Gd Concentration Estimates

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Introduction: Dynamic Contrast-Enhanced MRI (DCE-MRI) is used to characterize the microcirculation in pathologies ranging from cancer to multiple sclerosis. With the extended Tofts model, tissue contrast concentration, C_t, is given by,

$$C_t = v_p C_p + k_{trans} \int_0^t C_p(t') e^{\frac{-k^{trans}}{v_e}(t-t')} dt \qquad [1]$$

where C_p is the plasma concentration v_p the fractional plasma volume, v_e the volume of the extravascular, extracellular space and K^{trans} the vascular transfer constant (1). Given C_p the other parameters may be estimated by fitting Eq. [1] to the measured tissue concentration curve. Contrast concentration is normally calculated assuming that the change in relaxation rate is linearly proportional to gadolinium concentration, [Gd]. However, this is known to be untrue in tissue (2,3). In this study we used computer simulations to investigate the effect of non-linearities on the accuracy of first-pass, T2* weighted DCE MRI estimates (4) of v_p, v_e and K^{trans}.

Methods: C_p was simulated using the bolus shape function described by Johnson et al. (4) with parameters found by averaging measurements in five glioma patients. C_t was then calculated using Eq. [1] with typical parameters for meningiomas (v_p = 0.08, v_e = 0.4, and K^{trans} = 0.3 min^{-1}) and gliomas (v_p = 0.05, v_e = 0.2, K^{trans} = 0.08 min^{-1}) (5). Signal intensity curves were then calculated for a T2* weighted sequence assuming that

$$\Delta R2^* = aC_t + bC_t^2 \qquad [2]$$

and with values of a and b measured in a yeast phantom (6). Erroneous estimates of concentration, C_t', were then obtained from these signal intensity curves by assuming a linear relationship between $\Delta R2^*$ and concentration (i.e., assuming b in Eq. [2] is zero). Finally, Eq. [1] was fitted to these estimates to obtain the erroneous estimates of of v_p, v_e and K^{trans}.

Results: Figure 1 shows plots of simulated C_t and C_t' for a standard dose of Gd (0.1 mM). Figure 2 shows a plot of fractional error in v_p, v_e and K^{trans} plotted against Gd dose for glioma and meningioma. With standard dose, the error in estimated parameters ranges from 5 – 10% in meningioma and 1-5% in glioma. Triple dose increases errors in meningioma and glioma estimates to between 20 – 30% and 5 – 15% respectively.

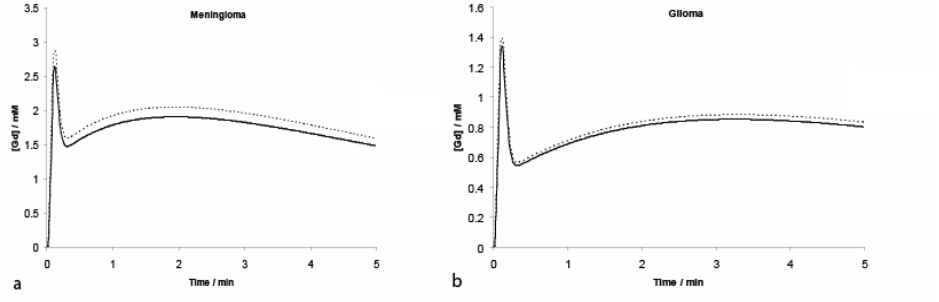

Figure 1. Simulated values of C_t (true concentration, solid) and C_t' (estimated concentration, dashed) for **a:** meningioma and **b:** glioma.

Discussion and Conclusion: Fractional error increases approximately linearly with dose in all three estimated parameters. This finding can be confirmed theoretically using the Tofts model. Errors in parameter estimates are relatively small using a standard dose of Gd even with the vascular, leaky meningioma. However, larger doses may lead to more substantial errors. Similarly errors may be greater when concentrations are derived from T1 or T2 weighted sequences or with different tracers.

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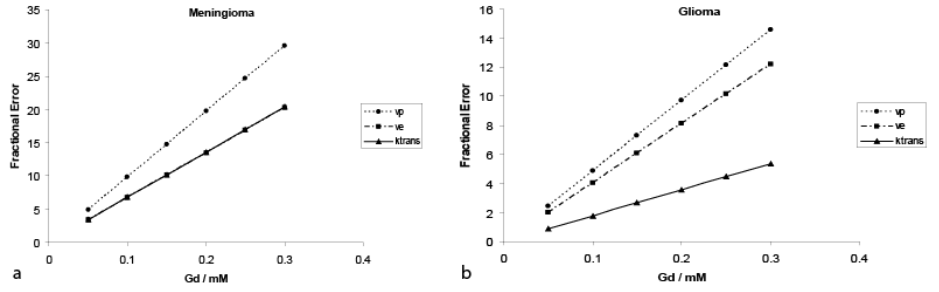

Figure 2. Fractional error in parameter estimates plotted against Gd concentration for **a:** meningioma and **b:** glioma.

References: 1. Tofts PS: J Magn Reson Imaging. 1997 Jan-Feb;7(1):91-101. 2. Kiselev VG: Magnetic Resonance in Medicine 2001; 46(6):1113-22. 2. Landis CS et al. Magn. Reson. Med. 2000; 44:563-574.4. Johnson G. et al.: Magn Reson Med. 2004 May;51(5):961-8. 5. Cheng H-L Margret: J Magn Reson Imaging. 2008 Sep;28(3):736-43. 6. Patil V. et al. ISMRM Abstract Submission, 2008.