Relative SNR benefits and optimal dosing of $\Delta\varphi$ and ΔR_2* arterial input functions determined by simulations at 1.5T and 3T

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INTRODUCTION: Dynamic susceptibility contrast-enhanced magnetic resonance imaging (DSC-MRI) has been applied to attempt to quantitate cerebral perfusion. One shortcoming of quantitative DSC-MR perfusion imaging is the difficultly in determining a reliable arterial input function (AIF). While initial results suggest that $\Delta\phi$ AIFs may have an SNR advantage over magnitude-based (ΔR_2*) AIFs *(1)*, the noise and SNR properties of ΔR_2* and $\Delta\phi$ AIFs have not been fully investigated. Here, ΔR_2* and $\Delta\phi$ AIF curves are simulated for three goals: 1) to study the noise and SNR characteristics of the AIF curves at 1.5T and 3T, 2) to determine the optimal dose for maximal SNR, and 3) to assess the relative SNR benefits of $\Delta\phi$ and ΔR_2* AIF methods.

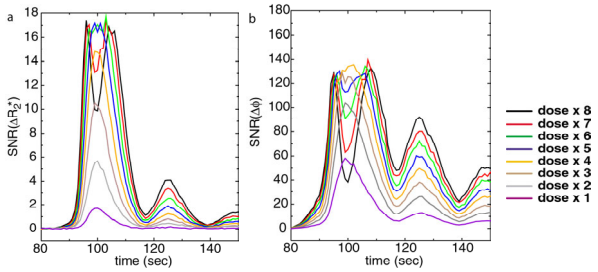

Figure 1. SNR(ΔR_2) (a) and SNR($\Delta\phi$) (b) for AIFs simulated with 8 doses at 3T and SNR(I_0) = 50.*

METHODS: Simulated ΔR_2* and $\Delta\phi$ AIF curves were produced from an ideal $\Delta\phi$ AIF curve derived from a different 3T human data set (0.03 mmol/kg, 4 cc/s, TE = 13 ms) that was smoothed and interpolated *(2,3)*. The ideal $\Delta\phi$ AIF curve was scaled to each simulated dose, the concentration and ΔR_2* curves were generated *(4,5)*, and noise was added in quadrature to produce simulated ΔR_2* and $\Delta\phi$ AIF curves at specific baseline magnitude SNR levels [SNR(I_0)]. One-thousand noisy AIF curves were generated using 1000 sets of noise realizations, and then repeated at 10 doses factors (multiples of 0.03 mmol/kg) and 29 SNR(I_0) levels. The mean, standard deviation, and SNR of the 1000 ΔR_2* and $\Delta\phi$ AIF curves were calculated at each time frame. The dose that produced the highest SNR at the peak of the AIF was taken to be optimal, and the corresponding peak percent signal change was determined.

RESULTS: Figure 1 shows the SNR(ΔR_2*) (a) and SNR($\Delta\phi$) (b) results at 3T. The SNR increases during bolus passage for both signals. The AIF noise elevation during bolus passage is overcome by the AIF response. At higher doses, there is a point of inflection where the noise gain is greater than the signal gain. Figure 2 shows the SNR(ΔR_2*) (a) and SNR($\Delta\phi$) (b) at the AIF peak as a function of dose at 3T and 1.5T. For SNR(I_0) > 13 at 3T, the optimal dose occurs at 67% signal drop (0.16 mmol/kg) for ΔR_2* and 43% signal drop (0.11 mmol/kg) for $\Delta\phi$. The optima occur at higher doses for 1.5T. For lower SNR(I_0) (<13), the optimal dose is the highest possible dose that is not saturated.

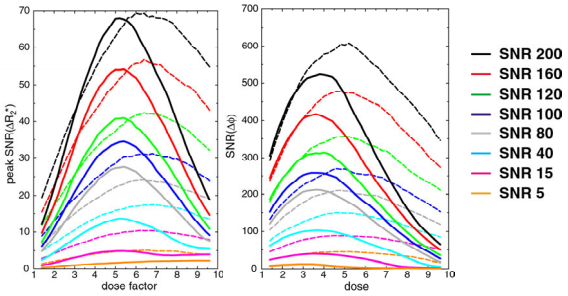

Figure 2. Peak SNR(ΔR_2) (a) and SNR($\Delta\phi$) (b) for many SNR(I_0) levels at 3T (solid lines) and 1.5T (dashed lines).*

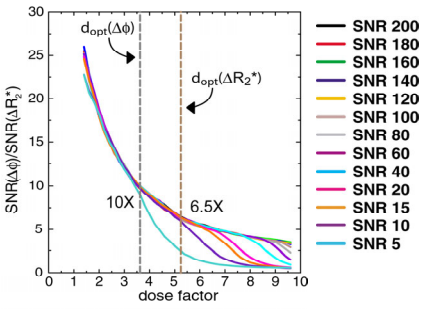

Figure 3. Ratio of SNR($\Delta\phi$) to SNR(ΔR_2) as a function of dose for several SNR(I_0) levels at 3T. The $\Delta\phi$ and $\Delta R2$* optimal doses are indicated by gray and brown vertical lines, respectively.*

Figure 3 shows the ratio of SNR($\Delta\phi$) to SNR(ΔR_2*) for several SNR(I_0) levels at 3T. At all doses, the $\Delta\phi$ signal has a significant advantage over ΔR_2* (by a factor of 4-26 across doses).

CONCLUSION: Simulations show that the noise of both the ΔR_2* and $\Delta\phi$ AIFs increase during bolus passage, but the noise is overcome by the AIF signal so that the AIF SNR increases for doses up to the optimal dose. The optimal dose depends on field strength and signal type, and the $\Delta\phi$ AIF has a substantial SNR advantage over the ΔR_2* AIF.

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