Implications of unequal interstitium and plasma contrast reagent relaxivities in pharmacokinetic analysis of DCE-MRI

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Purpose: Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCE-MRI) indirectly detects contrast reagent (CR) concentration through water proton relaxivity change. Within a single tissue compartment, a linear relationship is assumed, $\Delta R_1 = r_1 \Delta [CR]$. The slope $r_1$, the longitudinal relaxivity, quantifies the CR potency to change water proton $T_1$. It is current practice to assume that $r_1$ is the same in blood plasma and all interstitial compartments. However, there is evidence that a potential increase in the interstitium $r_1$ (1, 2). Based on human prostate data, we demonstrate the implications of differences of $r_1$ (interstitium relaxivity) to $r_1p$ (plasma relaxivity) values on DCE-MRI pharmacokinetic parameters.

Methods: Prostate DCE-MRI data were acquired on 13 subjects with a Siemens TIM Trio (3T) system under an IRB-approved protocol. RF transmitting was through the whole body coil and RF receiving was with a combination of Spin Matrix and flexible Body Matrix coil arrays. The DCE-MRI acquisition employed a 3D TurboFLASH pulse sequence with a 256*144*16 matrix size and a 360*203 mm$^2$ FOV, resulting in (1.4)$^3$ mm$^3$ in-plane resolution. Other parameters are: slice thickness: 3 or 3.2 mm; TR/TE/FW: 5.0 ms/1.57 ms/15º, image frame sampling interval: 6.3 s. A 0.1 mmol/kg CR (ProHance; Bracco) bolus was administered starting ~38 s after initiation of the DCE-MRI sequence. In general, the protocol of (3) was used. All subjects subsequently underwent standard ten-core prostate biopsies with ultrasound guidance. Malignancies were found in 5 subjects and the remaining were benign cases. One region of interest (ROI) was selected for each subject, resulting in 5 malignant and 8 benign ROI time-courses. Simulations were performed on ROI data from the subjects (one ROI per subject). $r_1p$ is assumed to be 3.8 mM$^{-1}$s$^{-1}$. $\Delta [CR]$ was obtained from the best fit of the 20 trials for each combination were then selected as the fitted results.

Results: Fig. 1 shows representative malignant (red) and benign (black) Ktrans values with increasing $r_1o$ change (not shown) is much smaller. This is quite reasonable since $\tau_1$ measures water exchange kinetics while $K_\text{trans}$ measures plasma/interstitium CR transfer kinetics. Results from this simulation study may partially explain the observations that DCE-MRI often obtains larger ve values than one would normally expect. In addition, $K_\text{trans} = k_o$, the CR intravasation rate constant (3-5). These results also suggest that $k_o$ could be a more reliable imaging biomarker in certain in vivo applications. Current work underscores the importance of quantifying $r_1o$ independently.

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