45

The effect of the presence of a freely diffusing compartment on observation of restricted diffusion in single- and double-PFG experiments

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Introduction: Studies of restricted diffusion are commonly conducted using single pulsed-field-gradients (s-PFG) diffusion experiments[1]. In homogenous samples, the diffusion-diffraction phenomenon arising from a single population of diffusing species has been observed, and the restricted diffusion profile was used to extract important structural features from the sample[2]. However, systems that are more realistic such as biological tissue and porous media are characterized by compartmentation which may complicate the interpretation of structural features. Double-PFG (d-PFG) experiments have lately been gaining interest due to their ability to extract small compartmental dimensions even at low q values[3]. Therefore, in this study, we characterized the superposition of restricted and free diffusion in s- and d-PFG both experimentally and theoretically using a novel composite bi-compartmental phantom, in which the „ground-truth“ is known *a-priori*.
Subjects and Methods: Figure 1 shows a cartoon of the bi-compartmental phantom. Freely diffusing water in the Fast-Diffusion-Compartment (FDC) undergoes Gaussian (free) diffusion while water in the microcapillaries experiences restricted diffusion forming the Slow-Diffusion-Compartment (SDC) of the bi-compartmental phantom.
Results: Figure 2 shows the s-PFG experiment conducted with varying diffusion periods on the bi-compartmental model. Two phenomena can be seen in the different q-regimes. For high q-values, the diffraction patterns from water diffusing in the SDC can be gradually observed. At Δ>100 ms, the diffusion profile doesn't change at high q-values. However, at lower q-values, e.g., q<200 cm^{-1}, the diffusion curves change dramatically for each value of Δ, and shows increased attenuation of the signal with increasing Δ. Solid lines represent the theoretical curves.
Figures 3A and 3B show the angular d-PFG experiment in the bi-compartmental model at low and high q-values respectively. At the low-q regime, the angular dependence is lost, and the size of the compartment cannot be accurately extracted. However, at higher q-values, the angular dependence is retained, and the accurate size of the compartment is extracted.
Conclusions: The effect of adding an FDC on the observation of restricted diffusion was studied using s-PFG and d-PFG experiments. Importantly, structural information can be extracted at higher q-values where the restricted diffusion is accentuated, and the free diffusion is suppressed. This may be of importance in biological tissue and porous media.
References:
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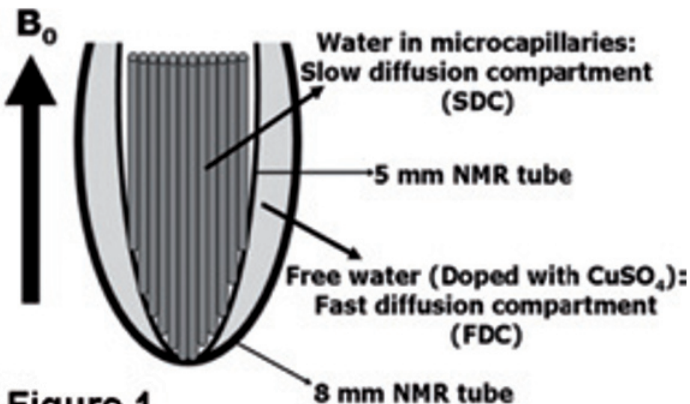

Figure 1

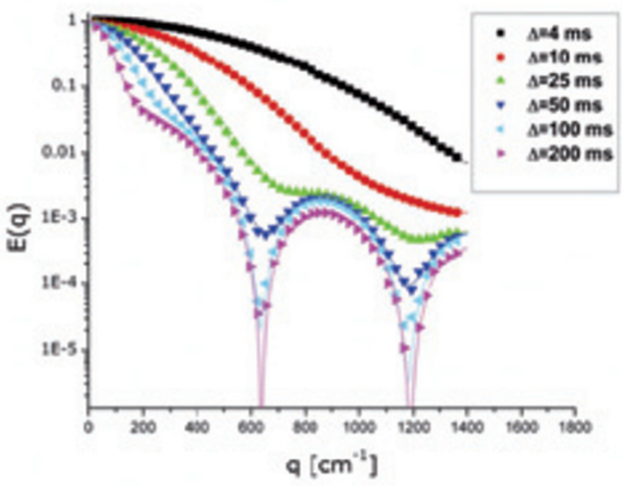

Figure 2

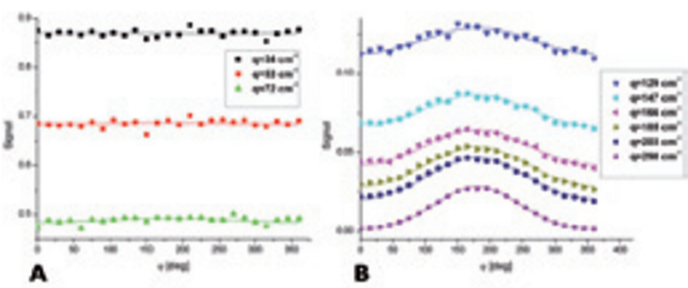

Figure 3