ON THE EFFECTS OF DEPHASING DUE TO LOCAL GRADIENTS IN DTI EXPERIMENTS: RELEVANCE FOR DTI FIBER PHANTOMS

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Introduction

We recently proposed a circular DTI phantom [1] that allows high packing densities which enables high fractional anisotropy (FA) values. We observed that the transversal relaxation time T_2 depends on the fiber orientation towards B_0. It is well known that locally varying gradients can cause such an additional orientation dependent dephasing [2], and that they can falsify diffusion measurements [3,4]. Till now, however, the impact of local gradients on the usability of DTI-phantoms was not investigated and no effort was made to match susceptibilities. Hence, the purpose of this work was to overcome these limitations.

Fig.1: Packing types for Monte-Carlo simulations

Methods

The circular DTI-phantom was constructed as described in [5]. Distilled water and an aqueous sodium chloride solution (83 g NaCl per kg water) were used as fluid. The concentration of sodium chloride was adapted to match the susceptibility of fibers and fluid. The phantom properties were measured at 1.5 T and 3.0 T (Magnetom Avanto and TRIO, Siemens Medical Solutions, Erlangen, Germany). All diffusion weighted images were acquired using a single shot, spin echo, echo planar imaging sequence with twice refocused spin echo diffusion preparation. Parameters were FOV = 200x151 mm², voxel size = 0.87x0.87x5 mm³, TR = 3 s, TE = 120 ms, 3 averages, bandwidth = 1368 Hz/Px, partial fourier factor = 5/8, b=0, 100, …, 1000 s/mm², Grappa x2. Diffusion gradients were applied in slice, read, and phase encoding direction. The transversal relaxation time T_2 of the phantoms was measured by means of a single-echo spin echo sequence. Parameters were FOV = 256x64 mm², voxel size = 2x2x5 mm³, TR = 5 s, TE = 100 ms, 10 averages, bandwidth = 130 Hz/Px. A Monte-Carlo Code was implemented to simulate the spin dephasing theoretically (Fig.1).
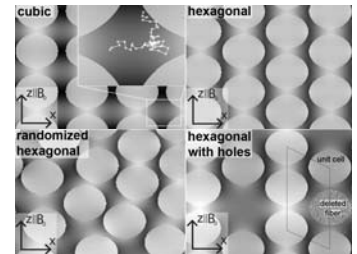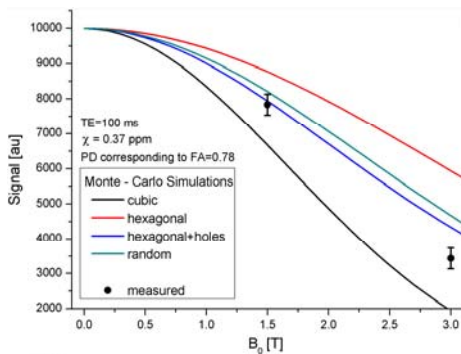

Fig.2: The signal decreases for fibers perpendicular to B_0 with pure water as fluid due to locally varying gradients. This causes orientation dependent SNR.
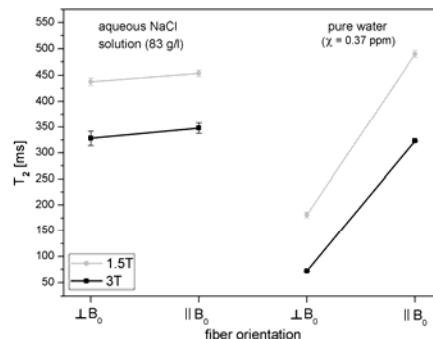

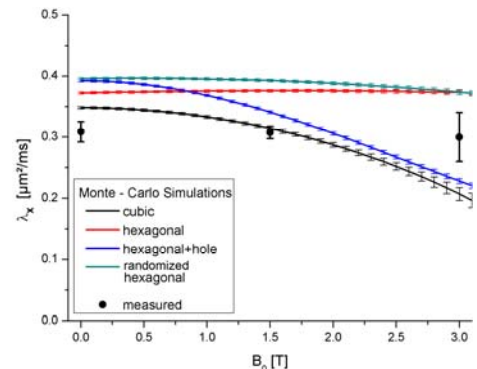**Fig.3:** Adapting the susceptibility of fluid and fibers by solving NaCl removes the orientation dependent T_2 effect.

Fig.4: The eigenvalues depend on B_0 with water as fluid for fibers perpendicular to B_0. The diffusion is measured incorrectly.

Results

Fig. 2 shows the normalized signals dependency on the field strength for a spin echo experiment with water as fluid. At higher field strengths, the relaxation becomes more and more prominent, 12% to 33% of the signal is decayed at 1.5 T and 41% to 81% is decayed at 3.0 T. The simulated relaxation rate depends strongly on the exact packing type. Fig. 3 shows the measured transversal relaxation time T_2 for fibers running parallel and perpendicular to B_0. Using the aqueous 83 g/l sodium chloride solution, T_2 varies less than 4% for fibers running parallel and perpendicular to B_0. When using pure water as fluid, T_2 is markedly decreased (by 60% at 3 T) for fibers running perpendicular to B_0. Due to this varying relaxation rate, signal intensities become dependent on fiber orientation. Fig. 4 shows the dependence of the measured diffusion in x-direction on B_0 for fibers perpendicular to B_0 with pure water as fluid. For some packing types, there is a clear field strength dependency. However in the real phantom, no difference between fibers running perpendicular and parallel to B_0 could be observed. The diffusion values of fibers running parallel to B_0 at 1.5 T were interpreted as values for $B_0 = 0$ T.

Fig.5: Adapting the susceptibilities yields field strength independent and reliable diffusion measurements.

Discussion

The susceptibility matching of fibers and fluid, for instance with sodium chloride, is a clear step forward towards a widespread and reliable use of DTI phantoms and is very advisable in two regards: First, the transversal relaxation time becomes independent of the fiber orientation and it is elongated for fibers running perpendicular to B_0. This allows an arbitrary orientation of the phantom without SNR variations. Secondly, the diffusion measurement is reliable, since local gradients cannot falsify the diffusion weighting.

References

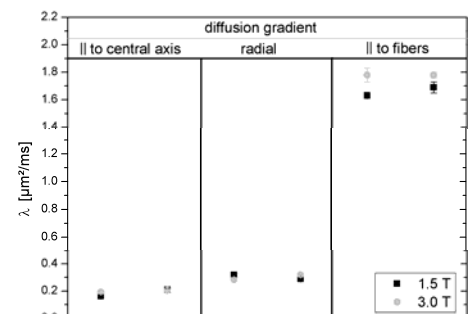[1] Laun et al. ISMRM 2007 [2] Yablonksiy et al. MRM 1997 [3] Kiselev et al. J Magn Reson 2004 [4] Zhong et al. J Magn Reson 1991 [5] Laun et al. MRI 2008