Physical orientation in the magnetic field affects diffusion measures: a hardware phantom study

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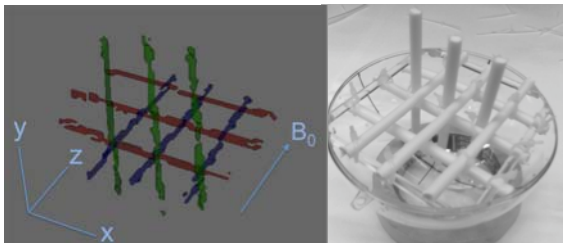
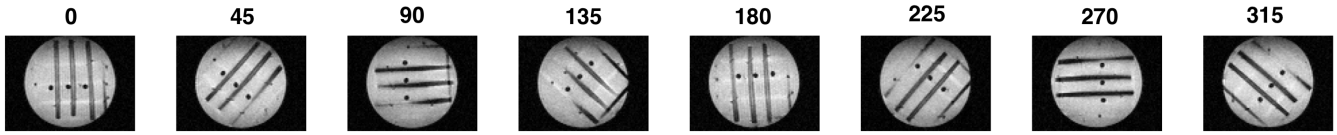
Introduction It was shown recently in an isotropic water phantom that ADC values are not equal in each measured diffusion direction due to gradient mis-calibrations [1]. MR resonance frequency is also dependent on the orientation of anisotropic structures in the magnetic field [2], which possibly contributes to deviations in the diffusion measurement. We investigated the effect of orientation of an anisotropic diffusion phantom on the non-DW (b0) signal, FA and the first eigen value (λ_1). Our results show considerable variations in b0, FA and λ_1 in the anisotropic phantom at different orientations in the magnetic field.

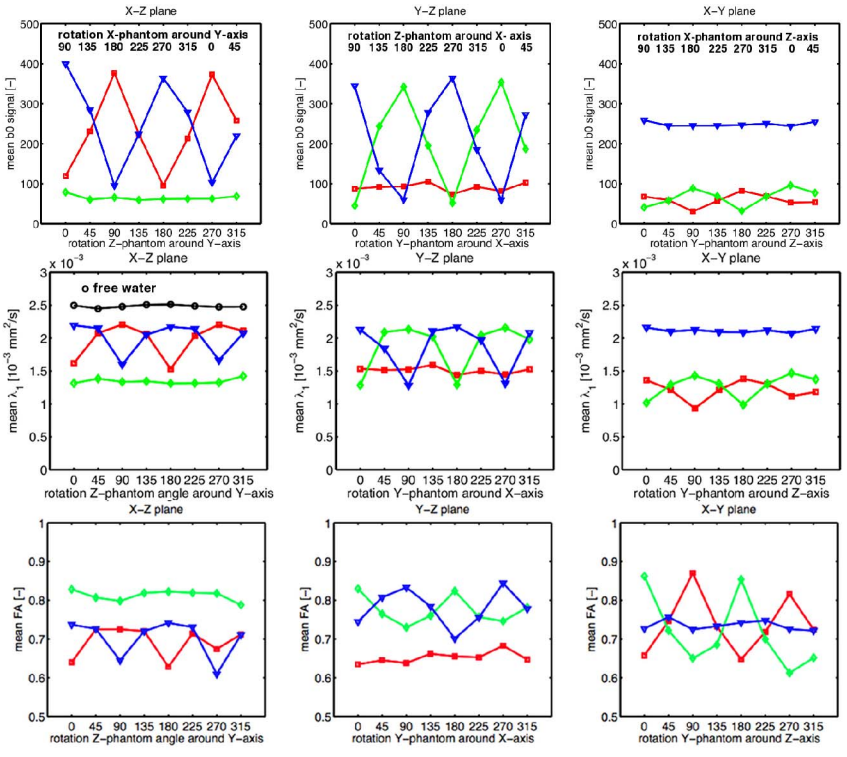
Methods *Acquisition* A commercially available spherical diffusion phantom (Brain Innovation, NL)[3] with 3 tubular anisotropic phantoms in each principal direction was used. **Fig 1** shows the opened physical phantom and a rendering of the phantoms x: red, y: green, z: blue. The sphere, marked with an angular grid was rotated in 3 planes in the scanner (x-z, y-z and x-y plane) in steps of ~45 degrees. At each orientation, a DW-MRI scan was made: Siemens Allegra 3T birdcage coil, FOV 192x192mm, 70 slices, 2x2x2 mm voxel size. b-value 1000 s/mm^2, 27 diffusion directions and 1 b0 image. A GRE phase and magnitude image were also obtained at the same resolution. TE(1)=10.0ms, TE(2)=12.46ms. *Data Analysis* Data analysis was done in FSL (FMRIB, UK). FA and the first eigenvector λ_1 were calculated in each phantom orientation. The b0 image from each orientation was co-registered with the reference orientation (X, Y and Z phantoms aligned with x, y, z scanner axis) and the FA and λ_1 images were transformed into the same principal orientation. The mean, re-oriented FA map was skeletonized to obtain ROIs containing voxels from the tubular phantoms for each principal direction.



Results Fig 2 shows the *b0* images of the phantom rotated in the x-z plane, with the angle of the z-phantom wrt the scanner's z-axis. The phantom was rotated in a similar fashion in the other two planes.



In **Fig 3** we show the mean b0 signal, FA and λ_1 values from ROIs in the X phantom (red), Y phantom (green) and Z phantom (blue). b0 intensity changes wrt orientation of the phantoms. The phantoms that are rotated wrt the original position show a change in b0 signal intensity, FA and λ_1, while the values in the phantoms that stay at their original orientation do not change significantly. Apart from that we also observe differences in absolute values of b0, FA and λ_1 across the 3 measured planes.



Discussion We observe considerable changes in b0 signal, FA and λ_1 in the anisotropic phantom while rotating it in the magnetic field in 3 orthogonal planes. The free water λ_1 in the phantom is not affected by the rotation. Susceptibility is homogenous inside the phantom as revealed by the susceptibility image. The observed b0, FA and λ_1 signal changes might therefore originate from susceptibility changes due orientation change alone as demonstrated earlier in [2]. Gradient mis-calibration likely adds to this effect as ADC is affected by mis-calibrated gradients [1]. Further studies are needed to investigate the source of the variations. Our results consequently indicate that tissue characterization with DW-MRI in tissue with varying fiber structure orientation (e.g. white matter) will probably be affected by this phenomenon.

References [1] *MRM* 58:763-768(2007) [2] *PNAS* 107:5130-5135 (2010) [3] *jMRI* 32:482-488 (2010)