A flexible hardware phantom for validation of diffusion imaging sequences.

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Introduction

The aimed application for DTI is to study the white matter geometry of the human brain in vivo. To determine the accuracy and precision a validation is necessary which requires a phantom with a well known structure. We propose a flexible hardware phantom by using parallel fibers of woven strands of Micro Dyneema®. An evaluation of susceptibility artifacts using standard EPI and spiral acquisition techniques was performed on this DTI-phantom.

Materials and methods

Phantom: The phantom fascicles consists of 400 parallel fibers (diameter 170 μm), each made of woven strands of Ultrahigh -Molecular Weight Polyethylene (UHMWPE) Fibers (Micro Dyneema®) with a diameter of 15 μm. The fibers are tightly held together by a flexible, polyolefin low-temperature shrinking tube (diameter 4.5mm) (**Fig. 1**). Two fascicles were fixed in a closed container filled with Gd doped physiological saline. To evaluate the influence of susceptibility artifacts a spherical air cavity was positioned between the two fascicles.

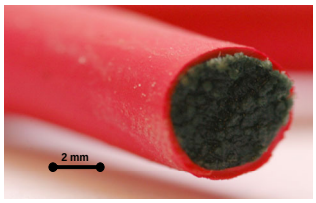

Fig.1. Photograph of phantom fascicle.

Imaging: Imaging was performed on a 1.5T Siemens Symphony scanner using a 8 elements head coil. Diffusion-weighted images were acquired in 6 directions with b-factors of 0 and 1000 s/mm^2. To minimize the influence of given eddy currents, a twice-refocused- spin echo (TRSE) diffusion preparation is used [1]. K-space was sampled with a 8-interleaved Archimedean spiral trajectory with a maximum gradient amplitude of 19.5 mT/m and a maximum slew rate of 94 mT/m/s [2]. For comparison, also single shot echo planar images (EPI) are acquired with a bandwidth of 1346 Hz/Px and 20 averages. For both sequences, the image resolution was 2.5 x 2.5 x 2.5 mm (64 x 64 matrix, 160 x 160 mm FOV, 2.5 mm slice thickness). A total of 20 slices were acquired for a TR of 2000 ms with TE = 80ms.

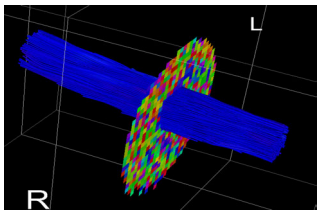

Fig.2. Fiber tracking of phantom fascicle

Results

Measured fractional anisotropy (FA) values of the phantom fascicles were 0.45 (± σ = 0.15). Fractional anisotropy was unidirectional along the bundle axis. **Figure 2** shows the tracking results in one of the fascicles obtained with the FACT [3] algorithm.

In **Figure 3** the diffusion unweighted (b = 0) images are shown for both methods as well as a standard T_{2w} TSE image as reference. The spatial distortions are less pronounced in the spiral image than compared to the EPI-image. Figure 3c and d illustrate the dependence of the susceptibility artifacts on the phase encoding (PE) direction.

Discussion and Future Perspectives

Thanks to the shrinking tubes, fractional anisotropy was large enough to perform fiber tracking. The tracking results fitted with reality. Measured FA values of the phantom fascicles correspond to those observed in the human brain. This phantom allows quantitative analysis of the effect of image artifacts and SNR on diffusion parameters such as FA and ADC (apparent diffusion coefficient). It also allows for the optimization of sequence design and image parameters.

Fast sequences, like EPI and spiral scans are sensitive to susceptibility artifacts.

The radial symmetric point spread function of a spiral induces mainly blurring artifacts and less geometric distortion compared to the significant anisotropy of EPI-artifacts. Spiral scanning offers several advantages for diffusion studies such as insensitivity to motion [4] and a smoother k-space sampling trajectory. Future research will be conducted to optimize spiral sequences for DTI.

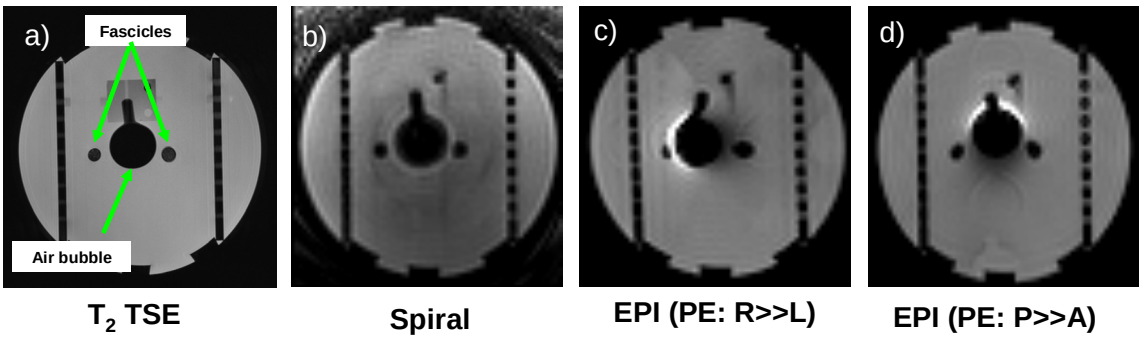

Fig. 3: DTI-phantom images: T_2-weighted (a), diffusion-unweighted images (b = 0) (b,c,d).

References:

[1] TG Reese et al., *MRM*, 49: 177-182 (2003); [2] GH Glover, *MRM*, 42: 412-415 (1999); [3] R Bammer et al, EUR J RADIOL, 45: 223-234 (2003); [4] V Rasche, IEEE trans med imag, 18:385-392 (1999)