A dedicated Phantom for Diffusion Tensor Imaging Studies

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Introduction :

EPI-Diffusion Tensor Imaging (DTI) is a relatively rapid and established method for the studies of white matter myelin fiber bundles [1]. Parallel imaging (SENSE) [2] can be conveniently combined with DTI to reduce susceptibility artefacts by shortening the duration of the echo train [3]. To study the influence of different choices of acquisition parameters (e.g. Sense reduction factor, number and distribution of directions of diffusion gradients…) on fiber tracking results, the availability of a "tracking phantom" can be useful. In this work, we describe and evaluate the phantom built for optimising DTI acquisition parameters for fiber tracking applications.

Materials and methods:

Phantom: The phantom was built using a Plexiglas box filled with doped water where three different bundles of parallel textile fibers were fixed on the two opposite sides (see Fig.1). Simple cotton, rayon and mercerised cotton were used. A portion of each bundle was wrapped with adhesive tape to achieve various degree of fiber compression.

Imaging: Studies were performed on a 1.5T Philips Intera (Philips Medical System) scanner equipped with 60 mT/m gradient coils using a 8 elements SENSE head coil. Before DTI, a reference scan was acquired in order to calculate sensitivity maps of SENSE head coil. Diffusion-Tensor SENSE EPI images were acquired with b factors of 0, 500, 1000 and 2000 s/mm^2 along six non-collinear directions of the gradients. The following parameters were used to image 7 axial slices: FOV=240x240 mm^2, matrix=128x128, slice thickness=7 mm, NEX=10, reduction factor=2, TE=54, 66, 76 msec, TR= 907, 1535, 2237 msec, respectively. The diffusion tensor parameters were estimated in each voxel using Brainvisa software [4]. Maps of apparent diffusion coefficient (ADC), fractional anisotropy (FA) and FA-weighted directionally color encoded maps (RGB-FA) were generated. Regions of Interest (ROIs) were positioned in the different tissues and in areas with different degrees of tape compression. Fibers passing through ROI located on the textile bundles were tracked using the FACT algorithm [5].

Results:

FA and ADC of water were first measured in different ROIs to evaluate influence of eddy current artefacts, and then in the regions containing fiber bundles. FA increases with tape compression. Figure 2 shows the b=0, the ADC, the FA and the RGB-FA maps of an exemplificative slice. Figure 3 shows the fiber tracks obtained from a ROI drawn in the rayon bundle superimposed to ADC map.

Discussion and Conclusions:

Among the three different bundles, rayon gave the best results showing less susceptibility artefacts. The measured values of rayon FA were always higher with respect to the other tissues probably because of its inner fiber structure. Each rayon fiber, in fact, consists of long 50 parallel micro-fibers whose diameters are about 20 µm. This inner structure makes the bundle easier to be stretch, reduces the crossing between the micro-fibers and thus increases the anisotropy of the water in these regions. RGB maps showed a strong and correct orientation of the fibers and the tracking obtained by the FACT algorithm fits with the reality. This phantom might be useful for the optimisation of DTI acquisition parameters and the evaluation of fiber tracking algorithms

References:

[1] D Le Bihan et al., *JMRI*, 13: 534-547 (2001); [2] KP Pruessmann et al., *MRM*, 42: 952-962 (1999) [3] P. Scifo et al, ISMRM 2003, 2128, [4] Y.Cointepas et al, *Neuroimage* 2003, (19): S810, [5] Mori *et al* Ann Neurol 1999, 45:265-269

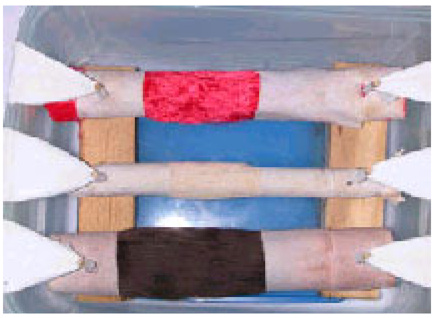

Fig.1: upper view of the phantom showing the 3 bundles: rayon (up), cotton (middle), mercerised cotton (down)

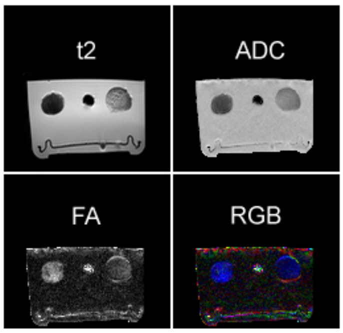

Fig.2: T2, ADC, FA, RGB axial maps of the phantom. Rayon is the 1st bundle from left

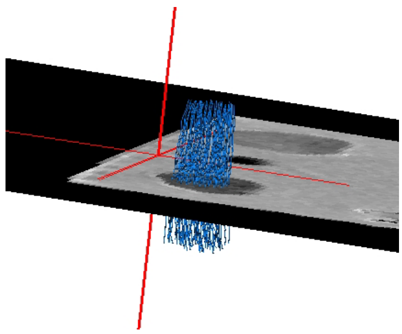

Fig.3: Fiber tracking of the rayon bundle