Diffusion tensor imaging of thirty-five anisotropic DTI phantoms for CENTER-TBI

Pim Pullens[1], Michael Bach[2], Bram Stieltjes[3], Dirk Smeets[4], and Paul M Parizel[1]

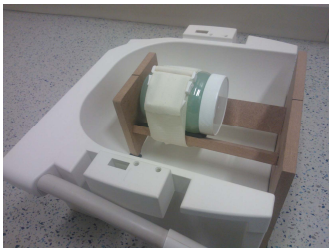
[1]*Radiology, University Hospital Antwerp & University of Antwerp, Antwerp, Antwerp, Belgium,* [2]*Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany,* [3]*Radiology, Universitätsspital Basel, Basel, Switzerland,* [4]*icoMetrix, Leuven, Belgium*

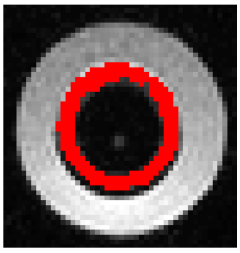
Target audience: Multi-center study researchers, MR physicists, neuro-radiologists.

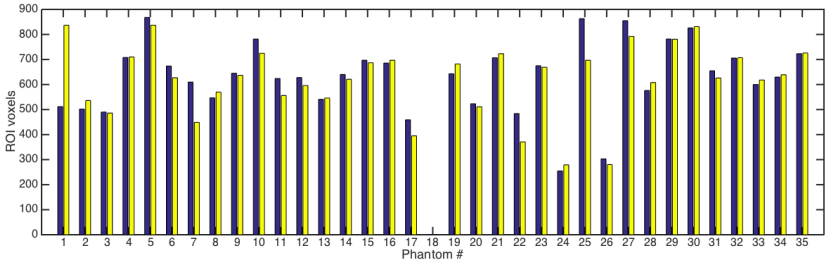
Purpose For CENTER-TBI, a large European multi-center study on Traumatic Brain Injury [1], diffusion tensor imaging (DTI) is one of the main imaging modalities. 35 clinical sites across Europe will be included to participate in the MRI study. To be able to acquire DTI data that is cross-site comparable it is of fundamental importance to assess the quality and variability of DTI measurements across sites. For this purpose, each site will receive both an anisotropic [2] and an isotropic diffusion phantom [3]. In this work the anisotropic phantoms were DTI-scanned in 2 runs, in order to construct a set of baseline measurements.

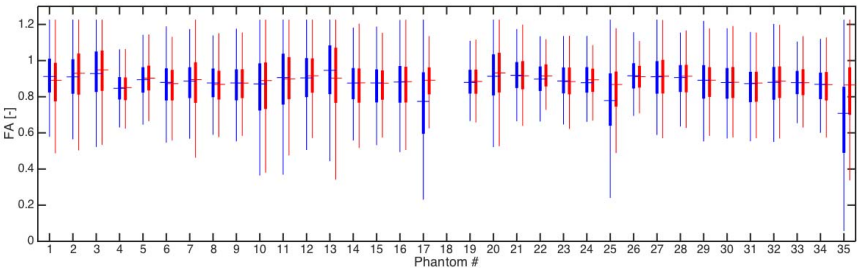
Methods Thirty-five anisotropic DTI phantoms were produced according to [2]. A phantom consists of a plastic (polyoximethylene) spindle with a square groove. The groove is filled with a 15µm polyester fiber. Between the fibers a saline solution (83g/l NaCl) is embedded. This solution has the same susceptibility as polyester. Therefore, mesoscopic B_0-field variations are minimized [2]. The fiber bundle is sealed with hot glue, and the spindle is placed in a plastic container filled with ~1.5% Agar gel + 1.2g/l CuSO4 for conservation. DTI scans The 35 phantoms were scanned *in random order* on a 3T Siemens TIM Trio system with a 12-channel head coil. A phantom holder was especially designed to fit the head coil and to make sure the phantoms were carefully positioned. Sandbags were placed on the phantom to prevent vibration artifacts. A 32-direction axial DTI scan with b=1000 s/mm^2, 2mm isotropic voxels, was repeated twice. Post-processing Bash/Matlab scripts were written to perform the following tasks: on each phantom dataset, standard deviation of the DWI images (without b0) was calculated. This image was thresholded, and a Gaussian filter with a kernel of 5x5 voxels and $\sigma = 0.6$ was applied. Next Otsu segmentation [4] was carried out to obtain a mask containing the fiber ring. The masks were manually edited to remove non-fiber voxels. FA maps were calculated in FSL using weighted-least squares tensor estimation and masked with the ring mask.

Results – Phantom holder | Automatic segmentation example phantom #32 | #ROI voxels per phantom for both runs









The number of voxels found by the automated segmentation procedure differs slightly across phantoms but in phantom #1 significantly between runs. In phantom 18, the procedure failed. FA per phantom Mean(std) FA = 0.855(0.0466) across phantoms in run 1. Mean FA ranges from 0.70 to 0.93. Median FA ranges from 0.71 to 0.95. Data from phantom 18 was not suitable for analysis. In run 2, mean (std) FA = 0.86(0.17). Mean FA ranges from 0.80 to 0.93. Median FA ranges from 0.85 to 0.95.

Discussion It is a challenge to obtain highly comparable DTI data in phantoms. While care has been taken to produce the phantoms as similarly as possible, there is substantial variation in the post-processed data. The phantoms are scanned in a custom holder, but the phantom spindle is not always in the same position, which may lead to measurement errors due to partial volume effects [5]. The most probable cause for the variation in the FA values is the post-processing method. Although reasonably robust in separating the fibers from the background from the DWI data, we did not obtain similar ROI sizes for each phantom, while the physical fiber strands are highly similar. What is also striking is the consistent over-estimation of FA values. In every phantom, a large amount of voxels has an FA > 1. Potentially, non-linear tensor estimation will produce more stable and reliable results [6].

Conclusion We have produced and scanned 35 identical DTI phantoms. There is a considerable range of FA values between phantoms, but this may be attributed to post-processing and/or partial volume effects.

References [1] www.center-tbi.eu [2] MRI 27(2009) 541-548 [3] Submitted ISMRM 2015 [4] IEEE Trans. Syst. Man Cybern. 9:62-66;1979 [5] MRM 71(2014) 1108-1116 [6] NeuroImage 73 (2013) 239-254