Posttraumatic white matter diffusivity changes in postmortem brain

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Introduction: Diffuse axonal injury can be observed following traumatic brain injury (TBI), and might be associated with changes of molecular diffusivity. Diffusion tensor imaging (DTI) allows the assessment of mean diffusivity (MD) and fractional anisotropy (FA) as an expression of mean diffusion rates and the direction of the average diffusion vector. A posttraumatic increase of MD values in white matter regions has been reported in living subjects [1], and DTI of postmortem brain has shown that diffusivity values are influenced by brain trauma [2]. Therefore, postmortem DTI could be a useful non-invasive aid in detecting and quantifying brain parenchyma damage due to blunt head trauma.
In this postmortem human brain study, we applied postmortem DTI to determine differences in MD and FA between a group of subjects having died from TBI and an age and temperature matched group of deceased without head injury. To evaluate a potential influence of edema on diffusion values, wet-to-dry mass ratios of tissue samples in the same individuals and regions of interest were assessed after MRI.

Materials and methods: 5 corpses (1♀, 4♂, age 37–89 years, mean age 63±21 years) with a history of accidental blunt head trauma confirmed by external lesions and 12 deceased subjects without head trauma (3♀, 9♂, age 48-81 years, mean age 66±10 years) underwent DTI at 3T (Magnetom Trio, Siemens Erlangen, Germany). The period between death and MRI was 35±16 hours for the TBI group and 36±16 hours for controls; body temperature was 13.7±7.5°C (TBI) and 13.8±6.5°C (controls), respectively. In situ DTI data (Fig. 1) were obtained using a diffusion weighted spin echo EPI sequence (TR/TE=6.7s/95ms) with gradients in 12 independent directions at b-values of 0 and 2000 s/mm² to account for reduced diffusivity in cooled tissue [3]. Acquisition time covering the whole brain was 13:03 min. FA and temperature corrected MD values [4] were calculated in left and right sub-cortical frontal, temporal and occipital white matter regions and the body of corpus callosum.
To obtain wet-to-dry mass ratios tissue samples from these regions of interest were excised and weighed before and after freeze drying. Independent samples t-tests for FA and MD values as well as for wet-to-dry mass ratios were applied to investigate differences between the TBI and control group. A p-value<0.05 was considered as statistically significant.

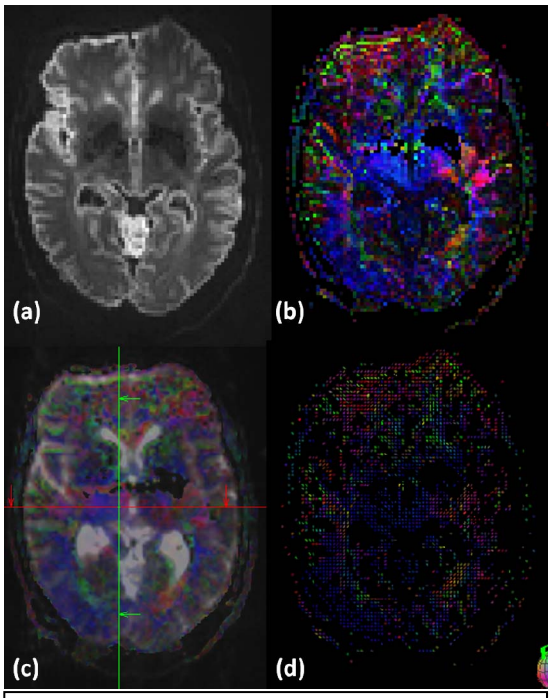

Figure 1 a) Trace- b) FA texture diffusion- c) FA fusion mode- and d) Diffusion tensor image of a 56-year old male (control case)

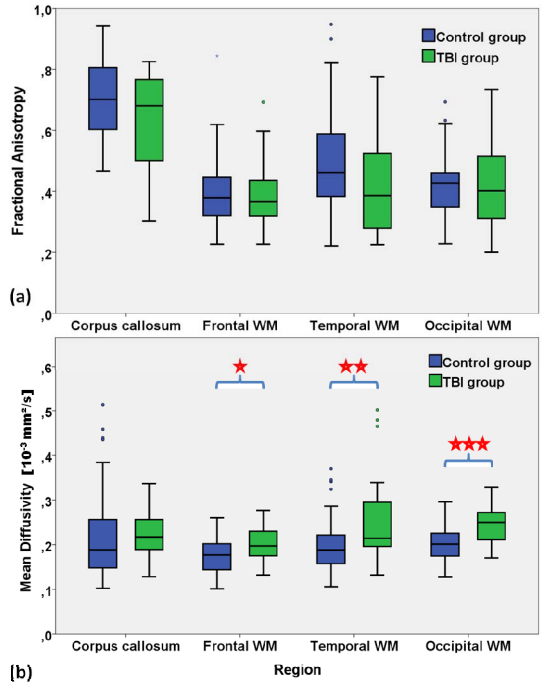

Figure 2 a) FA and b) MD values of TBI and control cases (box: median, IQR; whiskers: 1.5×IQR); * p<0.005; ** p<0.001; *** p<0.0001

Results: FA values were lower in subjects with TBI compared to controls in all regions of interest (Fig. 2a). However, differences did not reach significance. MD values in sub-cortical frontal (p<0.005), temporal (p<0.001) and occipital (p<0.0001) white matter regions were significantly increased in the TBI group (Fig. 2b) whereas MD values in corpus callosum were insignificantly increased. Concerning tissue water content there was no significant difference in wet-to-dry mass ratios between the two investigated groups in all regions of interest (data not shown).

Discussion and conclusion: In situ DTI of postmortem brain yielded excellent quantitative imaging data. We observed significantly increased MD values in sub-cortical white matter regions of subjects having died from TBI compared to controls whereas mean FA values were decreased in TBI cases but not significantly changed. There were no significant changes in water content between both groups which might indicate a minor effect from posttraumatic brain edema on this DTI dataset. Therefore, the measured diffusivity changes suggest a direct association with TBI. Although the processes underlying our observations are not completely understood in detail yet, and various factors such as the postmortem interval and body temperature need to be accounted for, the use of DTI might progress the fundamental understanding in neuropathological and forensic assessment of TBI.

References: [1] Mamere AE et al., AJNR 2009. 30(5):947-52. [2] Scheurer E et al., AJNR 2011. 32(8): 1518-24. [3] Schmierer K et al., MRM 2008. 59(2):268-77. [4] Quesson B et al., JMRI 2000. 12(4):525-33.