Diffusion Tensor Imaging of Blast Induced Traumatic Brain Injury in Rodent Model

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TARGET AUDIENCE: Scientists and clinicians interested in imaging biomarkers for traumatic brain injuries.

Introduction: Traumatic brain injury (TBI) due to blasts by improvised explosive devices (IEDs), is increasingly seen in several countries. It creates various neuropsychological dysfunctions such as attention deficit, working function, motor skills etc in both animals and humans. In this study, we have investigated the effect of open field blast injuries on rat brain using Diffusion tensor imaging (DTI), which provides the degree as well as directionality of water diffusion in brain [1]. In particular, we studied the major brain structures like the corpus callosum (CC), hippocampus (HC), and cortex (CX).

Methods: 5 kg of 2,4,6-trinitrotoluene (TNT) with a penta-erythritol tetra-nitrate (PETN) booster was detonated at 1 m height in each blast. A metal cage along with the pressure transducer was set up at 3 m from the blast source. All the animals were randomly grouped into 1) Sham: where the subjects were not exposed to blast but anaesthetized; and 2) Blast (with no body armor): where subjects were exposed to a single blast at ~180 kPa at 3 m from the blast source [2].

DTI and high resolution MPRAGE images were acquired on 7T ClinScan (Bruker BioSpin, Germany) equipped with 4 channel RAPID phased array coil before blast (Baseline, BL), and on day 1, 3, 5, 14 and 28 after blast (#Rat = 6). DTI was performed using EPI based DWI sequence (TR/TE/slice thickness/#slice/FOV/matrix size/#direction = 5000 ms/50 ms/1.2 mm/28/36 mm × 28 mm/128×100/ 20). Four averages were acquired with b-factors of 0 s/mm^2 and 1000 s/mm^2. MPRAGE images were acquired with TR/TE/ flip angle/slice thickness/#slice/FOV/matrix size/#average= 2000 ms/1.6 ms/20º/0.5 mm/52/35 mm × 28.44 mm/256×208 (zero filled to 512 × 512)/4. A Java based ImageJ (National Institute of Health, USA) plugin was developed for processing the DTI and ROI analysis. Pixel by pixel computation was performed for the calculation of 3 × 3 diffusion tensor matrix followed by analytic computation of eigenvalues and eigenvectors [1, 4, 5]. The fractional anisotropy (FA), mean diffusivity MD), axial diffusivity (AD, eigenvalue corresponding to the principle eigenvector) and radial diffusivity (RD) were calculated in standard methods [1]. IBA-1 immunostaining of microglia at CC was also performed to evaluate the axonal damage[2, 3].

Results: The mean values of FA, AD and RD in CC, and MD, AD and RD in HC and CX at different time points are shown in Fig. 1 and Fig. 2 respectively (values of MD, AD and RD are in 10^{-3}×mm^2/s and FA is dimensionless). The IBA-1 immunostaining of microglia at CC is showing a similar trend (Fig. 3). The colour-coded eigenvector maps overlaid on b0 images (FA ≥ 0.15) and MPRAGE at different time points are shown in the Fig. 4. The MPRAGE is not showing any damage to either white matter (CC) or grey matter (HC, CX). There was a significant increase in FA, AD and decrease in RD at day 1 and 28 when compared to BL and had a decreasing trend in between them. In hippocampus the MD, AD and RD decreased till day 3 (significant on day 3), followed by an increase at day 5 and we found a significant decrease on day 14 when compared to BL.The MD, AD (except at day 1) and RD values in CX significantly decreased at all time points up to day 14 with respect to BL; on day28, all the parameters showed a significant increase.

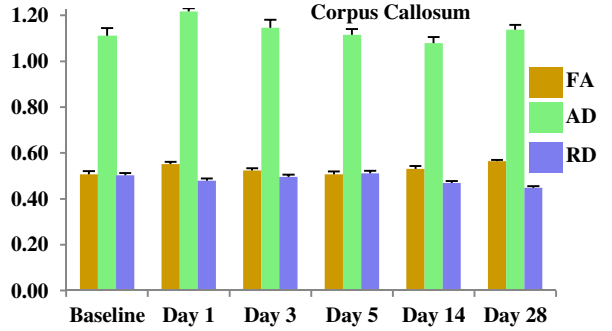
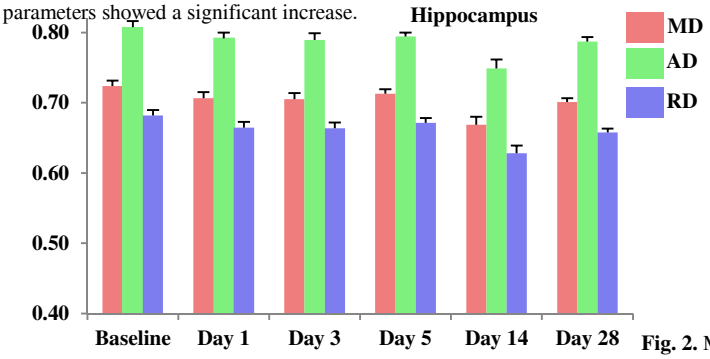


Fig. 1. Mean FA, AD and RD values at different time points at CC.



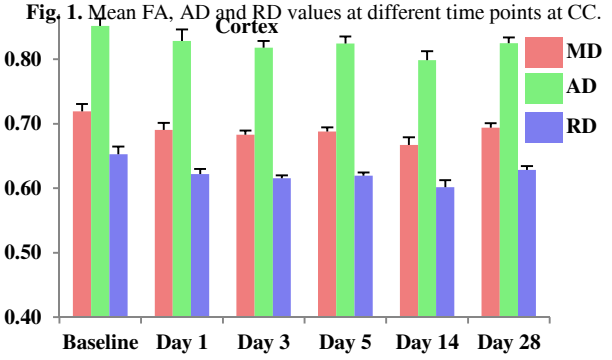


Fig. 2. Mean MD, AD and RD values at different time points at HC (left) and CX (right).

Conclusions and Discussions: We have performed DTI of blast injuries in rodent model. The increase in FA , AD and decrease in RD at day 1 in CC may be probably due to edema or change in the water content within the myelin sheath[6]. Decrease in the diffusivity in the CX indicates the cytotoxic edema and slight increase at day 28 from day 14 probably due to reduced tissue cellularity [7]. Decrease in the value of MD in HC on day 3 may point to the presence of cytotoxic edema [6, 7, 8].

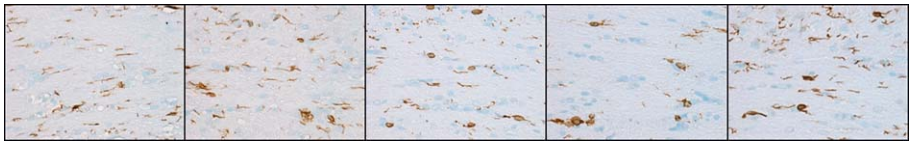


Fig. 3. IBA-1 immunostaining of microglia at corpus callosum at different time points, 40x.

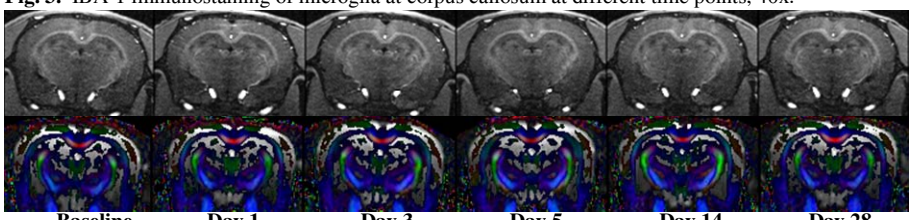


Fig. 4. MPRAGE (top) and FA (>0.15) color- coded eigenvector (bottom) map at different time points.

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