Hybrid Diffusion Imaging to Detect Acute White Matter Injury after Mild TBI

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Introduction:

In the present study we used multi-shell Hybrid Diffusion Imaging (HYDI) to study white matter changes in the acute stage of mild traumatic brain injury (mTBI). Non-parametric diffusion analysis, q-space imaging as well as parametric analyses including conventional DTI and novel neurite orientation dispersion and density imaging (NODDI) were used to analyze the HYDI data.

Method:

Nineteen mTBI patients and 23 trauma-controlled subjects were recruited from the Emergency Department. Participants received T1W SPGR and HYDI in a Philips 3T Achieve TX scanner with 8-channel head coil and SENSE parallel imaging. The diffusion-weighting (DW) pulse sequence scan-time was about 24 min similar to (1).

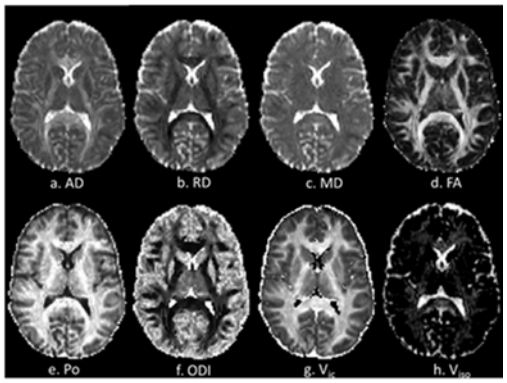

Figure 1: DTI, Po and NODDI maps for an mTBI subject is shown. The gray scales of AD, RD and MD are 0 to 3, 2 and $2*10^{-3}$ mm^2/s, respectively. The FA, Po, ODI, V_{ic} and V_{iso} has been scaled from 0 to 1.

Results:

Forty-eight WM ROIs were defined in the standard MNI space by intersecting subjects' mean WM skeleton with WM atlas of Johns Hopkins University (JHU) ICBM-DTI-81(2)**.** Linear model analysis was used to test the significance of diffusion metrics between mTBI and trauma-controlled groups with gender and age as covariates (model 3 in **Table 1**). Maps of DTI, q-space and NODDI diffusion metrics of an mTBI subject are shown in **Figure 1**. Among various diffusion metrics, only the NODDI derived parenchymal axonal density (V_{ic}) was sensitive to mTBI with significant decreases in 60% of WM ROIs (**Table 1**). The mTBI subjects had an approximately 4% decrease in V_{ic}. The affected WM tracts concentrated on pyramidal tracts and its cortical projections (bilateral corona radiatae). Most of the cerebella related tracts and hippocampal tracts are spared.

White Matter ROI	Acronym	Model 3
Middle Cerebellar Penduncle	MCP	Sig
Pontine Crossing Tract	PCT	Sig
Genu of Corpus Callosum	GCC	Sig
Body of Corpus Callosum	BCC	Sig
Splenium of Corpus Callosum	SCC	Sig
Fornix (column and body)	Fx	NS
Corticospinal tract -Right	CST-R	NS
Corticospinal tract -Left	CST-L	Sig
Medial lemniscus-Right	ML-R	NS
Medial lemniscus-Left	ML-L	NS
Inferior cerebellular penduncle -Right	ICP-R	NS
Inferior cerebellular penduncle -Left	ICP-L	NS
Superior Cerebellar penduncle-Right	SCP-R	NS
Superior Cerebellar penduncle-Left	SCP-L	NS
Cerebral Penduncle-Right	CP-R	NS
Cerebral Penduncle-Left	CR-L	Sig
Anterior limb of internal capsule-Right	ALIC-R	NS
Anterior limb of internal capsule-Left	ALIC-L	NS
Posterior limb of internal capsule-Right	PLIC-R	Sig
Posterior limb of internal capsule-Left	PLIC-L	Sig
Retrolenticular part of internal capsule -Right	RLIC-R	Sig
Retrolenticular part of internal capsule -Left	RLIC-L	Sig
Anterior corona radiata -Right	ACR-R	Sig
Anterior corona radiata -Left	ACR-L	Sig
Superior corona radiata -Right	SCR-R	Sig
Superior corona radiata -Left	SCR-L	Sig
Posterior corona radiata -Right	PCR-R	Sig
Posterior corona radiata -Left	PCR-L	Sig
Posterior thalamic radiation -Right	PTR-R	NS
Posterior thalamic radiation -Left	PTR-L	NS
Saggital Stratum -Right	SS-R	Sig
Saggital Stratum -Left	SS-L	Sig
External Capsule -Right	EC-R	Sig
External Capsule -Left	EC-L	Sig
Cingulum (cingulate gyrus)-Right	CGC-R	Sig
Cingulum (cingulate gyrus)-Left	CGC-L	Sig
Cingulum (hippocampus)-Right	CGH-R	NS
Cingulum (hippocampus)-Left	CGH-L	NS
Fornix(cres)-Right	Fx-ST-R	Sig
Fornix(cres)-Left	Fx-ST-L	NS
Superior longitudinal fasciculus-Right	SLF-R	Sig
Superior longitudinal fasciculus-Left	SLF-L	NS
Superior fronto-occipital fasciculus -Right	SFO-R	Sig
Superior fronto-occipital fasciculus -Left	SFO-L	Sig
Uncinate fasciculus-Right	UNC-R	NS
Uncinate fasciculus-Left	UNC-L	Sig
Tapatum-Right	TAP-R	Sig
Tapatum-Left	TAP-L	NS

Table 1: Statistic results of V_{ic} across 48 white matter ROIs. Green denotes decrease in mTBI group. Sig denotes significant with FDR q-value < 0.05. NS denotes non-significant.

Conclusion:

HYDI and its diffusion metrics provide insights about microstructural changes of WM in the acute stage of mTBI and may prove useful as a marker of injury.

References:

1. Wu YC, Alexander AL. Neuroimage. 2007;36(3):617-29.

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