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Impact of Traumatic Brain Injury on Vision

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Traumatic brain injury (TBI), defined as brain damage caused by an external physical force or a rapid movement, can cause significant visual disabilities. Even mild TBI (concussion or mTBI), has been reported to create visual problems in children and adults from both clinical reports and research studies(Kerr, Ingram, Callahan, Nedimyer, Chandran, Kossman, Hoang, Gildner & Register-Mihalik, 2021, Lee, Davis, Purt & DesRosiers, 2022, Master, Bacal, Grady, Hertle, Shah, Strominger, Whitecross, Bradford, Lum & Donahue, 2022, Rauchman, Albert, Pinkhasov & Reiss, 2022) . Due, in part, to the publicity of findings consistent with chronic traumatic encephalopathy (CTE) at autopsy in former American football players, there is increasing concern about the possible long-term effects secondary to repetitive head impact exposure. But, TBI affects many other individuals, including athletes, military personnel, and civilians, as a result of falls or vehicle accidents. This special issue encompasses a broad scope of current research from experimental models to clinical studies with the aim of understanding the visual sequelae related to TBI.

Many studies focus on identifying reliable biomarkers that can detect visual defects with TBI. Several of the articles in this special issue focus on oculomotor disorders that occur including convergence and accommodation insufficiency, particularly in children and adolescents. Scheiman et al (2021)(Scheiman, Grady, Jenewein, Shoge, Podolak, Howell & Master, 2021) performed a prospective study to investigate the sensitivity and specificity of physician-administered screening for detecting convergence and accommodative insufficiency in adolescents with persistent post-concussion symptoms (PPCS) 4–12 weeks after a concussion diagnosis. This study found that oculomotor disorders were common, occurring in 70% of participants with PPCS. However, the accuracy of physician screening

measures for detecting convergence and accommodative insufficiency ranged from 43–63%. Thus, the authors conclude that a comprehensive visual evaluation is needed for patients with persistent concussion symptoms.

Examining longer post-concussion periods, Wiecek et al (2021)(Wiecek, Roberts, Shah & Raghuram, 2021) performed a retrospective study to evaluate visual dysfunction in children and adolescents from 21–1192 days after experiencing chronic post-concussion symptoms. In this dataset, 95% of the patients had vergence, accommodation or visual tracking deficits. These data suggest that sensorimotor evaluations are needed for patients following concussion.

Walker et al (2021)(Walker, Wilson, Seehusen, Provance & Howell, 2021) found that adolescents with a greater near point of convergence or maximum convergence at initial evaluation post-concussion experienced more persistent somatic symptoms (greater than 28 days). Similarly, a receded near point of convergence was associated with headaches at initial assessment and greater overall cognitive and somatic symptom severity.

Vergence eye movements were found to be different in children after concussion in the study by Alvarez et al. (2021)(Alvarez, Yaramothu, Scheiman, Goodman, Cotter, Huang, Chen, Grady, Mozel, Podolak, Koutures & Master, 2021). They found that children between 11–17 years old with PPCS had receded near point of convergence, decreased accommodative amplitude, and slower convergent and divergent peak velocities. The authors suggest that therapeutic interventions for typical convergence insufficiency might be beneficial in children with convergence deficiency following concussion injury.

Screening tools for sport concussions include the Vestibular/Oculomotor Screening (VOMS) and the Sport Concussion Assessment Tool (SCAT). Ferris et al (2022)(Ferris L.M., 2022) evaluated whether VOMS with eight components of smooth pursuits, saccades, convergence, and vestibulo-ocular reflex could be reliably shortened to provide a quicker screening tool. The authors showed that a modified VOMS with only four components was robust and that incorporating this into the SCAT improved the sensitivity to detect acute concussion.

Similarly, Fortenbaugh et al (2021)(Fortenbaugh, Gustafson, Fonda, Fortier, Milberg & McGlinchey, 2021) report that chronic convergence insufficiency is present after mild TBI caused by blast exposure. In addition, they report an increase in myopia in individuals that have blast exposure and an association between refractive error and number of blast mTBIs during military service.

This special issue also includes a mini-review by Ciuffreda and Thiagarajan (2021) (Ciuffreda & Thiagarajan, 2022) on primary studies using objective measures of vergence and accommodative dynamics in patients with mTBI. The authors found that these measures were abnormal at baseline and that a short period of oculomotor-based vision therapy provided some remediation.

Two studies in this special issue evaluate pupillometry as a biomarker for TBI. Tapper et al. (2021)(Tapper, Gonzalez, Nouredanesh & Niechwiej-Szwedo, 2021) examined visual system consequences of concussion by evaluating if pupillometry, as a non-invasive index

of arousal and cognitive load, could explain deficits in dual-task performance. The results suggest that patients with concussions, in contrast to the control group, had similar pupil sizes during single and dual task conditions, suggesting that patients with concussion injury may require greater effort when performing easier tasks.

Mostafa et al. (2021)(Mostafa, Porter, Queener & Ostrin, 2021) compared pupillography on participants with TBI to controls using red and blue stimuli, to stimulate rod/cone versus intrinsically photosensitive retinal ganglion cells (ipRGCs), respectively. The results indicated that pupil constriction was not affected by TBI and the response to blue light stimulation were unchanged. The authors concluded that ipRGCs were not selectively damaged by TBI.

Animal models of TBI attempt to model the various clinical manifestations in individuals with TBI. Allen et al. (2021)(Allen, Motz, Singh, Feola, Hutson, Douglass, Ramachandra Rao, Skelton, Cardelle, Bales, Chesler, Gudapati, Ethier, Harper, Fliesler & Pardue, 2021) explored the difference in visual and cognitive outcomes after blast injury using two different experimental animal holders. The results showed significant differences between holders, with the enclosed holder (window for blast exposure to eye) causing secondary damage to the contralateral eye and the open holder (head and neck exposed) showing cognitive deficits. These results reveal the complexities of modeling blast injury in animals.

In conclusion, this set of papers provides further evidence that the binocular oculomotor system is affected by concussion, may be important to evaluate in order to detect visual abnormalities after TBI, and may serve as a target for intervention in future clinical trials.

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