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Automated Perimetry and Visual Dysfunction in Blast-Related Traumatic Brain Injury

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Purpose: To evaluate feasibility and results of automated perimetry in veterans with combat blast neurotrauma.

Design: Prospective, longitudinal, observational case series.

Participants: Sixty-one patients in a Veterans Affairs Polytrauma Center diagnosed with traumatic brain injury (TBI) from combat blast exposure.

Methods: Study participants underwent automated perimetry at baseline (median interval, 2 months after injury) (Humphrey Field Analyzer, Carl Zeiss Meditec, Dublin, CA, Swedish Interactive Threshold Algorithm 30-2 Standard or Fast), and 36 of them were followed up (median interval, 10 months after baseline). Presence of significant mean deviation and pattern standard deviation were determined for testing with reliability indices $\leq$20% for fixation loss, 15% for false-positives, and 33% for false-negatives. Test–retest stability of global visual field indices was assessed for tests with these cutoffs or with elevated fixation loss. Associations between global visual field defects and predictors were examined.

Main Outcome Measures: Global visual field indices (mean deviation and pattern standard deviation).

Results: Among 61 study participants (109 study eyes) with baseline testing, a field that met reliability cutoffs was obtained for 48 participants (79%) and 78 eyes (72%). Fixation loss was found in 29% of eyes in initial testing. Nine study participants (15%) demonstrated hemianopia or quadrantanopia, and an additional 36% had an abnormal global visual field index. Global indices were relatively stable at follow-up testing for tests meeting fixation-loss cutoffs and tests that did not. Visual scotomas due to post-chiasmal lesions were associated with moderate to severe TBI or penetrating head injury, but other visual field deficits were prevalent across the range of mild to severe TBI. Ocular injury to the retina or choroid, poorer visual acuity, and pupillary defect were associated with visual field defects. Participants with depressed visual field sensitivity reported lower visual quality of life.

Conclusions: Reliable automated perimetry can be accomplished in most patients with TBI from combat blast exposure and reveals high rates of visual field deficits, indicating that blast forces may significantly affect the eye and visual pathways. *Ophthalmology 2015;■:1–10 © 2015 Published by Elsevier on behalf of the American Academy of Ophthalmology.*

Traumatic brain injury (TBI), often associated with blast exposure, has been diagnosed in more than 330 000 military personnel since 2000.[1–3] Blast forces alter visual functioning through their effects on ocular tissues, visual pathways, or cortical regions.[4] Determination of visual fields through perimetry assesses the integrity of the anterior and posterior afferent visual pathways and may serve an important role in the evaluation of patients with TBI from blast exposure, provided that testing can be accomplished with sufficient reliability. Challenges to reliability in this population may include impaired concentration, rapid fatigability, or poor control of fixation.

Previous reports on post-chiasmal scotomas (hemianopia or quadrantanopia due to post-chiasmal lesions) in the population with TBI have used confrontation visual field testing or manual kinetic perimetry, which have the advantage of continuous interaction between patient and examiner, with direct discernment of fatigue or inattention.[5–9] However, these tests are relatively time-consuming and do not provide systematic normative comparisons. Moreover, Goldmann kinetic perimetry units are no longer commercially available. Automated perimetry, available in most eye clinics, is used extensively for screening and management of afferent disorders, including glaucoma and retinal conditions. In addition to availability of age-based norms, common automatic perimeters use reliability indices to detect inattention, poor concentration, or response inconsistencies.

We evaluate the usefulness of automated perimetry for this population by reporting on their ability to successfully complete testing, including their performance on the built-in reliability indices and the prevalence of visual field abnormalities. To shed further light on the utility of this test procedure, we examine the influence of fixation loss, measured both in terms of the test index and in terms of disparities on the gaze tracker and the distribution and stability of global visual field indices. We also report on the associations between identified visual field deficits and TBI severity, ocular injury, relative afferent pupillary defect (RAPD), visual acuity, and visual quality of life.

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Methods

Study Subjects

Institutional Review Board/Ethics Committee approval for the study procedures, which adhered to the tenets of the Declaration of Helsinki, was obtained. All work is Health Insurance Portability and Accountability Act compliant. Written informed consent was given by participants or their legally authorized representatives. At baseline, study participants were inpatients at the VA Palo Alto Health Care System Polytrauma Rehabilitation Center (PRC) who met inclusion criteria: documented TBI from combat blast exposure, at least 1 eye without open-globe injury, and ability to complete test procedures in a comprehensive evaluation.

The sample was diverse in TBI severity level and accompanying injuries; most had remained in inpatient status during evacuation from the war zone to military hospitals and then to the PRC for subacute rehabilitation, whereas approximately one third had been admitted to the PRC from outpatient ambulatory status for evaluation of possible TBI from earlier blast exposure. Of 66 consecutively eligible patients in the PRC, 65 enrolled in the study and 61 completed baseline visual field testing. Among those who did not complete baseline testing, 3 were monocular as the result of enucleation with optic nerve damage or significant vision loss in the fellow eye, and 1 entered the study when testing was not available. Thirty-seven study participants returned for follow-up testing 3 to 27 months after baseline testing (median interval of 10 months).

Baseline visual field testing was completed with 58 men and 3 women (Table 1), ages 19 to 45 years (median age, 25 years), at an interval of 2 weeks to more than 6 years after injury (median interval of 2 months). The TBI severity level was assigned by the Defense Veterans Brain Injury Center local manager, based on duration of loss of consciousness, duration of post-traumatic amnesia, neuroimaging, and Glasgow Coma Scale scores[10,11]; 22 were rated as mild, 8 as moderate, 15 as severe, and 16 as penetrating head injury. Eleven eyes were excluded from testing because of enucleation, phthisis, or optic nerve damage, and 2 were excluded because of penetrating injury. One additional participant was not able to tolerate testing of the second eye, resulting in visual field testing for 109 eyes.

Measures and Test Procedure

The need for visual attention for successful testing was discussed with patient and caregivers, and testing was delayed until the patient felt capable of meeting test demands. Visual field testing was generally performed in the morning, before other appointments. Medications known to affect attention, including pain medications and benzodiazepines,[12,13] were discontinued at least 24 hours before testing. A dedicated research technician monitored the participant and the gaze tracker throughout testing, and short breaks or rescheduling were used as needed.

Table 1. Characteristics of Study Participants with Blast-Related Traumatic Brain Injury (n = 61)

Participant Characteristics	N (%)
Male	58 (95)
Median age, yrs	25
Median mos since injury	2
TBI Severity Level	
Mild	22 (37)
Moderate	8 (13)
Severe	15 (25)
Penetrating	16 (27)

TBI = traumatic brain injury.

Participants underwent automated perimetry using Goldmann size III stimuli with appropriate refraction in 30-2 Swedish Interactive Threshold Algorithm (SITA) (Humphrey Field Analyzer 750i, Carl Zeiss Meditec, Dublin, CA). Out of concern for ability to complete testing, we initially used SITA 30-2 Fast protocol for 11 participants. We found that most were able to manage test demands, and we therefore subsequently switched to the Standard protocol for the remaining participants and for all follow-up testing. If, during initial testing, patients appeared inattentive or had high fixation losses as monitored by the gaze tracker or video monitor, they were invited to return for repeat testing, which occurred within 6 weeks.

Testing produces 3 reliability indices to aid in test interpretation[14,15]: fixation loss (determined by retesting of the blind spot throughout perimetry), false-positives (a response in the absence of a stimulus), and false-negatives (no response to a stimulus in a location with a previous response for a lower-intensity stimulus). For initial analyses, we used cutoffs of $\leq$20% for fixation loss, 15% for false-positives, and 33% for false-negatives.[16,17] In addition, readouts from the gaze tracker at the bottom of the test printout were copied to a separate sheet and anonymized. A count was made of fixation disparities of 6° or more, and these counts were adjusted for the length of testing.[18,19]

Testing produces 2 global visual field indices. Mean deviation measures overall sensitivity within the visual field as the average deviation from age-corrected threshold values across all test points. From zero, the mean deviation is increasingly negative as sensitivity decreases. Pattern standard deviation measures contiguous irregularities within the visual field and increases as these irregularities increase. A significant mean or pattern standard deviation is an index with a probability of normality of less than 5%. Two reviewers, working independently with de-identified visual field printouts, determined the presence of hemianopia or quadrantanopia; any discrepancies were resolved by the neuro-ophthalmologist (K.P.C.).

Ocular trauma examinations were performed by subspecialist ophthalmologists as previously described, and ocular injuries were reported by trauma zone.[20,21] The RAPDs were detected by a swinging flashlight test using a muscle light in a dark room, with the participant fixated at distance. The light was shown on each eye for 2 to 3 seconds for several cycles, with asymmetric results graded as 1 to 4 plus. Later in the study, neutral density filters were used to quantitate results. Relative afferent pupillary defect was considered present for any result of 1 plus or 0.3 log unit or higher. Best-corrected visual acuity was obtained for each eye in standardized photopic conditions using high-contrast (100%) Early Treatment Diabetic Retinopathy Study Sloan optotypes on an illuminated cabinet (Precision Vision, La Salle, IL). To assess subjective visual functioning, participants completed the National Eye Institute Visual Function Questionnaire (VFQ-25) in interview format.[22] The VFQ-25 includes 25 items, answered on a 5- or 6-point scale. Scores are available for a general visual quality item and for an average percentage score on 23 items, with 0 representing the worst possible score and 100 the best.

Analyses

Descriptive statistics were calculated for reliability indices and global visual field indices. Fixation loss was the only reliability index that was elevated with any frequency, and it was therefore the focus of additional analyses, including examination of its stability on retesting. Data from longitudinal testing were used to assess the influence of elevated fixation loss on the test–retest stability of global