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Closed-Globe Injuries of the Ocular Surface Associated with Combat Blast Exposure

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Purpose: To describe closed-globe conjunctival and corneal injuries and endothelial cell abnormalities associated with blast exposure and their relationships to other closed-globe injuries and blast-event characteristics.

Design: Observational cross-sectional study.

Participants: Veterans with a history of blast-related traumatic brain injury (TBI).

Methods: History and ocular examination, including slit-lamp biomicroscopy, gonioscopy, specular microscopy.

Main Outcome Measures: Type and location of blast injuries to the conjunctiva and cornea.

Results: Ocular surface injuries were present in 25% (16 of 65) of blast-exposed veterans with TBI. Injuries included partial-thickness anterior stromal corneal scars (15 eyes), Descemet membrane ruptures (6 eyes), and conjunctival or corneal foreign bodies (7 eyes). Based on normative information from an age-matched comparison group, endothelial cell abnormalities were identified in 37% of participants. Eyes with ocular surface injury were more likely to have lower endothelial cell density, higher coefficient of variation of cell area, and lower percentage of hexagonal cells compared with eyes without injury. Presence of ocular surface injury or endothelial cell abnormalities was associated with elevated rates of other anterior and posterior segment injuries, as well as impairment of visual acuity. We found no relationship between ballistic eyewear use or severity level of TBI and presence of ocular surface injuries from blast.

Conclusions: Independent of TBI severity or use of protective eyewear, ocular surface injuries and endothelial cell abnormalities were found in significant numbers of veterans with blast-related brain injury. Descemet membrane ruptures from blast exposure were described. Ocular surface trauma was associated with other ocular injuries throughout the globe. Potential mechanisms for the types and locations of ocular injuries seen were discussed. Any corneal or conjunctival injury in a blast survivor should prompt a thorough ocular trauma examination, including gonioscopy and specular microscopy, with appropriate follow-up for associated injuries. Longitudinal studies are required to determine long-term visual outcomes after blast exposure. *Ophthalmology 2014;■:1–8 © 2014 by the American Academy of Ophthalmology.*

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High-energy blast forces from improvised explosive devices (IEDs) have become an important cause of multiple injuries (polytrauma), including traumatic brain injury (TBI), for military members in recent conflicts, as well as for civilians involved in terrorist attacks.[1–3] More than 294 000 United States military personnel have been diagnosed with TBI since 2000, many of these attributable to IED blast.[4] Blast-related open-globe injuries, typically globe ruptures or penetrating or perforating injury, have been described in military and civilian casualties.[5–13] Open-globe injuries are detected early in casualty care triage with prompt surgical management in the theatre of operations, and are well documented. Less is known about the incidence and types of closed-globe injury associated with blast exposure. Closed-globe injuries from blast generally are less obvious than open-globe injuries and may exist with normal or near-normal vision.[14] In the present article, we describe the prevalence and types of injuries of zone 1 (cornea and conjunctiva, ocular surface) in a sample of veterans exposed to combat blast, as well as associated endothelial abnormalities.[15] We also evaluate associations between zone 1 injury and visual acuity, injuries in other ocular zones, and characteristics of the blast event, including use of ballistic eyewear, location during blast, and TBI severity level.

Methods

Sample

This component was part of a larger study of ocular injury and visual dysfunction in veterans after exposure to combat blast. The Stanford University Institutional Review Board and VA Palo Alto Health Care System Research and Development Committee

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approved the research, and all work complied with the Health Insurance Portability and Accountability Act. Written informed consent was obtained from all participants or their legal authorized representative.

At study intake, participants were current inpatients in the Polytrauma Rehabilitation Center in the Palo Alto Veterans Administration Health Care System. Study inclusion criteria were documented history of combat blast exposure, resultant traumatic brain injury of any severity level, and the ability to undergo testing and ocular examination. Of 66 consecutively eligible patients in this program during the study period, 65 enrolled in the study. Eyes with open-globe injury were excluded from analysis. During the study period, most Polytrauma Rehabilitation Center patients were in continuous inpatient status after referral from military hospitals for subacute rehabilitation after TBI and other battlefield injuries. However, during that period, there was growing concern regarding detection and treatment of mild TBI, and as a consequence, approximately one-third of the sample was admitted to the Polytrauma Rehabilitation Center from outpatient ambulatory status for evaluation and treatment for mild TBI from previous blast exposure. Thus, all participants experienced significant blast exposure, but represent a range of TBI severity and accompanying physical injuries.

Measures

Historical data were obtained from the medical record or from self-report. These included blast exposure characteristics such as date of injury and location (in an armored vehicle or on foot) and use of protective ballistic eyewear during the blast event. Ocular history variables assessed were previous eye injury or ocular surgery and contact lens use. Traumatic brain injury severity levels, classified as mild, moderate, severe, or penetrating, were assigned by the Defense Veterans Brain Injury Center local manager based on duration of loss of consciousness and on posttraumatic amnesia, neuroimaging results, and Glasgow coma scale scores (Appendix 1, available at www.aaojournal.org).

Each study eye was tested for best spectacle-corrected visual acuity with high-contrast (100%) Sloan optotypes in an illuminated cabinet (Precision Vision, La Salle, IL). Intraocular pressure (IOP) was measured by calibrated Goldman tonometry. A complete ocular trauma examination performed by subspecialist ophthalmologists included slit-lamp biomicroscopy with external photography, gonioscopy, peripheral retinal examination with scleral depression, and stereoscopic inspection of the macula and optic nerve. All corneal examinations were performed by the same examiner (G.C.C.). Injury location was described by ocular trauma zone.[15] Specular microscopy was performed with the SP-9000 Non-Con Analyzer (Konan Medical USA, Irvine, CA), using automated analysis with KSS-300 software of either 100 adjacent endothelial cells manually marked with center dot method or the highest number available within the image.[16,17] For 44 participants, 2 concurrent scans per eye were available, and in these cases, the average values from the 2 scans were used for analysis. Results were compared with normative data obtained using an alternately selected right or left eye from a sample of 26 age-matched individuals without a history of blast exposure and tested under similar conditions. Based on the means and standard deviations from this comparison group, we defined abnormalities as standard scores that were less than -1.64 standard deviations (5th percentile) for endothelial cell density (ECD) and for percentage hexagonal cells and more than 1.64 for the coefficient of cell variation.

Statistical Analyses

Descriptive statistics were obtained for the characteristics of study participants, their ocular injuries, and visual acuity. Because the distributions of most measures were highly skewed, we used categorical variables and chi-square tests to assess the relationships among visual functioning measures and between visual functioning and characteristics of the blast event. For all analyses involving individual eyes, the chi-square statistic was corrected to account for the lack of independence between individuals' 2 eyes (i.e., the chi-square statistic was adjusted for the intraclass correlation between eyes, based on a previously published procedure[18]). Because many of the measures were not strongly bilateral, these corrections generally were slight. For group comparisons of continuous variables with nonnormal distributions, we relied on the Mann–Whitney U test, which compares the sums of the score ranks in the 2 groups. The resultant U statistic is evaluated in terms of its known distribution to produce a Z value, comparable with that produced by other tests of group differences.

Results

Sample Characteristics

Baseline examination was completed with 65 veterans with diagnosed TBI from blast exposure. Fifteen participants had a single study eye, resulting in a sample of 115 eyes; 9 eyes were excluded from study because of enucleation, 3 because of phthisis, and 3 because of open-globe injury. The sample consisted of 62 men and 3 women, with a median age of 25 years and an age range between 19 and 45 years (Table 1). At the baseline examination, the time since injury ranged from 2 weeks to more than 6 years, with a median of 2 months. Five study participants had a history of ocular injury before the blast exposure, 5 had undergone past refractive surgery (LASIK or photorefractive keratectomy), and 10 had previous history of contact lens use, although none had worn contact lenses within 3 months of examination. The TBI severity level was rated as mild for 24 patients, moderate to severe for 24 patients, and penetrating head injury for 17 patients. At the time of blast exposure, 35 (54%) study participants were riding in a vehicle and 46 (71%) reported they were wearing ballistic eye protection.

Ocular Surface Injury

Slit-lamp examination detected injuries of the conjunctiva or cornea (zone 1) consistent with blast exposure in 16 individuals (25% of study participants), with a total of 17 study eyes (15%) affected. Specific zone 1 injuries included 3 eyes with metallic conjunctival foreign bodies, 3 eyes with metallic corneal foreign bodies or oxidized scars denoting prior removal, and 1 eye with nonmetallic corneal foreign bodies (Figs 1 and 2). In addition, 15 eyes showed partial-thickness anterior stromal scars, consistent with superficial lacerations or previous foreign bodies that were removed, extruded, or dissolved (Figs 2 and 3). Six eyes had grey linear or oval scars at the level of Descemet membrane (DM) consistent with healed or partially healed ruptures (Figs 2–4). One linear scar was located beneath a row of multiple corneal foreign bodies and oxidized scars (Fig 1), although others were not associated with overlying surface disturbances. Three posterior scars were attached to clear scrolls of DM (Figs 5 and 6). Subconjunctival hemorrhage was present in 1 eye, at an interval of 12 days after injury.

Overall, median ECD did not differ significantly between the blast-exposed subjects and comparison group (right eyes: