Traumatic Brain Injury Associated With Combat Ocular Trauma

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Purpose: To determine the impact of traumatic brain injury (TBI) on visual outcomes in combat ocular trauma (COT) and determine the association between TBI severity and types of ocular injuries. Participants: One hundred fifty-two US casualties sustained 207 globe/oculoplastic combat injuries. Methods: Retrospective, hospital-based cross-sectional study of US service members injured during Operations Iraqi Freedom and Enduring Freedom were treated by the Ophthalmology Service at Walter Reed Army Medical Center and screened for TBI by the Defense and Veterans Brain Injury Center from August 2004 to October 2006. Main Outcome Measures: The frequency of COT with positive TBI screening was 101 of 152 cases (66%) in comparison with negative TBI screening, which was 51 of 152 (34%) cases. The Defense and Veterans Brain Injury Center found TBI with concomitant ocular trauma in 101 of 474 (21%) consecutive casualties. Explosive fragmentary munitions accounted for 79% of TBI-associated COT. The median follow-up was 185 days. Traumatic brain injury severity did not correlate with worse final BCVA (Spearman coefficient, r = 0.12). The odds that BCVA worse than 20/200 was present with TBI was not statistically significant (OR: 1.5; 95% CI, 0.9–2.6; P = .10). The presence of TBI in COT was not associated with worse visual outcome (Mann-Whitney U test, P = .10). Globe injuries were more common than oculoplastic or neuro-ophthalmic injury. Closed-globe injuries were more likely to have TBI than open-globe injuries (OR: 2.17; 95% CI, 1.12–4.21; P = .03). Traumatic brain injury severity associated with COT included mild TBI (31%), moderate TBI (30%), severe TBI (25%), and penetrating TBI (14%). Severe TBI is more frequently associated with COT. Conclusion: Traumatic brain injury occurs in two thirds of all COT and ocular trauma is a common finding in all TBI cases. Closed-globe injuries are at highest risk for TBI while TBI does not appear to lead to poorer visual outcomes. Every patient with COT needs TBI screening. Those service members who are screened TBI positive need a referral to a TBI rehabilitation specialist. Keywords: closed-globe, ocular trauma, open-globe, Operation Iraqi Freedom, traumatic brain injury

Combat ocular trauma (COT) is defined as injury sustained during combat operations to the globe, periorcular anatomy, or neurologic pathways involved with visual acuity (VA) or ocular motility (Fig 1). Combat ocular trauma has increased from 0.5% of all injuries during the US Civil War, 8% during the Vietnam War, and 13% during Operation Desert Storm to approximately 13% during the present wars in Iraq and Afghanistan.1–7 From March 19, 2003, to September 8, 2008, during Operation Iraqi Freedom and Operation Enduring Freedom (OIF/OEF), there have been 3739 military deaths and 33,077 wounded secondary to hostile fire.8,9

The estimated prevalence of traumatic brain injury (TBI) in the United States is 5.3 million people.10,11 From January 2003 to January 2006, the Defense and Veterans Brain Injury Center (DVBIC) at Walter Reed Army Medical Center (WRAMC) diagnosed more than 600 soldiers with TBI from OIF/OEF. That effort included all COT soldiers with TBI described in this study. Warden12 diagnosed TBI in 28% of all soldiers seen at WRAMC. In a separate study, the researchers at the WRAMC DVBIC found that 91% of injured soldiers had postconcussive symptoms and 43% had a psychiatric disorder. However, no information regarding visual outcomes was provided in either study.13 In this article, we report the visual outcomes and severity of TBI associated with COT.

Combat ocular trauma is frequently associated with polytrauma in 85% of cases with TBI and facial and extremity injuries the most common findings.14 Therefore, the typical treatment course is part of a multidisciplinary approach by many different specialists at the same time. Soldiers with obvious brain injury are easily identified. Those with COT and the potential of more
occult brain injury are initially screened for TBI using the Military Acute Concussion Evaluation and treated by an ophthalmologist in Iraq or Afghanistan. Injured soldiers are air evacuated to Germany for a TBI rescreening and reevaluation by a team of medical and surgical specialists. After stabilization, the soldiers are flown to a tertiary referral center within the continental United States and again screened for TBI. The military tertiary referral centers are staffed with a full complement of ophthalmology subspecialties and include a DVBIC or other dedicated brain injury resources.

The main differences between military TBI and non-military TBI relate to the demographics and activity during injury for each patient population. Military TBI is acquired over the age of 18 years and is most commonly caused by explosions, gunshot wounds, and motor vehicle accidents. During OIF/OEF, the most common causes of COT are explosive blast injuries from either unconventional or conventional fragmentary munitions in 82% of cases, whereas falls accounted for only 1% of injuries. In contrast, nonmilitary TBI can be congenital or acquired and is most commonly caused by falls (32%) or motor vehicle accidents (19%). Acquired non-military TBI also has a high incidence of drug or alcohol use prior to trauma, which is rarely seen in the current conflicts in Iraq and Afghanistan.

Vision loss from non-COT TBI occurs in both congenital and acquired forms. Congenital TBI has a higher incidence of eye alignment disorders causing amblyopia while acquired pediatric TBI can result in vision loss in up to 20% of children with shaken baby syndrome secondary to vitreous hemorrhage or retinal damage. Acquired adult nonmilitary TBI secondary to falls or motor vehicle accidents more frequently causes orbital bone fractures and cranial nerve palsies than military COT, which causes more penetrating globe injuries.

Overall, vision is very important for sensory processing in patients with TBI. Poor visual outcomes are common with COT with 33% of eyes worse than a best-corrected visual acuity (BCVA) of 20/200 and 4% of patients legally blind. Goodrich and colleagues found that polytrauma from blast injuries doubled the risk of visual impairment in comparison with other polytrauma causes. Impaired vision can also lead to dependence on others for activities of daily living and may lead to problems with community reintegration.

After 5 years of OIF/OEF, significant numbers of patients have been discharged from the Department of Defense (DOD) healthcare systems and are moving on to VA or private healthcare in every community in the United States. The effects of TBI take many years of rehabilitation for a soldier to integrate back into civilian life. Traumatic brain injury ophthalmic patients frequently have difficulty with memory loss, reading comprehension, and become impatient and agitated easily. When caring for these soldiers, patience and extra time is
needed to educate the soldiers as to the treatment plan. A printed list of medications and dosage frequency as well as appointment times and dates is extremely helpful for the TBI patient with poor memory retention.\textsuperscript{24–27} Surgical ophthalmic patients with TBI with or without posttraumatic stress disorder frequently have posttraumatic agitation. Posttraumatic agitation defined as aggression, disinhibition, emotional lability, or combativeness can cause intraoperative movement while viewing under the operating microscope.\textsuperscript{28,29} Postoperative positioning following vitreoretinal surgery may be extremely difficult for some TBI patients.\textsuperscript{30} In this article, we wanted to find an association between presence of COT and TBI severity or an association between presence of TBI and types of COT, which may help improve treatment plan and postoperative care among soldiers with both COT and TBI.

**METHODS**

The protocol was institutional review board/ethics board approved for publication clearance by the Walter Reed Department of Clinical Investigation. The information in this article was also reviewed and approved for operational security content. This retrospective cross-sectional study examined all US soldiers injured during OIF/OEF evacuated to WRAMC and screened by the WRAMC DVBIC and seen by the WRAMC Ophthalmology Service.

The US soldiers were evacuated from Iraq or Afghanistan through Germany to WRAMC, Washington, DC, from August 2004 to October 2006. All patients in this study were examined and followed at WRAMC until the soldiers’ return to duty or until the time of discharge into the Veterans Affairs medical system. We included only soldiers injured during combat operations in the theatre of Iraq or Afghanistan. The study excluded US soldier nonbattle injuries, US soldier injuries sustained outside a combat zone, ocular trauma in Iraqi/Afghan civilians, and trauma in enemy combatants. Because the ophthalmology service at WRAMC is usually consulted for ocular injury defined by the Birmingham Eye Trauma Terminology, patients with symptoms of only visual dysfunction without signs of globe, oculoplastic, or cranial nerve injury were not examined and therefore excluded from this study.\textsuperscript{31}

**TBI SEVERITY AND OCULAR OR NONOCULAR TRAUMA**

Data collection was performed retrospectively from a Global War on Terrorism database, developed and maintained by the WRAMC Ophthalmology Service since the onset of OIF in 2003. A total of 201 ocular trauma variables from the time of injury to the end of follow-up were included during data collection. All data points were collected and analyzed using the Statistics Package for the Social Sciences version 15.0 (SPSS, Chicago, Illinois). TBI screening and severity classification is assessed by WRAMC DVBIC according to Table 1. The age and follow-up time was written as the median ± the standard deviation.

The standard protocol is that all individuals evacuated to WRAMC and admitted on an inpatient basis are screened for TBI. Initial screening is based on examination of the patient evacuation manifests. All individuals injured in a way known to be a high-risk mechanism for TBI (blast injury, motor vehicle accident, gunshot wound to the head or neck, fall), as well as those previously flagged as having a brain injury on screens earlier in the evacuation process, are seen individually by members of the TBI service in the hospital. Individuals are interviewed about their recall of the circumstances surrounding their injury, medical records from the point of injury are reviewed, and interviews are conducted with collateral informants and witnesses when possible.

TBI is diagnosed on the basis of American Congress of Rehabilitation Medicine criteria, namely, that someone has an external force to the head that causes a disruption in brain function as manifested by alteration or loss of consciousness (LOC), or abnormalities seen on imaging.\textsuperscript{32} After the presence of a brain injury is established, the severity of that injury is characterized on the basis of the duration of that alteration of consciousness. According to the criteria used, mild TBI involves LOC lasting less than 1 hour or amnesia lasting less than 24 hours. Moderate TBI involves LOC lasting between 1 and 24 hours or posttraumatic amnesia.
for 1 to 7 days. Severe TBI involves LOC for more than 24 hours or posttraumatic amnesia for more than a week. Penetrating TBI involves penetration of the dura by a foreign object or fragments of the skull. When an individual had injury characteristics that spanned more than 1 severity category, the more severe classification was used (eg, with LOC in the mild range and posttraumatic amnesia in the moderate range, the service member was classified as having sustained a TBI of moderate severity). In some cases, TBI screening is deferred until after medical stabilization or for other reasons. In the time epoch of this study, TBI screening was somewhat more complete in the inpatient population than it was in the outpatient group. Comparison of TBI severity between ocular trauma and nonocular trauma was analyzed using \( \chi^2 \) 2-sided test.

**TBI AND TYPES OF COT**

The classifications of COT injuries are shown in Figure 1. The major classifications include closed-globe, open-globe, oculoplastic, and neuroophthalmic trauma. Injuries were classified as closed- or open-globe in accordance with the Birmingham Eye Trauma Terminology.\(^{31,33,34}\) Injuries not involving the globe were categorized as oculoplastic or neuro-ophthalmic injuries. The category of globe injury in this study was defined as 1 eye with an open- or closed-globe injury. A globe injury could also have an oculoplastic and/or a neuroophthalmic injury as well as all 3 categories of injury. The category of oculoplastic injury included periocular injury and/or neuroophthalmic injury. The category of neuroophthalmic injury included only cranial nerve or direct brain injury. Nevertheless, the severity of ophthalmic injury in this study was greatest in the globe category, followed by the oculoplastic category and lastly the neuroophthalmic injury. The globe category was given the highest severity because injury to the globe has the highest of VA loss, which was the main outcome measure in this study.

When both globe and adnexal injury occurred on the same side in the same person, it was counted as 1 injury for this study. Bilateral injuries were categorized as globe/globe, globe/oculoplastic, globe/neuro-ophthalmic, oculoplastic/oculoplastic, oculoplastic/neuroophthalmic, and neuroophthalmic/neuroophthalmic (Table 2).

Closed-globe trauma was defined by zones 1, 2, and 3 according to the Ocular Trauma Classification Group and the Birmingham Eye Trauma Terminology system.\(^{33,35}\) Zone 1 is the ocular surface to include the conjunctiva and corneal surface. The most common COT injuries include corneal abrasions and retained foreign bodies in the conjunctiva or corneal epithelium/stroma. Zone 2 injury includes the anterior chamber, lens, and *pars plicata*. Hyphema and traumatic cataract are the most common injury in this group, which is frequently complicated by high intraocular pressures. Zone 3 injuries involve the vitreous cavity and retina. Vitreous hemorrhage, traumatic macular hole, and retinal detachment are the most common zone 3 nonpenetrating ocular injuries.

Open-globe injuries are categorized as laceration or rupture.\(^{31}\) The lacerations are further subdivided into intraocular foreign body, perforation (through-and-through), rupture, and penetrating. These open-globe injuries are also defined as zone 1, II, and III. Zone 1 open-globe injury involves the full-thickness injury isolated to the cornea from limbus to limbus. Zone 2 open-globe injury starts at the limbus and extends posteriorly 5 mm. Zone 3 open-globe injury begins 5 mm posterior to the limbus and extends to the optic nerve. Evaluation of open-globe injury versus closed-globe injury in the presence or absence of TBI was computed by using exact

<table>
<thead>
<tr>
<th>Injury</th>
<th>No. of Patients (% of n = 152)</th>
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<tbody>
<tr>
<td>Unilateral</td>
<td>95</td>
</tr>
<tr>
<td>Bilateral</td>
<td>56</td>
</tr>
<tr>
<td>Globe/globe</td>
<td>42</td>
</tr>
<tr>
<td>Globe/oculoplastic</td>
<td>8</td>
</tr>
<tr>
<td>Globe/neuroophthalmic</td>
<td>1</td>
</tr>
<tr>
<td>Oculoplastic/oculoplastic</td>
<td>4</td>
</tr>
<tr>
<td>Neuroophthalmic/neuroophthalmic</td>
<td>1</td>
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<table>
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<tr>
<th>No. of Cases (% of n = 207)</th>
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<tbody>
<tr>
<td>Total globe injury</td>
</tr>
<tr>
<td>Globe/oculoplastic/neuroophthalmic</td>
</tr>
<tr>
<td>Globe/oculoplastic</td>
</tr>
<tr>
<td>Globe/neuroophthalmic</td>
</tr>
<tr>
<td>Open-globe only</td>
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<tr>
<td>Closed-globe only</td>
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<tr>
<td>Oculoplastic/neuroophthalmic</td>
</tr>
<tr>
<td>Oculoplastic only</td>
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<tr>
<td>Neuroophthalmic only</td>
</tr>
<tr>
<td>Total open-globe</td>
</tr>
<tr>
<td>Penetrating</td>
</tr>
<tr>
<td>Intraocular foreign body</td>
</tr>
<tr>
<td>Perforating</td>
</tr>
<tr>
<td>Rupture</td>
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<tr>
<td>Primary enucleation</td>
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<tr>
<td>Open-globe zone 1</td>
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<tr>
<td>Open-globe zone 2</td>
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<tr>
<td>Open-globe zone 3</td>
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<tr>
<td>Total closed-globe</td>
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<tr>
<td>Closed-globe zone 1</td>
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<td>Closed-globe zone 2</td>
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<td>Closed-globe zone 3</td>
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2-sided $\chi^2$ analysis with risk estimate odds ratio and 95% confidence intervals.

Adnexal injury included eyelid laceration or avulsion, lacrimal system injury, or burn injury to the lids. Orbital injury included orbital fractures, orbital foreign bodies, and retrobulbar hemorrhage. Cranial nerve injury included traumatic optic neuropathy, motility limitations from intracranial or extracranial etiology (cranial nerves 3, 4, and 6), or eyelid movement (cranial nerve 7). Direct brain injury resulting from penetrating TBI had visual field defects on Humphrey visual field test 24-2 or 30-2.

Table 2 shows the distribution of the different types of ocular injuries included in this study. Each eye injury was counted independent from the opposite eye. Evaluation of open-globe injury versus closed-globe injury in the presence or absence of TBI was computed by using exact 2-sided $\chi^2$ analysis with risk estimate odds ratio and 95% confidence intervals.

**TBI AND BCVA**

We were unable to convert Snellen VAs into logarithm of the minimum angle of resolution units due to the large percentage of eyes with BCVA worse than 20/200. Grade I BCVA was 20/20 to 20/40. Grade II was 20/50 to 20/200. Grade III was 19/200 to 1/200 (count fingers). Grade IV was hand motions/light perception. Grade V was no light perception. The postinjury VA was separately analyzed in this study at the 30-day, 180-day, and the last documented VA date.

The timing of initial VA measurement was highly variable because of the circumstances in which the injuries occurred. In general, VA is recorded as early in the course of care as possible in every case. Injured soldiers were rapidly evacuated to a combat support hospital (CSH), where the initial eye evaluation and primary surgical repair were performed by an experienced ophthalmologist, often within hours of the injury. Once patients were stabilized at the CSH, they were evacuated through Germany, and then on to the United States, often within 72 to 96 hours of injury. Not infrequently, patients experienced devastating nonocular injuries, including orthopedic and neurosurgical emergencies, with resulting delay in ocular evaluation and intervention. As a rule, vision could be adequately assessed only after the soldier regained consciousness and/or following extubation. For some soldiers, this was within hours of injury in the CSH, whereas for others it was at Germany during the air evacuation process. For still others, the initial documentation of VA was delayed significantly and may have occurred after surgical intervention to explore or repair a ruptured globe.

Soldiers arrived at WRAMC from Germany and were evaluated either in the clinic or in the surgical intensive care unit. Visual acuity in immobile soldiers was obtained at the bedside using a Rosenbaum pocket screener at 14 inches. Visual acuity measurements were recorded when the soldier was able to accurately communicate the VA. For this analysis, intubated and noncommunicative soldiers did not have recorded initial acuities until they were extubated. For ambulatory patients, examination was performed in the eye clinic with standard Snellen VA. Best-corrected Snellen VA was obtained on every visit during care in the WRAMC Ophthalmology Clinic. The 2-tailed $t$ test was used to compare the mean duration with the standard error of the mean for the duration of follow-up in the TBI and non-TBI subgroups.

To evaluate TBI severity and final BCVA, the initial VA grade was subtracted from the final VA grade. The change in rank was calculated using the Wilcoxon rank sum test with a 2-tailed Spearman correlation coefficient. The mean final BCVA difference in both TBI negative and positive cases was determined using a Mann-Whitney $U$ test.

**RESULTS**

From August 2004 to October 2006, 218 US service members were treated for COT by the WRAMC Ophthalmology Service. One hundred fifty-two of these 218 soldiers (69%) were formally screened by the DVBIC for TBI diagnosis and severity. The median age was 25 ± 7.5 years (range, 19–53 years). Ninety-seven percent of the cases were men and 3% women. The median follow-up was 185 ± 230 days (range, 3–1084 days). The mean duration between the initial and final BCVA readings was similar in the TBI-screened positive group (234 ± 26 days) in comparison with the TBI-screened negative group (206 ± 26 days) (2-tailed $t$ test, $P = .49$). One death occurred in this study at 25 days postinjury.

The etiology of injury was unconventional fragmentary munitions (63%), conventional fragmentary munitions (16%), gunshot wound (13%), and motor vehicle accident (8%). Eighty-five percent of the cases had associated polytrauma. The most common concomitant injuries are TBI (66%) followed by facial injury (58%) and extremity injury (44%). Traumatic limb amputation accounted for 12% of cases.

Eye protection was worn at the time of injury in 31% of these injuries. Twenty-two percent of the ocular injuries had no eye protection, whereas 47% had no documentation of eye protection. Those without known status of eye protection had LOC and posttraumatic amnesia preventing the soldier from accurately answering the question of eye protection usage. Of the 152 DVBIC-screened patients with ocular trauma, 101 (66%) were diagnosed with TBI. During the study period, the DVBIC consecutively diagnosed TBI in 474 soldiers.
from OIF/OEF. Thus, the rate of COT and identified TBI was 101 of 474 cases (21%).

**TBI SEVERITY AND OCULAR OR NONOCULAR TRAUMA**

The severity of TBI with COT includes mild TBI (31%), moderate TBI (30%), severe TBI (25%), and penetrating TBI (14%) (Table 3). This was comparable to the overall known severity of TBI in all 474 combat trauma cases. The severity of all TBI cases included mild TBI (52%), moderate TBI (27%), severe TBI (15%), and penetrating TBI (5%). We subtracted 77 unknown severity levels of TBI patients from 474, giving a total of 397 TBI patients with known severity. Of these 397 cases with documented severity level, 101 cases had ocular trauma (Fig 2).

This study compared 101 known severity of TBI with COT to 296 TBI cases without ocular trauma in the same patient population. The statistical analysis demonstrates that mild TBI is more common in the non-ocular trauma group (59%) than in the ocular group (31%). However, there was no significant difference between the frequency of moderate TBI in the ocular trauma and no-ocular trauma groups. In contrast to mild TBI, the statistical analysis also shows that severe TBI is more common in the ocular group (25%) than in the no-ocular trauma group (12%). Similarly, penetrating TBI is also more common in the ocular group (14%) than in the no-ocular trauma group (3%) (Table 3).

**TBI AND TYPES OF COT**

Of those with globe injuries ($n = 166$) (Table 2), closed-globe injuries were 98 cases in comparison with 68 open-globe injuries. The most common injury pattern seen in this study was a unilateral closed-globe zone 3 injury with an associated oculoplastic injury ($n = 53$). Other common injury patterns were open-globe zone 3 and closed-globe zone 1 injuries. The rate of TBI was higher in closed-globe (75%) than open-globe injuries (57%).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Traumatic brain injury severity with and without ocular trauma*</th>
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<tr>
<td></td>
<td>Ocular trauma ($n = 101$)</td>
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<tr>
<td>Mild TBI</td>
<td>31 (31%)</td>
</tr>
<tr>
<td>Moderate TBI</td>
<td>31 (31%)</td>
</tr>
<tr>
<td>Severe TBI</td>
<td>25 (25%)</td>
</tr>
<tr>
<td>Penetrating TBI</td>
<td>14 (14%)</td>
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*TBI indicates traumatic brain injury.
The odds of having TBI in a closed-globe injury are 2.2 times higher when compared with having TBI in open-globe injuries (OR: 2.17; 95% CI, 1.12–4.21; \( P = .03 \)). On the other hand, when comparing the number of soldiers instead of injuries, no statistical difference was found in TBI association with the closed-globe group versus open-globe group (OR: 1.8; 95% CI, 0.87–3.9; \( P = .13 \)).

**TBI AND BCVA**

The initial and final VA of TBI versus non-TBI cases is presented using grades 1 to 5 (Figs 3a and b). We could not obtain VA on 24 of 207 (12%) eyes because of the inability of the patient to communicate. The majority of patients in both the negative and positive TBI groups had BCVA 20/20 to 20/40 at both initial and last documented VA. Within this study group, 6 (3%) of 152 soldiers had worse than 20/200 final BCVA in the better eye. TBI severity did not correlate with a change in the final VA grade (Spearman correlation coefficient, \( r = 0.14, n = 152, P = .08 \)). Using univariate analysis for all 152 COT with TBI, the rate of final BCVA of 20/200 or worse was found in 36% of TBI patients with COT in comparison with 26% of non-TBI patients with COT (OR: 0.6; 95% CI, 0.3–1.2; \( P = .17 \)), demonstrating no statistical difference in poor visual outcomes between the 2 groups. Finally, evaluation in change in grade from initial to final VA found no difference between TBI and non-TBI groups. In the non-TBI group, 33% appeared to improve 1 or more grade in VA in comparison with 22% in the TBI group, but this was not statistically significant (Mann-Whitney \( U \) test, \( P = .10 \)).

**DISCUSSION**

Traumatic brain injury has a significant association with COT. Two thirds of all ophthalmic injuries have associated TBI during OIF/OEF and 21% of all TBI patients have ocular injuries. These statistics represent only anatomic ocular injuries during OIF/OEF. This study excluded cases with only visual dysfunction, which, if included as TBI injury, would only add to the numbers of affected soldiers.

Soldiers injured in OIF/OEF frequently sustain polytraumatic injuries. Combat ocular trauma occurs in 13% of all combat-related injuries. The DVBIC has treated 5591 soldiers with TBI through January 2008, with 1464 of those at WRAMC. Of those screened positive at WRAMC, evaluation of the first 433 (January 2003 to April 2005) showed 57% with moderate to severe TBI and 43% mild TBI based on length of posttraumatic amnesia. We found that severe and penetrating TBI are more likely associated with the presence of COT than with no COT, whereas mild TBI is more likely associated with the absence of COT.

Unlike skeletal injuries where TBI causes excessive bone healing such as heterotopic ossification, this study did not find significant correlation between presence of TBI and vision loss related to anatomic ocular injuries.38–40 However, we examined only Snellen VA and did not use any other outcome measures to determine the extent of visual dysfunction in TBI cases versus non-TBI cases. The study compared the initial to last documented BCVA on both TBI and non-TBI ocular trauma cases. There was a trend toward better vision in the negative TBI group but not statistically significant. This cross-sectional study suggests that TBI does not contribute to VA loss in COT. However, a prospective cohort study may better demonstrate any correlation or lack thereof of TBI and VA loss in COT.

The most important finding of injury pattern was the statistical significance of closed-globe injuries with
higher rates of TBI when compared with open-globe injuries. Both groups were caused by explosive fragmentary munitions in 79% of cases. In our series of all COT, open- and closed-globe injuries are roughly equal in number. We hypothesize that the explosive blast wave may contribute to TBI in closed-globe ocular injury. Blast-related combat open-globe injuries can occur from a few feet to hundreds of yards from the site of the explosion secondary to projected shrapnel. Those open-globe injuries farther away from the blast may not experience the primary, tertiary, and quaternary blast wave effects on the globe. However, those with closed-globe injuries are usually closer to a blast with resultant damage from primary, tertiary, and quaternary blast waves effects.

The use of eye protection is important and recommended to all soldiers to prevent ocular trauma. Unfortunately, most soldiers with TBI experience LOC and posttraumatic or retrograde amnesia, which prevent accurate documentation of eye protection usage. The statistical analysis on visual outcomes and eye protection is therefore flawed and inaccurate.

There are many limitations of this retrospective study to include follow-up less than 6 months in 50% of the patients. Our documented follow-up time was limited because of patient transfer out of the DOD healthcare system to a VA TBI rehabilitation center. The specific loss of vision loss during follow-up was not specifically categorized as TBI-related vision loss compared to complications related to trauma. In addition, other types of visual dysfunction related to TBI aside from vision loss due to COT were not assessed in this study, which may underestimate the relationship of visual dysfunction and TBI. We also used the term final VA, which is only the last documented VA and not the final VA of that patient. These traumatized eyes may have worsening vision over the long term. The VA to provide objective measures is also limited particularly in TBI patients who may be incapable of responding to Snellen eye charts. Finally, as mentioned earlier, the cross-sectional design may not be the best design to demonstrate the true relationship of TBI and vision loss in COT.

**FUTURE DIRECTIONS**

Significant progress has been made in the area of TBI screening and treatment. From the start of OIF on September 11, 2001, until August 2004, no formal screening program was routinely used to diagnose TBI. Within this study period of August 2004 to October 2006, only 69% of COT soldiers were screened for TBI. The DVBIC and the DOD have instituted standardized TBI screening after an injury event in the combat theater of operations using the Military Acute Concussion Evaluation. Currently, all casualties are screened for TBI as they progress through the medical evacuation process in Germany. The US Army has now mandated TBI screening for all casualties and all troops receive TBI screening upon postdeployment. The goal is to identify all TBI injuries including all mild TBI patients who may have postconcussive symptoms.41,42

TBI-associated vision loss and visual disturbances are not a well-understood phenomenon. Traditional main outcome measures such as VA and objective visual field loss may not define overall visual disability in TBI patients. Unfortunately, limited data beyond VA and confrontation fields were measured in this group. Goodrich and colleagues19 recently published findings on visual dysfunction in polytrauma OIF/OEF TBI patients. Subjective main outcome measures such as difficulties with contrast sensitivity, color vision, reading, and/or diplopia have been hypothesized to cause visual dysfunction in TBI patients.43 However, no randomized, prospective, long-term trials have been conducted to evaluate these outcome measures.

During 2007, legislation was signed into law to create a Traumatic Brain Injury Center of Excellence. In January of 2008, the President of the United States signed into law the Military Eye Trauma Treatment Act of 2007.44,45 This federal mandate requires a creation of a vision center of excellence in prevention, diagnosis, mitigation, treatment, and rehabilitation of military eye injuries. The DOD and VA are currently working together to create a registry to track soldiers from the time of injury through the VA medical system. Another ongoing critical area of cooperation between the DOD and VA is the ability to access both electronic medical records systems to follow patients over the long term. Most importantly, the TBI and Military Eye Trauma Center of Excellence will study ways to protect and prevent TBI vision loss.

**CONCLUSIONS**

This study demonstrates that soldiers with ocular trauma are at very high risk to have associated TBI and must be screened and treated appropriately. Although TBI is found in the majority of COT, TBI comorbidity did not statistically demonstrate a greater risk for vision loss. The medical treatment plan must include a teamwork approach to address the specific needs of every soldier.46

Combat ocular trauma and TBI frequently occur together. Care can be improved by screening for one in the presence of the other, and understanding how the diagnosis of one can have an effect on outcome in the other. Traumatic brain injury–related motivational or cognitive difficulties can affect treatment compliance.47,48 Combat ocular trauma can affect TBI outcome through the additive effects of sensory loss or aesthetic concerns. Those veterans with any COT should be screened for the diagnosis of TBI. Traumatic brain injury–positive
patients need referred to a TBI specialist who can address their symptoms and oversee the long rehabilita-
tion process toward community reintegration that may be required in some individuals.

REFERENCES


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