The Relationship Between Severe Visual Acuity Loss, Traumatic Brain Injuries, and Ocular Injuries in American Service Members From 2001 to 2015

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ABSTRACT

Introduction

Although traumatic brain injury (TBI) is known to cause many visual problems, the correlation between the extent of severe visual acuity loss (SVAL) and severity of TBI has not been widely explored. In this retrospective analysis, combined information from Department of Defense (DoD)/Veterans Affairs ocular injury and TBI repositories were used to evaluate the relationship between chronic SVAL, TBI, ocular injuries, and associated ocular sequelae for U.S. service members serving between 2001 and 2015.

Materials and Methods

The Defense and Veterans Eye Injury and Vision Registry (DVEIVR) is an initiative led by the DoD and Veterans Affairs that consists of clinical and related data for service members serving in theater since 2001. The Defense and Veterans Brain Injury Center (DVBIC) is the DoD's office for tracking TBI data in the military and maintains data on active-duty service members with a TBI diagnosis since 2000. Longitudinal data from these 2 resources for encounters between February 2001 and October 2015 were analyzed to understand the relation between SVAL, and TBI while adjusting for ocular covariates such as open globe injury (OGI), disorders of the anterior segment and disorders of the posterior segment in a logistic regression model. TBI cases in DVEIVR were identified using DVBIC data and classified according to International Statistical Classification of Diseases criteria established by DVBIC. Head trauma and other open head wounds (OOHW) were also included. SVAL cases in DVEIVR were identified using both International Statistical Classification of Diseases criteria for blindness and low vision as well as visual acuity test data recorded in DVEIVR.

Results

Data for a total of 25,193 unique patients with 88,996 encounters were recorded in DVEIVR from February, 2001 to November, 2015. Of these, 7,217 TBI and 1,367 low vision cases were identified, with 638 patients experiencing both. In a full logistic model, neither UTBI nor differentiated TBI (DTBI, ie, mild, moderate, severe, penetrating, or unclassified) were significant risk factors for SVAL although ocular injuries (disorders of the anterior segment, disorders of the posterior segment, and OGI) and OOHW were significant.

Conclusion

Any direct injury to the eye or head risks SVAL but the location and severity will modify that risk. After adjusting for OGIs, OOHW and their sequelae, TBI was found to not be a significant risk factor for SVAL in patients recorded in DVEIVR. Further research is needed to explore whether TBI is associated with more moderate levels of vision acuity loss.

INTRODUCTION

From the year 2000 to the first quarter of 2018, nearly 384,000 military members were reported to have sustained a traumatic brain injury (TBI).[1] Because blasts have been the leading cause of injury in the conflicts in Iraq and Afghanistan,[2] a large number of veterans and U.S. military service members (SMs) have blast-related TBIs. The high rate of TBI and blast-related concussion events resulting from combat operations directly impacts the level of unit readiness and troop retention.

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TBI is known to cause multiple neurologic health problems and related symptoms,[3,4] so it is not surprising that TBI is also associated with numerous deleterious changes affecting the visual system. Reported TBI-related vision impairments include measurable dysfunctions of the oculomotor and binocular vision systems[5] as well as visual acuity (VA), visual fields, reading abilities,[6] dark adaptation,[7] and subjective complaints of visual disturbances, reading difficulties, and photophobia.[8–11]

The Defense and Veterans Eye Injury and Vision Registry (DVEIVR) is a joint Department of Defense/Veterans' Affairs (DoD/VA) initiative to track longitudinal ocular care data including examination findings, diagnoses, surgical/pharmacological interventions, and rehabilitation outcomes. The Defense and Veterans Brain Injury Center (DVBIC) TBI clinical patient registry maintains data on active-duty SMs with TBI and the associated severity since 2000. These registries serve as a foundation for research on prevention, diagnosis, mitigation, treatment and rehabilitation of vision, and brain injury.

Post-traumatic VA loss results from damage to the eye, the nerve fibers that carry signals from the retina in the eye to the brain, or to the visual cortex.[12] Reports on the association between TBI and severe visual acuity loss (SVAL), ie, vision less than Snellen 20/70, for large populations are lacking. A number of studies of post-TBI visual dysfunction report that VA remained normal or near normal in most cases of TBI independent of severity.[13–15] On the other hand, a study of 68 VA polytrauma patients with moderate to severe TBI (MTBI–STBI) found that 32.3% had visual acuities of 20/60 or worse.[11] Similar studies involving manual review of relatively small numbers of patients reported legal blindness to be present in 3% to 14% of TBI patients.[16,17] Our effort is the first to employ "big data" from 2 large DoD registries, ie, the DVEIVR and DVBIC dataset, toward the study of SVAL following TBI.

METHODS

Classification System, Semantic Modeling

The study framework employs ontologies which systematically categorize the basic concepts and relationships in TBI and ocular injuries. Ontologies and semantic models are used frequently in medical informatics as they provide a framework for describing and understanding concepts and causal relationships of disease and problem specific health issues, including brain[18] injury and vision loss.[19] The TBI ontology used in this study is based on the DVBIC TBI severity classifications (with associated International Statistical Classification of Diseases and Related Health Problems [ICD] codes).[20] In ocular injuries, a well-known ontology is the open globe injuries (OGI) ontology as described by the Birmingham Eye Trauma Terminology System.[21] To support this study, beyond OGI, categorizations of ocular diagnoses into disorders of the anterior segment (DAS) and disorders of the posterior segment (DPS)[22,23] were employed.

The models used in the present analysis serve to integrate conceptual model relationships with codes (eg, ICD, RxNorm, Current Procedural Terminology [CPT]) used to document theater care encounters recorded therein. In addition, DVEIVR data types include customized data elements/-value sets used by medical record abstractors who populate the DVEIVR. The data types used for this project include unstructured free text (eg, chief complaints), structured and coded data elements (eg, ICD codes), and structured but uncoded data elements (eg, non-numeric VA value sets).

Patient Population

The DVEIVR, an initiative of the DoD/VA Vision Center of Excellence, consists of clinical data for SMs serving in theater since 2001.[24,25] DVEIVR compiles data for "service members who sustained eye or vision injuries during combat and vision problems related to traumatic brain injuries". Various defense companies were contracted to provide abstraction services of SM medical records for DVEIVR and the procedures used were outlined in a recent Defense Health Agency memorandum.[26] For this study, TBI cases in DVEIVR were identified by "cross walking" DVEIVR patients with those in DVBIC to establish TBI severity classifications associated with SM's who suffered ocular injury. Notably, in the DVBIC TBI ICD-based ontology,[20] TBI includes skull fractures but excludes facial fractures (ie, TBI includes ICD-9 800-804 but excludes 802 series codes). In addition, the preponderance of DVEIVR injury data were collected before November, 2015 using ICD-9 codes rather than ICD-10 codes and so only ICD-9 codes were evaluated.

Study Design

This study is a case-control study where a case is defined as a patient who has suffered SVAL within the DVEIVR cohort and the null hypothesis is that there is no association between SVAL and TBI after adjusting for covariates. The relationship between SVAL and TBI (mild, moderate, severe, penetrating, and unclassified) is explored while controlling for confounders such as OGI, DAS, DPS, and head trauma (HT) which includes skull fractures and other open head wounds (OOHW). A logistic regression model is employed to control for the confounding that can occur when multiple variables can all influence SVAL.

Case Definition

Vision Loss

In 2015, ICD-9 codes range 360 to 379 define "Disorders of The Eye and Adnexa", where 369 describes levels of blindness and low vision. The system was originally created based on the recommendations for visual impairment categories made by a World Health Organization Study Group in 1972.[27] The 6

TABLE I. Key Study Semantic Model Classes

ICD-9-CM Code Group	Description	Injury Category
360, 379	Disorders of the globe/Other disorders of eye	DAS/DPS/OGI
361–363, 377	Retinal/chorioretinal/optic nerve/visual pathway disorders	DPS
364–366, 370–372	Disorders of Iris/ciliary body, glaucoma, cataract, keratitis, Other cornea/conjunctiva disorders	DAS
369	Blindness and low vision	SVAL
310.2, 800–804 (excluding 802 facial fractures for TBI), 850–854	Postconcussion syndrome, fracture of skull; intracranial Injury	TBI/HT
871	Open wound of eyeball	OGI
873	Other open head wound	HT

categories for vision acuity impairment begin at 20/70 Snellen acuity and progress to no light perception with the sixth category being undetermined or unspecified. Notably, visual field constriction of 10° or less is also used to define vision impairment but this criterion was not employed for the present analysis.

Inclusion criteria for the SVAL group were one or more of the following:

1) ≤20/70 VA
2) ICD-9: 369
3) Non-numeric terms such as light perception, no light perception, hand motion, count fingers, prosthesis, or anophthalmos
4) No diagnosis of amblyopia
5) No diagnosis of only superficial ocular injury without TBI

To capture cases that might be missed by the above criteria, we performed an analysis of refraction type (best-corrected) and achievable acuity. The control group comprised all entries in DVEIVR for whom refractions and best-corrected acuity were better than 20/70 regardless of TBI diagnosis. This population comprised 2,206 SMs, reflecting that best-corrected acuity was consistently recorded in ∼10% of the DVEIVR population. Notably, clinicians recorded VA using a logMar, ETDRS or Snellen chart; all data were converted to Snellen fraction readings where the denominator was used to classify patients as a case or control subject.

Time of VA Measure

The timing of measurement of VA during the postinjury period to determine some final value was not fixed for the study population. For SVAL cases, the best-corrected VA associated with the latest injury episode of care described by the ICD code was used, recognizing that acuity might have further improved.

Head and Ocular Trauma

ICD-9 coding was relied upon to identify TBI, ocular injury, sequelae, and HT cases. Table I describes the code categories that were TBI according to the semantic model employed for this study.

OBI, Posterior Segment Disorders, and Anterior Segment Disorders

Table I also shows those ICD-9 codes that were used to classify SVAL, OGI, DPS, and DAS. OGI classification was assigned for open wound of eyeball (871), DPS for disorders of the optic nerve and visual pathways (377), disorders of the vitreous body (379.2) and posterior wall complex including retinal and choroidal disorders and defects. DAS codes include the 364, 365, 366, 370, 371, 372, and 379 series.

Identification and Classification of SM's with TBI and HT

TBI cases were identified and classified by cross-walking DVEIVR patients with DVBIC registry data. The DVIBC registry receives date from multiple sources including the Armed Forces Health Surveillance Branch, which operates the Defense Medical Surveillance System, and the Theater Medical Data Store, a web-based application used to track, analyze, and manage a SMs' medical treatment information recorded on the battlefield.[20]

With the changes to the International Classification of Diseases from version 9 (ICD-9) to 10 (ICD-10) in 2015, DVBIC updated the TBI criteria to include definitions of concussion/mild TBI (mTBI), MTBI, STBI, penetrating TBI (PTBI), and unclassified TBI. DVBIC tracks the TBI definition for the military health system and, together with DoD and the Department of Health and Human Services, has updated the original definition several times since 2008. This analysis uses the current definitions of TBI as recently updated by DVBIC.[28] Specifically, DVBIC cases are classified based on ICD code criteria that includes a crosswalk between the general definitions of TBI severity listed and ICD-9 codes of the 800–804 and 850–854 series[29, 30]. The ICD-9 code of 873 for OOHW was also used to evaluate the effect on SVAL despite not being included in the DVBIC criteria for defining TBI severity. Although DVBIC excludes skull fractures of the

face bones (ICD-9 802) from the TBI classifications, this code was included in the present analysis for HT.

Statistical Analysis

Logistic regression was employed to assess the relationship of the SVAL dependent variable with the independent, categorical variables in this case-control study that allowed for confounder adjustment.[31] The odds ratio (OR) assesses the risk for SVAL for each variable.

RESULTS

DVEIVR Study Population

Data for a total of 25,193 unique patients with 88,996 encounters were recorded in DVEIVR from February, 2001 to November, 2015. A total of 7,371 DVEIVR patients with 44,745 associated encounters were identified as having a DVBIC-defined TBI. The median number of days between first and last encounter dates in this DVEIVR cohort was 1,160 days (range 5,560 days) with a median 4 encounters for the controls and 17 encounters for SVAL cases with at least 1 inclusion criterion. The search identified 2,206 controls of whom 32% suffered TBI as well as 1,367 SVAL cases. For the first 3 SVAL inclusion criteria, that is: (1) VA $\leq$ 20/70, (2) ICD-9 369, or (3) visual acuities recorded as non-numeric types (eg, light perception, no light perception, hand motion, and count fingers) there were 93,363 and 527 unique patients, respectively. Many patients were found to fit more than one of these criteria; there were 43 SM's for whom all 3 criteria applied, 341 SM's for whom 2 applied and 983 SM's for whom at least 1 applied. The most common diagnoses in DVEIVR are listed in Table IV. Closed-globe injuries, specifically, superficial injuries of eye and adnexa (918) and foreign bodies (930) account for <50% of all cases.

A difference in the OR of at least 1.25 for SVAL in TBI subjects relative to those without a TBI was considered significant. The sample size described in Table III would permit rejection of the null hypothesis (ie, this OR = 1) with a probability (power) of 0.86 at an alpha level of 0.05.

DVBIC Cross Walk

The numbers of patients in DVEIVR with TBI confirmed by cross-walking data with the DVBIC database is presented in Table II. Of the 7,371 patients with TBI, 5,399 were diagnosed with mTBI; this represented 21.4% of all patients in DVEIVR.

Statistical Analysis

In the full logistic regression model, shown in Table III, only DAS, DPS, OGI, and OOHW show significant risk for SVAL whereas neither skull fractures nor UTBI influenced SVAL after confounder adjustment. With unclassified severity as the reference category for comparison to classified severities including "no TBI" (none) in the full logistic regression model, neither mTBI, MTBI, STBI, or PTBI appear to show an effect on SVAL; Table IV presents the OR for DTBI.

TABLE II. Frequency of DVEIVR Patients With DVBIC-Classified TBI

TBI Severity	Total Frequency	%DVEIVR Population
Mild	5,399	21.4%
Moderate	1,063	4.2%
Penetrating	451	1.8%
Severe	195	0.8%
Unclassified	263	1.0%
Total	7,371	29.3%

TABLE III. Odds Ratio Estimates With Undifferentiated TBI (UTBI). (0 = Control Group, 1 = Cases Group)

Effect	Point Estimate	95% Wald Confidence Limits Lower	Upper
UTBI No TBI vs. TBI present	1.16	0.98	1.38
DAS 0 vs. 1	1.72*	1.46	2.03
DPS 0 vs. 1	2.41*	2.02	2.88
OGI 0 vs. 1	3.92*	3.11	4.93
Skull vault 0 vs. 1	1.06	0.67	1.69
Skull base 0 vs. 1	1.47	0.95	2.27
Skull face 0 vs. 1	0.89	0.69	1.16
Skull other 0 vs. 1	2.17	0.84	5.59
Skull multiple 0 vs. 1	1.11	0.20	6.23
Other open head wound 0 vs. 1	2.13*	1.66	2.73

*Significant association.

DISCUSSION

The urgency of understanding the impact of brain injury on vision cannot be understated. Between 13% and 16% of wounded U.S. SMs were med-evacuated during the Iraq and Afghanistan Wars because of ocular injuries. These numbers increased from corresponding rates in World War II (2%), the Vietnam War (9%), and the Gulf War (13%).[11,32] Approximately 65% to 75% of these events were secondary to blast injury from devices such as improvised explosive devices and rocket propelled grenades, devices which can cause complex direct and indirect injuries to the brain and ocular systems.[33] Eskridge reports that mTBI is the most common single injury in the Iraq and Afghanistan cohort usually arising from explosions according to the DVBIC; 82.3% of all SMs between 2000 and 2018 were classified as mTBI.[20,34] Aside from this human cost, it has been estimated that the annual financial cost of treatment, benefit-support, and lost productivity from visual-system (eye and brain) injuries related to the ongoing U.S. military participation in the middle east conflict is $2.4 billion annually.[35]

TABLE IV. Odds Ratio Estimates With Differentiated TBI. (0 = Control Group, 1 = Cases Group)

Effect	Point Estimate	95% Wald Confidence Limits	
TBI severity: mild vs. unclassified	1.15	0.65	2.04
TBI severity: moderate vs. unclassified	1.00	0.54	1.85
TBI severity: none vs. unclassified	1.29	0.74	2.27
TBI severity: penetrating vs. unclassified	0.86	0.44	1.67
TBI severity: severe vs. unclassified	1.96	0.85	4.54
DAS 0 vs. 1	1.73*	1.47	2.04
DPS 0 vs. 1	2.40*	2.01	2.86
OGI 0 vs. 1	3.91*	3.10	4.93
Skull Vault 0 vs. 1	0.96	0.59	1.57
Skull Base 0 vs. 1	1.43	0.92	2.23
Skull Face 0 vs. 1	0.881	0.677	1.146
Skull other 0 vs. 1	2.072	0.798	5.379
Skull multiple 0 vs. 1	1.223	0.217	6.901
Other open head 0 vs. 1	2.124*	1.653	2.729

*Significant association.

The key result of this study is that TBI alone is not correlated with SVAL. This is in concert with previous studies of the effect of TBI upon vision, where visual field-, visuomotor-, and higher-order visual functioning suffer more than VA.[36,37] This raises the question of why one might expect skull fractures to cause reduction of acuity, aside from the relatively uncommon condition of indirect traumatic optic neuropathy, in which the optic nerve is damaged by head injury from a currently unexplained mechanism.[38–40]

Not surprising is the finding that DAS, DPS sequelae, and OGI act as significant factors in explaining SVAL. More difficult to explain is how OOHW which may indicate an indirect effect (such as indirect traumatic optic neuropathy or other prechiasmal effects) correlates positively with SVAL. Notably, SMs with OOHW frequently suffer polytrauma. For example, of the SVAL cases with OOHW, 61.5% also experienced an OGI; more specifically, 58.1% of these OGI cases were recorded to have ICD-9 code 871.3, avulsion of the eye. Therefore, it may be that OOHW cannot be sufficiently distinguishable from OGI and other eye injuries for statistical analysis.

SVAL related to TBI following a dose-response trend has been documented by Brahm.[11] On the other hand, Weichel et al.[41] found that when ocular trauma occurs in combat, two-thirds of SMs also have an associated TBI but that TBI severity did not correlate with SVAL. The absence of this relationship in the current study may indicate the shortcomings of the currently popular severity-classification system for TBI.

Perhaps a new severity-classification system is needed to fully describe TBI and predict outcomes. It has been reported that current tools vary substantially in this regard.[42] Hawryluk[43] describes various classification schemes such as physical mechanism, pathoanatomy, prognosis, and symptoms/severity. Kristman[44] found inconsistencies in mTBI definitions in their review to update the World Health Organization Collaborating Centre for Neurotrauma Prevention, Management and Rehabilitation Task Force on Mild Traumatic Brain Injury; for example, although most studies include the Glasgow Coma Scale (GCS) score as a key component, others apply only LOC or post-traumatic amnesia criteria. The symptoms/severity score system that is used here in the United States, including DVBIC, is based on the GCS where a score of 13 to 15, 9 to 12, or <9 are classified as mTBI, MTBI, or STBI respectively. Corrigan et al.[45] found that an index utilizing GCS, Abbreviated Injury Score and Barell categorization provided a better predictive short-term health outcome. Researchers expect the current clinical classification scheme will eventually be replaced by one based on biomarkers that more closely reflects the underlying pathophysiology.[46,47]

The question of how TBI induces visual impairment is still being explored. In his literature review, Sen[48] states that optic nerve injury from the indirect forces of trauma is very common but is difficult for the clinician to evaluate visually. Hill et al.[49] suggest that the most severe types of TBI that can cause SVAL result in diffuse axonal injury Translational research using animal models receiving closed-skull injuries have documented mechanical deformation of axons and altered neuronal metabolisms in the visual pathway,[50] as well as retinal cell death, increased oxidative stress, and microglial reactivity[51,52]; notably, the level of damage caused by these mechanisms may not result in SVAL. If dose response is gauged by the frequency of repetitive TBI events, then perhaps vision loss may ultimately result from some mechanism similar to that described for progressive neurodegenerative disorders such as chronic traumatic encephalopathy (CTE).[50] Notably, there is no published literature exploring VA losses in patients suffering CTE, although pathology in the superior colliculus (a structure subserving visuomotor function) related to CTE has been found.[53]

Of interest in the military population is the type of trauma SM's experience. Blunt, ballistic and blast injuries subject SM's to logarithmically increasing levels of energy and blast injury is the predominant inciting trauma in SMs[54] nearly 75% of all U.S. combat injuries from 2005 to 2009 were because of explosions. Blast exposure can involve both direct and indirect injuries to the brain and eye. Blast injuries generally are categorized according to the interaction of the body with the shock wave (primary), energized particulate matter (secondary), blast wind (tertiary, includes bodily displacement and structural effects), and chemical effects (quaternary).[55]

Blast-related TBIs cause both focal and diffuse brain injuries. A primary blast brain injury results directly from the blast wave and the subsequent changes in atmospheric pressure (eg, brain contusions, shearing/stretching of brain tissues).[56–58] Objects put into motion by a blast cause

secondary blast-induced TBI. Shrapnel, debris, and other flying objects can cause PTBI or non-PTBI and other injuries. A tertiary blast injury occurs when a body, put into motion by a blast, strikes an object. Most blast-related TBIs are probably not the result of an isolated mechanism, and many are caused by primary blast exposure in addition to secondary and/or tertiary injury mechanisms.[57,59] Notably, a review of outcomes associated with blast and nonblast injuries suggested there were similar rates of vision loss.[60]

Ocular injury following blast exposure is also common, arising in up to 28% of survivors.[61] The nature and extent of ocular injury from the primary blast is less clear, unlike secondary blast injuries (eg, penetrating foreign bodies) associated with flying debris.[62] Tertiary and quaternary blast injuries occur when the eye experiences blunt force (eg, contusions) and chemical/thermal wounds, respectively.[62] Recent studies on primary ocular blast injury (primarily animal models) have yielded evidence of blast-associated changes in the cornea and retina at very low levels of blast exposure. Blast injuries to the anterior chamber appear to arise from inertial displacement of the lens and ciliary body, whereas posterior damage seems to arise from contrecoup interactions of the vitreous and retina. These studies convincingly demonstrated that following primary blast exposure, damage arose in the anterior segment, with angle recession, corneal edema, and hyphema. In severe cases, damage occurred in the posterior segment leading to retinal detachment, epiretinal membrane formation, and associated SVAL.[61,63] It seems reasonable to suggest that SVAL after blast is far more likely from ocular than brain injuries.

There are several limitations inherent in studies of this type. Concerning SM's with SVAL, any analysis attempting to isolate the effects of one variable requires a sophisticated, multivariate approach that adjusts for the confounding caused by other factors. It is well documented that in-theater wounds to the visual system are usually accompanied by trauma to other body parts including the brain. This is referred to as polytrauma by the VA.[33,61] The present analysis assesses the effect on SVAL from ocular injuries, DAS, DPS, and TBI using multivariate statistical techniques to control for the confounding that can occur since these variables can all influence SVAL individually.[64] A limitation of this effort is that analysis was dependent upon ICD-9 codes rather than on individual patient charts. Published data suggest that the quality and repeatability of this classification system was acceptable for common ophthalmic conditions[65] and mTBI[66] although for all brain injury it might underestimate incidence.[67]

A limitation imposed by studying databases rather than patient records is that the recorded visual outcomes were presumed to be permanent (based on ICD-9 code 369), even though they might have improved past the period where care was documented. It is presumed that postinjury treatment regimens always attempt to improve VA to the best achievable. For this study, the latest corrected VA measured during the treatment episode assigned the SM to the case- or control group, presuming that acuity was not immediately after eye surgery.

The choice of final acuity has varied among studies published by investigators from the VA and Walter Reed National Military Medical Center. In a prospective study by Cockerham et al.,[68] the time ranged between 2 weeks and <6 years although Brahm[11] measured acuity at bedside for inpatients with injuries and chairside for outpatient SMs.[11] Vlasov excluded subjects with better than 20/200 acuity and monitored acuity at 30, 60, and 180 days postinjury in a study of SMs at Walter Reed National Military Medical Center.[69] Therefore, it seems reasonable to conclude in the present study that the long terms of follow-up and numerous encounters documented for the SVAL group enable valid categorizations of those SMs with SVAL.

Future research in this area should explore whether more moderate degrees of VA loss might be associated with TBI. In addition, large database analyses should be employed to evaluate whether there is a dose-response relationship between other visual complaints (eg, photophobia, eyestrain, etc.) and TBI. Finally, and perhaps most importantly, these data could be included in studies of how TBI affects quality of life and activities of daily living for our wounded heroes.

CONCLUSIONS

This is the first study to explore a relationship between SVAL and TBI using big data provided by DoD vision and TBI databases. The main conclusion from studying a large cohort of wounded warriors suggests that although SVAL is a common sequela after ocular trauma, it is not commonly seen after TBI when there is no accompanying ocular injury. Future efforts of this type should include determining whether there might be a relationship between mild VA loss and TBI, and how other visual complaints such as photophobia and visual field loss correlate with TBI severity. Finally, these data could be incorporated into studies exploring how TBI affects quality of life and activities of daily living for service personnel suffering from TBI.

SUPPLEMENTAL DATA

The most frequently coded wounds and disorders for the SVAL cases are listed in Supplement 1. The top 10 frequencies of ICD-9 codes for TBI are listed in Supplement 2. The most frequent ICD-9 codes for the SVAL cases are listed in Supplement 3.

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