Eye (2018) 32, 687–692

www.nature.com/eye

CLINICAL STUDY

Gun trauma and ophthalmic outcomes

N Chopra[1,2], KA Gervasio[1,2,3], B Kalosza[4] and AY Wu[1,2,5]

Abstract

Purpose **This retrospective cohort study assesses the visual outcomes of patients who survive gunshot wounds to the head.**

Methods **The Elmhurst City Hospital Trauma Registry and Mount Sinai Data Warehouse were queried for gun trauma resulting in ocular injury over a 16-year period. Thirty-one patients over 16 years of age were found who suffered a gunshot wound to the head and resultant ocular trauma: orbital fracture, ruptured globe, foreign body, or optic nerve injury. Gun types included all firearms and air guns. Nine patients were excluded due to incorrect coding or unavailable charts. Statistical analysis was performed using a simple bivariate analysis (χ^2).**

Results **Of the 915 victims of gun trauma to the head, 27 (3.0%) sustained ocular injuries. Of the 22 patients whose records were accessible, 18 survived. Eight of the 18 surviving patients (44%) suffered long-term visual damage, defined as permanent loss of vision in at least one eye to the level of counting fingers or worse. Neither location of injury ($P = 0.243$), nor type of gun used ($P = 0.296$), nor cause of gun trauma ($P = 0.348$) predicted visual loss outcome. The Glasgow Coma Scale eye response score on arrival to the hospital also did not predict visual loss outcome ($P = 0.793$).**

Conclusion **There has been a dearth of research into gun trauma and even less research on the visual outcomes following gun trauma. Our study finds that survivors of gun trauma to the head suffer long-term visual damage 44% of the time after injury.**

Eye (2018) **32,** 687–692; doi:10.1038/eye.2017.249; published online 22 December 2017

Introduction

Gun trauma is an important issue that attracts national and international attention. In 2014, 33 599 persons died from firearm injuries in the United States, which accounted for 16.8% of all injury deaths in that year.[1] Despite the magnitude of this issue, there has been a dearth of research into gun trauma. A 2017 study found that gun trauma kills roughly as many people as sepsis; funding for gun trauma research, however, amounted to ~0.7% of the funding dedicated to researching sepsis, and the volume of research published on gun trauma was roughly 4% of the research published on sepsis.[2]

Contributing factors likely include restrictions on collecting and sharing gun data as well as limited funding towards gun research. When performing background checks on gun purchases, for example, any identifying information collected must be destroyed within 24 h of a decision (28 CFR 25.9—Retention and destruction of records in the system, 1998). Furthermore, legislation specifically prohibits any national registry of firearms, firearms owners, or firearms transactions at the federal level (Firearms Owners' Protection Act, 1986). While there are exceptions—guns reported as stolen, various registries at the state level—there is no national repository for collecting and sharing gun data. At the international level, the United Nations has sought to limit illicit trading of conventional arms, encouraging national recordkeeping requirements and the sharing of such records; however, the treaty specifically reaffirms the right of member states to regulate and control conventional arms exclusively within their own territories, pursuant to their own legal systems (United Nations Arms Trade Treaty, 2013).

In addition to limited information on gun ownership, there is also a lack of federal funding for gun research in the United States as referenced above. The reasons for this are multifaceted but are partly influenced by legislation. For example, in 1996 it was stipulated that 'none of the funds made available for injury prevention and control at the Centers for Disease Control and Prevention may be used to advocate or promote gun control'.[3]

To the extent that there is limited research on gun trauma overall, there is even less research on the ophthalmic outcomes following gun trauma. Furthermore, existing research focuses

[1]Department of Ophthalmology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

[2]Department of Ophthalmology, Elmhurst Hospital Center, Elmhurst, NY, USA

[3]Department of Medicine, Memorial Sloan Kettering Cancer Center, New York, NY, USA

[4]Department of Trauma Research, Elmhurst Hospital Center, Elmhurst, NY, USA

[5]Department of Ophthalmology, Stanford University School of Medicine, Palo Alto, CA, USA

Correspondence:
AY Wu, Department of Ophthalmology, Stanford University School of Medicine, 2370 Watson Court, Suite 200, Palo Alto, CA 94303, USA
Tel: +1 650 497 0758;
Fax: +1 650 736 8232.
E-mail: awu1@stanford.edu

Received: 7 March 2017
Accepted in revised form: 4 October 2017
Published online: 22 December 2017

heavily on deaths from gun trauma; however, gun trauma results in many more nonfatal injuries than deaths, resulting in the potential for years of life lived with disability.[4] Given the magnitude of this issue, and to increase research in this important area, we explore the effects of gun trauma to assess the visual outcomes of patients who survive gunshot wounds to the head.

Materials and methods

The Elmhurst City Hospital Trauma Registry and Mount Sinai Data Warehouse were queried for International Classification of Diseases Ninth Revision (ICD-9) and Tenth Revision (ICD-10) codes for gun trauma resulting in ocular injury, and paper charts were obtained to evaluate ophthalmology notes. The study protocol received institutional review board approval from both the Elmhurst Research Committee and Mount Sinai Hospital to conduct a comprehensive paper chart review. The Elmhurst City Hospital is a level 1 trauma center serving a population of approximately one million people throughout the ethnically diverse neighborhoods of northwestern Queens, New York City. Mount Sinai Hospital is a 1183-bed general medical and surgical facility with 102 267 emergency department visits in the most recent year reported, serving communities in East Harlem and surrounding Manhattan, New York City. In 2015, there were 50 088 violent crimes in New York City.[5]

The Elmhurst City Hospital Trauma Registry and Mount Sinai Data Warehouse were initially queried for all patients presenting with any form of gun trauma between 1 January 2000 and 8 May 2016, using internal record keeping that tracks injuries from guns. Gun types included all firearms and air guns. This data set was further filtered by ICD-specific ocular codes that capture direct and indirect 'injuries to the head' as well as 'diseases of the eye and adnexa' to account for secondary injury such as sequelae from retained foreign bodies (Table 1). All causes of gun trauma were considered, including violence, accidents, and self-harm.

Thirty-one patients who suffered a gunshot wound to the head with resultant ocular trauma were identified having diagnoses including orbital fracture, ruptured globe, foreign body, and optic nerve injury. Of the 31 patients queried, four were excluded due to incorrect coding upon chart review, and five were excluded because their charts were unavailable. Data from the 22 remaining patients were then assessed. We defined long-term visual damage as permanent loss of vision from enucleation/evisceration or traumatic optic neuropathy, resulting in impaired vision to the level of counting fingers or worse. We used a simple bivariate analysis (χ^2) to evaluate the ability of any given metric to predict long-term visual damage. The study was Health Insurance Portability and Accountability Act compliant, with protection of all individually identifiable health information.

Table 1 Ocular trauma codes queried

ICD-9 code	*Description*
802	Closed fracture of nasal bones
802.1	Open fracture of nasal bones
802.6	Closed fracture of orbital floor (blow-out)
802.7	Open fracture of orbital floor (blow-out)
802.8	Closed fracture of other facial bones
802.9	Open fracture of other facial bones
870.0 – 870.9	Open wound of ocular adnexa
871.0 – 871.9	Open wound of eyeball
905	Late effect of fracture of skull and face bones
918.0 – 918.9	Superficial injury of eye and adnexa
921.0 – 921.9	Contusion of eye and adnexa
925.1	Crushing injury of face and scalp
930.0 – 930.9	Foreign body on external eye
950.0 – 950.9	Injury to optic nerve and pathways
951	Injury to oculomotor nerve
951.1	Injury to trochlear nerve
951.3	Injury to abducens nerve
ICD-10	*Description*
H05.5	Retained (old) foreign body following penetrating wound of orbit
H53	Visual disturbances
H54	Blindness and low vision
H57.1	Ocular pain
S00.1	Contusion of eyelid and periocular area
S00.20	Unspecified superficial injury of eyelid and periocular area
S00.21	Abrasion of eyelid and periocular area
S00.25	Superficial foreign body of eyelid and periocular area
S01.1	Open wound of eyelid and periocular area
S02.3	Fracture of orbital floor
S04.0	Injury of optic nerve and pathways
S04.1	Injury of oculomotor nerve
S04.2	Injury of trochlear nerve
S04.4	Injury of abducent nerve
S05	Injury of eye and orbit
T15	Foreign body on external eye

The Elmhurst City Hospital Trauma Registry and Mount Sinai Data Warehouse were queried for gun trauma cases over a 16-year period; these results were filtered for cases resulting in ocular injury using the ICD codes listed here.

Results

Of 915 patients presenting to the Elmhurst and Mount Sinai Hospital Emergency Departments with injuries due to gun trauma, 27 (3%) sustained ocular injuries. Of the 22 patients whose records were accessible, four were noted to have ocular injury on presentation but then died in the operating room. Blood loss was a major contributing factor in each of these cases, as three of the four patients had been found down after an unknown amount of time

since their injuries and the fourth patient sustained significant bleeding above the neck. The causes of gun trauma in these four patients were violence (50%) and self-harm (50%). Analysis was conducted on the remaining 18 patients.

Of the surviving 18 patients, the median age was 28 years (range, 13–57 years), 15 (83%) of whom were male. The average Injury Severity Score of patients at presentation was 14.15 (±9.69). The average Glasgow Coma Scale (GCS) score was 12.85 (±4.16). On average, the length of stay for each patient was 9.27 days (±12.31). Two patients (11%) were shot directly to the globe, 5 (28%) were shot to the orbit, and 11 (61%) were shot elsewhere to the head. For the cases where data were available, six patients (46%) were shot with a handgun, four (31%) with an air gun, and three (23%) with a shotgun. For the cases where data were available, the causes of gun trauma included violence in nine cases (64%), accidents in four cases (29%), and self-harm in one case (7%). Five of the 18 patients (28%) sustained bilateral ocular injury, with the remaining 13 (72%) sustaining injury to just one eye. Ten patients (56%) suffered wounds beyond their direct ocular injuries, including facial fractures, facial nerve injury, gunshot wounds to the trunk and extremities, and, in the most severe cases, traumatic brain injury. Table 2 summarizes gunshot locations, types of gun involved, injuries, and causes of injury for all 18 patients.

In total, 8 of the 18 surviving patients (44%) suffered long-term visual damage, defined as permanent loss of vision in at least one eye to the level of counting fingers or worse. Two of these eight patients underwent enucleation in both eyes because of their injuries, five underwent enucleation in one eye, and the eighth patient suffered permanent loss of vision to the level of hand motion in one eye due to traumatic optic neuropathy. The two patients needing bilateral enucleations were the two patients in our study with associated traumatic brain injury from their gunshot wounds. Neither location of injury ($p = 0.243$), nor type of gun used ($p = 0.296$), nor cause of gun trauma ($p = 0.348$) predicted visual loss outcome. The GCS eye response score on arrival to the hospital also did not predict visual loss outcome ($p = 0.793$). Table 3 summarizes the predictive value of injury location, type of gun used, cause of gun trauma, and GCS eye response score on arrival on long-term vision loss.

Discussion

There has been a dearth of research into gun trauma and even less research on the visual outcomes following gun trauma. A subset of the research on visual outcomes has focused on accidental gun trauma, particularly in pediatric populations from air and pellet guns. In a Finnish study of 202 children's eye injuries, 9% of patients were left with a permanent disability; guns, fireworks, tools, and pellet guns were found to be the most dangerous objects.[6] Haring *et al*[7] found that among sports-related eye injuries in the United States, activities involving projectiles pose the greatest risk for visual impairment in the short term, although in their study long-term outcomes were unavailable.

While these studies are important, they do not address gun trauma due to violence or self-harm in adults. Studies exploring visual outcomes following suicide attempts with guns include Kucuker *et al*[8] who offer a treatment algorithm to restoring visual functionality and appearance following severe maxillofacial and ocular injuries in failed suicide attempts using long-barreled guns. In a case study of two suicide attempts in Germany, via gunshot wounds to the lateral orbit in attempted suicides, one patient presented with a double penetration of both orbits and destruction of both globes, making reconstruction not possible. The other patient presented with multiple shots to the head from a small caliber gun (5.6 mm), where one bullet entered the right orbit behind the globe; the bullet was localized using computed tomography and surgically removed with preservation of the globe and with a postoperative visual acuity of 20/60.[9]

Recent research has looked at military injury due to gunshot wounds, comparing outcomes between military and civilian patients. A 2016 study saw important differences regarding the anatomic location, gender, and race distribution of maxillofacial GSWs between the military and civilian populations. For example, the mandible is the most commonly affected region of the maxillofacial skeleton in civilians, while the maxilla is more commonly affected in military gunshot wounds. Military victims are more likely to be white (34%) and male (99%) when compared with their civilian counterparts (27% and 87%, respectively).[10]

In addition to injury from bullets and explosive fragments themselves, injury from blast effects or high-energy transfer in the closed space of the head are important causes of adverse visual outcomes. The effects of indirect injury from blast effects have been noted on several occasions, including blast lung injury, tympanic membrane damage, and even colonic injury, where one study found indirect damage to the colon by propagation of energy by the missile, remote from the track of the projectile.[11–13]

With regards to blast effects in the head specifically, an 11-year, multi-institutional study of 720 patients with gunshot wounds and blast injuries to the face found high mortality and associated morbidity in these cases, with 26% of patients dying and 67% of patients hospitalized

Table 2 Visual outcomes in patients after gunshot wound to the head

Patient	*Gunshot location*	*Type of gun*	*Ocular injuries*	*OD*[a]	*OS*[a]	*Bilateral?*	*Other significant injuries*	*Cause*
Suffered permanent visual loss[b]								
1	Left orbit	Handgun	OS: orbital ridge fracture, optic nerve injury	20/30	Hand motion only	No	None	Violence
2	Through both temples	Handgun	OU: orbital fracture, ruptured globe containing FB	Enucleation	Enucleation	Yes	TBI, with bilateral frontal SAH. Intraparenchymal hematoma. Multiple facial fractures	Violence
3	Through both temples	Shotgun	OU: ruptured globe	Enucleation	Enucleation	Yes	TBI, with subsequent frontal lobe damage and cognitive changes	Violence
4	Left globe	Air gun	OS: orbital floor fracture, retained FB	20/30	Enucleation	No	None	Accident
5	Right anterior scalp	Shotgun	OD: ruptured globe, retained FB	Enucleation	20/20	No	Multiple GSWs to neck, chest, and L arm. L hand numbness in distribution of ulnar nerve. Neurologically intact otherwise	Violence
6	Right orbit	Handgun	OD: ruptured globe	Enucleation	20/30	No	R facial paralysis with no evidence of facial nerve transection; injury assumed to be 2/2 thermal injury from bullet. R thumb fracture 2/2 penetrating bullet wound	NA
7	Right globe	Air gun	OD: ruptured globe	Enucleation	20/40	No	None	Accident
8	Right orbit	Shotgun	OD: orbital fracture	Enucleation	20/30	No	R mandiublar fracture	Accident
No permanent visual loss[b]								
9	Left orbit	Air gun	OS: FB in globe, adjacent hemoatoma	20/20	20/40	No	None	Accidcent
10	Left orbit	Air gun	OS: FB in medial aspect of orbit, contusion	20/20	20/30	No	None	NA
11	Left cheek	Handgun	OS: orbital fracture	20/25	20/400	No	None	Violence
12	Face	Handgun	OS: orbital fracture OU: retrobulbar hematoma	20/20	20/20	Yes	Severe facial trauma with multiple fractures	Violence
13	Nose	NA	OD: corneal abrasion OS: orbital fracture	20/20	20/20	Yes	Comminuted fracture of the nose	Violence
14	Left cheek	NA	OD: comminuted fractures involving medial wall orbit OU: metallic bullet fragments present in and around orbits	20/400	20/200	Yes	Shattered R nasal bone	Self-harm
15	Left parietal lobe	Handgun	OS: orbital fracture, corneal abrasion	20/20	20/30	No	GSWs to both arms and chest. Multiple facial fractures, multiple bilateral rib fractures, lung contusions, hemopneumothorax	Violence
16	Right maxillary bone	NA	OD: orbital fracture	20/200	20/20	No	Severe facial trauma with multiple fractures	NA
17	Left temporal lobe	NA	OS: orbital fracture	20/20	20/25	No	None	Violence
18	Nose	NA	OS: orbital fracture	20/400	20/100	No	None	NA

Abbreviations: NA, data were not available; GSW, gunshot wound; FB, foreign body; TBI, traumatic brain injury; SAH, subarachnoid hemorrhage. [a]Most recent visual acuity assessment at the time of discharge.
[b]Permanent loss of vision in at least one eye to the level of counting fingers or worse.

Table 3 Bivariate analysis–χ^2

	Total population N = *18*	*Long-term vision loss* N = *8*	*No long-term vision loss* N = *10*	P-*value*
Location of injury, % (n)				0.243
Globe	11.11 (2)	25.00 (2)	0.00 (0)	
Orbit	27.28 (5)	25.00 (2)	30.00 (3)	
Elsewhere	61.11 (11)	50.00 (4)	70.00 (7)	
Type of gun, % (n)				0.296
Air gun	30.77 (4)	25.00 (2)	40.00 (2)	
Handgun	46.15 (6)	37.50 (3)	60.00 (3)	
Shotgun	23.08 (3)	37.50 (3)	0 (0)	
Cause of gun trauma				0.348
Violence	64.29 (9)	57.14 (4)	71.43 (5)	
Accidents	28.57 (4)	42.86 (3)	14.29 (1)	
Self-harm	7.14 (1)	0.00 (0)	14.29 (1)	
Arrival GCS, eye, (%) (n)				0.793
Open spontaneously	83.33 (10)	80.00 (4)	85.71 (6)	
No eye opening	16.67 (2)	20.00 (1)	14.29 (1)	

Abbreviation: GCS, Glasgow Coma Scale.
Population statistics. Predictive value of location of injury, type of gun, cause of gun trauma, and Glasgow Coma Scale eye response on arrival on long-term vision loss.
Note: Where totals do not add to 18, the relevant data were not available.

>48 h.[14] In 2015 Rex *et al*[15] noted that ocular injury is among the most common terrorist blast morbidities, arising in up to 28% of survivors, and yet the nature and extent of ocular injury from the primary blast itself, independent of flying debris, has been poorly explored. The study found that over the course of 1 month from exposure to blast injury, various forms of ocular damage arose from corneal edema to retinal detachment with associated vision loss. Importantly, this study highlights the need for close follow-up with patients exposed to blast injuries, as their prognosis may change over time.

One of the more serious complications from blast injury to the head is traumatic brain injury. A 2013 study of visual quality of life in 60 veterans found that individuals with blast-induced traumatic brain injury reported significant decrements in their subjective visual experiences.[16] An earlier study that explored an individual's useful field of view after traumatic brain injury found greater functional loss of peripheral vision when compared to controls.[17] As mentioned earlier, two of our patients suffered traumatic brain injury secondary to their gunshot wounds to the head; in one of these patients, this resulted in cognitive decline necessitating specialized care. In terms of visual outcomes, both patients underwent bilateral enucleation due to their injuries.

Through a variety of mechanisms, gun trauma results in significant morbidity and mortality for victims. Previous studies have explored many different facets of gun trauma, including the effects of direct damage, indirect damage from blast effects, traumatic brain injury, outcomes in military *vs* civilian populations, causes of gun trauma, and others. However, the magnitude of this issue warrants increased focus on these and other aspects of gun trauma. Investigation into long-term visual outcomes in the setting of gun trauma to the head has been limited; our study seeks to add to this area of research.

Limitations of this study predominantly include small sample size, lack of available data, and skewed patient outcomes. The limitation of small sample size was further compounded when paper charts for 5 of 27 patients were unavailable and therefore unable to be analyzed. Furthermore, the remaining charts, having been collected over 16 years in paper form, were not consistent in their recording of data; potentially important information such as whether a patient lost consciousness was therefore not able to be considered. Finally, of the eight patients with long-term vision loss, seven underwent an evisceration or enucleation. The findings of our study may be less relevant for victims of gun trauma with ocular involvement who retain their globe. Future studies should include a larger sample size, a greater number of metrics to consider, more patients with indirect injury to the visual system from gun trauma (eg, traumatic brain injury), and more patients without evisceration/enucleation whose outcomes can be evaluated at various points in time.

As caretakers of patients with gunshot wounds to the head, ophthalmologists should be able to manage these

difficult cases and council patients with regard to their visual prognosis. Ocular damage from gunshot wounds to the head can arise in many ways, including direct injury to the visual system by projectiles or blast effects, or indirect damage via traumatic brain injury. More research is needed to tease out the most important factors predicting long-term visual damage. Gunshot wounds to the head are deadly, with 18% of the study patients not surviving their wounds. Our data show that survivors of gun trauma to the head suffer long-term visual damage 44% of the time after injury. This research helps to quantify the harm from gun trauma as well as encourages increased focus on this important topic.

Summary

What was known before

- Gun trauma is an important issue that attracts national and international attention and results in significant morbidity and mortality for victims.
- Previous studies have explored many different facets of gun trauma, including the effects of direct damage, indirect damage from blast effects, traumatic brain injury, outcomes in military *vs* civilian populations, causes of gun trauma, and others.
- However, investigation into long-term visual outcomes in the setting of gun trauma to the head has been limited.

What this study adds

- We find that survivors of gun trauma to the head suffer permanent visual loss 44% of the time after injury.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We would like to acknowledge our colleagues at Elmhurst Hospital Center, Elmhurst NY, for access to their trauma registry database and statistical support. Specifically, we thank George Agriantonis, MD, Anju Galer, MSN, APRN, ANP-BC, and Praise Nesamony. We would also like to acknowledge support from Research to Prevent Blindness, Inc. and the National Eye Institute (P30-EY026877).

References

1 Xu J, Murphy SL, Kochanek KD, Bastian BA. Deaths. Final data for 2013. *Natl Vital Stat Rep* 2016; **64**(2): 1–119.

2 Stark DE, Shah NH. Funding and publication of research on gun violence and other leading causes of death. *JAMA* 2017; **317**(1): 84–85.

3 House US. *Omnibus Consolidated Appropriations Act, 1997*. Departments of Commerce J, and State, the Judiciary, and Related Agencies. Government Publishing Office: Washington, DC, 1997.

4 Fahimi J, Larimer E, Hamud-Ahmed W, Anderson E, Schnorr CD, Yen I *et al.* Long-term mortality of patients surviving firearm violence. *Inj Prev* 2016; **22**(2): 129–134.

5 Newsday. Major crime in New York City, 2009–2015 2016 (updated 31 August 2016). Available at: http://data.newsday.com/long-island/data/crime/new-york-city-crime-rate/.

6 Haavisto AK, Sahraravand A, Holopainen JM, Leivo T. Paediatric eye injuries in Finland-Helsinki eye trauma study. *Acta Ophthalmol* 2016; **95**(4): 392–399.

7 Haring RS, Sheffield ID, Canner JK, Schneider EB. Epidemiology of sports-related eye injuries in the United States. *JAMA Ophthalmol* 2016; **134**(12): 1382–1390.

8 Kucuker I, Simsek T, Keles MK, Yosma E, Aksakal IA, Demir A. Our treatment approaches in severe maxillofacial injuries occurring after failed suicide attempts using long-barreled guns. *J Craniofac Surg* 2016; **27**(2): e133–e138.

9 Schargus M, Kawa D, Elling M, Kunkel M. Management of suicidal orbital gunshot wounds to the temple. *Ophthalmologe* 2014; **111**(10): 965–969.

10 Guevara C, Pirgousis P, Steinberg B. Maxillofacial gunshot injuries: a comparison of civilian and military data. *J Oral Maxillofac Surg* 2016; **74**(4): 795 e1–795 e7.

11 MacFadden LN, Chan PC, Ho KH, Stuhmiller JH. A model for predicting primary blast lung injury. *J Trauma Acute Care Surg* 2012; **73**(5): 1121–1129.

12 Waterworth TA, Carr MJ. Report on injuries sustained by patients treated at the Birmingham General Hospital following the recent bomb explosions. *BMJ* 1975; **2**(5961): 25–27.

13 Webster C, Mercer S, Schrager J, Carrell TW, Bowley D. Indirect colonic injury after military wounding: a case series. *J Trauma* 2011; **71**(5): 1475–1477.

14 Shackford SR, Kahl JE, Calvo RY, Kozar RA, Haugen CE, Kaups KL *et al.* Gunshot wounds and blast injuries to the face are associated with significant morbidity and mortality: results of an 11-year multi-institutional study of 720 patients. *J Trauma Acute Care Surg* 2014; **76**(2): 347–352.

15 Rex TS, Reilly MA, Sponsel WE. Elucidating the effects of primary blast on the eye. *Clin Exp Ophthalmol* 2015; **43**(3): 197–199.

16 Lemke S, Cockerham GC, Glynn-Milley C, Cockerham KP. Visual quality of life in veterans with blast-induced traumatic brain injury. *JAMA Ophthalmol* 2013; **131**(12): 1602–1609.

17 Fisk GD, Novack T, Mennemeier M, Roenker D. Useful field of view after traumatic brain injury. *J Head Trauma Rehabil* 2002; **17**(1): 16–25.