ORIGINAL ARTICLE

Combat-related ocular trauma and visual outcomes during counter-terrorism urban warfare operations in Turkey

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ABSTRACT

BACKGROUND: The study was to report the clinical features and post-operative outcomes in military personnel admitted to the Ocular Trauma Center of Gülhane Training and Research Hospital after sustaining combat injuries in urban warfare.

METHODS: This is a retrospective, non-comparative, interventional case series analyzing Turkish military personnel transferred to our tertiary ocular trauma center from the warfare zone and combat support hospitals. Ocular injuries were subdivided into zones and ocular trauma classification.

RESULTS: There were 103 combat ocular injuries in 74 military personnel. The average age was 27.31±4.64 years (range; 21–48 years), and all were men (100%). The average follow-up was 529.34±213.98 days (288–1464 days). There were 84 open-globe and 19 closed-globe injuries. Thirty-six (34.9%) had final vision of 20/40 or better. Pars plana vitrectomy was the most common surgery (79.6%). Five eyes underwent evisceration, and seven eyes developed phthisis bulbi. The globe survival rate was 88.3%. Zone III injuries (32.2%) were the most common cause of unfavorable visual outcomes, and most injuries were caused by improvised explosive devices (IEDs) (59.2%). These devices also had the worst impact on globe survival and visual improvement. These eyes had a higher likelihood ratio of requiring globe removal surgery or developing phthisis bulbi [odds ratio: 21.5 (95% CI: 1.23–373)]. Two eyes that underwent keratoprosthesis-assisted pars plana vitrectomy followed by penetrating keratoplasty (PKP) during the same session developed PKP failure while failure was not seen in any of the cases that underwent PKP in a later session.

CONCLUSION: Ocular injuries related to IEDs had the most significant impact on both visual and anatomic prognoses, and globe survival was less likely in eyes with zone III trauma, in which intraocular foreign bodies penetrated the choroid. There is a higher possibility of PKP failure if this procedure is performed during the same session as other ocular surgery.

Keywords: Combat; eye; ocular; trauma; urban warfare.

INTRODUCTION

Pre-firearm battles were traditionally fought with swords and crossbows in open fields. However, today, open areas are being increasingly urbanized, and weapons used in modern warfare have greater explosive power and fragmentation ability. Urbanized environment exposes soldiers to improvised explosive devices (IEDs) and small arms munitions in a closer range. Furthermore, high-velocity projectiles with tiny glasses and fragments cause injuries to the face of soldiers in intense explosions. On the other hand, the ocular casualty rate is expected to be <1% since the ocular surface area is only 0.27% of the total body surface. Revolutions in military tactics and weaponry of warfare increased ocular casualties during combat from 0.65% in the early 19th century to 13% in the late 19th century.[1] Similarly, Weichel et al.[2] reported the percentage of US soldiers that were evacuated from Iraq due to significant ocular injuries as 13% between 2002 and 2007.

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Eye removal is considered as the last resort by both physicians and patients. However, unusual presentations and devastating visual results due to severe eye injuries are common in terror-related open-globe injuries.[3] These soldiers often become unfit for further military service and many civilian occupations.[1] This paper highlights the ocular manifestations of combat ocular trauma (COT) seen during counter-terrorism operations in Southeastern Turkey during urban warfare.

MATERIALS AND METHODS

Our study followed the tenets of the Declaration of Helsinki after obtaining the institutional review board from Gülhane Training and Research Hospital. This is a retrospective, non-comparative, interventional case series analyzing Turkish military personnel transferred from the district of urban warfare operations to Ocular Trauma Center in Gülhane, which is a level 3 trauma center for the Turkish Ministry of Defense.

Initial ophthalmological evaluations were performed at combat support hospitals (CSHs) by an ophthalmologist, and primary surgical treatments were performed when necessary. A few cases were directly referred from local CSHs to Gülhane. Following urgent medical or surgical interventions, all patients were transferred to our hospital by an air ambulance. Wide-spectrum antibiotic prophylaxis treatments were administered to all patients. Full-thickness wound of the eyeball (Sclera, cornea, or both) was defined as open-globe injury, and the Ocular Trauma Classification Group criteria were applied to divide the patients into groups according to the type (mechanism), grade (visual acuity at presentation) and zone (location and extent) of injury, and the presence or absence of a relative afferent pupillary defect.[4] Patient records, transfer summaries, and operation reports were reviewed, and the initial visual acuity was obtained from the CSH records where available. In patients that were not responsive during the initial examination, visual acuity was measured once the patient was able to communicate. Visual acuity values were converted to logMAR and vision grades for the statistical analysis. Grade 1 was defined as ≥20/40, grade 2 as 20/50–19/200, grade 3 as 20/200–1/200 (counting fingers), grade 4 as hand motion and light perception, grade 5 as no light perception. The primary goal of our study was to determine the types of ocular injuries, surgical procedures performed, and source of injury. The secondary goal was to determine visual outcomes, causes of unfavorable visual outcomes, and globe survival rates. The inclusion criteria were working as security forces and being injured during urban warfare operations in Southeastern Turkey. The exclusion criteria were trauma and injuries not related to battle or sustained outside the warfare zone.

In this study, we defined a favorable visual outcome as the final visual acuity of counting fingers at 1 m or further.[5] An unfavorable visual outcome was defined as the final visual acuity of less than counting fingers at 1 m and the presence of evisceration. A multivariate analysis was conducted using binominal logistic regression to determine any relationship between the final visual outcome (best-corrected visual acuity at the most recent follow-up visit) and various baseline

Table 1. Overall summary of the study cohort

Days of follow-up (mean±SD)	529.34±213.98 days (288–1464 days)
Laterality, n (%)	
Right eye	56 (54.4)
Left eye	47 (45.6)
Bilateral	31 (41.9)
Type of injury, n (%)	
Closed-globe	19 (18.4)
Anterior segment	11 (10.7)
Posterior segment	8 (7.7)
Open-globe	84 (81.6)
Penetrating	8 (7.7%)
Perforating	18 (17.4)
IOFB	55 (53.3)
Traumatic evisceration	3 (2.9)
Mechanism of injury, n (%)	
IED	61 (59.2)
RPG	11 (10.7)
Grenade	14 (13.6)
Mine	3 (2.9)
Gunshot wound	11 (10.7)
Mortar	3 (2.9)
Surgeries, n (%)	
PPV	77 (79.6)
Conventional	69 (66.9)
Keratoprosthesis-assisted	5 (4.9)
Endoscopic	3 (2.9)
Lens removal	52 (50.5)
IOFB removal	55 (53.3)
Keratoplasty	
Penetrating	5 (4.9)
Rotational	2 (1.9)
Tube shunt	2 (1.9)
Iris reconstruction	7 (6.8)
Evisceration	2 (1.9)
Number of surgeries per patient, n (%)	
1–4	78 (75.8)
5–7	19 (18.5)
8–10	6 (5.7)

IOFB: Intraocular foreign body; IED: Improvised explosive device; RPG: Ruchnaya Protivotankovaya Granata (Hand-held anti-tank grenade); PPV: Pars plana vitrectomy; SD: Standard deviation.

characteristics. The alpha value was set at 0.05 for all analyses. The relative odds of favorable visual outcomes [odds ratio (OR)] were also calculated for a specific variable of the category in relation to a reference variable in the same category.

RESULTS

There were 74 military personnel (103 eyes) with ocular injuries transferred from the warfare zone to Gülhane. The average age was 27.31±4.64 years (range; 21–48 years), and all were men (100%). We had a mean follow-up period of 529.34±213.98 days (288–1464 days). All personnel were equipped with protective eyewear, but the use of protective eyewear at the time of trauma was determined to be 16.5% of the known 32 patients analyzed. The remainder of the patients (n=42) had missing data. The most common reason for the military personnel not to wear their protective eyewear was foggy lenses during military engagements in urban terrain. Injury and surgical statistics are shown in Table 1. All primary open-globe repair procedures were performed within the first 24 h. Thirty-two (38%) eyes underwent primary open-globe repair once at Gülhane, while 52 (62%) eyes had been previously operated at CSHs. Pars plana vitrectomy (PPV) was the most common surgery, performed on 77 (79.6%) eyes (Table 1). Four (3.9%) eyes had neuro-ophthalmologic injuries that occurred at the time of initial trauma (traumatic optic neuropathy), and 16 (15.5%) eyes had eyelid

Table 2. OTS grades, Initial and final visual acuity grades in the study cohort

Initial visual acuity	n (%)	Final visual acuity	n (%)	OTS grades	n (%)
Grade 1 (≥20/40)	11 (10.6)	Grade1	46 (44.6)	Grade1 (0–44)	35 (33.9)
Grade 2 (20/50–20/200)	25 (24.2)	Grade 2	17 (16.5)	Grade 2 (45–65)	24 (23.3)
Grade 3 (19/200–1/200)	11 (10.6)	Grade 3	8 (7.8)	Grade 3 (66–80)	22 (21.3)
Grade 4 (HM/LP)	42 (40.7)	Grade 4	18 (17.5)	Grade 4 (81–90)	9 (8.7)
Grade 5 (NLP)	14 (13.5)	Grade 5	14 (13.6)	Grade 5 (91–100)	13 (12.8)

OTS: Ocular trauma scores; HM: Hand movements; LP: Light perception; NLP: No light perception.

Table 3. Visual outcome in 103 eyes by the zone and grade of injury and type of weaponry

Preoperative findings		Visual outcomes*		p	OR (95% CI)
Factor	n (%)	Favorable	Unfavorable		
Zone of injury					
I	59 (57.2)	55	4	<0.001	36.66 (10.28–130.78)
II	11 (10.6)	9	2	0.004	12 (2.16–66.54)
III	33 (32.2)	9	24	–	–†
Grade of injury					
OTS 1	35 (33.9)	8	27	–	–†
OTS 2	24 (23.3)	18	6	<0.001	0.09 (0.02–0.33)
OTS 3	22 (21.3)	15	7	<0.001	0.13 (0.04–0.45)
OTS 4	9 (8.7)	7	2	0.006	0.08 (09.01–0.49)
OTS 5	13 (12.6)	11	2	<0.001	0.05 (0.009–0.29)
Weaponry					
RPG	11 (10.7)	7	4	0.28	0.48 (0.12–1.83)
Hand grenade	14 (13.6)	8	6	0.45	0.63 (0.19–2.05)
Mine	3 (2.9)	2	1	0.49	0.42 (0.03–4.93)
Mortar	3 (2.9)	2	1	0.49	0.42 (0.03–4.93)
Gunshot	11 (10.7)	7	4	0.28	0.48 (0.12–1.83)
IED	61 (59.2)	28	33	–	–†

*Unfavorable: Less than counting fingers at 1 m. †Reference category. OTS: Ocular trauma scores; OR: Odds ratio; CI: Confidence interval; RPG: Ruchnaya Protivotankovaya Granata (Hand-held anti-tank grenade);IED: Improvised explosive device.

and ocular adnexal injuries. Associated extraocular injuries were also recorded. Twenty-eight (37.8%) patients had hearing loss, which was the most common extraocular injury in patients with COT. Table 2 summarizes visual acuity and ocular trauma scores in the study cohort. The incidence of unfavorable visual outcomes (grade 4 and grade 5) was higher in the eyes with injuries to zone 3 (Table 3). Figure 1 presents the incidence of unfavorable visual outcomes by the zone involved. Five eyes experiencing open-globe zone-3 injuries were eviscerated. Three of these eyes were unsalvageable at the time of initial repair, and two were eviscerated within the first 14 days of injury due to unsuccessful surgical efforts. Seven (6.7%) eyes developed phthisis bulbi. From these data, the globe survival rate was calculated as 88.3%. Finally, the most common reason for unfavorable visual outcomes was optic atrophy (Fig. 2).

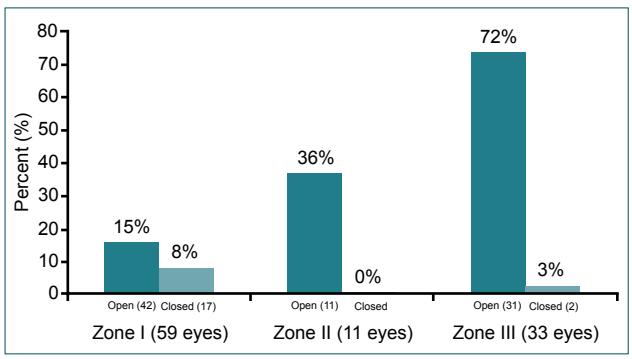

Figure 1. Incidence of unfavorable visual outcomes by zone involved. Zone I: Cornea and limbus, Zone II: 0–5 mm posterior to limbus, Zone III: >5 mm posterior to the limbus, *An unfavorable visual outcome was defined as the final visual acuity of less than counting fingers at 1 m.

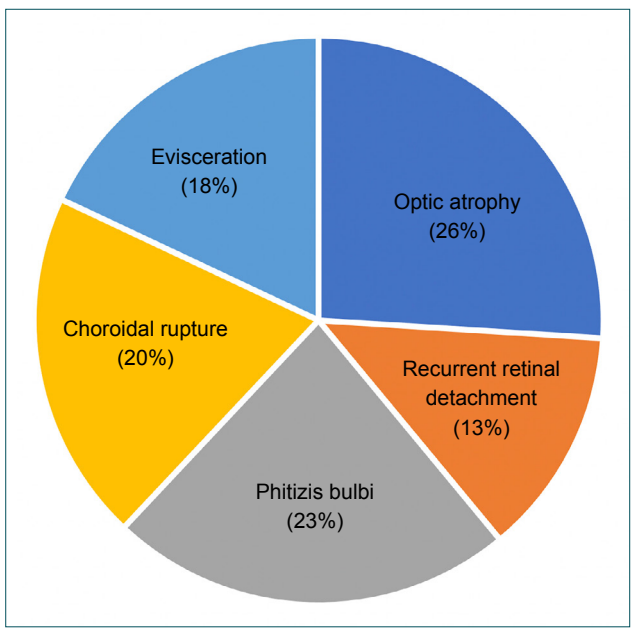

Figure 2. Major sources of unfavorable visual outcomes due to combat ocular trauma. *An unfavorable visual outcome was defined as the final visual acuity of less than counting fingers at 1 m.

DISCUSSION

Prevention is the best course of management for COT due to the extremely destructive nature of weaponry in urban battlefields. On the other hand, modern warfare tactics include the use of non-lethal, disabling laser weapons, which are very formidable since they lead to a few soldiers leaving the front line to take an injured soldier, who is unable to see due to the flash of the laser light, to the hospital. Weaponry development is very fast and terrorist groups easily acquire these weapons; therefore, it is essential for soldiers to have improved armors and protective equipment against bomb blasts, laser injuries, and high-velocity bullets.

IEDs are increasingly used in urban battlefields.[6] Evisceration and enucleation procedures may be the only treatment option available in the management of these types of injuries.[7] In a previous study reported by our department, among 61 eyes, the rate of evisceration/enucleation was reported to be 28% as a primary surgical intervention and 3% as a secondary surgical intervention due to irreparable COT caused by IEDs.[6] Five eyes were eviscerated in our study, primary surgical intervention in two (1.9%) and secondary surgical intervention in three (2.9%), and all cases were due to IEDs. Mader et al.[8] stated that IEDs played the most significant role in COT and frequently led to severe and often irreparable ocular injuries. IEDs still have the most significant role in COT, even though the technological advances of ophthalmic surgery continue to provide new techniques. Chorioretinectomy is a relatively new surgical method to reduce proliferative vitreoretinopathy (PVR) and demonstrates a positive effect on globe survival and visual prognosis.[9] We routinely perform chorioretinectomy in eyes with perforating globe injury or penetration of the choroid by foreign bodies. We observed post-operative PVR in 12 (15.5%) eyes of 77 patients that underwent PPV for any reason. All of these 12 eyes were injured by IEDs and had zone III trauma with an intraocular foreign body (IOFB) penetrating the choroid. Seven eyes with post-operative PVR subsequently became phthisic. In the remaining five eyes, retinal redetachment occurred due to severe PVR, but phthisis bulbi did not develop. Zone 3 injuries with an IOFB led to further surgical efforts with more disappointing visual results compared to other COT, as outlined in Table 3. In the literature, it is controversial whether PPV and IOFB removal should be undertaken immediately or delayed.[10,11] In the current study, 77 (79.6%) eyes underwent PPV in an average of 26.8 days (2–164). IOFB removal was completed in 55 (53.3.%) eyes in an average of 22.7 days (10–64). Colyer et al.[12] stated that there were no cases of endophthalmitis in 79 patients who underwent early closure and delayed removal of IOFB and received topical and oral antibiotics (median removal at 21 days). Furthermore, the time to IOFB removal was not found to be related to the development of PVR.[13] In our study, surgical procedures were often delayed due to orthopedic and neurosurgical trauma. In our experience, IOFB removal can be delayed if primary closure

surgery is performed within hours of injury, and patients are given both systemic levofloxacin and topical moxifloxacin. In addition, we experienced that delayed IOFB removal is better for spontaneous posterior vitreous detachment or for the resolution of media opacities.

In a previous study conducted in our department, endophthalmitis following open-globe injuries was reported in 9% of the 199 eyes.[14] Neither sympathetic ophthalmia nor endophthalmitis was observed in our study. COT with IOFB usually results from dirty material; therefore, having no case of endophthalmitis in the current sample was a remarkable finding. We believe that this is related to injuries caused by hot particles due to explosive materials and prompt medical intervention in the field. Visual acuity improved during the study, with 46 (44.6%) eyes having final vision of 20/40 or better. Eyes with Zone-I and Zone-II injuries had a higher likelihood of having better visual acuity than hand movements (Zone-I, OR: 36.6, Zone-II, OR: 12). as weaponry, IEDs had the worst impact on globe survival and visual improvement. The eyes injured by IEDs had a higher likelihood of requiring globe removal surgery or developing phthisis bulbi [OR: 21.5 (95% CI: 1.23–373)].

In this study, of the 103 eyes with COT, 9.8% underwent keratoplasty. Five eyes (4.9%) had keratoprosthesis-assisted PPV followed by penetrating keratoplasty (PKP). Five eyes (4.9%) had PKP following a few surgical interventions to restore vision. Two eyes that underwent PPV (1000 cs) and PKP during the same session developed PKP failure. For the cases in which PKP was performed in another surgical session, the survival rate was 100% during the follow-up timeline (555±146.07 days). This means there is a higher chance of PKP survival if there is sufficient time before this surgery to reduce inflammation generated by trauma and other procedures.

Conclusion

There is widespread use of high explosive fragmentary weapons, such as IEDs, which often cause IOFBs and are significantly associated with more severe ocular injuries. We observed that IOFB injuries were less often associated with neuro-ophthalmic and ocular adnexal injuries but rather solely ocular injuries. This means that more frequent use of protective eyewear could reduce COT. Preventing eye injury is much more critical than performing several surgical procedures to restore vision.

Ethics Committee Approval: This study was approved by the Health Sciences University Non-Invasive Research Ethics Committee (Date: 28.05.2019, Decision No: 19/2013).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: D.A., A.H.D.; Design: D.A., A.H.D.; Supervision: D.A., A.H.D.; Resource: D.A., A.H.D.; Materials: D.A.; Data: D.A.; Analysis: D.A., M.K.; Literature search: D.A., M.K.; Writing: D.A., M.K.; Critical revision: D.A., M.K., A.H.D.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Türkiye'de meskun mahalde terörle mücadele esnasında görülen oküler travma olguları ve görsel sonuçları

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AMAÇ: Hendek operasyonları sürecinde yaralanma sonrasında Gülhane Eğitim ve Araştırma Hastanesi Oküler Travma Merkezi'ne sevk edilen askeri personelin başvuru esnasındaki ve tedavi süreci sonrasındaki sonuçlarını raporlamak.

GEREÇ VE YÖNTEM: Çalışmamızda çatışma alanından ve bölgedeki sahra hastanelerinden üçüncü basamak oküler travma merkezimize sevk edilen güvenlik güçleri personelinin sevk, başvuru ve epikriz kayıtları incelenmiştir. Oküler yaralanmalar, gözdeki yaralanma bölgesine göre ve oküler travma sınıflamasına göre alt gruplar halinde değerlendirilmiştir.

BULGULAR: Yetmiş dört güvenlik personelinin 103 gözü değerlendirildi. Değerlendirilen olguların hepsi erkek (%100) ve ortalama yaş 27.31±4.64 yıl (dağılım, 21–48 yıl) idi. Ortalama takip süresi ise 529.34±213.98 gündü (dağılım, 288–1.464 gün). Seksen dört gözde açık göz yaralanması, on dokuz gözde ise kapalı göz yaralanması mevcut idi. Otuz altı (%34.9) gözde son görme keskinliği 20/40 veya daha iyi düzeyde idi. En sık uygulanan cerrahi pars plana vitrektomiydi (%79.6) Beş göze evisserasyon cerrahisi uygulanırken, yedi gözde takiplerde fitizis bulbi gelişimi gözlenmiştir. Göz küresinin bütünlüğünün korunma oranı %88.3 idi. Zayıf görsel sonuçlar için en önemli risk faktörü zon III yaralanma (%32.2) iken, yaralanmaların en sık sebebi el yapımı patlayıcı (EYP) (%59.2) olarak gözlemlenmiştir. Görsel ve anatomik yönden en kötü sonuçlar da EYP ile yaralanan gözlerde iken göz küresinin alınması veya fitizis bulbi gelişmesi riski de bu gözlerde daha fazla idi [Odds oranı: 21.5 (%95 GA: 1.23–323)]. Keratoprotez eşliğinde pars plana vitrektomi ile aynı seansta penetran keratoplasti (PK) cerrahisi uygulanan iki gözde donör yetmezliği görülmüş iken PK'nin daha sonraki seansta uygulandığı gözlerde donör yetmezliği görülmedi.

TARTIŞMA: El yapımı patlayıcı ile yaralanma sonrasında meydana gelen oküler yaralanmalar hem görsel hem de anatomik yönden en kötü prognoza sahip yaralanma çeşidi iken göz küresinin bütünlüğünün korunma ihtimali zon III yaralanmalarda ve koroidi penetre eden göz içi yabancı cismi bulunan olgularda daha düşük idi. Aynı seansta PK cerrahisinin uygulandığı gözlerde de donör yetmezliği riskinin daha fazla olduğu gözlendi.

Anahtar sözcükler: Göz; hendek savaşları; oküler; savaş; travma.

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