

Demographic and Clinical Factors Associated with Mechanisms of Open Globe Injury in the United States: A Multi-Center Study

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Purpose: We sought to examine the demographic and clinical risk factors associated with specific mechanisms of open globe injuries (OGIs) and identify predictors of Zone III injuries across multiple tertiary eye care centers.

Patients and methods: 1570 patients with OGIs presenting to the Wilmer Eye Institute, the Bascom Palmer Eye Institute, Massachusetts Eye and Ear, and Wills Eye Hospital between 2018–2021 were retrospectively reviewed. Multinomial and binomial logistic regression models were used to evaluate associations between demographic and clinical risk factors with injury mechanisms and Zone III injuries.

Results: Among the study population (74.2% male, mean age 48.2 years), falls (21.3%), construction work (16.2%), and assaults (10.0%) were the most common injury mechanisms. Black patients had higher risk of assault-related OGIs (relative risk ratio [RRR], 6.41; 95% confidence interval [CI], 2.06–19.93; $p < 0.001$) and elderly patients ≥ 61 years showed increased risk for falls (RRR, 10.45; 95% CI, 2.22–49.10; $p = 0.003$). Eyelid laceration was significantly associated with assaults (RRR, 5.58; 95% CI, 1.59–19.65; $p = 0.007$) and falls (RRR, 4.81; 95% CI, 1.61–14.34; $p = 0.005$), while iris prolapse was associated with assaults (RRR, 3.23; 95% CI, 1.12–9.32; $p = 0.03$) and construction work injuries (RRR, 1.99; 95% CI, 1.12–3.52; $p = 0.02$). Zone III injuries were independently associated with eyelid laceration (prevalence ratio [PR], 1.62; 95% CI, 1.20–2.18; $p < 0.001$), relative afferent pupillary defect (RAPD) (PR, 2.42; 95% CI, 1.71–3.43; $p < 0.001$), and retrobulbar hemorrhage (PR, 2.77; 95% CI, 1.76–4.36; $p < 0.001$).

Conclusion: This multi-institutional study identified distinct demographic risk profiles for different OGI mechanisms and clinical predictors of severe injuries. These findings suggest opportunities for targeted prevention strategies and may aid in early identification and triage of severe OGIs.

Plain Language Summary: Open globe injuries (OGIs), traumatic eye injuries that pierce through the eye wall, can lead to permanent vision loss if not treated quickly. Identifying which patient populations are most at risk for OGIs, and the specific factors that increased likelihood of injury, can guide more effective prevention and treatment efforts. Our study aimed to identify the common causes of OGIs and their risk factors by analyzing patient data from four major eye hospitals in the United States.

We reviewed the medical records of 1570 patients who presented to the hospital with OGIs. The most common causes of injury were falls, construction work, and assaults. Different populations faced different risks, such as: Black patients, who had a higher risk of assault-related injuries, and elderly individuals, especially women, who were more likely to be injured from falls. We found that lacerations of the eyelid were linked with assaults and falls, and iris prolapse (when the colored part of the eye is displaced) were linked to assaults and construction work injuries. Additionally, more severe injuries (Zone III injuries, which extend to the back of the eye) were associated with eyelid lacerations, changes in pupil response (relative afferent pupillary defect, or RAPD), and bleeding behind the eye (retrobulbar hemorrhage).

This study provides important insights into which demographic and clinical factors put patients at risk for different mechanisms of OGIs. Our findings may be used to help identify severe cases earlier and guide targeted prevention efforts.

Keywords: ocular trauma, epidemiology, demographics, etiology, prevention

Introduction

Over the past two decades, trauma to the eye has been identified as a leading cause of preventable vision loss.^{1–4} In the United States (US) alone, ocular trauma accounts for one-third of all eye-related emergency department visits.³

Open globe injuries (OGIs), a subset of ocular trauma, are full-thickness defects of the eyewall. Without timely surgical repair, OGIs can cause permanent vision loss. OGIs are classically categorized by type of injury into ruptures, caused by blunt trauma, and lacerations, caused by sharp trauma.^{5,6} OGIs can also be described by anatomical zone based on extent of injury, from Zone I (limited to the cornea and limbus) to Zone II (extending 5 millimeters [mm] posterior to the limbus) to Zone III (extending beyond 5 mm posterior to the limbus).^{5,7} The ocular trauma score (OTS) further stratifies OGIs based on injury characteristics, in order to predict visual outcomes and guide management strategies.^{5,6}

The worldwide incidence of OGIs is estimated at 3.5 injuries per 100,000 people, with more than 203,000 cases occurring per year globally.^{4,8,9} Previous studies have reported on the epidemiology of OGIs. Overall, OGIs most commonly affect young, male patients, with a secondary peak in incidence among elderly individuals 70 years or older.^{9–11} Assaults, recreational accidents, and occupational work injuries are the most common causes of ocular trauma in younger patients, while falls are the major cause among elderly patients.^{12–15} Disparities in incidence, apart from age and gender, have also been noted: patients with lower socioeconomic status, patients with residence in the South and West of the US, Black patients, and Hispanic patients are all groups more likely experience OGIs.^{9,10,16–18}

There, however, remains a gap in our knowledge of the demographic and clinical risk factors associated with specific mechanisms of OGIs, as well as risk factors associated with the most severe injuries. Such an understanding can help better characterize and triage OGI mechanisms, delineate mechanisms and exam findings that increase risk for the most severe injuries, and target prevention efforts toward demographics most at risk.

While previous work has reported important data on the epidemiology and demographics of OGIs, these data have been limited to single-center studies,^{15,19,20} or have used large inpatient databases based on sampling methods, such as the Nationwide Emergency Department Sample (NEDS) or National Inpatient Sample (NIS).^{9,16,21} One study leveraged the American Academy of Ophthalmology's Intelligent Research (IRIS) Registry to study the incidence, risk factors, and visual outcomes of open globe repairs, but did not study all patients initially presenting with injury or include information on their mechanisms of injury.¹⁰

To our knowledge, there has not been a large, multi-institution retrospective study on the association between granular, clinically relevant OGI characteristics and their specific mechanisms and classifications of injury. In our three-year retrospective chart review of traumatic OGIs across four high-volume eye centers, we investigated (1) the demographic, clinical characteristics, and visual outcomes of open globes presenting to emergency departments in the United States, (2) assessed the demographic and clinical characteristics associated with elevated risk for the most commonly reported mechanisms of injury, and (3) examined the demographic and clinical variables associated with the outcome of Zone III injury.

Methods

Study Population

We conducted a retrospective cohort study using data from patients who presented with OGIs to emergency departments at four tertiary care eye centers: the Wilmer Eye Institute in Baltimore, Maryland, the Bascom Palmer Eye Institute in Miami, Florida, Mass Eye and Ear in Boston, Massachusetts, and Wills Eye Hospital in Philadelphia, Pennsylvania, between January 1st, 2018 and December 31st, 2021. The study was approved by the Institutional Review Boards (IRBs) of all four participating centers (Wilmer Eye Institute: IRB00132759; Bascom Palmer Eye Institute: IRB20200719; Mass

Eye and Ear: IRBP002523; Wills Eye Hospital: IRB21E.828) and adheres to the tenets of the Declaration of Helsinki. A waiver of patient consent was granted to review medical records per IRB approval as this research involved no more than minimal risk to subjects. Patient data confidentiality was preserved by ensuring that only approved individuals collected data, and that data was accessed and stored only through secure storage avenues for research data.

Data Collection

All patients with an International Classification of Diseases, Tenth Revision (ICD-10) code for ocular lacerations and ruptures with or without prolapse or penetrating wounds of orbit with or without foreign body (ICD-10 codes: S05.2, S05.20, S05.21, S05.22, S05.3, S05.30, S05.31, S05.32, S05.4, S05.40, S05.41, S05.42, S05.5, S05.50, S05.51, S05.52, S05.6, S05.60, S05.61, S05.62) or a Current Procedural Terminology (CPT) code for open globe repair or intraocular foreign body (codes: 65235, 65260, 65265, 65275, 65280, 65285, 65286, 66250, 67413) were initially queried from the electronic medical record ([Supplement 1](#)).

Inclusion criteria for eyes included in the study were eyes with a documented history of OGI (defined by ICD-10 or CPT codes).

Demographic and Clinical Characteristics

Eyes from patients meeting inclusion criteria were retrospectively reviewed for patient demographics (including age, sex, race, ethnicity, insurance status, and occupational status) and clinical characteristics (including laterality, mechanism of injury, place of injury, type of object, object material, open globe type, laceration type, zone of injury, concomitant injuries, time to surgery, surgical management, and visual acuity).

Sex, race, ethnicity, and insurance status were self-reported by patients in the medical record. Race included standard options of White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, or “Other” race. Due to a minimal number of patients in categories other than White or Black race, all other reported race categories were condensed into the “Other” race categories for analysis purposes. Ethnicity included standard options of “Hispanic or Latino”, or “Not Hispanic or Latino”. Primary insurance status included standard options of private insurance, Medicaid, Medicare, on uninsured status.

Occupation was obtained from the medical record and grouped based on frequency into the following categories: construction work, industrial work, student, unemployed, or other occupation.

Reported mechanisms of injury were collected and categorized based on frequency into the following categories: assault, motor vehicle accident (MVA), fall, sports, firearms, construction work, or other causes. Visual acuity data was converted to logarithm of the minimum angle of resolution (logMAR) acuity for analysis. In cases where more than one zone of injury was involved, the classification of zone was based on the most posterior extent of the injury. Any demographic, clinical, or visual acuity characteristics not recorded in the medical record were identified and treated as missing observations for analysis purposes.

Demographic and clinical characteristics of the study population were summarized using means and standard deviations for continuous variables and proportions for categorical variables.

Statistical Analysis

Univariable and multivariable multinomial logistic regression models were used to analyze the associations between the most common mechanisms of OGI and demographic and clinical characteristics. Assumptions of the multinomial logistic regression model were verified, as follows. Categories of mechanism of injury were mutually exclusive and each observation was independent of other observations. Lack of multicollinearity between predictor variables was verified. To ensure adequate sample size for each combination of outcome variable categories and predictors, predictor variables with less than ten cases per variable per category were excluded from the model. Demographic and clinical predictor variables that were significant on univariable analysis were included in the final multivariable model.

Binomial logistic regression was used to analyze the relationship between Zone III injuries and demographic and clinical predictor variables. Predictor variables that were significant on univariable analysis were incorporated into a multivariable model.

Statistical analysis was performed using Stata version 14 (StataCorp). One-tailed and two-tailed p-values < 0.05 were considered statistically significant.

Results

Baseline Study Cohort Characteristics

1570 patients presented with OGIs. Most patients (1165, 74.2%) identified as male. The mean (SD) patient age at presentation was 48.2 (22.8) years. Demographically, most patients (920, 58.6%) identified as White race, 300 (19.1%) identified as Black race, and 32 (2.0%) were categorized as other races. 965 patients (61.5%) identified as not Hispanic or Latino, and 392 (25.0%) identified as Hispanic or Latino. 726 patients (46.2%) were privately insured, 339 (21.6%) were insured through Medicare, 155 (9.9%) were insured through Medicaid, and 272 (17.3%) were uninsured. Most patients' occupational status was not reported (72.0%), 3.9% (N=61) were construction workers, 1.8% (N=29) were industrial workers, 3.9% (N=62) were students, 6.0% (N=94) were unemployed, and 12.4% (N=194) had other occupations. All demographic characteristics of the cohort are summarized in Table 1.

Most patients (673, 41.8%) were not using any substances at the time of injury, were not using eye protection of any kind (673, 42.9%), and were first seen at a local hospital (954, 60.8%) before presentation to one of the four eye centers included in this study.

Table 1 Demographic Characteristics of Open Globe Injuries

	Summary
N	1570
Age at Presentation, Mean (SD)	48.2 (22.8)
Sex, N (%)	
Male	1165 (74.2%)
Female	405 (25.8%)
Race^a, N (%)	
White	920 (58.6%)
Black	300 (19.1%)
Other Race	32 (2.0%)
Not Reported	318 (20.3%)
Ethnicity, N (%)	
Not Hispanic or Latino	965 (61.5%)
Hispanic or Latino	392 (25.0%)
Not Reported	213 (13.6%)
Occupation, N (%)	
Construction worker	61 (3.9%)
Industrial worker	29 (1.8%)
Student	62 (3.9%)
Unemployed	94 (6.0%)
Other Occupation	194 (12.4%)
Not Reported	1130 (72.0%)
Insurance Status, N (%)	
Private Insurance	726 (46.2%)
Medicaid	155 (9.9%)
Medicare	339 (21.6%)
Uninsured	272 (17.3%)
Not Reported	78 (5.0%)

Notes: ^aOther Race category included 20 patients of Asian race, 7 American Indian, 1 Native Hawaiian, 3 more than one race, and 1 other race.

The most common mechanisms of injury were falls (334 patients, 21.3%), followed by construction work (255 patients, 16.2%), assaults (157 patients, 10.0%), sports (64 patients, 4.1%), MVAs (60 patients, 3.8%), and firearms (22 patients, 1.4%). Most injuries occurred at home (517, 32.9%) or at the workplace (256, 16.3%).

847 (53.9%) of patients presented with lacerations of the globe versus 691 (44.0%) who presented with globe ruptures. Further classifying open globes caused by lacerations, 638 (40.6%) were penetrating injuries with no exit wound, 36 (2.3%) were perforating injuries with both an entrance and exit wound, and 166 (10.6%) resulted in intraocular foreign bodies (IOFBs).

Most OGIs were Zone I injuries (779, 49.6%), followed by Zone II (418, 26.6%), and less commonly, Zone III (287, 18.3%). Iris prolapse, hyphema, relative afferent pupillary defect (RAPD), eyelid laceration, and orbital fracture were the most frequent concomitant injuries.

At presentation, most patients (818 patients, 52.1%) had visual acuity (VA) worse than 20/600, 267 patients had VA better than 20/100 to 20/600, 55 patients (3.5%) had VA better than 20/60 to 20/100, and 166 had VA between 20/20 and 20/60. By last follow-up, a majority of patients (982 patients, 62.5%) had improved to VA between 20/20 and 20/60, 66 patients (4.2%) had VA better than 20/60 to 20/100, 164 had VA better than 20/100 to 20/600, and 337 patients still had VA worse than 20/600. 1145 patients (72.9%) received primary surgical repair within 24 hours. Most patients (1547, 98.5%) underwent primary surgical repair, eight patients (0.5%) had self-sealing wounds, and three patients (0.2%) underwent enucleation of the injured eye. Clinical characteristics of the cohort are summarized in [Table 2](#).

Table 2 Clinical Characteristics of Open Globe Injuries

	Summary
N	1570
Eye Hospital, N (%)	
Wilmer Eye Institute	257 (16.4%)
Massachusetts Eye and Ear	364 (23.2%)
Wills Eye Hospital	424 (27.0%)
Bascom Palmer Eye Institute	525 (33.4%)
Laterality, N (%)	
OD	754 (48.0%)
OS	809 (51.5%)
Not Reported	7 (0.4%)
Substance use during injury, N (%)	
No	656 (41.8%)
Yes	69 (4.4%)
Not Reported	845 (53.8%)
Eye protection worn at time of injury, N (%)	
No	673 (42.9%)
Yes, safety glasses	33 (2.1%)
Yes, prescription eyeglasses	31 (2.0%)
Other	8 (0.5%)
Not Reported	825 (52.5%)
Patient seen first at local hospital, N (%)	
No	500 (31.8%)
Yes	954 (60.8%)
Not Reported	116 (7.4%)
If seen first at local hospital, did patient have eye shield on presentation, N (%)	
No	67 (4.3%)
Yes	50 (3.2%)
Not Reported	1453 (92.5%)

(Continued)

Table 2 (Continued).

	Summary
Mechanism of Injury, N (%)	
Assault	157 (10.0%)
Motor Vehicle Accident	60 (3.8%)
Fall	334 (21.3%)
Sports	64 (4.1%)
Firearms	22 (1.4%)
Construction work	255 (16.2%)
Other cause	645 (41.1%)
Not Reported	33 (2.1%)
Place of Injury, N (%)	
Home	517 (32.9%)
School	16 (1.0%)
Workplace	256 (16.3%)
Leisure or Sports Facility	86 (5.5%)
Street	112 (7.1%)
Other	73 (4.6%)
Not Reported	510 (32.5%)
Object Material, N (%)	
Vegetative matter	37 (2.4%)
Metal	544 (34.6%)
Fire	21 (1.3%)
Glass	114 (7.3%)
Wood	121 (7.7%)
Stone	90 (5.7%)
Plastic	78 (5.0%)
Other	238 (15.2%)
Not Reported	327 (20.8%)
Open Globe Type, N (%)	
Rupture ^a	691 (44.0%)
Laceration ^b	847 (53.9%)
Not Reported	32 (2.0%)
Laceration Type, N (%)	
No Laceration	691 (44.0%)
Penetrating Injury ^c	638 (40.6%)
Perforating Injury ^d	36 (2.3%)
Intraocular Foreign Body (IOFB)	166 (10.6%)
Not Reported	39 (2.5%)
Zone of Injury^e, N (%)	
Zone 1	779 (49.6%)
Zone 2	418 (26.6%)
Zone 3	287 (18.3%)
Not Reported	86 (5.5%)
Lens Status, N (%)	
Normal	387 (24.6%)
Preexisting cataract not related to trauma	87 (5.5%)
Cataract related to trauma with no capsular violation	111 (7.1%)
Traumatic cataract with anterior lens capsule violation	130 (8.3%)
Traumatic cataract with posterior lens capsule violation	24 (1.5%)
Subluxation or dislocation of lens	43 (2.7%)
Pseudophakic with no subluxation	73 (4.6%)

(Continued)

Table 2 (Continued).

	Summary
Pseudophakic subluxation or dislocation	48 (3.1%)
Expulsion of lens	118 (7.5%)
Aphakic	12 (0.8%)
Not Reported	537 (34.2%)
Eyelid Laceration, N (%)	
No	1311 (83.5%)
Yes	195 (12.4%)
Not Reported	64 (4.1%)
Prior surgical wound dehiscence noted at presentation, N (%)	
Not Applicable	1181 (75.2%)
No	129 (8.2%)
Yes	190 (12.1%)
Not Reported	70 (4.5%)
If wound dehiscence noted at presentation, specify surgery type, N (%) (Wound dehiscence: N=190)	
Extracapsular Cataract Extraction (ECCE)	15 (7.9%)
Corneal Transplant	137 (72.1%)
Phacoemulsification (phaco)	20 (10.5%)
Other surgery	15 (7.9%)
Not Reported	3 (1.6%)
Hyphema, N (%)	
No	760 (48.4%)
Yes	527 (33.6%)
Not Reported	283 (18.0%)
Hyphema Size, N (%) (Hyphema: N=527)	
< 1/3 of Anterior Chamber	213 (40.4%)
1/3 - 1/2 of Anterior Chamber	36 (6.8%)
1/2 - < Total Hyphema	69 (13.1%)
Total Hyphema	201 (38.1%)
Size not specified	8 (1.5%)
Iris Prolapse, N (%)	
No	722 (46.0%)
Yes	556 (35.4%)
Not Reported	292 (18.6%)
Relative Afferent Pupillary Defect, N (%)	
No	777 (49.5%)
Yes	293 (18.7%)
Could not be assessed	500 (31.8%)
Comotio Retinae, N (%)	
No	483 (30.8%)
Yes	35 (2.2%)
Could not be assessed	1052 (67.0%)
Orbital Fracture, N (%)	
No	1300 (82.8%)
Yes	123 (7.8%)
Not Reported	147 (9.4%)
Orbital Foreign Body, N (%)	
No	1364 (86.9%)
Yes	59 (3.8%)
Not Reported	147 (9.4%)

(Continued)

Table 2 (Continued).

	Summary
Retrobulbar Hemorrhage, N (%)	
No	1403 (89.4%)
Yes	20 (1.3%)
Not Reported	147 (9.4%)
Visual Acuity at Presentation, N (%)	
20/20 - 20/60	166 (10.6%)
>20/60 - 20/100	55 (3.5%)
>20/100 - 20/600	267 (17.0%)
<20/600	818 (52.1%)
Not Reported	264 (16.8%)
Time to Primary Surgical Repair, N (%)	
≤ 24 hr	1145 (72.9%)
> 24 hr	366 (23.3%)
Not Reported	59 (3.8%)
Surgical Management, N (%)	
Enucleation	3 (0.2%)
No primary surgical repair	4 (0.3%)
Not Reported	8 (0.5%)
Primary surgical repair	1547 (98.5%)
Self-sealed wound	8 (0.5%)
Visual Acuity at Follow-Up, N (%)	
20/20-20/60	982 (62.5%)
>20/60-20/100	66 (4.2%)
>20/100-20/600	164 (10.4%)
<20/600	337 (21.5%)
Not Reported	21 (1.3%)

Notes: ^aRuptures were defined as full-thickness wounds of the eye wall caused by blunt objects. ^bLacerations were defined as full-thickness wounds of the eye wall caused by sharp objects. ^cPenetrating injuries were defined as injuries with only an entrance wound. ^dPerforating injuries were defined as injuries with both an entrance and an exit wound. ^eZone 1 injuries were defined as injuries to the cornea or limbus, Zone 2 injuries were injuries posterior to the limbus to 5mm posterior to the sclera, and Zone 3 injuries were injuries >5mm posterior to the limbus.

Risk Factors for Most Common Mechanisms of Injury

Multinomial logistic regression examined associations between common mechanisms of injury and potential demographic and clinical risk factors (Table 3). Univariable multinomial logistic regression analysis revealed that sex, age at presentation, race, ethnicity, open globe type, zone of injury, eyelid laceration, hyphema, RAPD, iris prolapse, and VA at presentation were variables associated with assaults, falls, and construction work mechanisms of injury.

In an adjusted multivariable multinomial logistic regression model, age 41 to 60 years (relative risk ratio [RRR], 7.52 [95% confidence interval [CI], 1.30–43.52]; $p=0.02$), Black race (RRR, 6.41 [95% CI, 2.06–19.93]; $p<0.001$), eyelid laceration (RRR, 5.58 [95% CI, 1.59–19.65]; $p=0.007$), iris prolapse (RRR, 3.23 [95% CI, 1.12–9.32]; $p=0.03$), and VA at presentation $\leq 20/200$ (RRR, 0.69 [95% CI, 0.22–2.15]; $p=0.02$) remained risk factors for assault. Female sex (RRR, 2.61 [95% CI, 1.17–5.83]; $p=0.02$), age 61 years and older (RRR, 10.45 [95% CI, 2.22–49.10]; $p=0.003$), globe lacerations (RRR, 0.35 [95% CI, 0.13–0.93]; $p=0.03$), eyelid laceration (RRR, 4.81 [95% CI, 1.61–14.34]; $p=0.005$), RAPD (RRR, 0.41 [95% CI, 0.17–0.97]; $p=0.04$) remained associated with falls. Female sex (RRR, 0.05 [95% CI, 0.01–0.38]; $p=0.004$), age 21 to 40 years (RRR, 6.20 [95% CI, 2.14–17.96]; $p<0.001$), age 41 to 60 years (RRR, 4.11 [95% CI, 1.39–12.16]; $p=0.01$), age 61 years and older (RRR, 4.39 [95% CI, 1.09–17.94]; $p=0.04$), and iris prolapse (RRR, 1.99 [95% CI, 1.12–3.52]; $p=0.02$) were risk factors for construction work injuries.

Table 3 Multinomial Logistic Regression of Mechanism of Injury by Demographic and Clinical Characteristics

	Mechanism of Injury (Reference Group: Other Mechanisms of Injury) ^a					
	Assault		Fall		Construction Work	
	RRR (95% CI)	p-value	RRR (95% CI)	p-value	RRR (95% CI)	p-value
Characteristic						
Sex (base: Male)						
Female	1.94 (0.59–6.42)	0.28	2.61 (1.17–5.83)	0.02*	0.05 (0.01–0.38)	0.004**
Age (base: 0 to 20 years)						
21 to 40 years	3.90 (0.65–23.61)	0.14	0.24 (0.02–2.74)	0.25	6.20 (2.14–17.96)	<0.001***
41 to 60 years	7.52 (1.30–43.52)	0.02*	1.13 (0.24–5.38)	0.88	4.11 (1.39–12.16)	0.01*
≥ 61 years	0.19 (0.01–3.27)	0.25	10.45 (2.22–49.10)	0.003**	4.39 (1.09–17.64)	0.04*
Race (base: White)						
Black	6.41 (2.06–19.93)	<0.001***	1.71 (0.51–5.74)	0.39	0.46 (0.20–1.07)	0.07
Other Race	1.49 (0.11–20.59)	0.77	2.89 (0.25–33.58)	0.40	0.80 (0.17–3.81)	0.78
Ethnicity (base: Not Hispanic or Latino)						
Hispanic or Latino	2.34 (0.53–10.33)	0.26	0.40 (0.08–2.02)	0.27	1.05 (0.56–1.98)	0.87
Insurance Status (base: Private Insurance)						
Medicaid	1.61 (0.43–6.02)	0.48	0.57 (0.12–2.71)	0.48	0.71 (0.31–1.65)	0.43
Medicare	1.05 (0.16–6.91)	0.96	0.98 (0.40–2.45)	0.97	0.92 (0.30–2.83)	0.89
Uninsured	0.12 (0.01–1.15)	0.07	0.36 (0.03–3.87)	0.40	1.88 (0.98–3.62)	0.06
Open Globe Type (base: Rupture)						
Laceration	0.39 (0.11–1.39)	0.15	0.35 (0.13–0.93)	0.03*	1.61 (0.67–3.91)	0.29
Zone of Injury (base: Zone I)						
Zone 2	2.52 (0.81–7.82)	0.11	2.28 (0.90–5.76)	0.08	0.58 (0.31–1.10)	0.10
Zone 3	0.92 (0.21–4.08)	0.91	1.28 (0.46–3.58)	0.64	1.52 (0.62–3.70)	0.36
Concomitant Injury^b						
Eyelid Laceration	5.58 (1.59–19.65)	0.007**	4.81 (1.61–14.34)	0.005**	1.48 (0.56–3.93)	0.42
Hyphema	1.00 (0.97–1.02)	0.76	1.00 (0.98–1.02)	0.86	1.01 (0.99–1.02)	0.27
Relative Afferent Pupillary Defect (RAPD)	2.36 (0.79–7.11)	0.13	0.41 (0.17–0.97)	0.04*	0.74 (0.31–1.79)	0.51
Iris Prolapse	3.23 (1.12–9.32)	0.03*	1.07 (0.47–2.46)	0.87	1.99 (1.12–3.52)	0.02*
Visual Acuity at Presentation (base: >20/200)						
≤ 20/200	0.69 (0.22–2.15)	0.02*	1.93 (0.85–4.39)	0.12	0.94 (0.55–1.60)	0.82

Notes: ^aThe multivariable multinomial logistic regression model included all covariates found to be significantly associated with the outcome in univariable regression. Covariates included were sex, age, race, ethnicity, insurance status, open globe type, zone of injury, eyelid laceration, hyphema, RAPD, iris prolapse, and visual acuity at presentation. ^bPresence or absence of each concomitant injury was assessed independent of other risk factors. *p<0.05; **p<0.01; ***p<0.001.

Abbreviations: CI, confidence interval; RRR, relative risk ratio.

Risk Factors for Zone III Injury

Finally, binomial logistic regression was used to analyze associations between potential demographic and clinical risk factors and risk for Zone III injury (Table 4). Univariable logistic regression revealed that Hispanic or Latino ethnicity (prevalence ratio [PR], 0.67 [95% confidence interval [CI], 0.50–0.89]; p=0.005), uninsured patients (PR, 0.59 [95% CI,

Table 4 Demographic and Clinical Risk Factors Associated With Zone III Open Globe Injury

	Univariable Log Binomial Regression		Multivariable Log Binomial Regression ^a	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Age at Presentation				
0 to 20 years	Reference			
21 to 40 years	1.105 (0.752–1.624)	0.608		
41 to 60 years	1.181 (0.808–1.725)	0.389		
≥ 61 years	1.149 (0.789–1.675)	0.467		
Sex				
Female	Reference			
Male	0.876 (0.683–1.123)	0.298		
Race				
White	Reference			
Black	0.979 (0.737–1.296)	0.883		
Other	0.693 (0.274–1.751)	0.438		
Ethnicity				
Not Hispanic or Latino	Reference		Reference	
Hispanic or Latino	0.667 (0.502–0.885)	0.005**	0.943 (0.679–1.310)	0.727
Insurance Status				
Private Insurance	Reference		Reference	
Medicaid	1.098 (0.789–1.529)	0.579	1.361 (0.918–2.019)	0.125
Medicare	0.857 (0.650–1.129)	0.272	1.006 (0.669–1.513)	0.978
Uninsured	0.589 (0.412–0.841)	0.004**	0.778 (0.488–1.242)	0.294
Substance use during injury				
No	Reference		Reference	
Yes	2.292 (1.632–3.218)	<0.001***	1.543 (0.990–2.406)	0.055
Patient seen first at local hospital				
No	Reference			
Yes	0.994 (0.796–1.241)	0.955		
If seen first at local hospital, did patient have eye shield on presentation				
No	Reference			
Yes	1.13 (0.555–2.317)	0.731		
Mechanism of Injury				
Assault	2.361 (1.747–3.190)	<0.001***	0.969 (0.650–1.446)	0.878
Fall	1.443 (1.076–1.934)	0.014*	0.854 (0.551–1.325)	0.482
Construction Work	0.814 (0.545–1.215)	0.314	1.430 (0.943–2.171)	0.093
Other cause	Reference		Reference	
Object Material				
Other	Reference		Reference	
Metal	0.768 (0.591–0.997)	0.048*	1.292 (0.901–1.853)	0.163
Glass	1.017 (0.688–1.504)	0.929	1.583 (0.945–2.654)	0.081
Wood	0.767 (0.494–1.191)	0.237	0.988 (0.597–1.634)	0.961
Open Globe Type				
Rupture	Reference		Reference	
Laceration	0.529 (0.426–0.658)	<0.001***	1.128 (0.489–2.604)	0.778
Laceration Type				
No Laceration	Reference		Reference	
Penetrating Injury	0.519 (0.408–0.660)	<0.001***	0.657 (0.280–1.539)	0.333
Perforating Injury	0.785 (0.398–1.547)	0.486	0.821 (0.210–3.213)	0.777
Intraocular Foreign Body (IOFB)	0.463 (0.297–0.720)	<0.001***	0.720 (0.266–1.953)	0.519

(Continued)

Table 4 (Continued).

	Univariable Log Binomial Regression		Multivariable Log Binomial Regression ^a	
	PR (95% CI)	p-value	PR (95% CI)	p-value
Concomitant Injury^b				
Traumatic Cataract	0.291 (0.179–0.473)	<0.001***	0.372 (0.191–0.725)	0.004**
Dislocation of Lens	0.896 (0.557–1.441)	0.651		
Expulsion of Lens	1.935 (1.461–2.562)	<0.001***	1.063 (0.727–1.555)	0.752
Eyelid Laceration	2.798 (2.270–3.449)	<0.001***	1.616 (1.197–2.181)	0.002**
Hyphema	2.650 (2.066–3.398)	<0.001***	1.221 (0.850–1.755)	0.280
Iris Prolapse	1.174 (0.908–1.516)	0.220		
Relative Afferent Pupillary Defect (RAPD)	3.257 (2.561–4.141)	<0.001***	2.421 (1.709–3.429)	<0.001***
Comotio Retinae	1.357 (0.631–2.918)	0.434		
Orbital Fracture	2.794 (2.214–3.527)	<0.001***	1.578 (1.139–2.187)	0.006
Orbital Foreign Body	1.497 (0.971–2.310)	0.068		
Retrobulbar Hemorrhage	2.770 (1.764–4.359)	<0.001***	2.417 (1.352–4.320)	0.003**
Visual Acuity at Presentation				
20/20 - 20/60	Reference		Reference	
>20/60 - 20/100	3.449 (1.310–9.079)	0.012*	8.465 (2.233–32.086)	0.002**
>20/100 - 20/600	2.042 (0.896–4.656)	0.089	2.664 (0.764–9.290)	0.124
<20/600	5.479 (2.624–11.438)	<0.001***	4.250 (1.257–14.369)	0.020*
Time to Primary Surgical Repair				
< 24 hr	Reference		Reference	
> 24 hr	0.483 (0.351–0.666)	<0.001***	0.955 (0.624–1.462)	0.833
Surgical Management				
No primary surgical repair	Reference			
Primary surgical repair	4.252 (0.623–29.014)	0.140		

Notes: ^aThe multivariable logistic regression model included all covariates found to be significantly associated with the outcome in univariable regression. Covariates included were ethnicity, insurance status, substance use during injury, mechanism of injury, object material, open globe type, laceration type, traumatic cataract, expulsion of lens, eyelid laceration, hyphema, RAPD, orbital fracture, retrobulbar hemorrhage, and visual acuity at presentation, time to primary surgical repair, and surgical management. ^bPresence or absence of each concomitant injury was assessed independent of other risk factors. *p<0.05; **p<0.01; ***p<0.001.

Abbreviations: CI, confidence interval; PR, prevalence ratio.

0.41–0.84]; p=0.004), metal objects of injury (PR, 0.77 [95% CI, 0.59–1.00]; p=0.05), lacerations (PR, 0.53 [95% CI, 0.43–0.66]; p<0.001), penetrating injuries (PR, 0.52 [95% CI, 0.40–0.66]; p<0.001), intraocular foreign bodies (IOFBs) (PR, 0.46 [95% CI, 0.30–0.72]; p<0.001), traumatic cataract (PR, 0.29 [95% CI, 0.18–0.47]; p<0.001), and time to primary surgical repair greater than 24 hours (PR, 0.48 [95% CI, 0.35–0.67]; p=0.004) were negatively associated with Zone III injury. Substance use during injury (PR, 2.29 [95% CI, 1.63–3.22]; p<0.001), assault mechanisms of injury (PR, 2.36 [95% CI, 1.74–3.19]; p<0.001), expulsion of the lens (PR, 1.94 [95% CI, 1.46–2.56]; p<0.001), eyelid laceration (PR, 2.80 [95% CI, 2.27–3.45]; p<0.001), hyphema (PR, 2.65 [95% CI, 2.07–3.40]; p<0.001), RAPD (PR, 3.26 [95% CI, 2.56–4.14]; p<0.001), orbital fracture (PR, 2.79 [95% CI, 2.21–3.53]; p<0.001), retrobulbar hemorrhage (PR, 2.77 [95% CI, 1.76–4.36]; p<0.001), and VA greater than 20/60 to 20/100 (PR, 3.45 [95% CI, 1.31–9.08]; p=0.012) or less than 20/600 at presentation were positively associated with Zone III injury (PR, 5.48 [95% CI, 2.62–11.44]; p<0.001).

In a multivariable logistic regression including variables significant on univariable regression, traumatic cataract remained negatively associated with Zone III injury (PR, 0.37 [95% CI, 0.19–0.73]; p=0.004), and eyelid laceration (PR, 1.62 [95% CI, 1.20–2.18]; p=0.002), RAPD (PR, 2.42 [95% CI, 1.71–3.43]; p<0.001), retrobulbar hemorrhage (PR, 2.77 [95% CI, 1.76–4.36]; p<0.001), and presenting VA greater than 20/60 to 20/100 (PR, 8.47 [95% CI, 2.23–32.09]; p=0.002) or less than 20/600 (PR, 4.25 [95% CI, 1.26–14.37]; p=0.02) remained positively associated with Zone III injury.

Discussion

We used a large retrospective cohort of patients with open globe injuries to examine the association between demographic and clinical risk factors and specific open globe injury mechanisms, as well as to investigate risk factors for severe Zone III open globe injuries. We found that demographic factors including middle age (41 to 60 years) and Black race were associated with assault injuries, female sex and old age (61 years and older) were associated with falls, and working age (21 to 40 years), middle age, and old age were associated with construction work injuries. Further, we found that eyelid laceration was associated with assaults and falls, while iris prolapse was associated with assaults and construction work injuries. Poorer presenting VA ($\leq 20/200$) was associated with assault OGIs. In examining variables associated with Zone III injury, eyelid laceration, RAPD, and retrobulbar hemorrhage were key risk factors for Zone III injury.

The demographic profile of our cohort aligns with prior research showing that OGIs largely affect males and have a bimodal age distribution, with peaks in young adults and elderly individuals.^{9,16} However, our analysis reveals associations between specific mechanisms and demographic factors. Construction work injuries, which are an understudied mechanism of injury, showed a male predominance (95% lower risk in females compared to males) and peaked in working age adults, compared to those 20 years or younger, likely reflecting workforce demographics and corroborating current literature.^{22–24} Females had an over two times higher risk of fall-related OGI compared to males and elderly patients 61 years and older had a greater than ten-fold risk of falling compared to those 0 to 20 years. This is consistent with previous studies showing that elderly females are especially likely to sustain OGIs from falls.^{11,25,26}

Our finding that Black patients faced an over six-fold higher risk of assault-related OGIs compared to White patients highlights disparities that warrant further investigation. While prior studies have documented racial disparities in ocular trauma,^{10,16,27} including that Black and Hispanic patients are at higher overall risk for OGIs, our results specifically ties these disparities in Black patients to assault mechanisms. This suggests a need for targeted education and prevention strategies within vulnerable communities.

The clinical characteristics associated with each mechanism of injury, including vision and concomitant injuries, offer insights for emergency triage and management. Assault-related OGIs showed higher rates of eyelid laceration and iris prolapse, suggesting more extensive periocular trauma and direct impact to the globe. Construction injuries frequently involved iris prolapse but had better VA on presentation, possibly due to smaller, focused impact from construction materials or equipment. Prior studies support the relative severity and poor visual outcomes associated with assault injury mechanisms,^{18,24} and the association of construction work injuries with concomitant injuries including retinal detachments, vitreous hemorrhage, hyphema, and traumatic cataracts.^{24,28}

Our analysis of risk factors for posterior, Zone III OGIs, where some of the most severe complications of OGIs can occur, showed that eyelid laceration, RAPD, and retrobulbar hemorrhage were concomitant injuries independently associated with elevated risk for Zone III injuries. The presence of these concomitant injuries with Zone III injury likely reflects the severity and extent of globe injury. Lid trauma can be an indicator of high-energy mechanisms of injury or a trajectory of an injuring object that involves both extraocular and intraocular structures. RAPD may signal significant posterior segment involvement or optic nerve compromise, both of which are markers of severe ocular trauma. Finally, retrobulbar hemorrhage can occur emergently with blunt or penetrating OGIs, and is a marker of severe injury. In addition, as expected, severely decreased presenting vision was associated with Zone III injuries. Importantly, none of the mechanisms of injury delineated in our analysis were independent predictors of Zone III injury. Our results are consistent with and build on previous work showing that poor presenting vision is a prognostic factor for Zone III injury and that Zone III OGIs are overall associated with worse presenting vision, blunt trauma, traumatic cataract, hyphema, and RAPD, amongst other poor outcomes.^{29–31}

Our study is subject to certain limitations. The retrospective nature of the data collection may have led to patients being omitted if they were not categorized under the appropriate billing codes (ICD-10 or CPT codes) for open globe injury or open globe repair. Categorization of the variables included in data collection are limited to records available within patient charts, which can be subject to nonreporting or reporting inaccuracies. For example, collection of variables such as use of eye protection or mechanism of OGI is not standardly reported across patients, and variables such as race, ethnicity, and occupation were often not reported. Additionally, while our multi-center design can improve generalizability over single-

center studies and may be applicable to other urban, referral centers for eye trauma, it is not largely generalizable to the greater US population. Our cohort may include patients with a greater severity of injury, due to referrals from outside facilities, and likely underrepresents OGIs that occur in more rural settings. Furthermore, the timing of data collection (2018–2021) may have influenced the observed distribution of injuries. The COVID-19 pandemic, and associated lockdowns and lifestyle changes, could have decreased the frequency and types of injuries among patients presenting during our study period, and this temporal factor is an important consideration in interpreting the results presented here.

Conclusion

In conclusion, our large, multi-institutional study compiled demographic and etiological data on open globe injury, and identified significant demographic and clinical risk factors for OGI mechanisms and their severity. To our knowledge, it is one of the largest cohorts to study OGIs with relevant clinical and patient-level data. Assault injuries showed markedly higher risk among middle-aged adults and Black patients. Elderly patients and females were predominantly affected by falls, and construction injuries were associated with working-age adults. Clinical markers including eyelid laceration, iris prolapse, and poor presenting vision were mechanism-specific predictors that may help aid in early identification and triage of severe OGIs. Zone III injuries were strongly associated with poor prognostic indicators including RAPD and retrobulbar hemorrhage, highlighting the importance of careful posterior segment evaluation.

Future studies should evaluate targeted prevention programs for groups at increased risk for OGIs, evaluate risk assessment tools based on demographic and clinical variables to help stratify OGIs, and investigate the factors contributing to increased risk for certain mechanisms of injuries amongst demographic groups. Our findings suggest that such programs could include mandatory and enforced use of protective eyewear in high-risk occupations such as construction and industrial work, public awareness campaigns promoting awareness of fall risk and fall prevention safety measures among elderly populations, and community-based initiatives focused on reducing assault-related trauma, particularly in urban areas where interpersonal violence is a significant contributor to OGIs.

This study highlights key demographic and clinical risk factors associated with different mechanisms of injury. Our findings provide a foundation for the development of risk assessment tools that incorporate variables such as occupation, insurance status, and mechanism of injury to stratify OGI risk. Such tools could be implemented in emergency or primary care settings to guide screening, counseling, and referral. Future work should continue to explore these disparities, with the goal of developing more comprehensive, objective, and equity-informed interventions for OGIs.

Abbreviations

OGI, open globe injury.

Funding

There are no external funding sources for this work.

Disclosure

Dr Grayson Armstrong is a consultant to Ocular Technologies Inc, Kriya Therapeutics, Optomed, Xenon-VR, Chart Biopsy, McKinsey & Company, and Dynamed, and receives grants from the American Macular Degeneration Foundation, outside the submitted work. The authors report no other conflicts of interest in this work.

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