Open globe injuries from projectile impact: Initial presentation and outcomes

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Purpose: To describe the characteristics and correlates of open globe injuries secondary to projectile injury and outcomes following surgical open globe repair at an urban tertiary referral center. Methods: Records of all patients with a history of open globe injury secondary to projectile injury and surgical open globe at a tertiary referral hospital between January 1, 2010 and December 31, 2016 were reviewed. Demographics, type of trauma, wound extent, presence of foreign body, and presenting clinical findings are reported. Outcomes for patients with greater than 6 months of follow-up included additional surgeries, final visual acuity, and clinical findings. Results: Of 214 patients who underwent open globe repair, 73 (34.1%) were due to projectile impact. Mean age was 37.9 years and patients were primarily male (n = 66, P < 0.001). Most injuries resulted in globe laceration (68.5%, P < 0.001), and wound extent was zone 1 (45.2%), zone 2 (20.5%), zone 3 (27.4%), or unknown (6.8%). Associated findings included foreign body (35.6%) and orbital fracture (15%). Of 41 patients with at least 6 months of follow-up, 70% had additional surgeries following their initial surgical repair. Laceration injuries tended to be more anterior (P = 0.002) with better visual outcomes (P = 0.045) than those with globe rupture, and concomitant orbital fracture associated with poor visual outcomes. Overall, 58.5% of patients had 20/40 or better final best-corrected visual acuity. Conclusion: This is the largest report of open globe injury due to projectile impact. Visual prognosis in this population is very good, with most patients achieving better than 20/40 vision in our study.

Key words: Injury, ocular trauma, open globe injury, open globe repair, projectile

One third of eye-related emergency department visits in the United States are due to ocular trauma, and about a third of these injuries result in legal blindness. [1,2] In 2008, “being struck by an object or person” in the eye was the reason for one-third of emergency department visits involving eye injuries. [3] Projectile impact is the most common mechanism of open globe injury in men. [4,5] Injury extent, presence of relative afferent pupillary defect, and visual acuity at time of injury can help physicians predict visual survival after open globe injury. [6-11] and support patient education and setting realistic expectations at the time of initial surgery. Previous reports have described the epidemiology and clinical outcomes of open globe injury, [1,4,6] though none has specifically focused on outcomes in open globe injury secondary to projectile impact. The purpose of this study was to describe the epidemiology of open globe injuries secondary to projectile impact at an urban tertiary referral center and variables associated with favorable outcomes.

Methods

We conducted a retrospective cohort study. Records of all patients with a history of open globe injury who underwent surgical open globe repair at a tertiary referral hospital between January 1, 2010 and December 31, 2016 were reviewed. Charts of patients billed any of the following codes were reviewed: CPT 65273 (repair of laceration), ICD-9: (870.1–870.9, 871.1–871.9), and ICD-10: (S05.2XX-S05.9XX). Individuals with a history of open globe injury secondary to projectile mechanism were included. Individuals with open globe injury due to all other mechanisms were excluded. In this study, projectile mechanism was determined to be any open globe injury secondary to an object propelled through force. Patient demographics, initial visual acuity, type of trauma, wound extent, presence of a foreign body, and presenting clinical findings were reviewed for all patients. For patients with 6 months of follow-up available, outcomes including best-corrected visual acuity, clinical findings, and additional surgeries were analyzed. Snellen visual acuities were converted to logarithm of the minimal angle of resolution (LogMAR) form to analyze vision at presenting visit and final visit. LogMAR acuities were later converted back to Snellen format and categorized for further analysis: (1) greater than or equal to 20/40, (2) 20/50 to 20/200, (3) less than 20/200 to hand motion, (4) light perception, and (5) no light perception. This study received Institutional Review Board approval.

Injury classification

Injuries were classified according to the Birmingham Eye Trauma Terminology System, and the extent of injury was classified using the Ocular Trauma Classification Group. [11,12]

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Zone of injury was based on the most posterior point of injury: Zone 1 injuries involved the cornea and corneoscleral limbus, zone 2 injuries involved the corneoscleral limbus up to 5 mm posterior, and zone 3 included injuries posterior to the anterior 5 mm of the sclera.[12]

Data analysis

Descriptive statistics as well as t-tests and Chi-square tests were used to compare variables with a significance level of 0.05, and bivariate logistic regression was used to obtain odds ratios. Data was analyzed using SAS Institute Inc. 2018 (SAS 9.4M6, Cary, NC, USA).

Results

A total of 73 of 214 (34.1%) patients with open globe injury presented due to injury from projectile impact between January 1, 2010 and December 31, 2016. Almost all patients, 94.5%, reported injury due to accident rather than alteration [P < 0.001; Table 1]. The majority of patients presenting were male (P < 0.001) and had trauma resulting in globe laceration (P < 0.001). The most frequent cause of projectile injury were related to metal work (n = 23) followed by gun-related injuries (n = 6), injuries related to metal tools (n = 5), and projectile wood injuries while using a saw (n = 4).

| Characteristics                              | n (%)          |
|----------------------------------------------|----------------|
| Gender                                       |                |
| Male                                         | 66 (90.4)      |
| Female                                       | 7 (9.6)        |
| Mean age (years)                             | 37.9±17.8 (range 3-89) |
| Race                                         |                |
| Black/African American                       | 13 (17.8)      |
| White                                        | 27 (37.0)      |
| Hispanic                                     | 14 (19.2)      |
| Other/unknown                                | 19 (26)        |
| Insurance                                    |                |
| Commercial                                   | 19 (26.0)      |
| Medicaid                                     | 12 (16.4)      |
| Medicare                                     | 4 (5.5)        |
| Other                                        | 38 (52.0)      |
| Transfer from outside hospital               | 61 (83.6)      |
| Distance from clinic (miles)                 | 31.2±32.4 (range 1-175) |
| Cause of injury                              |                |
| Accident                                     | 69 (94.5)      |
| Altercation                                  | 4 (5.5)        |
| Location injury occurred                     |                |
| Work                                         | 21 (28.8)      |
| Home                                         | 11 (15.1)      |
| Other/Unknown                                | 41 (56.2)      |
| Zone of Injury                               |                |
| 1                                            | 33 (45.2)      |
| 2                                            | 15 (20.5)      |
| 3                                            | 20 (27.4)      |
| Unknown                                      | 5 (6.8)        |

Clinical findings at presentation included: corneal laceration (72.6%, n = 53), hyphema (46.6%, n = 34), iris or uveal prolapse (37.0%, n = 27), foreign body (35.6%, n = 26), lid laceration (24.6%, n = 18), shallow or collapsed anterior chamber (23.3%, n = 17), other iris abnormalities including dyscoria, tear, or iridodialysis (16.4%, n = 12), orbital fracture (15.0%, n = 11), and traumatic aniridia (2.7%, n = 2). The following were noted during the initial open globe surgical repair: excision of prolapsed iris tissue (24.7%, n = 18), primary lensectomy (11.0%, n = 8), and laceration too posterior to close (6.8%, n = 5). Pars plana vitrectomy was performed in two individuals (2.7%) at the time of repair, both of which were in patients with a reported intraocular foreign body.

Of 26 patients with foreign body on presentation, 84.6% (22/26) were of metallic origin. Of 11 patients with orbital fracture, 18.2% (2/11) were found to have muscle entrapment. Mean laceration length was 7.55 ± 6.6 mm (range 1–27; n = 34). When comparing vision, patients with globe laceration were 6.23 times more likely to have better entering visual acuity, noted as hand motion or better, than those with globe rupture (OR 6.23, CI 2.10, 18.43; P = 0.001). Most patients underwent surgical open globe repair within 1 day of injury (94.5%; range 0–4 days). One patient had an enucleation 15 days after initial open globe repair. Table 2 provides a comparison of clinical findings at presentation by trauma type.

Follow-up

Over half, 56% of patients, had at least 6 months of follow-up after open globe repair. Of these, 70% (n = 28) had a mean of 1.9 additional surgeries.

Visual acuity

There was visual improvement in most patients with greater than 6 months of follow-up compared to entering visual acuity [P < 0.001; Table 3]. In patients who completed six months of follow-up or more, those with globe laceration were almost 5 times more likely to have hand motion or better final visual acuity (OR 4.98 (1.03, 23.96); P = 0.045) than those with globe rupture. Final visual acuity was not affected by history of foreign body (P = 0.44); however, those with open globe injury and orbital fracture were 9.9 times more likely to have poorer vision than those without fracture (OR 9.86 (2.10, 46.36); P = 0.004).

Clinical outcomes

The following clinical findings were present in patients with at least 6 months of clinical follow-up available: corneal scarring (46.3%, n = 19), remaining corneal sutures (19.5%, n = 8), aphakia (14.6%, n = 6), history of retinal detachment (9.8%, n = 4), glaucoma (4.9%, n = 2), and optic nerve pallor (2.4%, n = 1). Additional surgeries in this subset of patients included: pars plana vitrectomy (53.6%, n = 15), lensectomy (32.1%, n = 9), pan retinal photocoagulation (17.9%, n = 5), corneal transplantation (7.1%, n = 2; Fig. 1), peripheral iridotomy (7.1%, n = 2), and anterior vitrectomy (3.6%, n = 1). No eyes were eviscerated, but four additional eyes were enucleated. All patients who underwent enucleation were fit with an ocular prosthesis.

Discussion

This is the largest case series of open globe injury due to projectile impact to date. The visual prognosis of open globe...
injuries secondary to projectile impact is fairly good, with 58.5% of those completing more than 6 months of follow-up achieving a final best-corrected visual acuity of 20/40 or better in this study population. Of 26 patients sustaining intraocular foreign body in our study, only four sustained a zone 3 injury, two of which required pars plana vitrectomy at the time of repair. The presence of posterior foreign bodies requiring pars plana vitrectomy likely would affect the management and final visual outcomes adversely. Visual outcomes in this study are better than previous reports. For example, Han et al. studied all open globe injuries presenting to their hospitals and found that only 36% of patients had a final visual acuity of 20/40 or better 1 year after their initial injury, though 27.3% sustained zone 3 injuries. In our study group, 27.4% of patients who underwent open globe repair secondary to projectile injury were classified as zone 3 injuries, though almost double had a final visual acuity of 20/40 or better. One study by Kolomeyer et al. looked at nail gun injuries, a mechanism of projectile injury, and found that only 40% of patients had a final visual acuity of 20/40 or better, though only 16% of eyes sustained

### Table 2: Comparison of clinical findings by trauma type

| Trauma type          | All  | Rupture n | Laceration n | Significance (P<0.05) |
|----------------------|------|-----------|--------------|-----------------------|
|                      | 73   | 23        | 50           |                       |
| Laceration length (mm) | 7.55±6.6 (1-27; n=34) | 12.55±8.5 (3-27, n=11) | 5.14±4.6 (1-15, n=23) | P=0.017* |
| Foreign body         | 26   | 7         | 19           |                       |

### Odds of rupture by zone of injury

| Zone of injury | n  | OR (95% CI) | Significance (P<0.05) |
|----------------|----|-------------|-----------------------|
| 1              | 33 | Ref         |                       |
| 2              | 15 | 2.036 (0.460, 9.020) | P=0.529 |
| 3              | 20 | OR 8.4 (2.275, 31.001) | P=0.016* |
| Unknown        | 5  | 3           |                       |

### Odds of additional surgery by trauma type

| Laceration | n  | OR (95% CI) | Significance (P<0.05) |
|------------|----|-------------|-----------------------|
| Rupture    | 15 | 11.0 (1.247, 97.014) | P=0.031* |

### Odds of having hand motion or better entering vision

| Laceration | n  | OR (95% CI) | Significance (P<0.05) |
|------------|----|-------------|-----------------------|
| Rupture    | 22 | Ref         |                       |

### Table 3: Visual outcomes of patients with at least 6 months of follow-up

| Entering Visual Acuity n (%) | Final Best Corrected Visual Acuity n (%) |
|------------------------------|-----------------------------------------|
| 24 (58.5)                   |                                         |
| 3 (7.3)                     |                                         |
| 5 (12.3)                    |                                         |
| 16 (39.0)                   |                                         |
| 12 (29.3)                   |                                         |
| 3 (7.3)                     |                                         |

### Odds of hand motion or better final vision by trauma type

| Laceration | n  | OR (95% CI) | Significance (P<0.05) |
|------------|----|-------------|-----------------------|
| Rupture    | 15 | Ref         |                       |

### Odds of hand motion or better final vision by history of foreign body

| Foreign body (no) | n  | OR (95% CI) | Significance (P<0.05) |
|-------------------|----|-------------|-----------------------|
| Foreign body (yes)| 10 | 1.83 (0.391, 8.532) | P=0.444 |

### Odds of no light perception vision by history of orbital fracture

| Orbital fracture (no) | n  | OR (95% CI) | Significance (P<0.05) |
|-----------------------|----|-------------|-----------------------|
| Orbital fracture (yes)| 7  | 9.86 (2.099, 46.355) | P=0.004* |
zone 3 injuries compared to 27.4% in our study group; however, 70% of the nail gun injuries resulted in vitreous hemorrhage on presentation compared to only 2.7% of eyes in our study. Perhaps the velocity or force of impact may be an additional predictor of visual outcome rather than mechanism or zone of injury alone.

This study population was similar to other open globe injury studies, with a mean age of 37.9 years and the majority of patients being male (90.4%; \( P < 0.001 \)). Males tend to have greater risk of exposure to ocular trauma due to occupation and responsibilities performed at home. Poor prognostic factors in the current study included globe rupture, more posterior injury, and presence of orbital fracture, which is consistent with other studies. There was no association between the presence of intraocular foreign body and visual outcomes in this study. Though size of foreign body was not documented in this study, a study by Liu et al. describes that small foreign body size is associated with better visual outcomes, suggesting that documentation of foreign body size could also assist in estimating visual prognosis.

In this study, patients with 6 months of follow-up required a mean of 1.9 additional surgeries, which is slightly higher than Kolomeyer et al. which reported 1.5 surgeries. No eyes were treated for suspected endophthalmitis which is consistent with Fujikawa et al., though several studies have noted higher estimates of infection from 2.0 to 13.3%. This is likely due to early intervention and antibiotic treatment. In addition, only 5 eyes (6.8%) were enucleated in this study, which is also lower than previously reported rates of 12–26%. As patients presenting with open globe injury due to projectile had more anterior injuries, the severity of injury was likely less than that of other studies. Without direct comparison to other mechanisms of injury, this suggests that visual survival in eyes presenting with injury from projectile impact is likely greater than that of other mechanisms of injury.

According to Prevent Blindness America, 90% of all eye injuries are preventable. Although U.S. trends have shown a decrease in the incidence of open globe injury, these injuries continue to occur and cause devastating consequences due to visual impairment. Prevention is important and strict safety with ocular protection measures should be adhered to whenever possible. The issue of eye protection has been highlighted previously, yet, these devastating injuries continue to occur both in the workplace and at home.

The retrospective design of this study was a limitation as documentation was not standardized and data collection was dependent on existing medical records. Good clinical documentation is critical to improve our knowledge of the epidemiology and clinical outcomes of individuals with such injuries. For example, limited documentation restricted the use of ocular trauma score calculations to predict visual outcomes. In addition, incomplete history including type of object, location where the injury occurred, and reported use of eye protection reduced our knowledge of the epidemiology of such injuries. In addition, surgical repair was completed by different surgeons based on the hospital on call system. There was also a large proportion of patients (44%) lost to follow-up after initial surgical repair. Though patient care likely continued for patients by outside eye care providers, records were only available for those who continued follow-up at our institution. This may have led to an overestimation of complications and subsequent surgeries or best-corrected visual acuity. Future prospective studies are needed to further define predictors of visual outcomes after projectile eye injury.

Conclusion

Though the visual prognosis after open globe injury due to projectile impact is mostly guarded, a number of patients achieved a best-corrected visual acuity better than 20/40 in this study. Further education and prevention efforts are needed to help inform the public and employers to prevent severe ocular injuries.

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Conflicts of interest

There are no conflicts of interest.

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