Spectrum of Ocular Injuries and Visual Outcome Following Firework Injury to the Eye

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Abstract

Background: Ocular injury due to fireworks requires urgent ophthalmic assessment and management to preserve vision. Methods: Spectrum of injury, type of intervention, visual outcome, and reasons for visual loss were assessed in consecutive patients presenting over 2 years with firework-related eye injury. The final visual outcome was recorded as best-corrected visual acuity. Results: In the 96 patients (75 males) enrolled, 122 eyes were involved. Twenty-six patients had bilateral eye injury. The median (interquartile) age was 14 (8, 28.5) years. Injuries occurred during Diwali festival (59.4%) and funeral processions (20.8%); over half (53.8%) were bystanders. Injury was due to negligence (78%), device malfunction (12.5%), and attempts to reignite (5.2%) or recover failed device (4.2%). Presenting symptoms were redness (100%), pain (97%), watering (86%), and reduced vision (77%). Facial laceration, contusion, or hematoma occurred in 13 patients. The most frequent adnexal and ocular surface injuries were lid burns (57.3%), edema (44.2%), charred eyelashes (24.6%), and laceration (13.9%). Open-globe injury occurred in 8 eyes. Common anterior segment injuries were corneal epithelial defect (51.6%) and hyphema (20.5%). Posterior segment injuries included commotio retinae (13.1%) and Berlin’s edema (7.4%). Surgical treatment was required in 15 eyes; 107 (88%) were managed conservatively. At study completion, of the 99 eyes evaluated, 21 had reduced visual acuity (<6/6) including 7 with monocular blindness. Factors associated with poor vision were open-globe injury (P < 0.001) and poor initial visual acuity (P = 0.05). Conclusions: Open-globe injury and poor visual acuity at presentation predict the final visual outcome. Monocular blindness following firecracker injury is common.

Keywords: Eye injury, fireworks, preventative measures, visual outcome

Introduction

Ocular trauma is a major preventable cause of ocular morbidity. Firecrackers have been increasingly found to cause ocular trauma in various studies across the globe with an estimated 12% of injuries involving the eye.[1] Firecrackers used during various Celebrations and events, if not handled appropriately, can lead to serious ocular morbidity, especially among youth and children. During festivals, fireworks are burst at homes, crowded side streets, and also in large playgrounds. Apart from festivals, firecrackers are also used in some Asian countries during funerals.[2] Firecracker injuries not only affect the individual involved in lighting the crackers but also bystanders in the vicinity.[3] Manipulation, misuse, and trying to reignite unlit firecrackers can lead to ocular trauma.[4] Awareness, education, and legislation[5] may help reduce ocular morbidity due to fireworks.

Although some studies have profiled the spectrum of ocular injuries and visual outcomes related to firecracker injury,[3,4,6-17] they are limited either by the retrospective nature of the study[6-11,14] or small numbers.[17] The occasions during which these injuries occur, the nature of injury, and the visual outcomes are likely to be different between developed and developing countries and are compounded by the lack of legislation in the sale and use of firecrackers in some developing countries.[5] This study was designed to evaluate the setting, contributing factors, spectrum of eye injury, and visual

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outcome in firework-related ocular injury from a developing country and thus make the public aware of the consequences and prevent such injuries.

Methods
This observational study was conducted in a tertiary care university-affiliated teaching hospital in a semi-urban setting in South India. The study group comprised of two arms. In the retrospective arm, patients who had sustained ocular injury due to firecrackers between October 2013 and July 2014 were called for follow-up and assessment 6 months after the injury. The initial data in these patients were collected from the emergency services record. In the prospective arm spanning 1 year (August 2014–August 2015), patients were recruited prospectively and followed up. Informed consent was obtained either from the patient or if they were children from the parent. The study was approved by the Institutional Review Board and Ethics Committee (IRB Min. No. 9003 [OBSERVE] dated August 4, 2014).

Demographic data, socioeconomic status, details of injury, type of firecracker involved in the injury, details on protective wear (if any), supervision by adults in cases where children were involved as well as the likely reason for mishap were collected. The modified Kuppuswamy scale,[19] validated in the Indian context, was used to assess socioeconomic status.

All patients received standard care which included a thorough systemic examination to rule out injuries or burns on the face and rest of the body; laceration, contusion, or hematoma was noted and recorded. Ocular examination included visual acuity testing, anterior segment examination using slit-lamp biomicroscope, posterior segment examination with +78D/+90D lens, indirect ophthalmoscopy using 20D lens, and tonometry. Where indicated, B-scan ultrasonography (hazy view precluding posterior segment examination) or computed tomography scan (if intraocular foreign body was suspected) was done. Ocular injuries were classified according to the Birmingham Eye Trauma Terminology as open-globe and closed-globe injuries.[19]

Appropriate medical or surgical treatment was given based on the nature of injury; trivial injuries were managed conservatively and followed up in the outpatient department till recovery. Medical management in closed-globe injuries consisted of thorough irrigation of the affected eyes with normal saline or Ringer’s lactate solution, with double eversion of the lids if the patient had any external foreign body debris. Following this, topical lubricants, antibiotics, steroids, and cycloplegics were administered as indicated. Patients with hyphema were admitted to monitor for rebleed and to control intraocular pressure if raised. The primary surgical management included lid tear repair, corneal, scleral, or corneoscleral tear repair, intraocular foreign body removal, lens matter aspiration, cataract extraction, intraocular lens implantation, and vitreoretinal surgery.

On discharge, patients were reviewed in the outpatient clinic till complete recovery. Patients were followed up for 6 months after the injury to ascertain their best-corrected visual acuity (BCVA). In those patients who had not completed the treatment within the study period, their final visual outcome was obtained on subsequent follow-up.

Statistical aspects
Data were entered in Epidata version 3.1 (The Epidata Association, Denmark) and analyzed using SPSS software (IBM SPSS statistics, New York, USA). Categorical variables were reported as frequency and percentage. Continuous variables were reported as mean with standard deviation (SD) or median with interquartile range (IQR) as appropriate. Chi-square test was used to evaluate the risk factors associated with poor visual outcome. Visual outcome was defined using the World Health Organization classification as the BCVA in the better eye.

Results
A total of 96 patients (122 eyes) were enrolled during the study period. Of these, 27 patients (34 eyes) were in the retrospective arm and 69 patients (88 eyes) were in the prospective arm. Twenty-six patients had bilateral eye injury. The median (IQR) age of the study group was 14 (8–28.5) years. Most of the patients (59/96; 61.5%) were <18 years of age, two-thirds of whom (66%) lit firecrackers without any supervision. There was a male preponderance with a male: female ratio of 3.5:1. Majority of those affected belonged to the upper-low income (49%) followed by the lower-middle-income group (36.5%). The commonplaces of occurrence were at home (55%) and public places (40.6%).

Injuries occurred during the popular festival of lights in India Diwali (59.4%) and funeral processions (20.8%). Other occasions (13.5%) included local temple, Christmas, and New Year celebrations. Over half (53.8%) of the injured were bystanders. Injury was due to negligence (78%), device malfunction (12.5%), and attempts to reignite (5.2%) or recover failed device (4.2%). Injury also occurred while trying to sweep away debris of half-lit and unused crackers. The main crackers which caused injury were bombs (25%), cone fountain (25%), string bomb (21.9%), sparkler (8.3%), bottle rocket (9.4%), and ground spinner (2.1%). The main methods used to light crackers were matchstick (43.8%), sparkler (28%), and incense stick (21.9%). A large number of injuries occurred in those who were in close proximity (within 1 m) to the crackers (78.1%) but flying particles from certain crackers traveled at high speed to cause ocular trauma even beyond 2 m in 14%.

Presenting symptoms were redness (100%), pain (97%), watering (86%), reduced vision (77%), and foreign body sensation (12%). Facial laceration, contusion, or hematoma occurred in 13 patients. Adnexal and ocular surface injuries [Figure 1] included lid burns (57.3%), edema (44.2%) or laceration (13.9%), charred eyelashes (24.6%), conjunctival...
tear (8%), subconjunctival hemorrhage (8%), and conjunctival foreign body (3%).

Majority of the ocular injuries were closed globe \(n = 114; 93.4\%\) [Figure 2]; 8 eyes (6.6%) had open-globe injury [Figure 3]. Of the 122 eyes that were injured, 82% had a contusion whereas 4.1% had a penetrating eye injury. Mixed closed injuries which included contusions and superficial foreign body were seen in 11.4%, and mixed open injuries which included penetrating injury with intraocular foreign body occurred in 2.5%.

At presentation, the visual acuity was 6/12 or better in 61 eyes (50%). Visual acuity ranging from 6/18 to 6/60 was noted in 43 eyes (35.3%), whereas in 18 eyes (14.7%), visual acuity was <6/60. Relative afferent pupillary defect was noted in 4 eyes (in 3 eyes with closed-globe injury and in 1 eye with open-globe injury).

Table 1 summarizes the spectrum of anterior segment injuries observed. Corneal epithelial defect was observed in 63 eyes (51.6%). Traumatic cataract [Figure 2] was seen in 15%. Partial- or full-thickness corneal tear [Figure 3] was seen in 13 patients. Hyphema and subluxated lens were nonsignificantly \(P = 0.06\) and 0.07, respectively) associated with open-globe injury than with closed-globe injury. Iridodialysis was seen in similar frequency in both open- and closed-globe injuries. Posterior segment injuries were seen in 29 eyes and comprised of commotio retinae (13.1%), Berlin’s edema (7.4%), macular edema (2.5%), and retinal detachment (0.8%). Three patients had traumatic macular hole.

All eyes with open-globe injury \(n = 8\) were managed surgically, including one patient who underwent surgery for bilateral open-globe injury. In addition, 7 eyes with closed-globe injuries required surgical intervention. All the closed-globe injuries requiring surgery had unilateral injury. The remaining patients were managed conservatively. Common procedures in the setting of firecracker injuries included lens matter aspiration (8%), corneal tear repair (7%), intraocular lens implantation (5%), foreign body removal (4%), wound exploration (2%), scleral tear repair, lid tear repair, and vitrectomy (1% each). Lens matter aspiration was more frequently required in open-globe (62.5%) than closed-globe injuries (4.4%), whereas implantation of intraocular lens was more frequently done in closed-globe injuries [Table 2].

Seven patients (10 eyes) were lost to follow-up. The mean (SD) duration of follow-up in 72 patients in whom the data were available was 11.5 (13.5) months. The final BCVA at the end of follow-up period was available in 99 eyes. Of these, 78 patients had a vision of 6/6; of the remaining 21 eyes, 7 patients, that included 2 children <5 years of age, were left with monocular blindness with visual acuity of perception of light \(n = 2\), hand movements \(n = 3\), and counting fingers at 1 m \(n = 2\). Seven patients had vision between 6/12 and 6/9, and another 7 patients had vision ranging from 6/18 to 6/36. The main causes of decreased vision at the end of follow-up were traumatic cataract (8.1%) and corneal and macular scar (3% each). Three eyes were aphakic. Other causes contributing
to decreased vision included epiretinal membrane, retinal detachment, corneal ulcer, and posterior capsular opacification. Factors associated with poor vision were open-globe injury \( (P < 0.001) \) and poor initial visual acuity \( (P = 0.05) \) of counting fingers at 1 m or less (Grade 4 injury).

**DISCUSSION**

In this cohort of 96 patients (122 eyes) with firecracker injury, with a median age of 14 years, 72% were prospectively enrolled; 26 patients (27%) had bilateral eye injury. Although the majority of injuries occurred during the local Diwali festival (59.4%), nearly half the injuries occurred in other settings such as funeral processions, local temple festivals, Christmas, and New Year. Over half (53.8%) of the injured were bystanders. A majority of the ocular injury was closed globe (93.4%); 82% had a contusion, whereas 4.1% had a penetrating eye injury. Corneal epithelial defect (51.6%) and commotio retinae (13.1%) were the most frequent anterior and posterior segment injuries, respectively. Surgical treatment was required in 15 (12%) eyes; the remaining \( (n = 107) \) were managed conservatively. At study completion, 21 (17.2%) eyes had reduced visual acuity (\(<6/6\)) including 7 with monocular blindness. Factors associated with poor vision were open-globe injury \( (P < 0.001) \) and poor initial visual acuity \( (P = 0.05) \).

It is interesting to note that over half (53.8%) of the injured were bystanders. These data are consistent with another study from India\(^\text{[13]}\) that reported that 48.9% of the ocular injuries due to fireworks occurred in bystanders. A systematic review of ocular injuries reported that 47% of the ocular injuries occurred in bystanders.\(^\text{[15]}\) These highlight the impact of such injuries on innocent bystanders.

Table 3 summarizes the key studies since 2005 that looked at eye injuries due to fireworks.\(^\text{[1,6-17]}\) Some studies were retrospective in nature;\(^\text{[6-11,14]}\) five prospective studies\(^\text{[3,12,15-17]}\) evaluated patients with ocular injuries due to fireworks recruiting 26–49 patients (26–57 eyes). One other prospective study by The Netherlands Society of Ophthalmology\(^\text{[16]}\) included 268 patients during the New Year period. The current study evaluated 96 patients (122 eyes). All but two studies\(^\text{[15,17]}\) looked at a specific occasion or period such as the Spring Festival in China,\(^\text{[10,12,14]}\) Diwali in India,\(^\text{[3,7,11]}\) Swiss National Day,\(^\text{[8]}\) New Year,\(^\text{[6,8,16]}\) July 4, in the USA,\(^\text{[9]}\) or the Aidil Fitri festival in Malaysia.\(^\text{[13]}\) Only three studies, including our study, prospectively enrolled all patients admitted with ocular trauma during a specific time period. In one study,\(^\text{[17]}\) patients were enrolled over 1 year, whereas in another study,\(^\text{[15]}\) patients were enrolled over 2 years. In our study, patients were enrolled over 2 years. In one study,\(^\text{[17]}\) 76.9% were enrolled during a 4-week period from October to November, whereas in our study, although 59.4% of the injuries occurred during a specific local festival (Diwali), the remaining injuries occurred during several other events, probably a truer reflection of injuries over time occurring during different events.

The current study enrolled patients across all ages in contrast to an earlier study from this region which included only pediatric patients.\(^\text{[11]}\) Barring two studies, one from Switzerland\(^\text{[8]}\) and another from China,\(^\text{[10]}\) where the mean age was over 30 years, the age of patients presenting with eye injuries due to fireworks was \(<25\) years in all the other studies, with 3 studies\(^\text{[3,12,17]}\) reporting an average age between 14.3 and 17.6 years, consistent with our study where the average age was 14 years. The age characteristic may be consistent with risk-taking behavior among the younger population during these events, often combined with the influence of alcohol, reported in some studies.\(^\text{[20]}\) In our study, 3.2% of the patients were under the influence of alcohol. In a study from Australia, firework injuries on a day other than territory day were more likely to have alcohol involvement.\(^\text{[20]}\)

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**Table 1: Spectrum of anterior segment injuries**

| Type of injury                               | Closed-globe injury \( (n = 114) \) eyes (%) | Open-globe injury \( (n = 8) \) eyes (%) | \( P \)  |
|----------------------------------------------|---------------------------------------------|----------------------------------------|--------|
| Corneal epithelial defect                    | 61 (53.5)                                   | 2 (25)                                 | 0.15   |
| Hyphema                                      | 21 (18.4)                                   | 4 (50)                                 | 0.06   |
| Subluxated lens                              | 0                                           | 1 (12.5)                               | 0.07   |
| Cataract                                     | 12 (10.5)                                   | 6 (75)                                 | <0.001 |
| Iridodialysis                                | 11 (9.6)                                    | 1 (12.5)                               | 0.58   |
| Partial-thickness corneal tear               | 2 (1.8)                                     | 1 (12.5)                               | 0.19   |
| Full-thickness corneal tear                  | 0                                           | 8 (100)                                | <0.001 |
| Intrastral foreign body                     | 12 (10.5)                                   | 0                                       | 1.0    |
| Foreign body in anterior chamber             | 0                                           | 3 (37.5)                               | <0.001 |
| Anterior capsule breach                      | 0                                           | 6 (75)                                 | <0.001 |

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**Table 2: Surgical interventions performed**

| Surgery                                | Closed-globe injuries \( (n = 114) \) eyes | Open-globe injuries \( (n = 8) \) eyes |
|----------------------------------------|--------------------------------------------|----------------------------------------|
| Lid tear repair                        | 1                                          | 0                                      |
| Foreign body removal (anterior chamber) | 0                                          | 3                                      |
| Pars plana vitrectomy                  | 1                                          | 0                                      |
| Intraocular lens implantation          | 5*                                         | 1†                                     |
| Lens matter aspiration                 | 5                                          | 5                                      |
| Wound exploration                      | 2                                          | 1                                      |
| Corneal tear repair                    | 0                                          | 8                                      |
| Scleral tear repair                    | 0                                          | 1                                      |

*Four of the five patients had primary intraocular lens implantation, †This patient had a secondary lens implantation
The nature and spectrum of injuries have been described in various studies, and consistent with our study, the authors have categorized injuries as open- or closed-globe injuries. The proportion of open-globe injuries was small (6.6%) in our study. The frequency of open-globe injuries was reported in 5 studies and was 5.9%,[11] 9.4%,[1] 3.1%,[17] 26.5%,[3] and 35.4%,[10] respectively. The frequency of open-globe injuries would reflect the type of firecracker use and the proximity of the eye to the firecracker when the injury occurred. The frequency of blindness in these studies appears to correlate with the proportion of patients presenting with open-globe injuries.

The requirement for surgical intervention was very varied ranging from 12% in our study to 91% in another study from China.[10] The low rates of need for surgical intervention in our study are surprising since our institution is the only tertiary care 24-h emergency unit available for ophthalmology for a radius of over 100 km. The low rates may also be a reflection of the use of milder forms of fireworks during the festivals in our setting in contrast to what may have been used in the studies reported from other centers.

Cohorts with high rates of surgical intervention appear to have had a higher frequency of residual blindness with the highest rate of blindness of the affected eye of 42.9% in a study from China.[10] However, the need for surgical intervention and the final visual acuity is largely dependent on the nature (closed vs. open) of the injury[10,17] as stated above, initial visual acuity at presentation,[10,17] absence of endophthalmitis,[10,17] intraocular foreign body,[10,17] and absence of relative afferent pupillary defect.[17] In our study, poor initial visual acuity and open-globe injury were associated with poor visual outcomes at the end of follow-up.

It is interesting to note, going by published reports from India that the proportion of ocular injuries requiring surgical intervention and the frequency of blindness due to such injury has reduced over time. Singh et al.[17] in 2005 reported that 85% of their patients required surgical intervention with blindness occurring in 30.8% of the patients. Publications over 10 years later between 2015 and 2017 from India[3,7,31] as well as our study show that the need for surgical intervention has reduced considerably from 85% to 12%–45% [Table 3] with blindness occurring in 7%–15.1%. It is possible that increased awareness on handling firecrackers has resulted in this change over time in India. Improved understanding of the management of firework injuries to the eye could have also contributed to improved visual outcomes.

The following limitations merit mention. The case-mix could have been influenced by the location of the institution in a semi-urban setting and thus reflects regional epidemiology of ocular injuries rather than that of the country as a whole. Location bias is, however, likely to be present in some form in all studies. The true epidemiology of ocular injuries can only be ascertained on a large-scale community-based survey. Second, being a tertiary care teaching institution, referral bias is likely with a predominance of severe ocular injuries or the more challenging ones. Despite this potential bias, it is interesting to note that the proportion of ocular injuries requiring surgical intervention was small (12%) and appears to have declined over time, as discussed above. Finally, about one-third of the patients belonged to the retrospective arm; however, their visual follow-up was done retrospectively. The frequency of blindness in these studies appears to correlate with the proportion of patients presenting with open-globe injuries.

Despite these limitations, this study provides a detailed description of the spectrum of ocular injuries, interventions,
and outcomes. This study provides a broader perspective of ocular injuries since it is not restricted to a particular event (e.g., Diwali). The study was thus able to identify that about one-fifth of the eye injuries in our setting occurred during a funeral event. Literature on this association is sparse[2] and may reflect the regional practice of the use of fireworks during a funeral procession in the Indian subcontinent. The study also provides good follow-up data on visual outcomes at 1 year. The study also supports our observation of changing trends of ocular injury requiring surgical intervention and visual outcomes.

**Conclusions**

Ocular trauma due to firecrackers continues to be an important cause of ocular morbidity and monocular blindness. In our semi-urban setting, the favorable visual outcome may be expected in firework-related ocular injury, probably reflecting the less serious nature of injury. Most of the patients were conservatively managed with 12% requiring surgical intervention and 7% left with residual monocular blindness.

The reduction of ocular morbidity over time highlights the importance of sustained inputs not only on the regulation of sale of fireworks but also in increased supervision and promoting awareness since bystanders are often the victim. Toward that end, following completion of the study, the department initiated educational campaigns that included display of visual aids in the outpatient area of the eye hospital as well as exhibitions for local schools on World Sight Day focusing on the dangers of fireworks including safe distance, protective gear, and supervision of children. Such educational activities need to be organized throughout the year (and continues to be done) since the occurrence of eye injuries in our country is not just restricted to one major event like Diwali but also throughout the year since they are used in many local events, temple festivals, other celebrations such as New Year as well as in funeral processions. It is hoped that these strategies would further reduce ocular morbidity due to firecracker-related injury, particularly among children in whom even mild ocular morbidity could affect their educational potential and future development.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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