Original Article

Incidence, clinical profile, and short-term outcomes of post-traumatic glaucoma in pediatric eyes

Charudutt Kalamkar, Amrita Mukherjee

Purpose: To report the incidence, modes of injury, treatment, and short-term outcomes in eyes with post-traumatic elevated intraocular pressure (IOP). **Methods:** This was a 5-year hospital-based retrospective study of children ≤16 years who presented with open (OGI) or closed globe injury (CGI) and developed elevated IOP >21 mmHg. Those with a minimum follow up of 3 months were included. Analysis of various parameters such as influence of demographics, mode of injury, IOP, best-corrected visual acuity (BCVA), and effect of medical and surgical treatment on IOP and BCVA was done. **Results:** Out of 205 pediatric eyes with ocular trauma, 121 (59%) had CGI and the remaining 84 (41%) had OGI. Thirty-two eyes (15.6%) developed elevated IOP. The incidence of elevated IOP following CGI [25 eyes (20.6%)] was significantly higher than that following OGI [7 eyes (8.3%, $P = 0.02$)]. Hyphema (37.5%) and lens-related mechanisms (18.75%) were the most common causes of elevated IOP. The mean IOP at the time of diagnosis was 29.8 + 6.3 mmHg and reduced to 16.2 ± 2.2 mmHg at last follow up ($P < 0.001$). Surgical management was required in 12 eyes (37%) and significantly more eyes with CGI required trabeculectomy (24% in CGI vs. 0% in OGI, $P = 0.03$). Poor baseline vision and vitreoretinal involvement [0.67 line decrement, 95% confidence interval (CI) =0.1–1.25 lines, $P = 0.025$] increased risk of poor visual outcome. **Conclusion:** Post-traumatic IOP elevation occurred in 15% pediatric eyes, was more common with CGI compared to OGI and nearly one-fourth of eyes with CGI required glaucoma filtering surgery for IOP control. Overall, medical management was needed in 63% eyes and 37% required surgical management. Visual acuity was poor in eyes with OGI due to posterior segment involvement.

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Ocular trauma in children <16 years of age is a significant cause of monocular vision loss. It is estimated that about 3.3–5.7 million children suffer from ocular trauma annually and 160,000–280,000 of children <15 years of age every year sustain ocular trauma serious enough to require hospitalization.[1] Pediatric ocular trauma is often preventable and previous epidemiological studies have demonstrated a range of scenarios and mechanisms by which ocular trauma can occur and have also provided potential preventive strategies.[2,3]

Prevention of childhood blindness forms an important part of the World Health Organization's (WHO) VISION 2020 initiative.[4] Recent WHO estimates show that >50% of childhood blindness is avoidable, including majority of ocular trauma. Despite it being relatively common, pediatric ocular trauma is one of the less studied causes of childhood blindness in developing countries especially amongst the rural population. Pediatric patients have different etiologies of trauma as compared to adults and hence the presentation as well as subsequent ocular complications may vary.

Pediatric glaucoma varies significantly in its epidemiology, etiology, and management strategies compared to adult glaucoma.[5] It is estimated that about a fifth of pediatric glaucomas are secondary to ocular trauma.[6] Though a few studies report on the incidence of glaucoma following pediatric ocular trauma, majority of previous studies do not focus on the treatment and outcomes in these eyes.[6–8] We performed a retrospective study on eyes with pediatric ocular trauma that either presented with or developed elevated IOP during the course of follow up to identify its incidence, clinical profile, treatment options, and outcomes.

Methods

This was a hospital-based retrospective study of eyes of pediatric patients, from rural area of central India, with post-traumatic glaucoma (PTG). The study was approved by the Institutional Review Board of the parent institution and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from parents of all children before undertaking treatment options.

Case records of all patients below the age of 16 years, presenting to our institution with a history of trauma from January 2011 till January 2016 were drawn from the medical records department using standard ICD coding for ocular

Glaucoma Unit, Shri Ganesh Vinayak Eye Hospital, Raipur, Chhattisgarh, India

Correspondence to: Dr. Charudutt Kalamkar, Shri Ganesh Vinayak Eye Hospital, Opposite Colors Mall, Dhamtari Road, Pachpedi Naka, Raipur, Chhattisgarh - 492 001, India. E-mail: charudutt03@yahoo.co.in

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trauma. All records were screened and treatment naïve eyes with intraocular pressure (IOP) above 21 mmHg at initial presentation or at any subsequent follow-up, requiring at least 3 months of anti-glaucoma medications (AGM) or surgical intervention for control of IOP (i.e. glaucoma filtration surgery, lens extraction, and/or glaucoma drainage device), were selected for the study. Those with a history of glaucoma or already using AGM and follow up of <3 months were excluded. The demographic profile, time lapse since injury, cause of injury, type of injury [open globe injury (OGI) or closed globe injury (CGI)], modality of treatment (medical or surgical), gonioscopy findings (when available), and duration of follow up were recorded for analyses. The type, grade, and zone of injury were recorded in accordance with the classification provided by the ocular trauma classification group.[9] All eyes with OGI underwent primary repair of the corneal or scleral tear without any other interventions. Lens-induced glaucoma was noted when there was elevated IOP with ruptured lens capsule and lens matter in the anterior chamber. Eyes with persistent anterior uveitis and elevated IOP without any other identifiable mechanism of glaucoma were labeled as uveitic glaucoma. Presence of more than one mechanism for elevated IOP was labeled as mixed mechanism glaucoma.

Clinical parameters including pre-treatment and post-treatment best-corrected visual acuity (BCVA) and pre- and post-treatment IOP, recorded by applanation tonometer, slit-lamp and gonioscopy findings, and dilated fundus evaluation findings were also recorded. In cases where posterior segment was not visible at presentation due to anterior segment abnormalities, ultrasound (USG B-scan) findings were noted. In such cases, posterior segment findings were recorded once media cleared on subsequent follow-ups. All patients were started on topical AGM at the time of detection of elevated IOP. Data from only those eyes with a minimum follow-up of 3 months following the trauma were considered for analysis. Blood test for diagnosing sickle cell disease or trait was conducted in all patients with hyphema.

Statistical analysis

All continuous variables were described as mean ± standard deviation (SD) or median with interquartile range (IQR) and categorical variables were expressed as proportions. Group differences in continuous variables were analyzed using the Student's *t* test for normally distributed variables and the Mann–Whitney *U* test for non-parametric variables. Normality of distribution was tested using the Kolmogorov–Smirnov Konglomerat Smirnov test. Group differences in categorical variables were analyzed using the Chi-square or Fisher's exact test. Vision was measured in Snellen's equivalent and was converted to logarithm of minimum angle of resolution (logMAR) for statistical analysis. The magnitude of IOP drop following treatment was calculated as pre-treatment IOP–post-treatment IOP. Univariate and multivariable linear regression analysis was performed to determine factors predicting IOP drop and final BCVA at last follow up. Pearson's correlation coefficient was calculated to understand the relationship between pre- and post-treatment IOP.

Results

A total of 205 pediatric eyes presented with ocular trauma during the study period out of which 121 (59%) had CGI and the remaining 84 (41%) had OGI. Thirty-two (15.6%) eyes either presented with or developed elevated IOP needing treatment during follow-up period. Out of 32 eyes, 25 (78%) had CGI and remaining 7 (22%) had OGI. The incidence of elevated IOP following CGI (20.6%) was significantly higher than that following OGI (8.3%, $P = 0.02$). None of the eyes had developed disc damage till last follow-up visit. Reliable visual field evaluation was possible in only six eyes with last visit reports being normal in all these eyes.

The mean patient age was 10.25 ± 3.45 years [median = 1.5 years, intertquartile range (IQR) =5 years, range: 3–15 years] and 27 (84.4%) were boys. Time to presentation ranged from 2 h to 15 days with a median of 3 days (IQR = 4.5 days) with only 5 (15.7%) patients presenting within 24 h of trauma. Injury with a ball (n = 5, 16%) and firecracker injuries (n = 5, 16%) were the commonest causes of CGI while injury with stone (n = 3, 43%) and bow–arrow (n = 2, 29%) were the most common causes of OGI.

Ten (31.25%) eyes had elevated IOP at presentation, another 15 (46.63%) eyes developed elevated IOP within 1 month of trauma and 7 (23.12%) eyes after 1 month of trauma. The mean IOP at the time of diagnosis was 29.8 ± 6.3 mmHg (median = 28 mmHg, IQR = 7 mmHg, range = 22–47 mmHg). All eyes with CGI had contusion of the globe (n = 25) and those with OGI had penetrating injury (n = 7) requiring corneoscleral wound repair under general anesthesia at the time of presentation. Overall, 3 eyes (9%) had injury involving Zone 1, 19 (59%) had Zone 2 injury, and 10 (32%) had Zone 3 injury. At presentation, 12 eyes (37.5%) had hyphema out of which 2 eyes had re-bleeding and all these were in the CGI group. Additionally, 13 out of the 32 eyes (41%) developed cataract during the course of follow up and required cataract extraction with intraocular lens implantation. On gonioscopy, 6 eyes (19%) showed angle recession with all belonging to CGI group. All eyes with OGI had corneoscleral lacerations. Dilated evaluation showed that 9 eyes (28%) had posterior segment involvement in the form of choroidal rupture (n = 1), retinal detachment (n = 2), vitreous hemorrhage (n = 2), macular hole (n = 1), Berlin's edema (n = 1), traumatic optic neuropathy (n = 1), and one eye had endophthalmitis and retained intraocular foreign body (IOFB). Hyphema was the commonest cause of glaucoma (n = 10), followed by angle recession (n = 6), lens induced (n = 6), mixed mechanism (n = 5), pigmentary glaucoma (n = 3), and uveitic glaucoma (n = 2). More than 180° angle recession was seen in all eyes that developed angle-recession glaucoma. Two eyes with retinal detachment underwent scleral buckling and one eye underwent vitrectomy for IOFB removal.

The mean BCVA at presentation was 1.55 ± 0.6 logMAR with 20 eyes (62.5%) having BCVA of 1/60 or worse vision. Table 1 shows a comparison between demographics and baseline characteristics in eyes with OGI and CGI. Majority of elevated IOP in CGI was at presentation or within 1 month of trauma while in OGI it occurred after 1 month of trauma. There was no visible glaucomatous disc damage in either of the categories till last follow-up visits. Similarly, the mechanisms attributable to elevated IOP were significantly different in eyes with CGI and OGI [Table 1].

Medical management with topical AGM was sufficient to control IOP in 20 (62.5%) eyes while 12 (37.5%) eyes required

Table 1: Comparison of demographics and baseline characteristics in eyes with closed and open globe injury

Variable	Closed globe injury (*n*=25)	Open globe injury (*n*=7)	*P*
Age (in years) (mean±standard deviation)	10.3±3.4	9.8±3.7	0.74
Gender (% boys)	22 (88%)	5 (71%)	0.29
Zone of injury			
Zone 1	2 (8%)	1 (14%)	0.59
Zone 2	16 (64%)	3 (43%)	
Zone 3	7 (28%)	3 (43%)	
Time of presentation (in days)	5.4±4.1	3.3±2.7	0.33
Mean IOP (mmHg)	30.4±6.8	27.5±3.1	0.45
Time of glaucoma diagnosis			
At first presentation	10 (40%)	0	<0.001
<1 month of trauma	14 (56%)	1 (14%)	
>1 month of trauma	1 (4%)	6 (86%)	
Hyphema (%)	12 (48%)	0	0.04
Cataract (%)	12 (48%)	1 (14%)	0.12
Posterior segment (%)	6 (24%)	3 (43%)	0.33
Baseline BCVA (logMAR) (mean±standard deviation)	1.5±0.6	1.7±0.5	0.37
Causes of IOP elevation			
Hyphema	10 (40%)	0	<0.001
Angle recession	6 (24%)	0	
Lens induced	5 (20%)	1 (14%)	
Mixed mechanism	0	5 (72%)	
Pigmentary	3 (12%)	0	
Uveitic	0	1 (14%)	

IOP=Intraocular pressure, BCVA=Best-corrected visual acuity

surgical intervention in form of hyphema drainage (n = 2 eyes), trabeculectomy with mitomycin-C (n = 4 eyes), cataract surgery (n = 4 eyes), and combined cataract and trabeculectomy surgery (n = 2 eyes). Surgical management was considered in cases where IOP was >21 mmHg on two consecutive visits even with maximally tolerated medical therapy. Ahmed glaucoma valve (AGV) implantation was done in two eyes where IOP was not controlled even after trabeculectomy. The mean IOP at last follow up was 16.2 ± 2.2 mmHg (median = 16 mmHg, IQR = 4 mmHg, range = 12–20 mmHg) was significantly lower than IOP at time of diagnosis (P < 0.001, paired t test). The mean BCVA at last follow up was 0.8 ± 0.6 logMAR (median = 0.6 logMAR, IQR = 0.3–1.25 logMAR <range = 0–2 logMAR) and had significantly improved compared to baseline (P < 0.001, paired t test). Poorer final visual outcomes (BCVA of HM or less) were seen in more eyes with OGI (n = 4, 57.1%) as compared to CGI (n = 1, 4%) (P < 0.001). Similarly, 85.7% of OGI had BCVA of 6/12 or worse compared to 56% of CGI eyes (P < 0.001). Mean follow-up duration was 10.50 ± 8.51 months (median 7 months, IQR = 7.5 months, range = 3–36 months). Table 2 shows comparison of treatment and outcomes in eyes with CGI vs. OGI. Overall, CGI required more surgical maneuvers to control IOP compared to OGI, though this difference was not statistically significant. However, significantly more number of eyes with CGI required trabeculectomy for IOP control.

Univariate and multivariable linear regression analysis showed that eyes with OGI experienced greater IOP reduction than those with CGI, though this association was not statistically significant [Table 3]. Similarly, on splitting drop in IOP into two groups based on median, logistic regression did not identify any factors predictive of greater IOP drop (data not shown). Eyes with involvement of posterior segment and those with worse baseline vision were found to have poor vision in the postoperative period as well [Table 4]. Baseline vision was moderately correlated with final vision (Pearson's correlation coefficient = 0.42, P = 0.02). In both OGI and CGI, pre-op and post-op IOPs had linear positive correlation with correlation coefficient of 0.32 for CGI (P = 0.31) and 0.21 (P = 0.54) for OGI [Fig. 1].

Discussion

In this 5-year retrospective study from rural India, we found that elevated IOP occurred in 15% of eyes following ocular trauma in children and that the incidence was significantly more in eyes with CGI compared to those with OGI. Most children did not present on the day of trauma. Eyes with OGI developed elevated IOP much later in the course of follow up i.e. beyond 1 month, compared to CGI in whom the elevated IOP was noted within 1 month of trauma. The underlying mechanisms causing elevated IOP were different in eyes with CGI and OGI. Additionally, severity of disease also appears to be greater in eyes with CGI who required more surgical interventions and significantly more number of trabeculectomies. The final visual outcome in these traumatized pediatric eyes depends on baseline vision and involvement of the posterior segment during trauma Heralds' poor visual outcome.

An overall incidence of post-traumatic elevated IOP was approximately 15% in our study, with incidence being significantly higher in eyes with CGI than with OGI. Though

Table 2: Comparison of treatment and outcomes in eyes with CGI vs. OGI

Variable	Closed globe injury (*n*=25)	Open globe injury (*n*=7)	*P*
Surgical management	11 (44%)	1 (14%)	0.16
Type of surgery			
AC wash	2 (8%)	0	0.44
Cataract extraction	12 (48%)	1 (14%)	0.12
Trabeculectomy±mitomycin-C	6 (24%)	0	0.03
Drainage implant (Ahmed glaucoma valve)	2 (8%)	0	0.44
Final IOP (mmHg)	16.3±2.4	15.6±1.8	0.44
Final BCVA	0.75±0.6	10.4±0.7	0.27
Follow-up duration (months)	10.3±7.9	11.3±11.4	0.89

AC=Anterior chamber, IOP=Intraocular pressure, BCVA=Best-corrected visual acuity, CGI=Closed globe injury, OGI=Open globe injury

Table 3: Univariate and multivariable linear regression analysis of factors predictive of IOP drop at final follow up

Variable	Interval	Univariate analysis			Multivariable analysis		
		β coeff	95% CI	*P*	β coeff	95% CI	*P*
Age	1 year increment	–0.03	–0.6 to 0.5	0.92	-	-	-
Gender	Male vs. female	–4.1	–9.6 to 1.4	0.14	-	-	-
Trauma	CGI vs. OGI	–2.12	–7.1 to 2.8	0.39	3.24	–6.2 to 12.2	0.48
Zone	Vs. Zone 1	0.56	–2.9 to 4.1	0.75	0.36	–3.4 to 4.2	0.84
Baseline BCVA	0.1 logMAR increment	0.90	–2.5 to 4.4	0.60	2.26	–2.1 to 6.6	0.30
Angle recession	Vs. no recession	4.32	–0.8 to 9.4	0.09	4.76	–5.2 to 14.7	0.34
Surgery	Vs. medical treatment	1.88	–2.3 to 6.2	0.37	1.56	–3.1 to 6.2	0.50
Timing of glaucoma	Vs. at presentation	–1.08	–3.9 to 1.8	0.45	–2.06	–6.9 to 2.8	0.39

BCVA=Best-corrected visual acuity, CGI=Closed globe injury, OGI=Open globe injury

Table 4: Univariate and multivariable linear regression analysis of factors predictive of BCVA at final follow up

Variable	Interval	Univariate analysis			Multivariable analysis		
		β coeff	95% CI	*P*	β coeff	95% CI	*P*
Age	1 year increment	–0.06	–0.2 to 0.03	0.6	-	-	-
Gender	Male vs. female	0.29	–0.4 to 0.9	0.37	-	-	-
Trauma	CGI vs. OGI	0.29	–0.3 to 0.8	0.31	0.11	–0.3 to 0.5	0.55
Zone	Vs. Zone 1	0.71	0.41-1.0	0.001	0.15	–0.3 to 0.5	0.48
Baseline BCVA	0.1 logMAR increment	0.59	0.25-0.92	0.001	0.31	0.02-0.6	0.03
Baseline IOP	1 mmHg increment	0.02	–0.1 to 0.1	0.24	-	-	-
Final IOP	1 mmHg increment	0.01	–0.1 to 0.1	0.28	-	-	-
Angle recession	Vs. no recession	0.65	0.09-1.2	0.02	0.29	–0.1 to 0.7	0.17
Post segment	Vs. no involvement	1.02	0.65-1.3	<0.001	0.67	0.1-1.25	0.025
Surgical treatment	Vs. medical treatment	0.29	–0.2 to 0.7	0.22	-	-	-

BCVA=Best-corrected visual acuity, CGI=Closed globe injury, OGI=Open globe injury, IOP=Intraocular pressure

trauma accounts for 5.6%–30% of all secondary glaucomas in pediatric age group, the incidence of glaucoma following pediatric ocular trauma is not well reported.[10–12] Previous cohort studies done on the general population in the USA shows much lower incidences (3%–5%) of post-traumatic glaucoma, though these studies were not restricted to pediatric population.[13,14] Additionally, our data also shows that elevated IOP following CGI develops much earlier and is more severe, difficult to treat, and requires more surgical interventions to control IOP than eyes with OGI. This may be explained by the different mechanisms leading to elevated IOP in different types of trauma. In CGI, there is greater risk of angle recession, mechanical damage to the trabecular meshwork, trabecular obstruction due to hyphema, and pigment dispersion, whereas in OGI, elevated IOP may be multifactorial such as lens trauma, subluxation, and traumatic uveitis without direct insult to the trabecular meshwork. This also explains why IOP elevation occurs much later in eyes with OGI than CGI and why greater proportion of eyes with CGI requires surgical intervention for IOP control.

Our patients sustained ocular trauma predominantly related to outdoor activities and sports. Gulli-danda is a traditional game played by boys in rural parts of India wherein

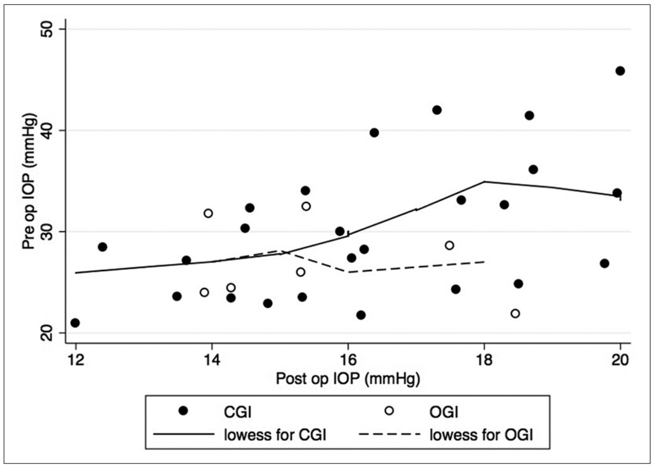

Figure 1: Scatter plot with LOWESS curve showing correlation between pre-treatment and post-treatment intraocular pressure in eyes with closed and open globe injury

Figure 2: "Gulli-danda" – small wooden projectile "gulli" and wooden stick "danda"

a small wooden projectile "gulli" is struck by a wooden stick "danda" [Fig. 2]. This projectile is required to be caught by bare hands as part of the game. During this game there is a risk of facial and ocular injury. Similar mechanisms occur while playing cricket, another popular sport amongst boys in India, wherein the rubber or tennis ball may hit the eye or face causing contusions, hyphema, and angle recession. A recent study reported an incidence of 18% of angle recession following cricket ball injury.[15] Even in our series, projectiles like cricket ball, gulli-danda, and stone accounted for 45% of injuries leading to glaucoma. Rural and tribal children also play with bow–arrow, which along with stone, resulted in 71.5% of OGI. Similar causes were found in other studies of pediatric trauma in India.[16–19]

Studies by Fung *et al*. and Kaur *et al*. have reported control of IOP with medical management in 86.7% cases and 58.3% cases, respectively.[6,10] We found that medical management worked well for elevated IOP post-OGI but almost half of eyes with CGI eventually required surgery to control IOP. Ozer *et al*., in a study from adult eyes, have reported factors associated with need for glaucoma surgery like hyphema, corneal injury, poor visual acuity, penetrating injuries, and optic atrophy.[20] In our series, only two eyes (20%) with hyphema required drainage while the rest could be managed medically.

We found that final visual recovery was mainly dependent on extent of posterior segment involvement and eyes with vitreoretinal complications tended to have poor visual outcome. Though, we found OGI to be associated with poorer visual outcome, this was not significant in multivariable analysis, suggesting that the greater posterior segment involvement in OGI eyes was the main driver of the visual outcome rather than the OGI itself.

Parents should be made aware of the various risk factors and long-term complications of childhood trauma including glaucoma. Children should be supervised while playing outdoor games in our settings and encouraged to wear safety goggles or sports helmets with eye cover, while playing, to protect themselves from various types of projectiles. Urgency in seeking treatment, even after minor trauma, should be strongly advocated. Undiagnosed glaucoma can result in permanent visual disability.

The retrospective nature and relatively small sample size are the main limitations of our study. Lack of serial fundus photographs and visual field testing were attempted but were not uniformly possible due to lack of patient cooperation.

Conclusion

In conclusion, glaucoma is an important cause of ocular morbidity following pediatric ocular trauma. Though CGI was a dominant cause of post-traumatic elevated IOP in pediatric eyes, OGI is also associated with late onset IOP elevations and requires careful follow up. Medical management is successful in controlling IOP in about two-third cases while the remaining requires surgery to achieve IOP control. Visual recovery depends on co-existent vitreoretinal injury which heralds poor visual outcome.

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Conflicts of interest

There are no conflicts of interest.

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