Graefe's Arch Clin Exp Ophthalmol (2000)
238:420–426

CLINICAL INVESTIGATION

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Open globe injuries in children

Received: 7 July 1999
Revised: 6 October 1999
Accepted: 5 November 1999

This paper was presented in part at the 96th Annual Meeting of the German Ophthalmological Society (DOG) in Berlin, September 1998

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Abstract *Background:* Eye injuries are the leading cause of monocular blindness in children. At present, however, only limited follow-up studies exist. *Methods:* The files of 38 consecutive patients aged 16 years or younger who had been treated for open globe injuries were examined. The type of injury was classified and the severity of injury was categorized in four grades. *Results:* Our series included 5 eyes (13%) with a rupture, 30 (79%) with a penetrating and 3 (8%) with a perforating injury. Follow-up varied from 3 days to 7 years (mean 15.5 months). The macula was attached at the last follow-up in all eyes. The final visual acuity ranged between 1.0 and light projection. In 47% of cases (18 eyes), the visual acuity was ≥0.5; 74% (28 eyes) achieved at least 0.1. Eighteen of 38 eyes (47%) had severe injury with posterior segment involvement. Visual acuity of at least 0.5 was achieved in 44% (8/18) of these. Eyes with grade 2–4 injury treated with early vitrectomy had a final visual acuity of ≥0.5 in 58% of cases (7/13). Twenty-one (55%) of 38 children were ≤8 years of age and eight of them (38%) had a final visual acuity of ≥0.5. *Conclusion:* Salvage of the eye with an attached macula was possible in all eyes. Even in severely injured eyes good visual acuity can be established in about 50% of cases.

Introduction

Eye injuries are the leading cause of monocular visual disability and monocular blindness in children [28, 33, 45]. Several large studies investigating the epidemiology of trauma in children have been published [1, 24, 27, 32, 39, 43]. Klopfer et al. [23] and Strahlman et al. [44] reported an average annual hospitalization rate of children with the diagnosis of ocular trauma of 15.2–15.8 per 100,000 in the USA. The rate of 29.1 per 100,000 per year was observed for patients of all ages with ocular trauma. Of all penetrating eye injuries, 27–48% affect children [12, 13, 25, 33, 34, 42, 43]. Thus, children represent a disproportionately large percentage of total ocular trauma.

The causes of pediatric ocular trauma include accidental injuries by the hand or foot of another child (12%) [30] or accidental blows and falls (37%) [39]. Sports and recreational activities account for up to 59% of all eye injuries in children [2, 32, 35, 44].

Preoperative evaluation of children is often hindered by inadequate history and poor patient cooperation during the physical examination. In addition, follow-up is often short, particular in eyes with less severe injuries. Difficulties in the examination of young children persist during the follow-up period. Consequently, there are only limited studies regarding the anatomical and functional outcome following eye injury in children.

Complex open globe injuries lead to vitreous hemorrhage and retinal detachment. Complications of infantile vitreous hemorrhage include tractional retinal detachment and occlusion amblyopia [18]. Furthermore, children may develop more extensive postoperative inflammation, scarring, and proliferative vitreoretinopathy (PVR) than adults [19, 30, 40].

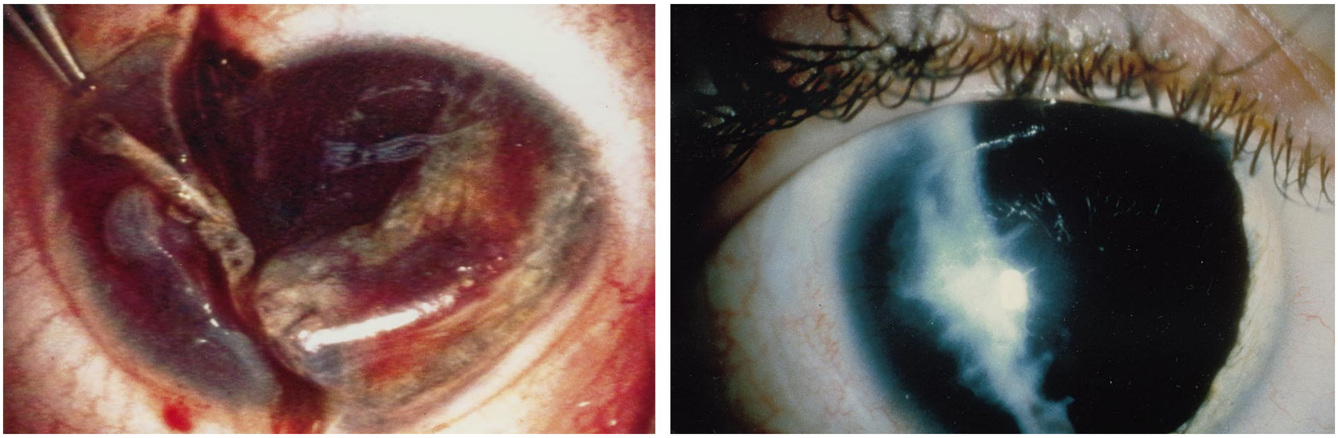

Fig. 1 The preoperative photo (*left*) of an 8-year-old boy shows a grade 4 injury with a cornea-sclera rupture extending 7 mm posterior of the limbus. During surgery we found additional lens loss, vitreous incarceration and retinal detachment. The patient underwent primary vitrectomy and silicone oil tamponade. The silicone oil was removed 5 weeks later. After 3 years' follow-up the visual acuity was 0.9 with a contact lens (*right*)

The purpose of this consecutive retrospective study was to analyze the causes, the types, and the severity of open globe injuries in children and compare these with the visual outcome achieved following surgery, especially early vitrectomy in complex injuries.

Patients and methods

The surgical records of the University Eye Hospital Benjamin Franklin for the period from January 1990 to September 1998 were reviewed for consecutive patients aged 16 years or younger who had undergone primary repair of an open globe injury or secondary surgery within 7 days after trauma. The patients' age and gender, the cause, type and severity of injury, and the past ocular history were determined from each patient's record.

The type of injury was classified, according to Kuhn et al. [24], as penetration, perforation, or rupture. The location of the eye injury was noted and the severity of injury was classified according to Eagling [14] in grades 1–4 (Table 3). Data regarding the anatomical and functional status of the eye before initial repair of the wound were obtained from the findings recorded during the initial examination or at the time of surgery. Follow-up data were obtained at regular postoperative intervals at 4–6 weeks and at 3, 6, and 12 months.

Postoperative treatment consisted of a combination of local antibiotics and steroids 3–5 times per day in all cases. In injuries graded 2–4, additional systemic antibiotics were given for 7–10 days.

Results

A total number of 38 patients aged 2–16 years with open globe injuries was examined over the above-mentioned 8-year period; of these 31 were boys and 7 were girls. The average age at the time of surgery was 8.7±4.4 years. Twenty-one patients were under the age of 9 years. The duration of follow-up ranged from 3 days to 7 years, with a mean of 15.5 months. Data on discharge only were available for five children who did not attend the scheduled follow-up appointment. No patient in this series had bilateral injuries. The distribution of ocular injuries did not vary greatly with age (Table 1). The causes of injury are summarized in Table 2. The most common causes of laceration eye injuries were darts, glass and knives.

In nine eyes, the injury was limited to the cornea or anterior sclera (grade 1). Wounds to the anterior segment

Table 1 Age distribution of children with open globe injury

Age (years)	n	%
2	3	7.9
3	3	7.9
4	2	0.3
5	6	15.8
6	1	2.6
7	3	7.9
8	3	7.9
9	2	5.3
10	4	10.5
11	2	5.3
12	2	5.3
13	2	5.3
14	1	2.6
15	1	2.6
16	3	7.9

Table 2 Causes of ocular injury (*n*=38)

	n	%
Dart, Nail	7	18.4
Glass	6	15.8
Knife	6	15.8
Stick, Blow	5	13.2
Pencil	2	5.3
Toy	3	7.9
Projectile	1	2.6
Miscellaneous	5	13.2
Unknown	3	7.9

Table 3 Visual outcome and severity of injury (n=38)

Extent of injury	*n*	Visual acuity	
		≥0.5	≥0.1
Grade 1: Cornea with or without uveal prolapse	9	4 (44%)	8 (89%)
Grade 2: Cornea plus lens damage	11	6 (55%)	7 (64%)
Grade 3: Posterior segment injury with vitreous loss	7	4 (57%)	7 (100%)
Grade 4: Extensive anterior and posterior injury	11	4 (36%)	6 (55%)

Table 4 Operative techniques

	n
Primary surgery	38
Primary closure	all
Vitrectomy+SF6	1 (2.6%)
Lentectomy	5 (13.1%)
Vitrectomy+SF6+pars plana lentectomy	2 (5.2%)
Vitrectomy+silicone oil	1 (2.6%)
Secondary surgery	19
Vitrectomy+SF6	2 (10.5%)
Re-vitrectomy+silicone oil	1 (5.3%)
Vitrectomy+SF6+pars plana lentectomy	6 (31.6%)
Vitrectomy+silicone oil+pars plana lentectomy	4 (21.1%)
Vitrectomy+silicone oil+pars plana lentectomy+encircling band	1 (5.3%)
Lentectomy	3 (15.8%)
Laser/Cryocoagulation of a foramina	2 (10.5%)
Tertiary surgery	9
Re-vitrectomy (silicone oil removal+SF6)	2 (22.2%)
Silicone oil removal	2 (22.2%)
Re-vitrectomy (silicone oil removal and repeated tamponade)	1 (11.1%)
Re-vitrectomy+SF6	1 (11.1%)
Episcleral sponge+cryocoagulation	1 (11.1%)
Lasercoagulation of a foramen	1 (11.1%)
Secondary IOL implantation	1 (11.1%)
Quaternary surgery	1
Re-vitrectomy+silicone oil (repeated)	1

which also involved the lens were seen in 11 eyes (grade 2). Injuries involving the posterior segment with vitreous loss were observed in seven eyes (grade 3). More extensive injuries involving the anterior and posterior segment with lens damage and vitreous loss (grade 4) occurred in 11 eyes (Table 3).

A rupture due to a blunt object was present in five eyes. All other eyes had a laceration injury. Penetrating eye injuries without an intraocular foreign body were the most frequent type, occurring in 27 eyes. Three additional eyes with penetrating injuries retained a foreign body. A perforating injury with two full-thickness lacerations of the eye wall was observed in three eyes.

Operation techniques used are listed in Table 4. The primary wound was closed on the day of injury in all eyes. During the initial procedure, a primary vitrectomy with 25–30% sulfur hexafluoride gas-air mixture (SF6) (*n*=4) or silicone oil (*n*=1) was additionally performed. In five eyes, a lentectomy with approach from the anterior chamber was performed. In 14 eyes a second operation was necessary: vitrectomy with SF6 (*n*=9) or silicone oil (*n*=3), combined in most cases with a lentectomy. One revitrectomy was performed with silicone oil tamponade 26 days after the primary operation. In three children only the lens was removed. In a third operation, a revitrectomy was carried out in four eyes (15, 196, 236 and 613 days after the second operation). Silicone oil removal was undertaken in two eyes. Due to a peripheral retinal detachment, an episcleral sponge with cryocoagulation of the break was performed in one eye. Laser treatment of a retinal break was carried out in one patient. In one child a fourth operation, vitrectomy with silicone oil, was performed due to recurrent retinal tractional detachment. We used silicone oil in cases with grade 4 injury and/or severe tractional retinal detachment.

Anatomical results

The macula was attached at the last follow-up examination in all eyes. Three eyes had a partial peripheral detachment in the inferior half of the eye. During follow-up five children developed PVR, which required further surgery.

Functional results

At the final visit, one patient could see light only and the best visual acuity was hand movement (HM) in four patients. Twenty-eight of 38 eyes (74%) achieved visual acuity of ≥0.1 and 18/38 (47%) of ≥0.5. Visual outcome in relation to the grade of injuries is shown in Table 3. There was no statistically difference regarding visual outcome between different grades of injuries. The poor visual outcome in grade 1 injuries of lesser severity is due to the very short follow-up period (3 days to 22.2 months, mean 6.8 months). Most of these children were discharged within 24 h of operation. In contrast, children with aphakia were followed very closely over a long period. The mean duration of follow-up with grade 2 injuries was 30 months and with grade 4 injuries, 15 months. Visual acuity in grade 2 injuries was in 7 of 11 eyes (64%) at least 0.1 and in 6 of 11 (55%) at least 0.5. In the most severe injuries (grade 4), final visual acuity ≥0.1 was achieved in 6 of 11 eyes (55%) and 0.5 or better in 4 of 11 (36%).

Table 5 shows the relationship between the type of injury and the final visual acuity. In our series, 23 of 30 eyes (77%) with a penetrating injury achieved a visual acuity of ≥0.1 and 15 of 30 (50%), ≥0.5. One of the three eyes with a perforating injury had only light projection (LP) and a second one achieved visual acuity of HM. The third eye with perforating injury obtained visual acuity of 0.6. Only five eyes had a rupture. All of these had a visual acuity ≥0.1 and 3 of them, ≥0.9. The numbers of the different types of injury are too small for meaningful statistical comparison.

The visual outcome appears worse for children under 9 years of age, due to amblyopia, despite attempts to reverse this with „patching“. Due to the non-compliance, only 8 (38%) of 21 children under the age of 9 years achieved visual acuity of ≥0.5. Older children obtained visual acuity of 0.5 or better in 11 of 17 cases (65%). Four (36%) of the 11 children with aphakia and younger than 9 years of age achieved a visual outcome of ≥0.5. In contrast, 7/11 (64%) children aged between 9 and 16 years with aphakia had final visual acuity of ≥0.5. The difference between these groups was, due to the small numbers, not statistically significant.

Twenty-four of the 38 children had a recorded initial visual acuity (Table 6). The other children were too young or their compliance too poor to obtain a reliable result. Final visual acuity was however available in all cases. Seventeen children (70.8%) presented with an initial visual acuity of HM or LM. Forty-seven percent of the patients with poor initial visual acuity recovered vision of 0.5 or better, and 76% achieved at least 0.1.

During the primary repair, vitrectomy was performed in four eyes. In nine eyes an additional vitrectomy was conducted within the first 2 weeks after primary wound closure. Eyes with grade 2–4 injuries that underwent vitrectomy, showed a tendency towards better visual outcome than those without. In eyes with vitrectomy, 7 of 13 (54%) achieved a visual acuity ≥0.5, compared to 7 of 17 eyes (41%) without vitrectomy. Silicone oil was used in six eyes and could be removed in four eyes at a later date. One of these eyes developed a tractional redetachment and required repeated silicone oil tamponade. One of the other two children with silicone oil had a follow-up of 4 months only, and the remaining child had a peripheral tractional retinal detachment and was non-compliant.

Table 5 Visual outcome and type of injury (n=38)

Injury type	*n*	Visual acuity	
		≥0.5	≥0.1
Penetrating	27	13 (48%)	20 (74%)
Intraocular foreign body	3	2 (67%)	3 (100%)
Perforating	3	1 (67%)	1 (34%)
Rupture	5	3 (60%)	5 (100%)

Table 6 Comparison of initial and final visual acuity in 24 of 38 patients

Initial visual acuity	Final Visual Acuity				Totals
	1.0 to 0.5	0.4 to 0.1	0.05 to 0.025	HM to LP	
1.0–0.5	1				1
0.4–0.1		1			1
0.05 to 0.025	4	1			5
HM to LP	8	5	1	3	17
Total	13	6	1	3	23

Discussion

Traumatic ocular injuries often cause significant visual loss in young patients, as well as in adults, and are a leading cause of noncongenital unilateral blindness in children [28, 31, 33, 43, 45]. Recent advances in therapeutic methods, including microsurgical techniques such as vitrectomy with perfluorocarbon liquids, permit better management of injured eyes [11, 38].

Table 7 Final visual acuity/anatomic status in published series of the use of vitrectomy in the repair of pediatric trauma related retinal detachments (*NR* data not reported)

Study	No. of eyes	Visual acuity		Macula attached
		≥0.1	≥0.025	
Ferrone et al. [19]	14	NR	NR	3 (21%)
Moisseeiev et al. [30]	11	0	0	1 (9%)
Rodriguez and Lewis [36]	10	NR	2 (20%)	2 (20%)
Scott et al. [40]	102	12 (12%)	19 (19%)	71 (70%)
Present study	13	9 (69%)	10 (77%)	13 (100%)

The reported boy-to-girl ratio in traumatic ocular injuries in the literature is 4:1 [3, 8, 25, 30, 33, 34]. A similar ratio was found in the current investigation. Age at the time of injury was, in this study, evenly distributed.

In agreement with other investigations [21, 28, 34, 43] of ocular trauma in children, penetrating injuries due to sharp objects were more common than injuries due to rupture: penetrating injuries accounted for 79% of cases (30/38), and injuries were due to rupture in 13% (5/38). This contrasts somewhat with the types of injuries encountered in adults, in whom blunt injuries are more frequent than in children [12] (28% vs 14%).

Rudd et al. [37] reported 46 children with traumatically ruptured globes and injuries of varying severity. Sixteen (34%) of them had final visual acuity of ≥0.4. Four eyes were enucleated and 11 had visual acuity varying form light perception to 0.05. Sternberg et al. [43] correlated injuries from blunt trauma with an unfavorable (<0.025) visual prognosis. In our series, all eyes could be saved, i.e., none were enucleated. Three of five children with a ruptured globe achieved a visual outcome of ≥0.9. The other two eyes achieved visual acuity of 0.1.

Final visual acuity of ≥0.5 was reported in grade 2 injuries (anterior damage with lens loss) in 71% of patients by Elder [16], in 32% by Niiranen and Raivio [33], and in 27% of patients by Patel [34]. In injuries with anterior and posterior segment involvement (grade 4), final visual acuity of at least 0.5 could be achieved in 6–17% of cases [8, 16, 17, 33, 34]. Compared to these studies the present study resulted in a final visual outcome of ≥0.5 in 55% of cases with grade 2 injuries and in 36% with grade 4 injuries.

Sternberg et al. [43] listed five factors associated with an unfavorable visual prognosis. One of these was an initial vision less than 0.025. In contrast, Rudd et al. [37] found that the initial vision was a less reliable predictor of final visual outcome. In this study, only 3 (18.7%) of 17 children with poor initial vision (HM to LP) had an unfavorable visual outcome.

Many studies in adults have shown that the most common cause of an unsuccessful outcome of retinal surgery following trauma is the development of PVR. An important factor in the development of PVR is the time between the injury and surgical repair [33]. PVR related to trauma occurs as early as 2 weeks after injury and starts in 40–100% of cases at the wound itself and can lead to subretinal strands [22]. Some authors [5, 34, 38] have suggested early pars plana vitrectomy for adult patients with penetrating injury when the posterior segment is involved. In severely traumatized eyes that underwent early (within 14 days) vitrectomy, a better final visual outcome and anatomical result were observed than in those eyes that underwent later vitrectomy [6, 26, 29]. A pronounced proliferative response was frequently seen in children, leading to recurrent membrane formation and retinal traction [19, 30, 40].

In contrast to adults, studies in children undergoing vitrectomy shows disappointing results [19, 30, 36] (Table 7). Moisseiev et al. [30] reported final retinal attachment in 1 of 11. Ferrone et al. [19] found a 35% reattachment rate. In the latter study, postoperative visual acuity of finger counting or better was observed in only 17% of patients. Scott et al. [40] reported a 70% reattachment rate, but the functional success rates were lower, and final visual acuity of ≥0.1 was achieved in only 12% of cases. In the current study the macula could be reattached in all eyes, and 75% of eyes with vitrectomy achieved visual acuity of ≥0.1 and 58% of at least 0.5. In previously published series [19, 30] all eyes underwent one or more surgical procedures before silicone oil injection. Their disappointing anatomical results may be related to the more aggressive scarring due to a longer period before vitrectomy was performed. Early vitrectomy (within 2 weeks) with removal of tractions to the wound and the scaffold for vitreoretinal proliferation could be predictive for the better anatomical results in the current study.

We used silicone oil in cases with grade 4 injury and/or severe tractional retinal detachment. Only five of our children developed PVR. In these children, there was no difference regarding functional outcome between the eyes with and those without early vitrectomy. Too few eyes in this series underwent vitreous surgery, however, to permit final comparison to similar cases managed by conventional techniques.

A particular problem in children with ocular trauma is the development of amblyopia in the injured eye. The younger the child at the time of visual deprivation, the faster amblyopia develops [41]. Children under the age of 8 years are at particular risk from open globe injuries.

One concern in children with open globe injuries is the development of occlusion amblyopia prior to surgery.

The current study showed, in cases with complex injuries, better visual results than other series [19, 30, 36, 40] (Table 7). This may be due to the performance of early vitrectomy, removing amblyogenic factors such as cataract, vitreous hemorrhage, and retinal detachment [18, 20].

Young children with additional lens involvement have a far worse postoperative prognosis due to the problems of correcting aphakia and of compliance [10, 14, 16]. Baxter et al. [3] reported that despite advances in contact lens material and improved surgical instrumentation, only a slight improvement in the visual outcome was observed. Contact lenses were found to have a very low acceptance rate in children under 8 years, accounting for the relatively poor results. They found that only 55% of patients achieved visual acuity of 0.3 or better. In the present study, we found similar problems with nine children under 9 years of age. Despite immediate contact lens correction and „patching," final visual acuity of ≥0.5 could be obtained in only 44% of cases.

Intraocular lenses were not implant in our cases, but other authors have done this [3, 7, 46]. They found a risk of severe uveitis after implantation. The visual acuity corrected with lens implantation in trauma cases was described to be just as poor as with contact lenses [3]. Zwaan et al. [46] observed a higher incidence of iris capture, synechiae, and IOL dislocation in trauma eyes than in cataracts of different etiology. Eckstein et al. [15] found a rapid capsular opacification in young children after extracapsular cataract extraction. In 92% of cases further intervention was required within 3 years of follow-up. Amblyopia was the most frequent cause of low visual acuity following IOL implantation. Churchill et al. [9] reported similar visual acuity in eyes with and without IOL implantation after traumatic unilateral cataract. In contrast, Benezra et al. [4] found a best corrected visual acuity of 0.5 in 65% of eyes with IOL implantation and in 35% of eyes with contact lens correction. IOL implantation was not performed in the present study because of the risk of uveitis, capsular opacification, and after-cataract.

In conclusion, immediate treatment with modern surgical techniques allows salvage of the eye with an attached retina in the most severely injured eyes of children. If additional treatment is necessary it should be performed within 2 weeks of initial wound closure. Early vitrectomy can reduce the incidence of severe complications such as occlusion amblyopia and tractional retinal detachment. In the case of severe injuries, the present study indicates that in the pediatric population, as in adults, early vitrectomy should be a standard option in the care of complex open globe injuries.

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