The epidemiology of traumatic open globe injuries in children: an overview of the last 21-years in a tertiary hospital in the Netherlands

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Introduction: Pediatric open globe injuries are an important cause of non-congenital monocular visual acuity loss in children. In young children, who are still in their visual development, amblyopia is of great concern. Predicting the final visual outcome is important for proper counselling and management. The aim of this retrospective study is to investigate the epidemiology, aetiology, and the final visual acuity of traumatic open-globe injuries in children in a tertiary referral centre in the Netherlands. Secondly, potential factors for a poor final vision will be examined.
Design: Retrospective cohort study
Methods: Medical data of 45 children with open globe injuries who visited the UMC Utrecht between 2000 and 2021 where reviewed. Data was analysed and compared between patients with a final vision of ≥6/12 and patients with a final vision <6/12. Also, children in the amblyopic age group were analysed separately.
Results: The median age was 7.5 years (range:1.5-18). Metal was the most prevalent type of material (36%). Involvement of the lens, iris and vitreous body were found to significant for a final vision of <6/12 (p=0.015, p=0.022, p=0.008). Endophthalmitis occurred in only one (2%) eye and a total of four (9%) eyes became non-functional. The most frequent secondary development were astigmatism (80%), and traumatic cataract (67%). A total of 22 (49%) eyes had a vision >6/12 of which 11 (55%) were of amblyopic age at trauma. The lens status showed to be significantly associated with the visual outcome (p=0.012).
Conclusion: Our study is the first to explore pediatric open globe injuries in the Netherlands. The nature of the trauma and the anatomical structures involved have a major influence on the final vision. In addition, the preservation of one's own lens makes for a better visual prognosis. About half of the children end up with a vision of less than 6/12, larger prospective research is needed. So that ultimately fewer children are left with an impaired vision.

Introduction

Worldwide, ocular trauma is an important cause of non-congenital monocular visual acuity loss and blindness in children.[1,2] When a trauma causes a full-thickness defect of the eyeball, this is called an open-globe injury.[3] Open-globe injuries peak in the 5-24 age group and above the 70 years age group.[1] Since the first seven years of life are crucial for visual development, open-globe injuries at a young age can cause serious and permanent visual damage. Which also affects their quality of life.[4,5,6] In young children, sharp objects are often the cause of these injuries.[2]

Current treatment consists of surgical repair, but despite adequate treatment the final visual acuity remains poor.[5] In industrialized countries, approximately 45% of the children remain with a permanent visual acuity of 6/12 or less.[7] Similar to adults, traumatic cataract, corneal scarring, and retinal detachment are vision-limiting complications in pediatric open globe injuries.[8] However, posttraumatic endophthalmitis has a higher incidence among children compared to adults. In addition, amblyopia is of serious concern due to the often long duration of visual rehabilitation and therapy after an open globe injury. Children under the age of seven are particularly at risk.[7,9]

For proper counselling and management of expectations, predicting the final visual acuity remains of great importance. The toddler and pediatric ocular trauma scores (TOTS and POTS), attempt this prediction based on findings at presentation. Unfortunately, they are based on small studies and are not yet widely used.[10-12]

Previous studies have described prognostic variables for visual acuity. However, these results are conflicting and not examined for the Dutch population.[5,13-16] To this day, no research has been published on pediatric open-globe injuries in the Netherlands. The aim of this retrospective study is to investigate the epidemiology, aetiology, and the final visual acuity of traumatic open-globe injuries in children in a tertiary referral centre in the Netherlands. Secondly, potential factors for a poor final vision will be examined.

Methods

Patient selection

All patients who had an open globe injury at childhood age (≤18) between January 2000 and December 2021, with a minimal follow-up of one month were included. All of the patients were evaluated by an orthoptist and ophthalmologist at the University Medical Centre Utrecht (UMCU) in the Netherlands. All data was reviewed anonymously between April and June of 2022.

Clinical characteristics

For each patient the following patient characteristics were documented: gender, years of follow-up, age at trauma, and ophthalmic medical history. Also, the trauma characteristics were noted as follows: object of trauma, material of object (glass, metal, wood, plastic and other), side affected eye, and time to first operation categorized in <48 hours and >48 hours. Ocular findings were collected, including: the presence of an intraocular foreign body (IOFB), the presence of a shallow anterior chamber and involvement of the lens, iris and vitreous body at first presentation. The Ocular Trauma Classification group was used to classify wound locations.[3] Zone 1 injuries were limited to the cornea and limbus, zone 2 injuries were limited to the anterior 5 mm from the limbus (not extending into the retina), and zone 3 injuries were more than 5 mm from the limbus and extended to the posterior. When all zones were involved, this was described as a separate group, ''all zones''. Post-operatively the following was noted: time to stitch removal, total number of surgeries needed during follow-up. If an eye was enucleated, eviscerated or phthisis occurred, this was referred to as non-functional.

Table 1: Objects

	N
Potato peeler	2
Bed corner	1
Book	1
Eyeglass	2
Diadem	1
Glass	5
Curtain rails	1
Hockey stick	1
Cats nail	1
Lego	1
Metal splinter	1
Metal plate	1
Palm leaf	1
Arrow – wood	3
Arrow – plastic	1
Pencil	1
Pin	1
Rubber strap	1
Scissors	4
Screw driver	2
Keys	2
Pliers	2
Wooden splinter	1
Branch	4
Fork	1
Fireworks	1
Unknown	3

Secondary development

During follow-up the development of the following complications was noted; traumatic cataract, astigmatism, endophthalmitis, glaucoma, retinal detachment (RD), vitreous haemorrhage. Also, the need for a penetrating keratoplasty (PKP) and the final lens status (phakia, aphakia, pseudophakia), were reported. For children under the age of seven, type of amblyopic treatment was noted (occlusion, contact lens or scleral lens). If an eye was non-functional directly on start follow-up, it was excluded for the analysis of post-trauma development.

Final visual acuity

For the affected eye the last measured best-corrected visual acuity (BCVA) at a regular in-hospital visit was noted. Also noted was the final refraction. The WHO criteria were used to classify the visual impairment as mild (<6/12), moderate (<6/18), severe (< 6/60), blindness (< 3/60).[17] Since children under the age of seven are still in their visual development, patients will be stratified for age at trauma ''<7 years'' and ''≥7 years'' in regards to their final visual outcome. A patients final BCVA was further stratified into a binomial outcome variable of either a BCVA of ≥6/12 or a BCVA of <6/12. Also, the amblyopic age group (<7 years) will be analysed separately and also be stratified into ''≥6/12'' and ''<6/12''.

Statistical analysis

For statistical analysis, SPSS version 26.0.0.1 was utilized. Descriptive statistics, frequencies and percentage, median, and range were reported. Due to the small sample size and therefore uncertainty of a normal variation, we used a non-parametric test. The Fisher's exact test was used to compare data between categorical variables, and the Mann-Whitney U test was used if the variables were continuous. A p-value below 0.050 was regarded as statistically significant.

Results

49 cases of pediatric open globe injury were identified. Hereafter, four patients were excluded, due to short follow-up (n=1), no available data (n=2), and one case appeared a re-trauma which had been treated elsewhere. A total of 45 patients were included and analysed.

Table 2: Baseline		
	All patients	
	N	**%**
Total	45	
Male	28	62
Age at trauma, median (range)	7.5 (1.5-18.0)	
Amblyopic age (<7years)	22	49
Follow-up years, median (range)	2.3 (0.25-22.0)	
OD	21	47
Material		
- Glass	8	18
- Metal	16	36
- Wood	7	16
- Plastic	2	4
- Other	12	27
Time to OR ≥ 48h	4	9
Ocular findings		
IOFB present	5	11
Shallow anterior chamber**	19	42
Zone of injury*		
- Zone 1	26	58
- Zone 2	9	20
- Zone 3	2	4
- All zones	7	16
Involvement		
- Lens	22	49
- Iris*	37	82
- Vitreous body*	15	33
Post-operative		
Stitch removal months, median (range)***	3.1 (0,7-8,7)	
Total number operations, median (range)	2 (1-10)	
Non-functional eyes	4	9
- Direct	2	4
Secondary development ¤		
Endophthalmitis	1	2
Cataract	30	67
Glaucoma	6	13
Astigmatism****	36	80
Retinal detachment (RD)	7	16
Vitreous hemorrhage	3	7
PKP	2	5
Lens status**		
Phakia	17	38
Aphakia	16	36
Pseudophakia	8	18
* Missing N=1 (2%) **Missing N=2 (4%) ***Missing N=7 (16%) ****Missing N=3 (7%) ¤Missing N=2 (7%) direct non-functional		

Baseline characteristics

The patient group included 28 (62%) males, with a median follow-up of 2.3 years. The median age at trauma was 7.5 years and ranged between 1.5 and 18.0 years. In total, 22 (49%) patients were of amblyopic age at trauma. All injuries were unilateral, and occurred in 21 right eyes and in 24 left eyes. A wide range of injury objects were identified (table 1). Glass (11%), scissors (9%) and branches (9%), were the most common. Metal was the most prevalent type of material (16 cases, 36%). In four cases the time till operation was >48 hours (table 2).

Ocular findings

IOFB was seen in five (11%) eyes, and a shallow anterior chamber in nineteen (42%). Zone 1 injuries were the most frequent (26 eyes, 58%). Involvement of the lens was found in 22 (49%) eyes, the iris in 37 (82%) eyes, and the vitreous body in fifteen (31%) eyes (table 2).

Table 3: Final visual acuity categorized by WHO*					
		All patients		**Age at trauma < 7 years**	
		N	**%**	**N**	**%**
Not impaired	≥6/12	22	49	11	55
Mild	<6/12	1	2	1	5
Moderate	<6/18	10	22	4	20
Severe	<6/60	3	7	3	15
Blind	<3/60	7	16	1	5
*Missing N=2 (4%) p-value = 0,087					

Post-operative

The median time till stitch removal was 3,1 months (range: 0,7-8,7 months). The total number of surgeries needed during follow-up ranged between one and ten. A total of four (9%) eyes were non-functional of which two were directly at trauma. Enucleation was performed in one case, evisceration in two and in one case a total retinectomy was performed after which phthisis occurred (table 2).

Secondary development

After the open globe injury was repaired, the most frequent secondary development during follow-up were astigmatism (80%), and traumatic cataract (67%) (see table 2). Endophthalmitis occurred in only one (2%) out of 45 eyes, this eye later became non-functional. At final follow-up seventeen (42%) eyes stayed phakic, sixteen (39%) eyes remained aphakic, and eight (20%) were pseudophakic.

Final visual acuity

In two cases the final BCVA was missing, because it had not been possible to measure it within the study period due to non-cooperation and age. A total of 22 (49%) eyes had a vision ≥6/12 of which eleven (55%) were of amblyopic age at trauma (table 3). Of the 21 eyes impaired eyes; one (2%) was mild impaired (<6/12), ten (22%) were moderate impaired (<6/18), three (7%) were severe impaired (<6/60), and seven (16%) eyes were blind (<3/60). No association was found between amblyopic age at trauma and the final BCVA categorized by the WHO (p=0,087).

Final BCVA ''≥6/12'' vs ''<6/12''

The male-female ratio was approximately the same between both BCVA groups (59% vs 67%). Also, the number of patients of amblyopic age was similar in both groups (50% vs 43%). None of the patient or trauma characteristics were found to be significantly different for both visual groups (see table 4). The injury zone was not associated with the final BCVA. Involvement of the lens, iris, and vitreous body were all individually significantly higher in the <6/12 group (p=0.015, p=0.022, p=0.008). The

Table 4: final vision analyzed¤										
	All patients final vision					Amblyopic age				
	BCVA ≥6/12		BCVA <6/12			BCVA ≥6/12		BCVA <6/12		
	N	%	N	%	P-value	N	%	N	%	P-value
Total	22	49	21	47		11	55	9	45	
Male	13	59	14	67	0.755	5	46	4	44	1.000
Age at trauma, median	7.2 (2.1-17.5)		7.9 (1.5-18.0)		0.903	5.0 (2,1-6,9)		3.8 (1,5-6,4)		0.160
Amblyopic age	11	50	9	43	0.763	-	-	-	-	-
Follow-up years, median (range)	1,0 (0,25-21,3)		3,6 (0,47-22,0)		0.076	2.9 (0.4-21.3)		3.6 (1.0-14.6)		0.732
Material										
- Glass	5	23	3	14	0.324	0	0	0	0	0.772
- Metal	5	23	10	48		4	36	4	44	
- Wood	4	18	3	14		3	27	1	11	
- Plastic	0	0	1	5		0	0	1	11	
- Other	8	36	4	19		4	36	3	33	
Time to OR > 48h	2	9	1	5	1.000	1	9	1	11	1.000
Ocular findings										
IOFB present	3	14	2	10	1.000	1	9	0	0	1.000
Shallow anterior chamber**	7	32	11	58	0.122	4	36	3	43	1.000
Zone of injury*										
- Zone 1	14	64	10	50	0.143	8	73	5	63	1.000
- Zone 2	6	27	3	15		2	18	2	25	
- Zone 3	1	5	1	5		1	9	1	13	
- All zones	1	5	6	30		0	0	0	0	
Involvement										
- Lens	7	32	15	71	**0.015**	2	18	6	67	0.065
- Iris*	16	73	20	100	**0.022**	7	64	8	100	0.103
- Vitreous body*	3	14	11	55	**0.008**	0	0	3	38	0.058
Post-operative										
Stitch removal months, median (range)****/**	3,5 (1,8-5,3)		2,4 (0,7-8,7)		0.110 **0.010**	3.6 (1.8-5.3)		3.3 (0.7-4.4)		0.424 0.180
Total number operations, median (range)	1 (1-4)		2 (1-10)			1 (1-3)		2 (1-4)		0.450
Non-functional eyes	0	0	4	19	**0.048**	0	0	1	11	
- Direct	0	0	2	10		0	0	0	0	
Development ¤¤										
Endophthalmitis	0	0	1	5	0.463	0	0	1	11	0.450
Cataract	10	46	18	95	**0.001**	4	36	8	89	**0.028**
Glaucoma	1	5	5	26	0.080	0	0	3	33	0.074
Astigmatism****/**	18	86	16	94	0.613	9	90	7	88	1.000
Retinal detachment	1	5	6	32	**0.036**	0	0	3	33	0.074
Vitreous hemorrhage	1	5	2	11	0.588	0	0	1	11	0.450
PKP	1	5	1	6	1.000	1	9	0	0	1.000
Lens status at final follow-up/***										
Phakia	14	64	3	18	**0.012**	8	73	2	25	0.052
Aphakia	5	23	11	65		1	9	5	63	
Pseudophakia	3	14	3	18		2	18	1	13	

¤Missing N=2 (no known final vision)
¤¤Missing N=2 (direct non-functional)

*Missing N=1
**Missing N=2
***Missing N=3
****Missing N=7

median number of surgeries was significantly higher in the impaired group (p=0.010).

Secondary development

The development of traumatic cataract, and RD were associated with the final BCVA (p=0.001, p=0.036). In the ≥6/12 group 64% remained phakic and in the <6/12 group 65% was aphakic at final follow-up. The lens status showed to be significantly associated with the visual outcome (p=0.012).

Amblyopic age

Twenty patients were of amblyopic age at trauma (see table 4). When divided, eleven (55%) patients were in the ≥6/12 BCVA group with a median age of 5.0 years (range: 2.1-6.9) and nine (45%) were in the <6/12 BCVA group with a median age of 3.8 years (range: 1.6-6.4). The development of traumatic cataract (36% vs 89%) showed a significant association with the final BCVA. Both glaucoma and RD occurred more frequently in the <6/12 group (0% vs

Table 5: Amblyopic age group						
Age	**BCVA***	**Zone**	**Involvement**	**Rear segment**	**Lens status**	**Amblyopic treatment**
Group ≥6/12						
4.5	0.8	1	Iris	-	Phakia	-
4.0	1.2	2	-	-	Phakia	-
5.0	0.6	1	Lens, iris	-	Aphakia	Occlusion + contact lens
2.1	0.8	1	Iris	-	Phakia	Occlusion + contact lens
6.9	0.8	1	Lens, shallow anterior chamber	-	Pseudophakia	-
6.6	1.0	2	Iris	-	Phakia	-
2.3	0.6	1	IOFB, shallow anterior chamber, PKP	-	Phakia	Occlusion + scleral lens
5.1	0.8	1	Iris, shallow anterior chamber	-	Phakia	Occlusion
5.3	1.0	3	Iris	-	Pseudophakia	-
6.8	0.6	1	shallow anterior chamber, central scar	-	Phakia	-
4.4	0.7	1	Iris, central scar	-	Phakia	Occlusion + SCL
Group <6/12						
6.0	0.3	3	Iris, vitreous body	Vitreous hemorrhage Macular scar	Phakia	-
3.7	0.1	1	Lens, iris, vitreous body, shallow anterior chamber	-	Aphakia	Occlusion + contact lens
3.4	0.05	1	Lens, iris, vitreous body	RD	Aphakia	Occlusion + scleral lens
4.7	0.05	2	Lens, iris	-	Aphakia	Scleral lens
3.9	0.1	1	Lens, iris	RD, glaucoma	Aphakia	Occlusion + scleral lens
3.5	0.33	1	Lens, iris, shallow anterior chamber	-	Pseudophakia	Occlusion + contact lens
1.6	0	2	Iris, vitreous body	Endophthalmitis, RD, glaucoma, evisceration	-	-
6.4	0.16	1	Iris, shallow anterior chamber, central scar	-	Phakia	Scleral lens
3.8	0.05	-	Lens	Glaucoma	Aphakia	Occlusion + contact lens
*= in Snellen decimal						

33%). However this was not significant. In the <6/12 BCVA group most eyes remained phakic (73%) and in the impaired group most eyes were aphakic (63%), this showed not to be significant (p=0.052).

Characteristics of the amblyopic age group are shown in table 5 (n=20). In the ≥6/12 BCVA group none had involvement of the vitreous body or complications in the posterior segment, and five patients received amblyopic treatment. In the <6/12 BCVA group the vitreous body was involved in four patients, RD occurred in three, and four had amblyopic treatment with a scleral lens. Two patients were older than the others (6,0 and 6,4).

Discussion

To our best knowledge this is the first study on pediatric open globe injuries in the Netherlands. We provided more insights on the subject and identified possible risk factors associated with a final BCVA of <6/12.

We found that 49% of the children had a final BCVA of 6/12 or better. This is in line with the results of other studies from industrialized countries, where percentages ranged from 40-56%.[5,9,18-21] This means about half of children with an open globe injury remain visually impaired, of which the consequences should not be underestimated. Karaman et al[22] showed that an traumatic eye injury influences the mental health and quality of life of children. In addition to functional and physical challenges, patients reported psychosocial issues related to their eye's appearance.[23,24] For parents, too, the sudden loss of their child's vision and uncertainty about the outcome remains difficult to cope with.[22]

Despite the fact that children under the age of seven are still in their visual development, our results showed no association between final BCVA and an amblyopic age at trauma. Children of amblyopic age did appear younger in the <6/12 group compared to the ≥6/12 group (median 3.8 vs 5.0). However, this difference was not significant. AlDahash et al[5], who split the group at 8 years, also found age not to be predictive of the final BCVA. On the other hand, Bunting et al[20] found age to be a risk factor for the final BCVA, but they split the group at the age of 5 years. Our results may be distorted, given the two outliers of >6 years in our amblyopic group with a BCVA of <6/12. One developed a big macular scar which explains the poor vision, and was therefore independent of the age at trauma. Nevertheless, we cannot draw any firm conclusions from this due to our relatively small sample size and inconclusive findings in current literature. A large meta-analysis on the association of age at trauma and final visual outcome would be very informative.

Involvement of the iris, lens, and vitreous body were associated with a the final BCVA. Therefore, it can be cautiously assumed that damaging these anatomical structures makes for a poorer visual prognosis. In addition, development of traumatic cataract showed to be associated with a final BCVA. Other studies

also show involvement of the lens to be an important risk factor for the visual prognosis after an open globe injury.[5,25] Due to issues with aphakia correction and compliance in young children, injuries involving the lens have a much worse visual prognosis.[15] This is also in line with our findings on the lens status, which showed the number eyes who remained phakic was higher in the ≥6/12 BCVA. It seems that keeping your own lens is very beneficial for the visual prognosis. When the own lens is affected and surgically removed aphakia treatment is necessary. In comparison to contact lens correction, intraocular lens (IOL) correction for aphakia in children with traumatic cataract results in a higher final BCVA and binocularity with a lower incidence of strabismus, especially for younger children.[26] It seems that placing the lens early rather than later seems to have positive effect on the BCVA in children after an open glove injury.[27,28] However, cataract surgery in young children comes with its challenges especially after a trauma due to corneal edema, hyphema, bad visibility and difficulty placing the IOL when there is no adequate support.[29] Also, an accurate power calculation is of challenge in a traumatic eye, but Sen et al[29] found calculation from the normal other eye to be satisfactory. In our study population, 65% of patients in the <6/12 group remained aphakic. However, the numbers of pseudophakic eyes were very low in both groups (3 eyes vs 3 eyes). Therefore we are unable to draw any conclusions based of our results on the difference in final BCVA between aphakic and pseudophakic children. It would be interesting to investigate whether placing an IOL rather than treatment with contact lens correction produces better visual results.

In addition to traumatic cataract, development of RD was found to be associated with the final BCVA. Other articles support this finding.[5,20,30] A recent Indian study showed 8,3% of pediatric open globe injuries developed post-traumatic glaucoma,[31] which is approximately equal in our population (13%). Post-traumatic glaucoma is less common in open globe injuries compared to closed globe injuries.[31,32] We found the development of glaucoma not to be associated with the final BCVA.

A number of limitations should be kept in mind when interpreting our results. Pediatric open globe injuries are not so common, around two to three children a year visit our hospital. Therefore, our study population is small. However, we have collected all patients over a time period of 20 years and therefore we have been able to get a good picture of the current situation. Another limiting factor of this study is its retrospective nature, which results in a lack of regular and comparable data being provided for each patient. Including only the affected eye in the final BCVA may have resulted in an underestimation of someone's overall vision. Since a patient might be able to compensate with a good eye. Yet, the most important question is about the final vision of the traumatized eye and therefore this is the best way to answer that question.

In conclusion, this study provided a better understanding of the epidemiology and potential prognostic factors of pediatric open globe injuries, which can provide a better and more realistic expectations of their visual outcome. The nature of the trauma and the anatomical structures involved have a major influence on the final vision. In addition, the preservation of one's own lens makes for a better visual prognosis. Despite good surgical treatment, about half of the children ended up with a vision of less than 6/12. Prevention is still the best defence against ocular harm. Still, it remains important to find the best possible treatment for these affected children. Therefore, larger prospective research is needed. So that ultimately fewer children are left with an impaired vision after an traumatic open globe injury.

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