Surgical Management and Predictive Factors for Visual Outcome in Pediatric Open-Globe Injuries: A Multivariate Analysis

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ABSTRACT

Purpose: The aim of this study was to present epidemiological characteristics, surgical management, and predictive variables for favorable (FVO) and poor visual outcome (PVO) in pediatric open-globe injuries (OGI).

Material and Methods: The study included papediatric cases aged <18 years who presented with OGI between December 1996 and January 2021. A record was made of injury characteristics (type, time of injury, time to treatment, cause, trauma scene, hospitalization days), and surgical interventions (initial and subsequent number and type of surgeries). VThe visual acuity at the final visit was categorized as PVO (<20/200) orand FVO (≥20/200) . Possible predictive factors for FVO and PVO were explored with logistic regression analyses.

Results: Evaluation was made of 57 eyes of 53 children with a median age of 7 years (range, 1-17 years) and median follow-up period of 74 months (range, 6-180 months). The OGI was terror-related in 6 eyes (11%). The primary repair surgeries were performed to most cases (90%) within six hours. Patients mostly underwent phakic lens removal and lens replacement combined with pars plana vitrectomy (PPV) surgery (37%). In the regression analyses, the independent factors for PVO were determined to be initial and additional PPV surgery, initial retinal detachment (RD), and terror-related trauma.

Conclusion: This study presents a detailed epidemiological perspective of pediatric OGI in Turkey. This study adds new variables (initial and additional PPV surgery, baseline RD and terror-related trauma) to forecast the likelihood of PVO in pediatric OGI cases. This is the first report presenting terror-related pediatric OGI cases.

Keywords: Pediatric, Open-globe injury, Surgery, Visual outcome.

INTRODUCTION

Ocular trauma is one of the most frequent reasons for non-congenital unilateral visual impairment in children.[1] The annual incidence of open globe injury (OGI) has been reported to be 3.8-5.2/100.000 in children.[2, 3] The pediatric population is vulnerable to ocular trauma due to premature neurological capability and limited caution, usually acting with no regards to the hazards and outcomes.[4]

As the course and postoperative results of trauma in children vary from those of adults, exclusive priority for pediatric patients is necessary.[5] Furthermore, excessive inflammatory healing response to ocular trauma in children with lower adherence to treatments and the risk of amblyopia make the operative management challenging in this population.[4]

Although most studies have focused on visual outcome, there has been little holistic analysis of pediatric OGI in Turkey including epidemiological and surgical characteristics with multivariate analysis for the visual outcome. The primary aim of this study was to present the epidemiological and surgical characteristics of pediatric OGI in conjunction with prognostic factors for the visual outcome.

MATERIAL AND METHODS

Study Subjects

The study was conducted in the ophthalmology clinic of the tertiary level Gulhane Research and Training Hospital (formerly Gulhane Military Medical Academy) in accordance with the principles of the Declaration

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of Helsinki after approval from the Local Ethics Commission (Health Sciences University, Kayseri City Hospital-2019/845). The trauma events examined were in an 18-year period from December 1996 to January 2021. The medical records were retrospectively reviewed of 602 patients with an initial diagnosis of OGI according to the Birmingham Eye Trauma Terminology System. Only the charts of patients aged< 18 years at the time of admission were included. Cases with missing data and closed-globe injuries were excluded from the study.

A record was made of patient demographic data, ocular trauma score (OTS), time from trauma to first treatment, length of stay in hospital (days), injury characteristics (type, cause, zone, time,), initial ocular findings, and surgery details (type, number)**.**

The variables used to specify prognostic predictors for either favorable visual outcome (FVO) or poor visual outcome (PVO) were male gender, terror-related trauma, initial visual acuity (VA), pars plana vitrectomy (PPV) (initial and additional), ocular findings (hyphemia, corneal laceration, iris prolapse, lens injury, vitreous prolapse/ hemorrhage, retinal detachment (RD), endophthalmitis, initial proliferative vitreoretinopathy (PVR), foreign body locations (retinal/vitreal), and zone 3 and OTS category 1 injuries. FVO (with simultaneous functional success) was defined as VA >20/200 at the final visit, and all other patients were categorized as PVO. Anatomical success was defined as no phthisis bulbi in the final follow-up examination. In all except preverbal cases, VA could be measured. In preverbal children (n:4), the VA was estimated by flash visual evoked potential and a positive response was accepted as LP (PVO). Further subgroup comparisons in respect of FVO/PVO were made according to age (<7, 7-12, and >13 years), duration to first treatment; (1 hour, 1-6 hours, >6 hours) and one or more operations.

Statistical Analysis

Descriptive statistics were presented as median with minimum and maximum values, frequency, and percentage (%). Chi-square analysis was used for categorical variables. SPSS for Windows 20.0 software (licensed for Health Sciences University) was used for regression analysis (univariate/multiple stepwise linear) to detect independent predictive contributors for FVO/PVO. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

Patient demographic data

Of the 602 patients with OGI during the specified period, 72 were in the pediatric age group. Of these 72 subjects, 19 were excluded due to incomplete data, so a total of 57 eyes of 53 patients were included for analysis in the study. The median age of the patients was 7 years (range, 1-17 years) and the median follow-up period was 74 months (range, 6-180 months). Male gender was more predominant than female gender (2.56-fold).

2.2. General characteristics and epidemiology of the injuries

The distribution of injury types was penetrating injury (75%), intraocular foreign body (IOFB) (16%) and ruptured globe (9%) injury, respectively. There were no cases with perforating injury. The leading causes of injury were a knife wound (16%) and broken glass (16%). The injuries most frequently involved zone I+ II (33%), followed by zone I (28%), and multiple zones (25%). The mean OTS category was 2.4. Most of the injured eyes were accumulated in OTS category 2 (42%) and 3 (26%) (Table 1).

Bilateral involvement was present in 8% of the total eyes. The OGI was due to a terror-related incident in 6 eyes (11%) (Table 1). Overall, the most common trauma scene was home accident in 26 eyes (46%) followed by school accidents (35%), playground injury (30%), and traffic accidents (4%). The peak injury time interval was between 3-6 pm (35%).

Baseline ocular findings

The rate of eyes with VA >20/200 increased from 40% at the time of first admission to 70% at the final visit (Table 1). Corneal laceration (72%), iris prolapse (60%) and hyphemia (47%) were the most common signs in the anterior segment whereas vitreous hemorrhage (53%), vitreous prolapse (35%), and RD (18%) were the leading ocular findings in the posterior segment.

FVO comparisons between groups according to age, number of surgeries, time to primary surgery, injury types, zone of injury and cause of injuries

The three age groups were similar in respect of FVO (p:0.162). The patient group that underwent a single surgery gained statistically better FVO compared to those who required additional operations (p:0.002). The groups of time from trauma to primary repair showed a statistically significant difference in respect of FVO (p:0.049). The length of hospital stay did not significantly differ among the groups (p:0.267) (not shown). There was a statistically significant difference between the injury type groups according to FVO (p:0.007). Penetrating injury cases obtained greater FVO than the other two injury type cases. The trauma zone had a significant effect on FVO (p:000). Zone 3 cases had worse VA outcomes compared to

Table 1: *Initial and Final Visual Acuities, OTS categories and Characteristics of Terror-Related Patients*

Initial and final visual acuities

	Initial VA		Final VA	
	(n)	%	(n)	%
NLP	5	9	5	9
LP	15	26	8	1
LP-HM	8	14	1	2
1/200-19/200	6	11	3	5
20/200-20/50	10	18	15	26
≥20/40	13	23	25	44
Total	57	100	57	100

OTS categories of our cases

OTS raw points	OTS Category	n	%
0-44	**1**	10	18
45-65	**2**	24	42
66-80	**3**	15	26
81-91	**4**	8	14
92-100	**5**	0	0

Characteristics of Terror-related Pediatric Patient

Case number	Affected eye	Gender	Age	Cause of injury	Type of injury	Follow-up time (month)	OTS category	Initial VA	Final VA	Number of surgeries
1	Right	Male	17	Hand grenade	Penetrating	77	2	HM	60/200	2
2*	Right	Female	13	Hand grenade	Rupture	76	1	NLP	NLP	5
3	Left	Female	13	Hand grenade	Rupture	76	2	1MCF	2MCF	5
4*	Right	Male	4	Land mines	IOFB	90	2	LP	LP	3
5	Left	Male	4	Land mines	IOFB	90	1	LP	LP	3
6	Left	male	16	Land mines	Penetrating	74	1	NLP	NLP	2

Abbreviations: n, number of cases; OTS, ocular trauma score; VA, visual acuity; NLP, no light perception; LP, light perception; HM, hand movements; 1MCF, counting fingers at 1 meter; 2MCF, counting fingers at 2 meters; IOFB, intraocular foreign body
* Bilateral injury

the other two zones. No significant differences were found in respect of FVO when comparisons were made according to the cause of injury ($p>0.05$) (not shown) (Table 2).

Surgical interventions

A total of 128 separate operative sessions with a median of 2 (1-6) surgeries were performed on 57 eyes. Surgery sessions were planned as required during the follow-up periods. The majority of the subjects (90%) had a primary repair within 6 hours and were discharged from hospital within a week (63%). Other than open globe repair, the most common procedures performed were lens aspiration (9/57; 16%) and intraocular lens (IOL) implantation (3/57; 5%) in the first operative session. A greater number of eyes (21, 37%) needed PPV surgery either as the first treatment (3 eyes, 5%) or additional intervention (18 eyes, 31%). Endophthalmitis developed in 2 (4%) eyes and both cases resulted in PVO.

Prognostic factors for FVO/PVO

Functional success and anatomical success were achieved in 40 eyes (70%) and 54 eyes (95%) respectively. In the univariate analysis, higher initial VA (>20/200), corneal laceration, iris prolapse, and vitreous hemorrhage were significantly associated with FVO; and PPV surgery (both primary and additional), terror-related trauma, zone 3 injury, OTS category 1, and RD were found to be significantly related with PVO (Table 3). In the multiple regression analysis, PPV surgery (both primary and additional), initial RD, and terror-related trauma were found to be the major contributors to PVO (Table 3).

DISCUSSION

Consistent with previous reports, OGI was determined to have occurred more frequently in boys in this study. [3, 6-8] The median age of trauma was 7 years, which is the age

Table 2: *Final visual acuity (FVA) comparisons between groups.*

Time interval to primary surgery and FVA comparisons between groups							
	n	**%**	**PVO** **n**	**%**	**FVO** **n**	**%**	**p[a]**
0-1 hour	12	21	2	17	10	83	0.049
1-6 hours	39	68	11	28	28	72	
>6 hours	6	10	4	67	2	33	
Injury types and FVA comparisons between groups							
Injury type	**n**	**%**	**PVO** **n**	**%**	**FVO** **n**	**%**	**p***
Penetrating	43	75	8	19	35	81	0.007
IOFB	9	16	6	67	3	33	
Globe rupture	5	9	3	60	2	40	
Perforating	0	0	0	0	0	0	-
Age groups and FVA comparisons between groups							
Year	n	%	**PVO** **n**	**%**	**FVO** **n**	**%**	**p***
7>	29	51	7	24	22	76	0.162
7-12	14	25	3	21	11	79	
>13	14	25	7	50	7	50	
FVA comparisons between one surgery and subsequent surgery groups							
Number of surgeries	n	%	**PVO** **n**	**%**	**FVO** **n**	**%**	**p***
1	37	65	6	16	31	84	0.002
>2	20	35	11	55	9	45	
Zone of injury and FVA comparisons between groups							
Zone of injury	**n**	**%**	**PVO** **n**	**%**	**FVO** **n**	**%**	**p***
Zone 1+2	19	33	2	11	17	90	0.000
Zone 1	16	28	0	0	16	100	
Zone 1+2+3	14	25	10	71	4	29	
Zone 3	4	7	3	75	1	25	
Zone 2+3	3	5	2	67	1	33	
Zone 2	1	2	0	0	1	100	

Abbreviations: n, number of cases; FVA, final visual acuity; FVO, favorable visual outcome; PVO, poor visual outcome; IOFB, intraocular foreign body; RR, relative risk
[a]chi-square test
*Fischer's exact test

of starting school in Turkey. This peak age for trauma is most likely due to the increased participation of children in playing with groups of friends either at home, in playgrounds, or at school.

The most common trauma circumstance varies from home accidents to playgrounds to sports injuries in different studies.[3, 8, 9] The current study showed a larger number of eyes injured in home accidents. The high-risk time interval for ocular trauma occurrence was the afternoon (3-6 pm), which was parallel to data in published reports.[7, 10] The mean length of hospital stay has been reported as 4.7 days to 6.3 days in previous studies.[3, 11] Unlike previous reports, a greater number of patients (84%) in this cohort required a hospital stay of at least 14 days. The preponderance of relatively more severe injuries (mean OTS= 2.4) in this report compared to other studies and the fact that health insurance is totally covered by the state in Turkey may have led to the longer hospital stays in the current study. Furthermore, all surgeries were performed at the same institution in this cohort, which may also have contributed

Table 3: *Prognostic variables on final visual acuity in univariate and multivariate analysis.*

Prognostic variables on final visual acuity in univariate analysis										
[a]		**PVO n**	**%**	**FVO n**	**%**	**B**	**p**	**OR**	**CI**	
IVA>20/200	**Present** **Absent**	0 17	0 45	19 21	100 55	-0.856	0.003	0.425	0.391	0.705
Corneal laceration	**Present** **Absent**	9 8	22 50	32 8	78 50	1.269	0.043	3.556	1.042	12.136
Iris prolapse	**Present** **Absent**	6 11	18 48	28 12	82 52	1.453	0.018	4.278	1.285	14.243
Vitreous hemorrhage	**Present** **Absent**	13 4	43 15	17 23	57 85	-1.481	0.024	0.227	0.063	0.821
Primary PPV surgery	**Present** **Absent**	3 14	100 26	0 40	0 74	-0.856	0.003	0.425	0.974	1.513
Additional PPV surgery	**Present** **Absent**	10 7	56 18	8 32	44 82	-1.743	0.006	0.175	0.051	0.604
Terror-related	**Yes** **No**	5 12	83 24	1 39	17 77	2.788	0.015	16.250	1.726	152.009
Retinal detachment	**Present** **Absent**	9 8	90 17	1 39	10 83	-3.781	0.001	0.023	0.003	0.206
Zone 3 injury	**Present** **Absent**	15 2	29 6	6 34	7 94	3.750	0.000	42.5	7.673	235.390
OTS category 1	**Present** **Absent**	9 8	90 17	1 39	10 83	3.781	0.001	43.785	4.854	396.6

Prognostic variables on PVO in multivariate analysis				
adjusted R^2: 0.676 **F: 24.361** **p:0.000**	**Beta***	**p**	**Collinearity statistics**	
			Tolerance	**VIF**
			0.935	1.070
Initial retinal detachment	0.629	0.000	0.785	1.274
Initial PPV surgery	0.356	0.000	0.937	1.068
Additional PPV surgery	0.258	0.002	0.796	1.256
Terror-relation	0.239	0.007	0.938	1.066

Abbreviations: n, number of cases; IVA, initial visual acuity; PVO, poor visual outcome; FVO, favorable visual outcome; PPV, pars plana vitrectomy; OTS, ocular trauma score; B, regression coefficient; OR, odds ratio (with 95% confidence interval); CI, confidence interval (95%) VIF; variance inflation factor

[a] Univariate analysis (binary logistic regression)

******Standardized coefficient*

to longer hospital stays compared to those in previous studies in which vitreoretinal surgeries were not performed at the same hospital.[3]

A distinctive characteristic of this study was the presence of four children who suffered terror-related OGI, which has never been published before. The mean OTS category and mean follow-up period of these children were 1.5 (lower) and 32.5 months (longer) than the non-terror-related cases (not shown). Land mines and hand grenades were the only cause of the injuries. All these 4 children needed at least 2 surgeries (2-5) and resulted in PVO. Furthermore, except for one, all the children were determined to have lost vision in at least one eye at the final visit (Table 1). This finding was different from adult terror-related injuries in many ways. In a previous adult cohort, PVO was reported as nearly 30% (lower), mostly blast injuries (improvised explosive devices), most eyes needed only 1 surgery (33%), and the follow-up period was shorter (11.5 months).[12] The prognosis was worse in pediatric terror-related OGI compared to adult terror-related injury patients.[12]

The most common causative objects in pediatric OGI include knives,[3, 7, 13] sharp objects,[6, 8] metallic objects,[6, 9]

and glass, [7] according to previous reports. Consistent with those findings, the causative objects for the injuries in this study were mostly knives and glass. In contrast to previous studies which have reported that the type of injury had no considerable impact on the final VA, the patients with penetrating-type injuries in this study had a significantly better prognosis. [5, 14] This finding may be due to the uneven distribution of the injury types and should therefore be interpreted with caution.

PPV was applied to 21 eyes (37%) in this cohort. Comparable with this study, a previous report presenting the effect of PPV on pediatric OGI, also included the number of eyes requiring vitrectomy and the detailed surgical methods accompanying the PPV (membranectomy, retinectomy, retinal tamponades etc.).[15]

The prevalence of endophthalmitis in pediatric OGI has been reported to range from 0%[11] to 54%.[16] In the current study, 2 eyes (4%) were diagnosed with endophthalmitis, which was consistent with the findings of the study by Al Dahash et al.[5]

Various studies have described the risk factors for PVO in pediatric OGI. Significant variables for PVO have been reported to be a younger age,[7, 9, 17] low initial VA,[5, 6, 11, 15, 17, 18] injury type,[7, 15] zone of injury (2 or 3),[6, 7, 11] iris prolapse,[5, 6] shallow anterior chamber,[5, 7] lens damage, [5] hyphemia,[5-7] size of the wound,[5, 7] vitreous hemorrhage,[15] RD,[5-7, 14, 15] endophthalmitis,[15] and PVR[15]. Likewise, baseline VA <20/200, RD, zone 3 injury, and IOFB were separately found to be significant contributors to PVO in the current study. In contrast to the above-mentioned studies, PPV (primary or additional), terror-related trauma, OTS category 1, land mine injury, and performance of more than two surgeries were also unique factors for PVO in this study.

Initial and additional PPV surgery, initial RD and terror-related trauma were determined to be independent variables for PVO in the current study. In contrast, a similar study analyzing an adult population reported that additional PPV, terror-related trauma, lens injury, OTS category 1, zone 3 injury and initial VA <20/200 were independent predictors for PVO. [19] Although PPV was linked to PVO in this report, the essential role of PPV in OGI should not be overlooked. [9] In a recent study, RD was found to a predictor for PVO in multivariate analysis irrespective of whether or not initial VA was added as a covariate.[13]

Major limitations of this study were the retrospective, non-randomized design, and relatively small sample size. However, to the best of our knowledge, this is the first study to have reported pediatric OGI including terror-related injuries.

CONCLUSIONS

A holistic analysis of pediatric OGI was performed including epidemiology, surgical management, and distinctive predictive factors for visual outcome. Further prospective randomized trials are needed to ascertain exact predictors for visual outcome. Education on the precautions to be taken against potential hazards should be encouraged to prevent pediatric OGI.

Conflicts of interest

The author(s) have nothing to disclose.

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