Pediatric open globe injury: A review of the literature

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ABSTRACT

Open globe injury (OGI) is a severe form of eye trauma estimated at 2-3.8/100,000 in the United States. Most pediatric cases occur at home and are the result of sharp object penetration. The aim of this article is to review the epidemiology, diagnosis, management, and prognosis of this condition by conducting a systematic literature search with inclusion of all case series on pediatric OGI published between 1996 and 2015. Diagnosis of OGI is based on patient history and clinical examination supplemented with imaging, especially computed tomography when indicated. Few prospective studies exist for the management of OGI in pediatric patients, but adult recommendations are often followed with success. The main goals of surgical management are to repair the open globe and remove intraocular foreign bodies. Systemic antibiotics are recommended as medical prophylaxis against globe infection, or endophthalmitis. Other complications are similar to those seen in adults, with the added focus of amblyopia therapy in children. Severe vision decline is most likely due to traumatic cataracts. The ocular trauma score, a system devised to predict final visual acuity (VA) in adults, has proven to be of prognostic value in pediatric OGI as well. Factors indicating poor visual prognosis are young age, poor initial VA, posterior eye involvement, long wound length, globe rupture, lens involvement, vitreous hemorrhage, retinal detachment, and endophthalmitis. A thorough understanding of OGI and the key differences in epidemiology, diagnosis, management, and prognosis between adults and children is critical to timely prevention of posttraumatic vision loss early in life.

Key Words: Amblyopia, eye trauma, open globe, pediatric trauma, surgery, visual impairment

INTRODUCTION

Trauma to the eye is a leading cause of monocular blindness worldwide, especially in developing countries.[1,2] About 2.4 million eye injuries occur in the United States annually, of which 35% are in children.[3] Although 95% of all ocular injuries do not require admission,[4] open compared to closed globe injuries in children are generally more severe and associated with more complications and surgical procedures, longer hospitalization times, and poorer visual prognoses.[2,5-11] This review summarizes the demographics and injury characteristics of pediatric open globe injury (OGI) and suggests a plan for diagnosis, management, and predicting outcome in these patients.

METHODS

For this literature review, PubMed was searched for combinations of the clusters of keywords: pediatric, eye trauma, open globe, pediatric trauma, surgery, visual impairment.
paediatric, children; eye, ocular; trauma, injury; open globe, globe rupture, laceration, intraocular foreign body (IOFB), penetrating, perforating. One keyword/phrase from each cluster was used, unless repeated. All English-language case series consisting of ≥5 patients published between January 1996 and January 2015 were included. Results are synthesized in Tables 1 and 2 and Supplementary Table 1.

**NOMENCLATURE**

Following a standardized approach,[26,27] we define an OGI as a full-thickness mechanical injury to the cornea and/or sclera. The two types of OGI are ruptures and lacerations. Ruptures result from blunt trauma causing a full-thickness defect at the weakest point of the eye wall. Lacerations, the result of a sharp object entering the globe, are further classified as penetrating (only an entrance wound or same entrance/exit wound) or perforating (separate entrance and exit wounds) injuries. A separate category indicates the presence of an IOFB [Figure 1].

OGI can also be categorized by zone of injury. Zone 1 includes the cornea and limbus. Zone 2 extends from the limbus to the anterior 5 mm of sclera, and Zone 3 extends posterior to Zone 2.[17,20]

**DEMOGRAPHICS AND NATURE OF INJURY**

As assessed by large-scale studies, the mean age for pediatric OGI during the last two decades ranges from 7.7 to 11.6 years [Supplementary Table 1].

The ratio of males to females presenting with OGIS ranges from 1.9:1 to 5.1:1,[10,13-19,22,23,25,30,31,36] though there is no significant difference across these studies in the incidence of right versus left eye affected. Pediatric OGI cases most frequently are caused by sharp objects such as knives,[7,15-21,30,33,39] making penetrating injury the most common.[13-17,22,23] The majority of injuries occur at home.[7,16,17,24,29,30,38,40] In some developing countries, outdoor and street injuries are more common.[13,14] Other accidental causes of OGI in children have been documented,[41-49] as well as cases of abuse or assault.[13,50] Globally, fireworks during cultural celebrations are a common cause of pediatric OGI.[7,16,30,51,52]

Penetrating trauma is consistently the most common form of OGI in children at hospitals across the world, ranging from 48.4% to 83% of all OGIS, followed by rupture (9.9-34%) and IOFB presence (4.0-16.1%), with perforation being least common type of injury (1.2-4%).[2,7,9,11-13,17,18,20,22,23] Zone 1 injuries are also the most common form of OGI in pediatric patients (44-79%),[2,11,13-18,22,23] whereas Zone 3 injuries are associated with worse visual prognosis [Figure 2 and Table 2].

| Table 1: Incidence of concurrent ocular conditions with OGI* in children |
|---|
| Ocular condition† | Incidence with OGI (%) |
| APD* | 20.7† |
| Lens involvement‡ | 24.2-73,44.6±3.6 |
| Hyphema | 9.4-15.4±3.6 |
| Uveal prolapse | 40.3-72,44.6±3.6 |
| Vitreous prolapse | 18.2-36,44.6±3.6 |
| VH | 3.3-34,44.6±3.6 |
| RD‡ | 37.0-32,44.6±3.6 |
| Endophthalmitis | 4.9-54,44.6±3.6 |

*OGI: Open globe injury; †Ocular conditions listed from anterior to posterior to midcular; ‡APD: Afferent pupillary defect; ‡Lens involvement includes cases of traumatic cataracts and trauma-induced aphakia; †VH: Vitreous hemorrhage; ‡RD: Retinal detachment

| Table 2: Factors significantly associated with a lower final VA from corroborating studies |
|---|
| Factor* associated with low final VA | First author of study |
| Young age (number of years at presentation) | Liu[18] (>6) Bunting[18] (<6) Farr[18] (<4) Acar[18] (<5) |
| Poor initial VA | Liu[18] Ilhan[18] Kadappu[18] Tok[18] |
| Zone 3/posterior segment involvement | Liu[18] Bunting[15] Dula[15] Kadappu[18] Lesniak[18] Tok[18] Liu[18] Lee[18] Acar[18] |
| Long wound length (mm) | Bunting[15] (>6) Ilhan[18] Kadappu[18] (>10) Liu[18] |
| Rupture | Bunting[15] Kadappu[18] Farr[18] |
| Lens involvement | Kadappu[18] Lee[18] Liu[18] Bunting[15] Lee[18] Liu[18] Bunting[15] Lee[18] |
| VH | Bunting[15] Lee[18] Liu[18] Bunting[15] Lee[18] Liu[18] Bunting[15] Lee[18] |
| RD‡ | Liu[18] Bunting[15] Lee[18] Liu[18] Naran[11] Omobolanle[18] |

*Factors are roughly listed in order of confirmation by the ophthalmologist: From history and initial assessment to concurrent ocular conditions either occurring at presentation of trauma or developing later during follow-up. Where applicable, significance in multivariate analysis is taken over univariate analysis. †VH: Vitreous hemorrhage; ‡RD: Retinal detachment (RD or re-detachment is often a result of proliferative vitreoretinopathy). The study consists of only penetrating injuries; ‡The study consists only of corneal lacerations. VA: Visual acuity.
HISTORY AND EXAMINATION

Clinical examination

During initial assessment of any patient following ocular trauma, life-threatening conditions are first stabilized before evaluating the globe. Taking a complete history is crucial: IOFB is suspected with a history of the explosion, gunshot wound, or sharp object entering the eye, and appropriate imaging should be requested (see “Diagnostic imaging”).

Physicians must be opportunistic in assessing OGI in infants and children due to their limited ability to cooperate. If possible, obtain an initial visual acuity (VA), assess for an afferent pupillary defect (APD), delineate confrontational visual fields, and determine the degree of ocular motility for orbital injuries. The conjunctiva, cornea, sclera, anterior chamber, iris,
In pediatric patients, due to if a retina specialist is not available, emergent clinically confirmed or ruled out. In detecting metallic IOFB or orbital fracture only in the absence of intraocular contents. Globe pathology may be detected incidentally on plain films. of intraocular contents. of radiation delivered to the lens during each CT scan, the possibility of motion artifact and the potentially harmful radiodensity over days. Other ocular signs commonly associated with pediatric OGI are hyphema, vitreous hemorrhage (VH), uveal/vitreous prolapse, cataract, lens subluxation, irido-dialysis, retinal detachment (RD), APD, or infection [endophthalmitis; Table 1].

**Diagnostic imaging**
OGI is generally diagnosed by history and clinical examination alone. Diagnostic imaging should be conducted to assess the presence of an IOFB if suspected and to evaluate the extent of globe damage. The main imaging modalities used are computerized tomography (CT) and B-scan ultrasonography (US); rarely, X-ray, and magnetic resonance imaging (MRI) are used.

**Computerized tomography**
In one study, CT was 94.9% sensitive for IOFB detection. It is highly sensitive for metallic IOFBs, and slightly less so but still more sensitive than MRI for glass. While metal and glass are hyperdense on CT, wooden fragments appear hypodense unless covered with lead-containing paint and can increase in radiodensity over days. In pediatric patients, due to the possibility of motion artifact and the potentially harmful dose of radiation delivered to the lens during each CT scan, ophthalmologists may use alternative methods such as US to confirm clinical suspicion of OGI.

**B-scan ultrasonography**
B-scan is a rapid, cost-efficient method that can be useful in diagnosing OGIs, especially in assessing posterior segment integrity. B-scan has been shown to have lower sensitivity in detecting IOFBs masked by intraocular air when compared to CT, but one study of 427 B-scan reports showed 100% positive predictive value for diagnosis of RD and IOFB. We recommend B-scan in compliant pediatric patients only when performed with extreme caution by an experienced technician or physician after primary globe closure to avoid further extrusion of intraocular contents.

**X-ray**
Globe pathology may be detected incidentally on plain films. The speed, availability, and low cost of X-ray makes it valuable in detecting metallic IOFB or orbital fracture only in the absence of more advanced imaging modalities and when OGI cannot be clinically confirmed or ruled out.

**Magnetic resonance imaging**
MRI is only used to detect nonmetallic IOFBs, especially when a wooden IOFB seen as an ambiguous hypodensity on CT can be mistaken for air. It is critical to definitively rule out the presence of a metallic IOFB, as well as any other magnetic metal in or on the patient, before ordering an MRI. Ferromagnetic material (e.g., nickel, iron, cobalt) will be displaced by the magnets in the MRI whereas other metals (e.g., tantalum) will not.

**TREATMENT**
If OGI is suspected, a rigid eye shield, supported by the orbital bones and not the soft tissues of the globe, should be placed over the injured eye after clinical examination for protection. Antibiotics, analgesics, and possibly anti-emetics should then be administered. A tetanus shot should be given if there is incomplete or uncertain history of recent immunization. Limited activity is recommended until surgical repair.

Broad-spectrum intravenous antibiotics with adequate ocular penetration are initiated as prophylaxis against endophthalmitis. Cefazolin, a first-generation cephalosporin, can be used as a first-line antibiotic. If IOFB is suspected, the patient should be admitted for a course of intravenous vancomycin and ceftazidime.

**Surgical management**
The main goals of surgical OGI management are to emergently close primary wounds, reposition prolapsed ocular contents or debride if extruded for more than 24 h, remove IOFBs, and treat or prevent complications with the ultimate goal of preserving VA.

Primary globe repair is performed similarly as with cases of adult OGI. The integrity of the cornea, limbus, and sclera should be maximally restored with intraoperative attention to reforming the anterior chamber and, if possible, avoiding distortion of the visual axis. Corneoscleral tissue grafts can be used for large open wounds that cannot be sutured closed.

During primary closure, anterior chamber IOFBs should be removed, and emergent pars plana vitrectomy (PPV) performed by a retina specialist in cases with confirmed posterior segment IOFB. If a retina specialist is not available, emergent globe repair may be performed before transferring the patient emergently for retina surgery.

Intravitreal vancomycin (1 mg/0.1 cc) and ceftazidime (2.25 mg/0.1 cc) can be considered during IOFB removal, but intracameral injections for endophthalmitis prophylaxis have not been tested in prospective trials in children. Decreased risk of endophthalmitis has only been shown in one prospective trial involving adult patients presenting with penetrating injuries.
and IOFBs who received prophylactic intravitreal injections of 40 μg of gentamicin sulfate and 45 μg of clindamycin, while risk was not decreased in patients on the regimen without an IOFB.\textsuperscript{70,71}

**COMPLICATIONS**

**Amblyopia**

In children, amblyopia is a major concern after OGI due to the often lengthy period of visual rehabilitation and therapy. Depending on the extent of injury, visual potential may be poor and amblyopia will further negatively affect the visual prognosis. Prevention of amblyopia has been studied extensively, with patching of the uninjured eye as the gold standard of therapy, along with atropine if the uninjured eye is hyperopic.\textsuperscript{68,74,72-73} The patient should be concurrently managed by a pediatric ophthalmologist following primary repair. Traumatic cataracts associated with corneal laceration are the most common cause for severe, refractory VA decline in children’s eyes after OGI.\textsuperscript{95,79}

**Endophthalmitis**

Endophthalmitis is a severe complication of OGIs and is associated with a significantly worse final VA.\textsuperscript{14,18,23} Necessitating proper prophylaxis, and aggressive management [Figure 2]. Compared with an incidence of 0.9-18.4% in adults, the incidence of posttraumatic endophthalmitis after OGI ranged from 4.9% to 54.2% in children [Table 2].\textsuperscript{90,70,77-88} Trauma is one of the most common causes of endophthalmitis in this population.\textsuperscript{86} Risk factors for traumatic endophthalmitis include presence of an IOFB, injury in a rural setting, wound contamination with organic matter,\textsuperscript{90} primary wound closure delayed for longer than 24 h postinjury, and involvement of the lens capsule.\textsuperscript{7,14,37,87}

The microbiological spectrum of posttraumatic endophthalmitis includes Gram-positive normal skin flora, e.g., *Staphylococcus epidermidis*, as well as more virulent species, e.g., *Bacillus* sp. *Streptococcus* is the most commonly isolated organism in pediatric patients, versus *Staphylococcus* in adults.\textsuperscript{65,88,89} Fungal infection can occur in association with organic matter, such as tree branch injury. Soil-contaminated injuries carry an increased risk of infection with *Bacillus* sp. and *Clostridium* sp., both of which are highly virulent organisms.

**Retinal detachment**

RD in the setting of an OGI in children is also associated with a worse visual prognosis, particularly if the injury involves Zone 3 [Figure 2 and Table 2].\textsuperscript{90} Surgical management of RD in children after OGI has been shown to improve visual prognosis.\textsuperscript{65,95} PPV followed by silicone oil infusion provides a relatively clear view for after OGI has been shown to improve visual prognosis.\textsuperscript{66} PPV should be considered for VH within 7-14 days of OGI, particularly if Zone 2 or 3 is involved, to prevent tractional RD.\textsuperscript{93}

**Vitreous hemorrhage**

VH is commonly seen with posterior segment injuries. Vitrectomy can be delayed for 2-3 weeks in cases of VH without RD; however, if VH is visually significant, observation must be balanced with the risk of amblyopia.\textsuperscript{90} PPV should be considered for VH within 7-14 days of OGI, particularly if Zone 2 or 3 is involved, to prevent tractional RD.\textsuperscript{93}

**Corneal opacities**

Posttraumatic corneal opacities can be due to scarring or band keratopathy. These conditions should be managed aggressively with definitive surgical treatment, especially when the central visual axis is involved, to prevent amblyopia.\textsuperscript{94}

**Sympathetic ophthalmia**

Sympathetic ophthalmia is a rare condition in which an autoimmune response causes granulomatous panuveitis in the uninjured sympathizing eye as well as in the injured eye. Its incidence after trauma has been reported to be rare (<1%) even in pediatric patients.\textsuperscript{90} The standard initial treatment is high-dose systemic corticosteroids often followed by steroid-sparing agents, with immunosuppressant therapy for refractory cases. Advances in medical management have dramatically decreased the need for prophylactic secondary enucleation or evisceration;\textsuperscript{90,98} should enucleation be needed or desired, e.g., for cosmetic reasons, it may be necessary to place a conformer to insure proper orbital bone growth.\textsuperscript{93} Enucleation and conformer placement often are managed by an ophthalmic plastic surgeon and oculist.

**Toxicity due to chronic intraocular foreign body**

An IOFB can go undetected for many years after OGI. Metal IOFBs are typically the most toxic, so a high clinical suspicion for occult IOFB is needed in patients with a history of OGI and signs of IOFB toxicity as detailed below.\textsuperscript{95} Definitive treatment for chronic IOFB toxicity is removal of the offending IOFB.

Copper IOFB toxicity is called chalcosis bulbi. An IOFB composed of more than 85% copper can produce an intense inflammatory response including hypopyon and may present as sterile fulminant endophthalmitis.\textsuperscript{98} IOFBs with lower copper content can show green discoloration of Descemet’s membrane, a red-brown cataract, and uveitis progressing to phthisis.\textsuperscript{65} Iron IOFB toxicity, termed siderosis bulbi, can induce retinal degeneration with progressive vision loss\textsuperscript{89} and retinal vascular change.\textsuperscript{98} An early sign is mydriasis progressing to rapidly increasing IOP. Decreased B waves are seen on the electroretinogram.\textsuperscript{100,101}

**PROGNOSIS**

The rate of successful treatment after pediatric OGI, defined as having a final VA of 20/40 or better, is between 54% and 56.5% in industrialized countries\textsuperscript{9,19,22} with a less favorable prognosis in nonindustrialized countries (15.5-25.7%).\textsuperscript{2,14,16,13} Table 2 and Figure 2 summarize the factors significantly associated with a
low final VA in pediatric OGI patients in more than one case series. Common causes of persistently low final VA in children who sustained OGI are residual corneal opacity and amblyopia.[13]

**Systems for prediction**

Various scoring systems have been devised to predict final VA in ocular trauma. Kuhn et al.[102] developed the ocular trauma score (OTS) in 2002 from the large-scale eye injury registries of Hungary and the United States, with poor initial VA, rupture, endophthalmitis, perforation, RD, and APD listed as factors negatively affecting the score and thus final predicted VA.

To devise a prospectively validated system for VA prognosis in OGI, Schmidt et al.[103] proposed a classification and regression tree (CART) model in 2008 on 221 OGI patients to measure vision survival (light perception or better) versus no vision, and minimal to severe vision loss (20/400 or better) versus profound vision loss.

Most recently, a pediatric OTS (POTS) was formulated that de-emphasized VA in predicting visual prognosis due to the difficulty in ascertaining an accurate initial VA in the youngest patients, a point also raised by other investigators.[18][21] Acar et al.[21] provided an equation to determine the POTS in patients in whom initial VA was unable to be obtained, doubling the weight of age and zone of injury in the score calculation. It also eliminated APD from the list of associated ocular pathologies that would deduct raw points from the total score and, thus, predict a poorer prognosis. APD has been associated with false positives due to severe hyphema or severe VH.[66]

Studies have shown that the OTS is an accurate prognostic indicator for pediatric OGI,[15,19,20,104] more so than either POTS[19,104] or CART.[105]

**CONCLUSIONS**

The pediatric population composes nearly 35% of all ocular trauma cases in the United States, despite a 17% decline in pediatric cases from 1990 to 2009 in the United States.[38] Boys sustain more OGI's than girls, and the most frequent mode of injury is penetration with sharp objects. OGI's occur more in children at home than anywhere else. Systems of classifying ocular trauma remain largely the same in pediatric as in adult patients, with Zone 1 being the most frequently affected region in pediatric OGI.

OGI diagnosis is clinical, with CT and US indicated to rule out IOFB and to visualize the posterior segment, respectively. Prophylactic antibiotics typically used include cefazolin or vancomycin plus ceftazidine in cases of IOFB. Emergent primary globe repair must be done to close the wound, remove IOFBs, and reposition prolapsed tissue. In addition to treating structural and infectious complications, management of pediatric OGI is focused on preventing amblyopia, because patient compliance with patching is generally low even at the expense of vision recovery. Traumatic cataracts secondary to corneal laceration are the most common cause for severe, refractory VA decline in children's eyes post-OGI. The number one organism isolated in pediatric OGI-associated endophthalmitis is *Streptococcus*.

Although devised for adults, the OTS has been shown to be an effective tool to gauge final VA after OGI in children as well. Factors indicating poor visual prognosis are young age, poor initial VA, posterior eye involvement, long wound length, globe rupture, lens involvement, VH, RD, and endophthalmitis.

Additional large-scale prospective studies are needed to improve evidence-based management of OGI for timely prevention of posttraumatic vision loss early in life.

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**Conflicts of interest**

There are no conflicts of interest.

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