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The Epidemiology and Incidence of Visual Deficits Following Ocular Trauma in Pediatric Patients

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THE EPIDEMIOLOGY AND INCIDENCE OF VISUAL DEFICITS FOLLOWING OCULAR TRAUMA IN PEDIATRIC PATIENTS

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ABSTRACT

THE EPIDEMIOLOGY AND INCIDENCE OF VISUAL DEFICITS FOLLOWING OCULAR TRAUMA IN PEDIATRIC PATIENTS. Viral V. Juthani and M. Bruce Shields. Department of Ophthalmology and Visual Sciences, Yale University School of Medicine, New Haven, CT.

Ocular trauma has long been a significant disabling American health problem and a leading cause of unilateral visual loss in children. These injuries have many diverse costs including human suffering, long-term disabilities, loss of productivity, and economic hardship. Although several studies have evaluated the epidemiology of specific types or mechanisms of ocular trauma, there are few that describe the epidemiology and visual outcomes of a comprehensive set of ocular trauma diagnoses. The purpose of this thesis is to describe the incidence of significant deficits in visual acuity following pediatric ocular trauma and to describe the overall epidemiology of pediatric ocular trauma presenting to the Yale Eye Center or Yale Ophthalmology consult service between 1999 and 2006.

A retrospective analysis of 396 cases of pediatric ocular trauma that presented to the Yale Eye Center or Yale Ophthalmology Consult Service between 1999 and 2006 was performed in which the study population was defined as children between 0 and 18 years of age with the following ICD-9 codes: 802.4-802.9 (malar, maxillary, orbital floor, and facial bone fractures), 870.0-870.9 (open wounds of the ocular adnexa), 871.0-871.9 (open wounds of the eyeball), 918.0-918.9 (superficial injury of the eye and adnexa), 921.0-921.9 (contusion of the eye and adnexa), 950.0-950.9 (injury to optic nerve and pathways), and 951.0-951.4 (injury to the other ocular cranial nerves). All data were

examined for any correlation between parameters studied. Statistical significance for categorical data was performed using 2x2 contingency tables, Fisher's exact test, and two-tailed P values.

A total of 61 patients (15.4 %) had a final visual acuity with some degree of deficit. However, only a small proportion (7.3%) of children seen for an ocular injury was significantly visually impaired in the affected eye as a result of the injury. Males had a disproportionately large representation in the blindness category where they made up 77.3% compared to 65% of the overall patient population. . Males in the 10-14 year age group were at the highest risk for eye injury (20.9%), and females in the 5-9 year age group were at the lowest risk (8.7%). The most common injuries were superficial injuries to the eye and ocular adnexa (33%) and contusions of the eye and adnexa (27.6%). In all age groups, the most common sites of injury were in the home (30.6%) and on streets/roads (30.6%).

The data presented demonstrate a clear need for primary prevention and control of pediatric ocular trauma. Education targeting parents, school teachers, and children regarding hazardous objects, toys and the devastating consequences of seemingly innocuous actions is needed to reduce the incidence of ocular trauma and its consequences. It will also be important to continue to recognize the geographic variability, and dynamic changes throughout time in the epidemiology of ocular trauma.

ACKNOWLEDGEMENTS

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INTRODUCTION

Ocular trauma is a significant disabling American health problem and a leading cause of visual loss in children. The costs of eye injuries are vast and diverse, in terms of human suffering, long-term disabilities, loss of productivity, and economic strain. While no segment of society escapes the risk of ocular trauma, those at greatest risk are primary the young [1]. According to one study by the National Society to Prevent Blindness, published in 1980, and the Annual Report of the United States Eye Injury Registry (a registry consisting of voluntary reports of serious, potentially vision-threatening trauma from 41 states), published in 2000, eye trauma is the leading cause of noncongenital monocular blindness in persons younger than 20 years of age in the United States [2]. In addition, injury is leading cause of eye-related hospital admissions [2].

Economic Costs

Current information regarding the public cost of eye injuries is limited to specific types of injuries and specific geographic regions. However, these figures may be extrapolated to the known frequency of eye injuries in America. Estimates place the cost for the projected 227,000 hospital days for eye trauma at $175 to 200 million [1]. These costs exclude any changes in career or other economic losses, which can be further compounded when considering the pediatric patient population. The National Safety Council estimates that job-related (approximately one-third of all eye injuries) eye trauma costs amount to $300 million annually [2]. This figure includes medical and hospital bills, workmen's compensation, and lost production time. Less than three cents of every dollar spent on eye research supports investigations primarily related to ocular trauma, despite the hundreds of millions of dollars in costs associated with eye injury [1]. In 1988, the Committee to Review the Status and Progress of the Injury Control Program at the Centers for Disease Control recognized that "injury research should be considered an investment that will more than pay for itself by reducing the economic burden of injury and disability." [3] Both eye trauma victims and society bear a large, potentially preventable burden. In terms of costs related to eye injury related hospitalization in the United States, according to the Kids' Inpatient Database for 3834 actual eye injury related hospitalizations inpatient charges for the treatment of these injuries were more than $88 million in 2000.[1]

There are various studies describing the epidemiology of ocular trauma in distinct locations with different demographics and distinct time frames. The next section will review the findings of these studies.

Age

Most studies report no significant difference in the prevalence of ocular trauma between age groups 0-5, 5-10, 10-15, and 15-18. According to one study which described the epidemiology of trauma in children 15 years and younger who underwent evaluation in an emergency room in Colombia found that approximately 71 percent of patients were 10 years or younger and the mean age was 7.78 years, but that the prevalence was not significantly different across the age groups [4]. According to another study which described ocular trauma in children registered in the National Pediatric Trauma Registry found that children with ocular trauma presented with a mean age of 8.6 years [5]. According to a recent European retrospective analysis of childhood eye injuries in children less than 12 years of age, the mean age of patients was 7.2 years [6]. The authors of a retrospective review in Turkey who studied children presenting with perforating eye injuries reported a mean age of 8.35 years [7]. The factors that influence the mean age data include ages included in review and type of injuries noted. It is understandable that a review excluding older patients, for example greater than 12 or 15 years would have a lower reported mean age.

Gender

Most studies in the literature show a higher prevalence of ocular injury involving males. The degree of increased prevalence among males usually varies by age group. Several studies have shown a male to female ratio ranging from 2.0 to 7.3:1 [1, 4-6]. Serrano, et al reported a male to female ration of 1.8:1, which was significant at $p<.001$. The study also found that the highest male to female ratio ocular trauma was found in the oldest age group (10-15 years) at 2.5:1. The youngest age group (0-5 years) showed a lower discrepancy between genders at 1.6:1 [4]. In a study of perforating eye injuries in children 14 and younger, in Turkey, Soylu, et al found an overall ratio of males to females of 2.6:1. This study also reported a lower ratio in the youngest age group (1.29:1). The ratio increased with older age groups; the 5-9 year old age group had a ratio of 2.6, and the 10-14 age group had a ratio of 5.2 [7]. According to a subset of pediatric ocular trauma patients registered in the national pediatric trauma registry (NPTR), the overall ratio of males to females ages 0-18 was 1.86. Males in the 11-18 year age group were at the highest risk for eye injury and females in the 6-10 year age group were at the lowest risk. In contrast, the American Academy of Pediatrics reported in 1987 a male to female predominance of approximately 4:1 [8]. Variations in gender predominance clearly exist by region, time period studied, and types of injuries studied.

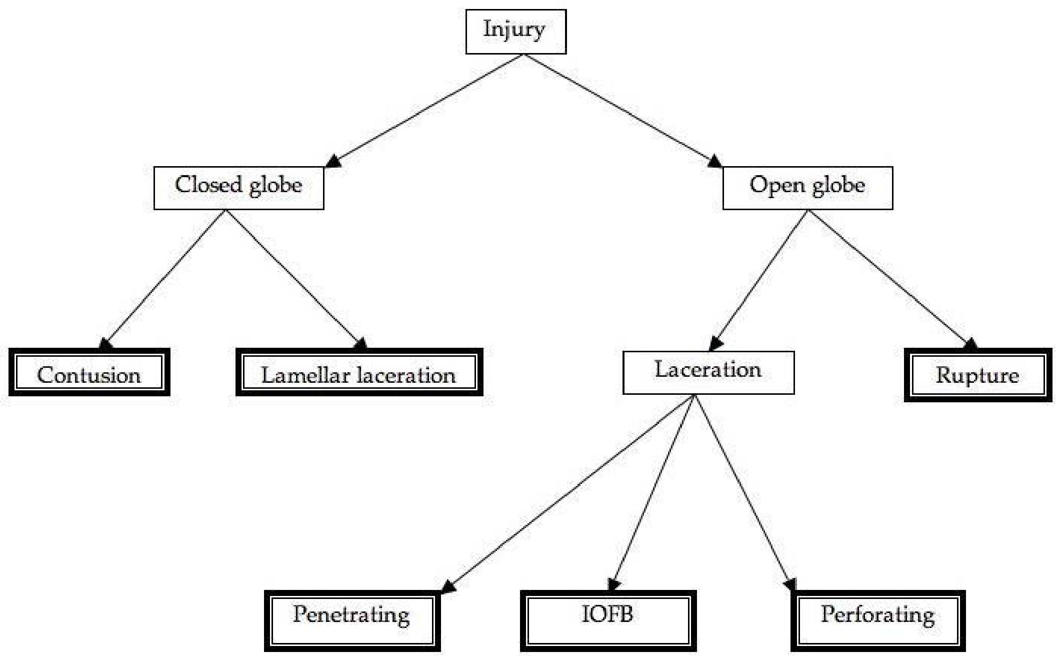
Location

Several studies report that the most common location for an injury to take place was the home, accounting for more than 50% of all accidents [9]. For children not yet in school or daycare, studies show that injuries occur almost exclusively in the home. Likewise, school-age children also suffered most injuries at home, which reflects the amount of time that children spend at home and the potential sources of injury in and around the home. The domestic setting has been long cited as a potentially dangerous location, especially with regard to penetrating injuries [10]. Other common locations for injury have been streets/roads, school/childcare, countryside, work premises, and recreation/sport [5,7,9]. Previous studies have shown different results as to the prevalence of these other locations in ocular injuries.

Classification of Ocular Trauma

The Birmingham Eye Trauma Terminology System (BETTS) is the most widely accepted, standardized system of categorizing ocular trauma (see figure 1) [11]. Ocular injuries are initially divided into open globe and closed globe injuries. Open globe injuries are then divided into lacerations (which include penetrating injuries, intraocular foreign bodies, and perforating injuries) and ruptures. Closed globe injuries are divided into contusions and lamellar lacerations. In open globe injuries there is a full-thickness wound of the eyewall, whereas in closed globe injuries, there is no such wound. Contusions of the eye are due to direct energy delivery by the object or changes in the shape of the globe. Lamellar lacerations involve partial thickness wounds of the eyewall. A ruptured globe is defined as a full thickness wound of the eyewall caused by a blunt object, whereas a laceration is a full-thickness wound caused by a sharp object. Penetrating (laceration) injuries involve entrance wounds only, while perforating injuries involve entrance and exit wounds. If a foreign body is retained intraocularly, it is technically a penetrating injury, although it is classified separately because it has a separate set of clinical implications. Some injuries are classified as mixed, for example, a BB gun injury is technically a IOFB, however, this is a blunt object that also involves an element of rupture.

Figure 1.



Types of Injury

Birth and Prenatal Trauma

Ocular injuries in the newborn are unusual, however they do occur. The most common traumatic injury is rupture of Descemet's membrane. This is usually caused by direct contact of forceps with the cornea, however periocular compression is also a possible mechanism [12]. The epithelial edema that results from this injury generally fades and the vertical line that results is usually insignificant, but true ruptures may lead to astigmatism and can result in anisometropic amblyopia [13]. Forceps injuries may also cause choroidal ruptures, even without external signs of injury [14]. Other pre/perinatal injuries that have been reported are periocular ecchymoses, lid and canalicular lacerations, ptosis, corneal edema, hyphema, and retinal hemorrhages [15-18]. Prenatal ocular injury has been reported to occur during amniocentesis, where ocular perforation may occur from the needle. The visual disability from this injury is variable [19-20].

Injuries to the Lids and Adnexa

Most orbital contusions due to blunt injuries cause soft tissue damage with very little disability, if any. Some trauma due to blunt objects can be associated with orbital fractures, hyphema, angle recession, iridodialysis, retinal edema, or retinal breaks. Deep bleeding can also cause compression of the optic nerve or ophthalmic artery. Occasionally, the distribution of the resulting hemorrhage may point to the nature of the injury. For example, blood under the superior conjunctiva suggests an orbital roof fracture, wheras hemorrhage in the lower lid and inferior orbit may suggest an orbital floor fracture. Basilar skull fractures may be seen as a ring-like distribution of blood around the orbit [21].

Lid Laceration

The most common causes of lid lacerations are injuries with sharp objects, animal bites, or even blunt objects such as elbows. Involvement of the canaliculi is also somewhat common and should be determined on examination [21].

Orbital Trauma

Blowout Fractures of the Orbital Floor

Orbital floor fractures can be divided into direct fractures which are orbital floor fractures that involve a fracture of the orbital rim, and indirect orbital floor fractures which are isolated orbital floor fractures. Indirect orbital floor fractures are commonly known as blowout fractures. These fractures are common when objects larger than the orbital opening, such as a fist, ball, or dashboard of an automobile, impact the orbit. The most common clinical sign of these fractures may be limitation of upward gaze. Limitation of downward gaze may also be present and often indicates entrapment of the inferior rectus or oblique muscle [22]. Small fractures sometimes produce articulated bone fragments which may lead to this condition. Other signs of blowout fractures are lid ecchymosis, orbital emphysema, and hypesthesia, resulting from disruption of the infraorbital nerve [21].

Injuries to the Globe

Injuries to the Conjunctiva and Sclera

A common injury following blunt trauma is a subconjunctival hemorrhage. In the absence of another injury, the blood gradually resorbs over 2 to 3 weeks. However, if conjunctival edema accompanies a minor injury, the possibility of scleral rupture or a retained foreign body should be entertained. When sharp objects such as a piece of glass, fingernail or metal objects strike the eye, a laceration of the conjunctiva is especially common. Sequelae of this injury include conjunctival hemorrhage, prolapse of Tenon's tissue or orbital fat [21]. Scleral ruptures can occur with blunt traumas, most notably at the limbus and posterior to the rectus muscle insertions, because the sclera is weakest at these sites [23]. Additional signs of scleral rupture may include an asymmetric drop in intraocular pressure, hyphema, irregularity of pupil shape, and decreased visual acuity.

Corneal Foreign Bodies and Abrasions

Corneal foreign bodies and abrasions are among the more common types of ocular injury and are common causes of acute ocular pain and foreign body sensation. A multitude of objects can lodge in the cornea or conjunctiva. While inert objects may have few secondary complications, other organic materials may cause deleterious reactions [21]. Foreign bodies may also lead to scleral injuries and one clinical sign of this is a conjunctiva that is not freely movable over the underlying sclera. Foreign bodies may also lead to corneal abrasions. When the corneal epithelium is scratched, denuded, or abraded, the superficial corneal nerves are exposed, causing pain, photophobia, and tearing. Extensive abrasions may lead to diminished visual acuity because the underlying layers of the cornea are not as reflective as the normal corneal epithelium [21].

Injuries to the Iris

Injuries to the iris may occur by direct blunt contusion to the eye or by traumatic injury to the ciliary ganglion. Blunt ocular traumas can injure the iris sphincter muscle, causing traumatic miosis, or pupillary constriction, followed by traumatic mydriasis, or pupillary dilation. Spasm or paralysis may be associated with this condition, resulting in blurred vision, pain, photophobia, perilimbal conjunctival injection, and anisocoria [21]. Clinical signs pointing to this condition include pigment cells in the anterior chamber and tears of the iris sphincter. Slow pupillary constriction to light may also be seen in the affected eye. A direct blunt trauma may also cause a cellular reaction in the anterior chamber.

In addition to direct contusion leading to injury of the iris, traumatic injury to the ciliary ganglion, which is located in the posterior orbit, may also occur, though rarely. This is often a complication of orbital floor fractures and results in traumatic mydriasis. Other more rare injuries involving the iris include iridodialysis, or disinsertion of the iris at its root, iris atrophy, and iridoschisis, or a split within the iris stroma. Iridodialysis is characterized by the appearance of multiple pupils, or polycoria, and is usually accompanied by hyphema [21].

Traumatic Hyphema

Although hyphemas are not always caused by trauma, the most common mechanism causing this condition is a blunt ocular injury which creates a tear in the face of the anterior ciliary body [21]. Patients with hyphema generally present with pain and children may even be somnolent [24]. Bleeding disorders, liver disease, or sickle cell disease would exacerbate the condition. Rebleeds generally occur from the second to fifth day following injury, are of greater magnitude, are more likely associated with raised intraocular pressure, and significantly reduce the visual prognosis [25].

Injuries to the Lens

Ocular contusion injuries may lead to a variety of pathologies related to the ocular lens, each with a series of complications. A contusion cataract occurs when the lens capsule is ruptured by a direct injury [21]. Patients present with opacification of the lens, decreased vision, elevated intraocular pressure, and intraocular inflammation. If the capsule is not ruptured, cataracts may form over the course of months, whereas if the capsule is ruptured, this process can occur within days or even hours. Cataracts secondary to ocular contusion injuries are often associated with severe posterior segment sequelae and poor visual outcomes [26].

Traumatic dislocation of the lens occurs when the contusion causes disruption of the zonules. Complete disruption leads to a completely dislocated lens, of which clinical signs include fluctuating vision, glare, monocular diplopia. Partial dislocations are also possible but are more difficult to diagnose [21]. Complications of dislocated lenses are pupillary block glaucoma and lenticular corneal touch, with possible damage to endothelial cells.

Any injury to the lens may cause amblyopia from occlusion or anisometropia in young children. Even patients in their late teens are susceptible to progressive axial myopia associated with traumatic glaucoma [27]. Injury to the lens may also induce glaucoma in mechanisms other than pupillary block, for example, lens proteins that are released by trauma can obstruct the trabecular meshwork. Alternatively, phacolytic glaucoma may be caused by macrophages which engulf lens material and become lodged in the anterior chamber angle.

Injuries to the Posterior Pole of the Eye

Severe trauma to the eye can result in a variety of injuries affecting the posterior pole including retinal detachment, tears, edema, choroidal ruptures, and avulsion of the optic nerve head. The severity of injury is correlated with involvement of the fovea. Severe trauma can lead to a disruption in the nerve fiber layer. If this disruption occurs in the macula, it is termed traumatic macular edema, and when it occurs in the periphery of the retina, it is called commotio retinae. In these cases, the retina appears grayish and translucent. Choroidal and chorioretinal ruptures are less common and occur when the trauma is significant enough to distort the globe and stretch the choroids [21]. Retinal tears usually result from severe impact directly over the retina from a small object, such as a BB pellet.

Optic nerve avulsion is the most severe injury that may result from a blunt trauma. It occurs when a small object strikes the globe and compresses it against the orbital roof. The clinical signs are brisk afferent pupillary defect, no light perception to light perception in the temporal field, followed by retinal infarction, retinal hemorrhages, and marked swelling of the retina.

Corneal and Corneoscleral Lacerations

Lacerations of the globe can be due to sharp objects or by objects smaller than the orbital opening at high energies, such as a racketball. Fortunately, many of these injuries are preventable.

Child Abuse

Child abuse continues to be one of the frequent and tragic causes of ocular injury in children today. Ophthalmic manifestations may exist from nonaccidental injury that is both obvious in nature, and more subtle such as a child that was violently shaken. These manifestations may be external or related to the anterior segment, or to the posterior segment.

External and Anterior Segment Manifestations

Injuries involving the Adnexa and anterior segment may be caused by direct blows to the head and face leading to corneal abrasions, traumatic cataracts, lid lacerations, chemical injuries, and ecchymoses [28-30].

Posterior Segment Manifestations

Retinal and vitreous hemorrhages are the most common posterior manifestations of child abuse [31-32]. They occur it 6 – 24% of all abused children and are more common in shaken baby syndrome [33-34]. They usually appear as flame-shaped hemorrhages in the posterior pole. Retinal hemorrhages in children under three years of age suggests nonaccidental trauma because other causes are extremely uncommon [35]. Other forms of retinal trauma may also be seen in child abuse, however other causes must be examined as well.

Sports and Recreational Injuries

Ocular injuries that result during sport or recreation may vary from a minor inconvenience to a potentially blinding injury. They are a major source of ocular trauma in the United States. Based on data from the U.S. Consumer Products Safety Commission, the distribution of injuries among various sports is age dependent, with injuries during basketball, baseball, and football being the most common. This is likely due to the widespread popularity of these sports. Racket sports are also a large threat due to the high speeds at which balls travel [36]. Ocular trauma during basketball usually occurs from contact with other players because the ball is too large to make direct contact with the globe [37]. On the other hand, injuries during baseball are usually related to the ball [38]. Fireworks are the most common cause of non-athletic recreational injuries [39]. Other common recreational activities involved in ocular trauma include fishhook injuries, paintball gun injuries, and BB pellet injuries [40-41].

Thermal Injuries

Common thermal injuries include exposure to fire and accidental burning injury of the eye via a lit cigarette. Exposure to fire usually results in thermal injuries to the lid rather than the globe itself. Complications may arise days to weeks later as scar tissue develops, possibly leading to fusion of the lid to the eye [8]. Cigarette burns generally cause mild, localized lesions that heal spontaneously within a few days [8].

Chemical Splash Injuries

Chemical injuries are a true ophthalmic emergency, which require immediate irrigation with copious amounts of water. Chemical burns from alkaline agents are more problematic because they dissolve body tissues by reacting with fats, and allowing deeper penetration of the substance. Acid burns are generally more superficial and less damaging because they have limited penetration to deeper structures [8].

Chemical eye burns are classified into four grades. The ultimate prognosis correlates with the extent of damage to conjunctival and episcleral tissue, and intraocular structures [42]. Grade I and II burns are associated with hyperemia, small conjunctival echymosis, and erosion of the corneal epithelium. Grades III and IV burns are accompanied by extensive and deep damage to the tissue.

Outcome

Final visual acuities vary widely by mechanism of injury and severity. Various studies have looked at subsets of ocular trauma populations with different findings; however, there are few studies that report final visual acuities in the pediatric population with comprehensive ocular trauma inclusion criteria. One retrospective study of severe childhood eye injuries requiring hospitalization in Hong Kong reported that 78% of patients had a visual outcome (defined as visual acuity at last recorded follow up visit) between 20/20 and 20/100 [43]. Prior studies report lower percentages, with 46-55% of patients having final visual outcomes between 20/20 and 20/100 [44-46].

STATEMENT OF PURPOSE

The etiology of pediatric eye injuries is directly related to the socioeconomic and educational status of the region being studied. In addition, the causes and location of injuries show differences in each population. Because of this, it is important not only to develop a national, comprehensive database of pediatric ocular injuries, but also to investigate the epidemiology of injuries in distinct regions, especially metropolitan areas with high rates of ocular trauma. Many eye injuries occurring in the pediatric population cannot be prevented, but by data collection to eventually identify any underlying factors in the etiology of serious injuries, it may be possible to determine the most effective methods of reducing the incidence of visually damaging trauma. Public education campaigns in the past have had a significant impact upon the incidence of some injuries. For example, reductions in eye trauma incidence of ice hockey injuries have been achieved through the mandatory use face guards in youth leagues [47]. Thus, new policies have changed the face of ocular trauma, and new studies need to be conducted in order to address the current common etiologies of pediatric ocular trauma.

The purpose of this thesis is to describe the incidence of significant deficits in visual acuity following pediatric ocular trauma and to describe the overall epidemiology of pediatric ocular trauma presenting to the Yale Eye Center or Yale Ophthalmology consult service between 1999 and 2006.

MATERIALS AND METHODS

A retrospective analysis of 400 cases of pediatric ocular trauma that presented to the Yale Eye Center or Yale Ophthalmology Consult Service between 1999 and 2006 was performed. For the purpose of this study, an ocular injury was defined as an injury of the surrounding bony structures, the adnexa, the eye, the optic nerve, and other ocular cranial nerves. ICD-9 coding is a method of clarifying diseases by assigning a unique numeric identifier to each disease. The study population was defined as children between 0 and 18 years of age with the following ICD-9 codes: 802.4-802.9 (malar, maxillary, orbital floor, and facial bone fractures), 870.0-870.9 (open wounds of the ocular adnexa), 871.0-871.9 (open wounds of the eyeball), 918.0-918.9 (superficial injury of the eye and adnexa), 921.0-921.9 (contusion of the eye and adnexa), 950.0-950.9 (injury to optic nerve and pathways), and 951.0-951.4 (injury to the other ocular cranial nerves). In addition, this analysis tabulated age, gender, eye involved, mechanism of injury (motor vehicle = MV, motorcycle = MCYC, bike, all terrain vehicle/recreational vehicle = ATV-RV, pedestrian = PED, gun shot wound = GSW, stab, assault, sport/recreation, blunt object = blunt, sharp object = sharp, animal related, fall, foreign body, chemical injury, thermal injury, and other), location of injury (home, street/road, school/childcare, countryside, work premises, recreation/sport, and other), object causing injury, visual acuity on presentation, and visual acuity at last recorded follow up appointment. The classification of severity of visual loss was defined as blindness < or = 10/200, significant deficit >20/200 and <20/100, mild deficit >20/70 and <20/40, and no loss >20/30. Children who did not meet the parameters of age, the ICD-9 codes listed above, or had no evidence of pediatric ocular trauma in the chart at the time of review were excluded and deleted. All data were examined for any correlation between parameters studied. This study was reviewed and approved by the Yale University School of Medicine Human Investigation Committee (HIC # 0608001689).

Statistical Analysis

Data analyses were conducted by using Microsoft Office Excel 2003 and GraphPad Statistical software 2005 (GraphPad Software, Inc., San Diego, CA). Excel was used to calculate frequencies, percentages, means, medians, and sums. The GraphPad software was used to calculate statistical significance categorical data using 2x2 contingency tables, Fisher's exact test, and two-tailed P values. Injury types, locations, and causes were examined against gender and age. Visual acuity on presentation and visual acuity upon most recent follow up exam (visual outcome) were correlated against gender, age, and type of injury using. Statistical significance for these correlations were also done using the GraphPad statistical software.

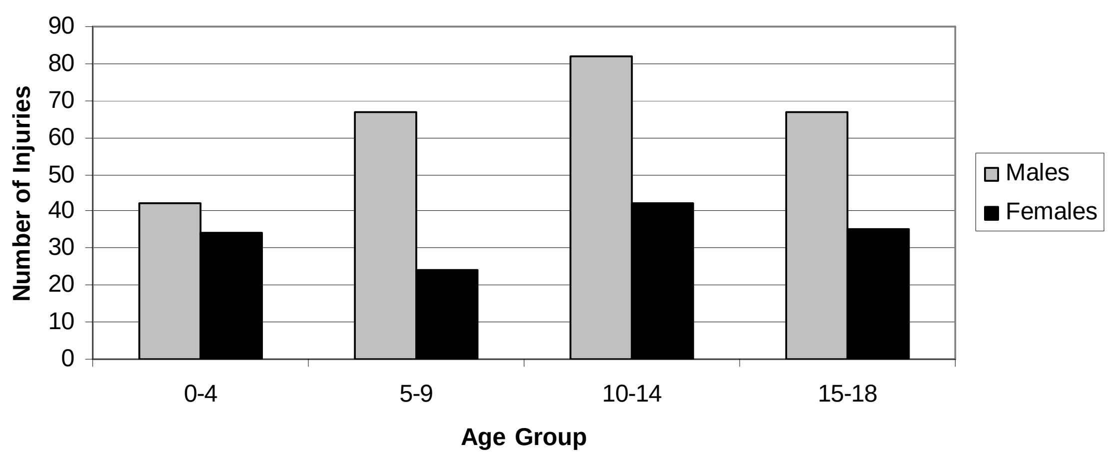
RESULTS

A total of 411 patients were seen by at the Yale Eye Center or Yale Ophthalmology Consult Service between 1999 and 2006. Of these patients, 396 were included for further data analysis. The fifteen remaining patients were excluded due to lack of available data.

Age and Gender

The age and gender of the cases are shown in Figure 2. The average age was 10.15 with SD 5.28. 19.2% (76 patients) of the study population was between the age of 0 and 4, 23.2% (91 patients) between 5 and 9 years, 31.6% (124 patients) between 10 and 14 years, and 26% (102 patients) between 15 and 18 years.

Figure 2



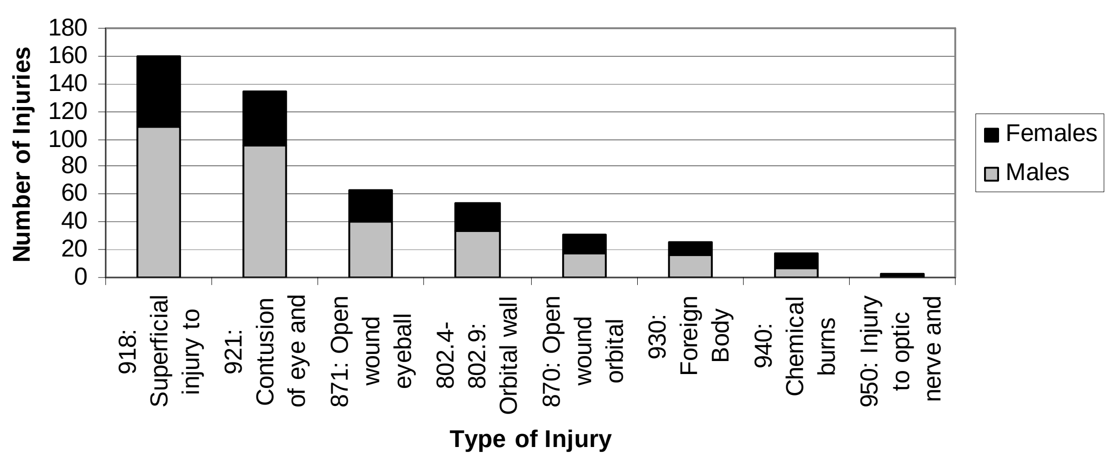
Males were nearly two times more likely to sustain an ocular injury from trauma as compared to females (1.91:1). Risk of ocular injury ranged from 8.7% to 10.9% for female age groups 0-4, 5-9, 11-14, and 15-18. Risk ranged from 10.6% to 20.9% for similar male age groups. Males in the 10-14 year age group were at the highest risk for eye injury (20.9%), and females in the 5-9 year age group were at the lowest risk (8.7%).

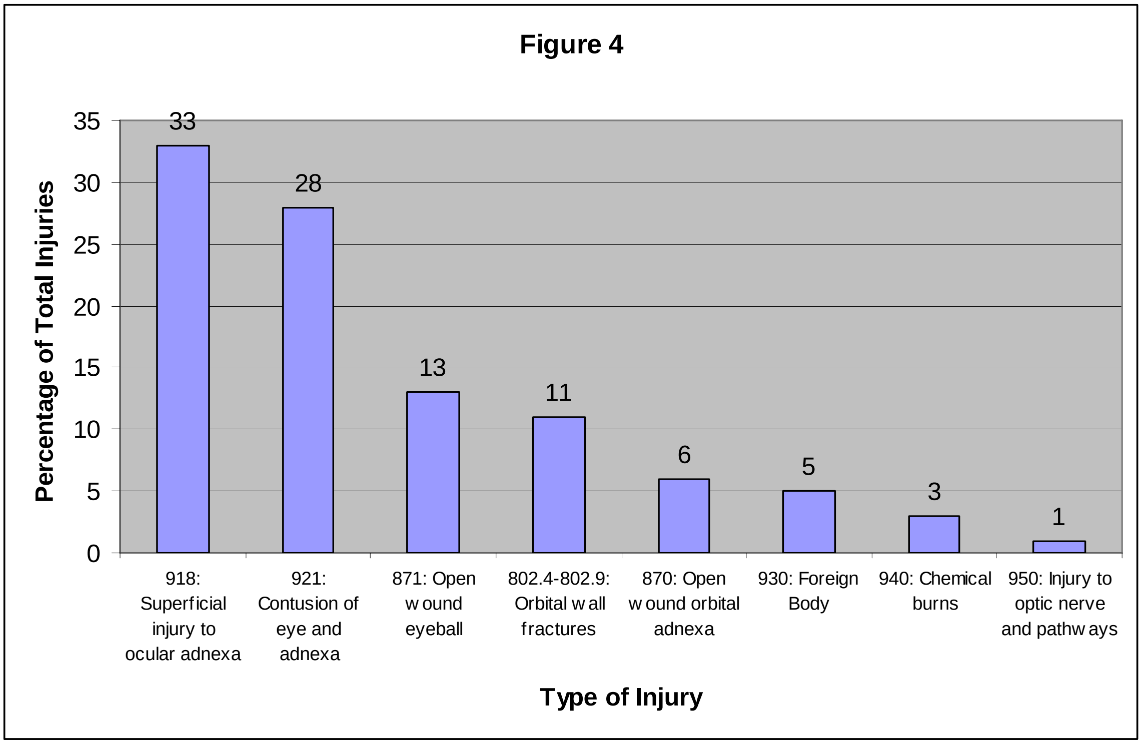
Type of Injury

There were 422 separate eye injuries to one or both eyes and/or the ocular adnexa among the 396 children with an eye injury, for an average of 1.07 separate eye injuries per child. The most common injuries were superficial injuries to the eye and ocular adnexa (33%) and contusions of the eye and adnexa (27.6%). There were 63 (12.9%) open wounds of the eyeball, 54 (11%) orbital wall fractures, 31 (6.3%) open wounds to the orbital adnexa, 26 (5.3%) foreign bodies, 17 (3.5%) chemical burns to the eye and adnexa, and 3 (0.6%) injuries to the optic nerve and pathways. With the exception of chemical injuries and injuries to the optic nerve and pathways, males had a higher rate of injury among the different injury types. The greatest gender discrepancy came among contusions of the eye and adnexa (70.1% male), followed by superficial injuries to the ocular adnexa (68.1% male). Among superficial injuries to the eye and adnexa, 140 (87.5%) cases involved a superficial injury to the cornea. 16 (10%) cases involved a superficial injury to the conjunctiva, and the remaining injuries were to the eyelids and periocular area. Among chemical injuries, alkaline chemical burns accounted for 53% of injuries, while acid chemical burns accounted for 24% of injuries. The remainders were unspecified chemical injuries. Among orbital fractures, 43 (79.6%) of injuries involved fractures of the orbital floor. 5 cases (9%) involved closed fractures of other facial bones.

Contusion injuries were also very common. 71 cases (52.6%) of contusion injuries resulted from contusions to the eyeball, while 34 cases (25.2%) of cases involved contusions of orbital tissues. 10 cases (7.4%) involved contusions of the eyelids and periocular area. Overall, there were 369 (75.5%) closed globe injuries, which include contusions and lamellar lacerations, and 120 (24.5%) open globe injuries, including penetrating wounds, perforations, IOFB, and ruptured globes.

Figure 3





Causes of Injury

There were a wide variety of causes of eye injury. The most common causes of injury are outlined in Table 1. The most common cause of injury was a sport or recreation related activity, which was associated with 68 (17%) injuries. The most common sports and recreational activities involved were baseball/softball (16), paintball (11), and soccer (9). In baseball and softball, the injuries were predominantly caused by blunt trauma from the ball itself, with only one instance of a patient being struck by a baseball bat. In paintball, the injuries usually were a result of impact by a paintball pellet. The injuries in soccer varied more, with some injuries caused by impact from another the extremities of another player, others by direct contact with the ball, and others from falls. Other common causes of injury included being hit by a sharp object, which accounted for 62 (15.7%) cases. The frequent sharp objects that caused an ocular injury were tree branches

(10), fingernails (10), and pens/pencils (8). Other objects involved were metal fragments, glass edges, sticks, utensils, and hangers. The next group causing injury were blunt objects other than fists (Injuries caused by fist impact were included in the assault group). Blunt objects causing injury in this review included snowballs (5), bottles (5), cardboard boxes (4), sticks (4), and many others. Motor vehicle accidents were another main cause of ocular injury in children. 35 cases were motor vehicle accident related, with seats, airbags, and other parts of the vehicle being the primary object causing the direct blow. There were just two cases in which a shattered windshield caused the injury. 27 injuries were caused by a chemical agent, most commonly a cleaning solution or detergent (12 cases). Assaults, falls, thermal injuries, animal related injuries (bites and scratches), foreign bodies, and BB pellets were other common causes of ocular trauma. Men and women were almost equally involved in injuries related to motor vehicles (18 injuries in males, 17 in females). Men were more commonly involved in an injury related to sport or recreational activity (49 versus 19), injuries related to blunt (45 versus 16) and sharp objects (44 versus 18), and BB pellet injuries, however these differences were not statistically significant. Surprisingly, there was also no statistical gender difference in the occurrence of assault.

Table 1.

Mechanisms of Injury	**Male**	**Female**	**Total**	**Age 0-4**	**Age 5-9**	**Age 10-14**	**Age 15-18**
MV	18	17	35	1	11	8	15
MCYC	1	0	1	0	1	0	0
Bike	3	3	6	0	3	3	0
GSW	2	1	3	0	1	0	2
Assault	10	6	16	1	1	2	8

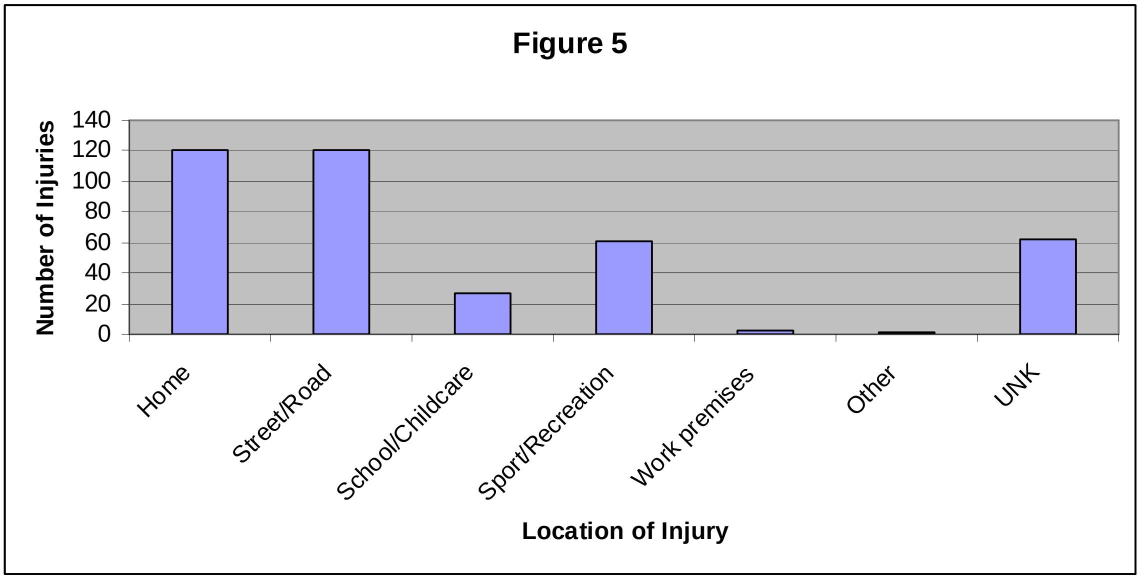
Sport/Recreation	49	19	68	3	9	31	25
Struck Animal	6	6	12	1	6	4	1
Fall	11	5	16	4	7	4	2
Blunt other than fist	45	16	61	8	16	27	12
Sharp	44	18	62	17	20	15	10
Chemical	9	18	27	10	5	6	9
BB pellet gun	5	1	6	0	2	2	2
Thermal	9	5	14	6	0	6	3
Foreign Body	9	4	13	4	3	4	2
Unknown	36	20	56	18	10	12	13

Location of Injury

The location of injury by age group is illustrated in Table 2. In all age groups, the most common sites of injury were in the home (30.6%) and on streets/roads (30.6%). The next most common locations were sport/recreational locales (15.4%), school/childcare (6.8%), workplace (0.8%), and other (0.3%). In the 0-4 year age group, there were a disproportionately large number of injuries occurring in the home at 57.3%. This was followed by streets/roads, school/childcare, and sport/recreation. In the 5-9 year age group, the home was the most common location for injury at 32.6%, followed by streets/roads at 31.5%, school/childcare, and sport/recreation. In the 10-14 year age group, streets/roads were the most common location for eye trauma at 34.4%, followed by home, sport/recreation, and work premises. In the 15-18 year age group, streets/roads were again the most common location for injury at 37.7%, followed by sport/recreation, home, work premises, and school. Injuries in the 0-4 year age group were significantly more likely to occur at home than in the other age groups ($p<0.002$ for all age groups). Injuries in the 15-18 year age group were significantly less likely to occur in school/childcare than in the 5-9 and 10-14 year age groups ($p<0.003$ for these age groups). Injuries that occurred in locations associated with sports or recreation were significantly more likely to occur in the 10-14 and 15-19 year age groups ($p<0.03$). Females in this study were statistically more likely to endure injury in the home than were men ($p<0.03$) with 38.1% of injuries in females occurring at home compared to 26.7% in males. 33.2% of males suffered eye injury on streets or roads, as opposed to 25.4% in females. This difference was not statistically significant, however. There was also no significant difference between males and females among injuries occurring at school or at the workplace. 17.6% of injuries in men occurred at locations associated with sport or recreation as opposed to 11.2% in females, however this difference was not statistically significant.

Table 2.

Location of Injury	**Male**	**Female**	**Total**	**Age 0-4**	**Age 5-9**	**Age 10-14**	**Age 15-18**
Home	70	51	121	43	30	30	19
Street/Road	87	34	121	8	29	43	40
School/Childcare	17	10	27	3	11	13	1
Work premises	2	1	3	0	0	0	3
Sport/Recreation	46	15	61	2	8	26	25
Other	1	0	1	0	0	0	1
Unknown	39	23	62	19	14	13	17
Total	262	134	396	75	92	125	106



Visual Acuity on Presentation

Out of the 396 patients whose data were analyzed, the visual acuities of 26 patients were unknown due to patient inability or uncooperativeness. Three patients had impaired visual acuities on presentation, but these were unchanged from their baseline acuities prior to injury, and therefore categorized separately. Overall, there were 52 cases (13.1%) in which patients presented initially with blindness, defined as visual acuity worse than 20/200. There were 32 cases (8.1%) in which patients presented with a significant visual deficit, which was defined as visual acuity < 20/100 and ≥ 20/200. 54 patients (13.6%) presented with a mild visual deficit, defined as visual acuity ≤ 20/40 and ≥ 20/100. 229 patients (57.8%) presented with no visual deficit, defined as having a visual acuity > 20/40. In summary, a total of 167 patients (42.2%) had some degree of visual deficit on presentation. Males had a disproportionately high representation in the blindness on presentation category where they made up 73.1% compared to only 65% of the overall patient population. However, the difference between male and female blindness cases was not statistically significant (p=0.22). In fact, there was no statistical significance in any category of visual deficit between genders. In the 0-4 year age group, 3 (3.7%) cases were associated with blindness on presentation, 0 cases (0%) were associated with a significant deficit, 9 (11.1%) cases were associated with a mild deficit, and 54 (66.7%) were associated with no visual deficit. In the 5-9 year age group, 7 (7.9%) cases were associated with blindness, 3 (3.4%) associated with a significant deficit, 16 (18.0%) associated with a mild deficit, and 56 (62.9%) associated with no deficit. In the 10-14 age group, 20 (16.1%) were associated with blindness, 11 (8.8%) with a significant deficit, 17 (13.7%) with a mild deficit, and 72 (58.1%) with no visual deficits. In the 15-18 year category, 22 (21.6%) were associated with blindness, 12 (11.8%) with a significant deficit, 12 (11.8%) with a mild deficit, and 53 (52.0%) with no deficits. Injuries in the 15-18 age group were significantly more commonly associated with blindness on presentation than the 0-4 and 5-9 year age groups ($p<0.02$ for these groups). Injuries associated with blindness on presentation in the 10-14 year age group were more common than the younger age groups as well (16.1% versus 3.7% and 7.9%), however this difference was not statistically significant. Inversely, Injuries associated with no visual deficit were significantly more common in the 0-4 age group compared to the 15-18 year age group ($p<0.05$). Visual outcomes by type of ocular injury are presented in table 3. Injury types most commonly associated with blindness on presentation were contusions of the eye and adnexa (38.5% of blindness cases) and open wounds of the eyeball (28.8% of blindness cases). Injuries most commonly associated with significant visual deficit were also contusions of the eye and adnexa, superficial injuries to the ocular adnexa, and open wounds to the eyeball. Superficial injury to the ocular adnexa was the most common cause of mild visual deficits (40.7% of mild deficit cases). Superficial injuries of the ocular adnexa were also the most common cause of patients presenting without any visual deficits. Injuries caused by open wounds of the eyeball were significantly more associated with blindness on presentation compared to any other type of injury ($p<0.02$), with the exception of injuries to the optic nerve and pathways. However, there were only two injuries of this type in our sample, making statistical significance difficult to achieve. In addition, the association between open wounds of the eyeball and any visual deficit overall was statistically significant, compared to any other type of injury.

Visual Outcome

Visual outcome is defined in this study as the visual acuity upon most recent follow up exam and prior to any separate injuries occurring at a later date.

Out of the 396 patients whose data were analyzed, the final visual acuities of 21 patients were unknown due to patient inability or uncooperativeness. Eleven patients had visual outcomes that were impaired, but unchanged from baseline. Overall, there were 22 cases (5.6%) in which blindness was the outcome (17 males and 5 females). There were 7 cases (1.8%) in which patients concluded with a significant visual deficit, 26 patients (6.6 %) with a mild visual deficit, and 308 patients (77.8 %) with no visual deficit. In summary, a total of 61 patients (15.4 %) had a final visual acuity with some degree of deficit. Males again had a disproportionately large representation in the blindness category where they made up 77.3% compared to 65% of the overall patient population.

6.5 % of males ended with blindness. Thus a larger percentage of men had a visual outcome of blindness compared to the percentage of men presenting with blindness (73.1%). This difference was statistically significant (p=0.003). 6.5% of males ended with blindness compared to 3.7% of women who ended with blindness. However, statistically, there was no gender that was significantly more likely to be associated with a final visual outcome of blindness (p=0.35). In addition, neither gender was significantly more likely to be associated with any level of visual deficit. In the 0-4 year age group, 4 (5.3%) cases had an outcome of blindness, 0 cases (0%) were associated with a significant deficit, 0 (0%) cases were associated with a mild deficit, and 69 (92.0%) were associated with no visual deficit. In the 5-9 year age group, 1 (1.1%) case was associated with blindness, 2 (2.2 %) associated with a significant deficit, 10 (10.9%) associated with a mild deficit, and 69 (75.0%) associated with no deficit. In the 10-14 age group, 8 (6.4%) were associated with blindness, 2 (1.6%) with a significant deficit, 10 (8.0%) with a mild deficit, and 94 (75.2%) with no visual deficits. In the 15-18 year category, 10 (9.6%) were associated with blindness, 3 (2.9%) with a significant deficit, 6 (5.8%) with a mild deficit, and 77 (74.0%) with no deficits. Injuries in the 15-18 age group were significantly more commonly associated with blindness than the 5-9 year age group (p<0.02). However, they were not more closely associated with blindness than the other age groups. The 15-18 and 10-14 age groups were significantly more associated with a long term visual deficit than the 0-4 age group. There was no significant difference between the 0-4 and 5-9 year age groups in terms of final visual deficit. Visual acuity outcomes by type of ocular injury are presented in table 3. Injury types most commonly associated with a final visual outcome of blindness were open wounds of the eyeball

(36.4% of blindness cases) and contusions of the eye and adnexa (31.8% of blindness cases). Injuries most commonly associated with significant visual deficit were also contusions of the eye and adnexa and and open wounds to the eyeball, which accounted for 100% of significant deficit causing injuries. Contusions to the eye and adnexa (30.8%), superficial injuries to the ocular adnexa (26.9%), and open wounds to the eyeball (26.9%) were the most common cause of mild, long-term visual deficits. Superficial injuries of the ocular adnexa were also the most common cause of patients presenting without any visual deficits. Injuries caused by open wounds of the eyeball were the most common cause of long-term blindness, however, this result was not statistically significant.

DISCUSSION

This study has identified that eye injuries continue to be a important problem in the pediatric population. However, only a small proportion (7.3%) of children seen for an ocular injury was significantly visually impaired in the affected eye as a result of the injury. This is an improvement compared to previous studies, and can be viewed as progress in ophthalmic management and injury prevention strategies. It is important to note, however that prevention is the optimal management of trauma and must remain a priority in order to reduce existing morbidity and costs associated with ocular trauma.

Age and Gender

As shown above, nearly twice as many males as females were involved in an ocular injury. This is was generally consistent with previous studies, though on the lower end of report ratios [4]. Compared to studies done in Columbia and Turkey [4,7] the ratio of males to females is lower in this study. This may be due, at least in part, to cultural differences with females having possibly more freedom outside the home in this region. The difference may also reflect the type of injury being studied. For example a study including only open globe injuries may have a higher rate of males, although this study reports no statistical difference between genders and injury type. Like previous studies, this study also reports no statistical difference in the rates of ocular injuries between age groups 0-4, 5-9, 10-14, and 15-18. However, given that the fourth age groups contains one fewer year of life, the actual rates of injury per age year may be higher with increasing age.

Location of Injury

In this study, the most common locations for ocular injury overall was the home and on streets or roads. This is consistent with most previous studies [10]. However, a larger percentage of patients were injured outside the home than reported previously. As stated earlier, the 0-4 age group and 5-8 year age groups incurred a large percentage of injuries in the home as has been shown in previous studies. Although parental education regarding dangers in the home has taken place, the home still contains several potential sources of injury. However the 10-14 and 15-18 year age groups sustained more injuries in streets and on roads than in the home. This trend likely reflects the amount of time spent engaged in some activity outdoors as age increases. This trend has also been seen in previous studies. In the New Haven area, the next common locations for injury are sport and recreational areas. Other studies have reported various other locations as the third most common, such as schools/childcare, work premises, and the countryside. Although all injuries occurring in sport and recreational areas are certainly not preventable, this finding may indicate that children in the New Haven area are less adherent to guidelines with regards to protective sporting equipment, such as face masks in paintball accidents, and face guards in hockey games. Where previous studies have reported a larger percentage of males injured on roads or streets, this study shows no statistically significant difference in the locations of male and female ocular injury. This likely reflects the equal amount of time males and females spend in the different locations, and this may differ from one region to another based on cultural norms.

Type of Injury

Most pediatric ocular trauma focus on a subset of injury types or injuries requiring hospitalization, and the research on a comprehensive set of ocular injury types is limited. For example, one study of pediatric eye injury related hospitalizations cited open wounds of the ocular adnexa as the leading type of injury requiring hospitalization, followed by orbital floor fractures and open wounds of the eyeball, contusions of the eye and adnexa, and superficial wounds of the eye and adnexa [1]. However, in this study, the leading types of injury were superficial wounds to the eye and adnexa, and contusions of the eye and adnexa. This reflects the fact that minor injuries are more common than the more severe injuries, and often do not require hospitalization. These findings are similar to a study of all ocular trauma in a Colombian region which showed that lamellar lacerations were the most common types of closed globe injuries [4]. Just as in this study, no significant differences in closed globe injuries were found by sex. However, unlike this study, they do report a significant difference by sex in open globe injuries.

Causes of Injury

Environmental circumstances also play an important role in eye injuries in New Haven. Many children play outdoors leading to blunt trauma from bicycles, motor vehicles, and other dangers in the environment. Sharp objects such as tree branches, glass, and metal fragments also frequently cause trauma outdoors. Smoking is common in many homes and other public areas, where children are unintentionally struck in the eye by cigarettes, leading to thermal injuries. Violence that is prevalent generates additional risks because the victims are frequently children. Fortunately, the percentage of ocular injuries resulting from assault was much lower in this study than in other reports, accounting for as much as 14% of injuries [9]. The wide variety of causes without one outstanding, predominant cause is a common finding in previous studies [4,7].

Visual Outcomes

The type of injury, its severity, and initial visual acuities are known prognostic factors of the visual outcome following ocular trauma [4]. Most cases were not severe closed-globe injuries and did not cause any initial visual impairment. In fact, more than 90% of cases that presented without any impairment ended with a visual outcome in this category. Closed globe injuries caused by contusions and injuries caused by open wounds of the eyeball were both significant causes of blindness as a visual outcome. However, whereas 15 open wound cases presented with blindness, only 8 had a final visual acuity of blindness. Likewise, 20 contusion cases presented with blindness, and just 7 had a resultant visual acuity of blindness. 73 total patients presented with significant visual impairment or blindness from all types of injury, and 30 had resultant blindness. Thus 41% of initially significantly impairing injuries caused severe visual impairment or blindness, with all the psychosocial, emotional, and economic implications that this condition places on the child, family, and society.

The visual prognosis of eye injuries thus improves greatly when prompt examination, diagnosis, and treatment are provided. Appropriate management by general physicians or emergency department physicians is also a key factor before ophthalmologic consultation in improving the visual prognosis. Therefore, adequate training of general practitioners should be provided to ensure the recognition of the severity of trauma, proper medical management, and prompt referral to an ophthalmologist.

Limitations

This study is limited by its retrospective nature. Since medical records are not always completed in a standardized manner, recording bias may result. In addition, final visual outcomes were limited to the last recorded visual acuity in the medical record; however the visual acuity of some patients may have improved after the last recorded data. This study was also unable to measure the incidence or prevalence of ocular trauma because the cases reviewed were all seen by an ophthalmologist, whereas many other cases are managed in the ambulatory setting and are not referred. As a result of this fact, more severe injuries that needed transfer to a tertiary-level center may magnify the incidence of more severe injuries in our data set.

Conclusions

The data presented here regarding the epidemiology of ocular trauma in children demonstrate a clear need for primary prevention and control. Education targeting parents, school teachers, and children regarding hazardous objects, toys and the devastating consequences of seemingly innocuous actions is needed to reduce the incidence of ocular trauma and its consequences. Dramatic improvements in the surgical management of ocular trauma have evolved over the past two decades, most notably the reduction in ice hockey eye injuries among youth players after full face protection was made compulsory [49-51]. However, the standardized documentation of eye injury morbidity and treatment will continue to improve techniques for preventing and improving the prognosis of serious eye trauma. The USEIR is a promising step and has a useful role in monitoring the epidemiology of eye injuries, their management, and recovery of vision. We must continue to strive to improve our techniques of salvaging injured eyes, and advocate prevention as the leading mechanism for change. Adult supervision has been found to be an important factor in the prevention of accidents and is of great value in preventing eye injuries in children [48]. It will also be important to continue to recognize the geographic variability, and dynamic changes throughout time in the epidemiology of ocular trauma.

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APPENDIX

Table 3. Visual Acuity on Presentation by Type of Injury

Type of Injury	Blindness <20/200	Significant Deficit 20/100-20/200	Mild Deficit 20/30-20/100	No Deficit	UNK	No change
802.4-802.9: Orbital wall fractures	1	0	5	39	2	0
870: Open wound orbital adnexa	2	2	4	14	1	0
871: Open wound eyeball	15	4	4	8	5	0
918: Superficial injury to ocular adnexa	5	7	22	92	10	2
921: Contusion of eye and adnexa	20	12	13	53	7	0
930: Foreign Body	2	1	4	15	2	1
940: Chemical burns	0	1	1	12	2	0
950: Injury to optic nerve and pathways	1	0	0	1	0	0
UNK	0	0	0	1	0	0

Table 4. Visual Acuity on Presentation by Gender and Age Group

Visual Outcome on Presentation	Male	Female	Total	Age 0-4	Age 5-9	Age 10-14	Age 15-18
Blindness 10/200	38	14	52	3	7	20	22
Significant Deficit 20/100-20/200	17	15	32	0	3	11	12
Mild Deficit 20/30-20/100	33	21	54	9	16	17	12
No Deficit	153	76	229	54	56	72	53
UNK	16	10	26	15	7	3	3
No change	1	2	3	0	0	1	0
Total	258	138	396	81	89	124	102

Table 5. Final Visual Acuity by Type of Injury

Type of Injury	Blindness <20/200	Significant Deficit 20/100-20/200	Mild Deficit 20/30-20/100	No Deficit	UNK	No change
802.4-802.9: Orbital wall fractures	4	0	1	43	2	0
870: Open wound orbital adnexa	2	0	1	20	1	0
871: Open wound eyeball	8	2	7	18	4	0
918: Superficial injury to ocular adnexa	2	0	7	115	5	10
921: Contusion of eye and adnexa	7	5	8	77	6	0
930: Foreign Body	0	0	2	21	0	1
940: Chemical burns	0	0	0	13	2	0
950: Injury to optic nerve and pathways	0	0	0	1	0	0
UNK	0	0	0	1	0	0

Table 6. Final Visual Acuity by Gender and Age Group

Visual Outcome	Male	Female	Total	Age 0-4	Age 5-9	Age 10-14	Age 15-18
Blindness 10/200	17	5	22	4	1	8	10
Significant Deficit 20/100-20/200	5	2	7	0	2	2	3
Mild Deficit 20/30-20/100	18	8	26	0	10	10	6
No Deficit	204	105	308	69	69	94	77
UNK	11	10	21	1	5	7	7
No change	5	6	11	1	5	4	1
Total	260	136	395	75	92	125	104