Chapter 8
Ocular Trauma

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Abstract Ocular trauma is a devastating cause of vision loss with a wide variety of presentations. Randomized controlled trials are uncommon in the field of ocular trauma, since each injury is unique and treatment decisions are generally made on a case-by-case basis. Instead, the majority of studies in this field are retrospective case series, often with a focus on open globe injuries. Early studies established standardized terminology for describing ocular injury. Subsequent research determined key factors that predict visual prognosis after ocular injury, such as presenting visual acuity and the presence of a relative afferent pupillary defect. Additional studies have focused on sequelae of open globe injuries such as retinal detachment, proliferative vitreoretinopathy and endophthalmitis. This research has guided the development of standardized protocols for the diagnosis and management of traumatic ocular injuries.

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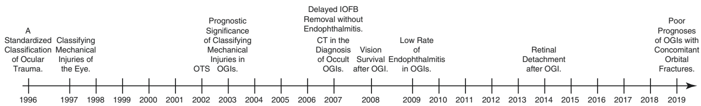

A Standardized Classification of Ocular Trauma – 1996 [1]

Purpose

To develop a standardized system for classifying ocular trauma. This publication was the first to establish consensus terminology and served as the basis for the Birmingham Eye Trauma Terminology (BETT) [2].

Method

A new system for classifying ocular trauma was developed by the authors and was presented internationally starting in 1993. A questionnaire was developed and responses from experts across the world were used to refine the classification system. After a three-year period of optimization, the consensus terminology was finalized [1].

Results

Ocular injuries were first divided into closed globe and open globe injuries. An open globe injury is defined as the presence of a full thickness wound through the cornea or sclera ("eyewall"). Conversely, a closed globe injury is one in which neither the cornea nor the sclera have been breached. A partial thickness eyewall injury is classified as a lamellar laceration. If there is no corneal or scleral wound but internal damage has occurred, then the injury is defined as a contusion. Open globe injuries were further subdivided into rupture or laceration injuries. Rupture occurs when blunt force causes a transient, sudden increase in intraocular pressure leading to a full thickness defect in the eyewall, frequently at its weakest location, and is often accompanied by tissue herniation. A laceration is caused by the direct entry of a sharp object. Laceration injuries were further subdivided into penetrating, intraocular foreign body and perforating injuries. Penetrating injury occurs when an object causes an entrance wound through the eyewall but no exit wound is present. An intraocular foreign body injury is a penetrating injury in which an object that causes the entrance wound is retained within the eye. Lastly, a perforating injury is one in which there is both a full thickness entrance wound and a full thickness exit wound [1].

Key Points
- Development of a single international terminology for ocular trauma provides clarity in clinical care and research settings.
- Using this system, open globe injuries can be subdivided into rupture, penetrating, intraocular foreign body and perforating injuries.

A System for Classifying Mechanical Injuries of the Eye – 1997 [3]

Purpose
To expand upon the classification developed by Kuhn et al. [1] to categorize ocular trauma in terms of anatomic and physiologic variables with previously demonstrated prognostic significance.

Methods
A group of 13 ophthalmologists from seven institutions, known as the Ocular Trauma Classification Group, reviewed the ocular trauma literature and developed a new classification system. The intent was to create a simplified system which relied on only a few variables with documented prognostic significance [3].

Results
Separate classification systems for open and closed globe trauma were created, each of which included the following four variables: type of injury, grade of injury, pupillary response and zone of injury. The type of injury was based on

the terminology previously developed by Kuhn et al. [1] and focused on the mechanism of trauma. For open globe injuries, it included rupture, penetrating, intraocular foreign body, perforating and mixed injuries. For closed globe injuries, it included contusion, lamellar laceration, superficial foreign body and mixed injuries. The grade of injury was based on the presenting visual acuity in the affected eye, with five categories ranging from ≥20/40 to no light perception. The pupillary response was defined by the presence or absence of a relative afferent pupillary defect. The zone of injury was based on the anatomical location of the open globe injury or the most posterior structure involved in closed globe injuries. In open globe injuries, Zone I included the cornea and limbus, Zone II included the anterior 5 mm of sclera and Zone III included any scleral injury more than 5 mm posterior to the limbus. In closed globe injuries, Zone I included the conjunctiva, sclera and cornea, Zone II included internal anterior segment structures and Zone III included posterior segment structures [3].

Key Points
- This classification system categorizes open and closed globe injuries based on key anatomic and functional variables with known prognostic utility.
- Because this system relies on only four variables, injuries can be easily categorized with minimal need for ancillary testing.

The Ocular Trauma Score (OTS) – 2002 [4]

Purpose
To develop a reliable method for determining visual prognosis after ocular injuries.

Methods
Over 2500 ocular injuries from the United States and Hungarian Eye Injury Registries were analyzed with attention to over 100 variables that might influence visual prognosis. An ocular trauma score was developed which incorporated six key factors that were determined to make substantial

contributions to final visual acuity and were straightforward to assess on initial examination [4].

Results

The ocular trauma score (OTS) was defined as the sum of numerical values corresponding to presenting visual acuity, presence of globe rupture, endophthalmitis, perforating injury, retinal detachment and relative afferent pupillary defect. The value assigned for visual acuity ranged from 60 (no light perception) to 100 (better than or equal to 20/40). The remaining factors were assigned negative values of different magnitudes. The sum of the raw points yields a number that can be used to stratify visual prognosis into five distinct prognostic groups. Patients with the lowest values have a 74% chance of no light perception vision and only a 1% chance of obtaining visual acuity better than or equal to 20/40 as their final result. Patients with the highest values have a 0% chance of no light perception vision and a 94% chance of obtaining visual acuity better than or equal to 20/40. While initial visual acuity plays a large role in the ocular trauma score, the authors report that the OTC outperforms prognostic methods based on presenting visual acuity alone [4].

Key Points

- The OTS can be used to stratify patients with ocular injuries into prognostic groups based on key presenting factors.
- Key factors in this metric include presenting visual acuity, the presence of globe rupture, perforating injury, endophthalmitis, retinal detachment and a relative afferent pupillary defect.

The Prognostic Significance of a System for Classifying Mechanical Injuries of the Eye in Open-Globe Injuries – 2003 [5]

Purpose

To determine the prognostic significance of the classification system developed by the Ocular Trauma Classification Group

[3], which was based on four key variables: the type of injury, grade of injury, pupil and zone of injury.

Methods

This was a retrospective chart review of open globe injuries presenting to the Wilmer Ophthalmological Institute between December 1985 and January 1993. Eyes were excluded if all four presenting variables were not documented, or if there were fewer than 3 months of follow-up. Based on these criteria, 150 eyes of 150 patients were included in the study. The correlation of each variable in the classification system with final visual acuity was examined. A good visual outcome was defined as visual acuity of 20/40 or better, whereas a poor visual outcome was defined as visual acuity worse than 5/200 [5].

Results

All four variables in the classification system were significant predictors of final visual outcome. For injury type, the probability of obtaining a good visual outcome was highest for penetrating injuries, followed by intraocular foreign body injuries, rupture injuries and finally perforating injuries. As expected, grade of injury was also a significant predictor of final visual outcome, such that presenting visual acuity was correlated with final visual acuity. The presence of a relative afferent pupillary defect was predictive of a poor visual outcome. For zone of injury, more posterior injuries were associated with the worst prognosis. The probability of a good visual outcome was highest for Zone I injuries followed by Zone II and Zone III injuries. A multiple logistic regression model was used to determine which variables were independently associated with visual prognosis. This revealed that the grade of injury (presenting visual acuity) and the pupil exam (presence of a relative afferent pupillary defect) were still significantly associated with final visual outcome after controlling for other variables [5].

Key Points

- The classification system developed by the Ocular Trauma Classification Group has prognostic utility in the setting of open globe injuries.

- Of the variables included in this classification system, presenting visual acuity and the presence of a relative afferent pupillary defect were key predictors of final visual acuity.

Computed Tomography in the Diagnosis of Occult Open-Globe Injuries – 2007 [6]

Purpose

To determine the utility of computed tomography (CT) in the diagnosis of occult open globe injuries, and to determine which specific radiographic signs are most predictive of this diagnosis.

Methods

This was a retrospective chart review of eyes that underwent surgical exploration due to concern for occult open globe injury after evaluation by CT scan between October 1998 and September 2003 at Parkland Memorial Hospital in Dallas, Texas. Eyes with obvious open globe injuries diagnosed at the slit lamp were excluded from this study, as were eyes with metallic intraocular foreign bodies identified on CT scan. In addition to the radiologist that made the original radiographic reading regarding the presence or absence of an open globe injury, the scans were re-evaluated by three masked observers: two neuroradiologists and one ophthalmologist [6].

Results

Forty-eight eyes of 46 patients were included in the analysis. Surgical exploration revealed that an open globe injury was present in 71% of these eyes. The original radiographic reading had a sensitivity of 79% and a specificity of 71% for determining the presence of an open globe injury. Between the three additional expert observers, sensitivity for open globe injury ranged from 56% to 68% and specificity ranged from 79% to 100%. Positive predictive value ranged from 86% to 100% and negative predictive value ranged from 42% to 50%. Positive predictive value was better for patients with blunt trauma compared to patients suffering projectile injuries (94% vs. 75%), whereas negative predictive value was worse for patients with blunt trauma compared to those suffering projectile injuries (33% vs. 70%). CT findings for which there was a statistically significant association with open globe injury included: change in globe contour, globe volume loss, absent/dislocated lens, vitreous hemorrhage and retinal detachment. The most common finding in confirmed open globe injuries was vitreous hemorrhage, and total vitreous hemorrhage was specific to eyes with open globe injuries. Other radiographic findings that were exclusively seen in open globe injuries included moderate change in globe contour, globe volume loss and absence of the lens [6].

Key Points

- CT scans are critical in the workup of potential open globe injuries.
- Certain radiographic findings, such as changes in globe contour and globe volume loss, are highly predictive of open globe injuries.
- CT scans are neither entirely sensitive nor specific for open globe injuries, so ambiguous cases require surgical exploration.

Delayed Intraocular Foreign Body Removal Without Endophthalmitis During Operations Iraqi Freedom and Enduring Freedom – 2007 [7]

Purpose

To determine the long-term outcomes and prognostic factors associated with delayed removal of intraocular foreign bodies (IOFBs) in United States military service members.

Methods

This was a retrospective case series of soldiers deployed during Operation Iraqi Freedom and Operation Enduring Freedom who sustained injuries involving IOFBs. The study included cases from February 2003 through November 2005. Soldiers with IOFBs underwent primary surgical closure of the globe at a local combat surgical hospital within hours of the injury. After medical stabilization, the patients were subsequently transported to Walter Reed Army Medical Center. Treatment primarily consisted of 20 gauge vitrectomy with IOFB removal, though some patients underwent primary enucleation or observation. The primary outcomes included final visual acuity and the rates of proliferative vitreoretinopathy (PVR) and endophthalmitis [7].

Results

Seventy-nine eyes of 70 soldiers were included in the study. The IOFBs were predominantly metallic, stone/concrete or glass. Overall, 10.1% of eyes had no light perception vision due to severe ocular injury and underwent enucleation, 6.3% of eyes did not undergo IOFB removal because the patient deferred it, while the remaining 83.5% of eyes underwent vitrectomy with IOFB removal. None of the eyes that were enucleated showed evidence of endophthalmitis. Eyes with retained foreign bodies were monitored with serial electroretinography and final visual acuity in these eyes ranged from 20/80 to 20/20. The time from injury to IOFB removal varied widely from two to 661 days, with a median time to removal of 21 days. Mean visual acuity was 20/400 preoperatively and 20/120 postoperatively. Endophthalmitis was not observed in any eyes. Extensive injury involving more than four intraocular structures was the only factor that was significantly associated with a poor visual outcome (visual acuity of 20/800 or worse). Extensive injury and poor presenting visual acuity were both associated with the development of PVR. Time to IOFB removal was not associated with either of these negative outcomes [7].

Key Points

- In a military setting, delayed removal of IOFBs after primary open globe repair does not result in increased rates of endophthalmitis. It remains unknown if these results can be generalized to civilian settings where self-sterilizing hot shrapnel is less common.

- In a military setting, time to IOFB removal is not associated with poor visual outcomes or development of PVR, whereas extensive intraocular injury is key predictor of these negative outcomes.

Vision Survival After Open Globe Injury Predicted by Classification and Regression Tree Analysis – 2008 [8]

Purpose
To develop and validate a prognostic model for predicting visual outcomes after open globe injuries. The authors sought to improve on the Ocular Trauma Score by providing the statistical basis for their model and validating it with an independent cohort.

Methods
This was a retrospective review of patients presenting to the Wilmer Ophthalmological Institute with open globe injuries from January 2001 through December 2004. For patients with bilateral open globe injuries, one eye was randomly selected for inclusion in the initial analysis. The analyzed variables included demographic information, the type and cause of the injury, initial visual acuity, the presence or absence of a relative afferent pupillary defect (rAPD), the anatomical location and length of the wound and the presence of additional ocular, adnexal and orbital injuries. Classification and regression tree (CART) analysis was used to develop a prognostic tree to determine the probability of vision survival (light perception or better) versus complete vision loss (no light perception, enucleation or evisceration). A secondary CART analysis was performed to determine the probability of minimal to severe vision loss (20/400 or better) versus profound vision loss (20/500 or worse, enucleation or evisceration). The models were tested using a validation cohort consisting of open globe injury patients who presented between January 2005 through October 2005, in addition to fellow eyes of patients with bilateral open globe injuries that were excluded from the initial training sample [8].

Results

The training sample consisted of 214 eyes from 214 patients. When CART analysis was used to determine the probability of vision survival versus complete vision loss, the presence of a rAPD was the most predictive variable. The vast majority (96.9%) of eyes without a rAPD maintained some vision. In eyes with an rAPD, poor initial visual acuity was the next highest predictor of complete vision loss, followed by the presence of an eyelid laceration and the presence of a posterior globe injury. In the validation cohort consisting of 51 eyes, the prognostic tree was found to have 85.7% sensitivity for predicting complete vision loss and 91.9% specificity for predicting vision survival. In the secondary CART analysis to determine the probability of minimal to severe vision loss versus profound vision loss, the presence of an rAPD and poor initial visual acuity remained the most predictive variables. However, the next most predictive variables for a poor visual outcome were globe rupture (as compared to laceration injury) and age greater than 38.5 years [8].

Key Points

- Prognostic trees based on a large dataset of open globe injuries can predict visual outcomes with good sensitivity and specificity.
- The presence of a rAPD and poor initial visual acuity are strong predictors of poor visual outcomes in patients with open globe injuries.

Low Rate of Endophthalmitis in a Large Series of Open Globe Injuries – 2009 [9]

Purpose

To quantify rates and risk factors for endophthalmitis in patients with open globe injuries.

Methods

This was a retrospective case series of patients treated surgically for open globe injuries at the Massachusetts Eye and Ear Infirmary from 2000 to 2007. All patients were subject to a standardized protocol which included: initial evaluation in a dedicated eye emergency room including CT scan of orbits, update of tetanus prophylaxis, admission for IV antibiotics (typically vancomycin q12h and ceftazidime q8h), urgent repair under general anesthesia by the trauma service (or retina service in the case of injuries involving posterior segment intraocular foreign bodies), daily inpatient follow-up and subsequent close outpatient follow up by the trauma service [9].

Results

Of the 675 open globe cases that underwent surgical repair, 558 patients met inclusion criteria (at least 30 days of follow-up, no enucleation within 30 days). Surgery was performed within 24 hours in 80% of cases in which the exact time of injury was known. There were 111 patients (20%) that required lensectomy, and six of these patients underwent intraocular lens placement at the time of the initial surgery. There were 95 patients (17%) with intraocular foreign bodies, and these were uniformly removed during the initial open globe repair. Five patients (<1%) met clinical criteria for endophthalmitis, three of whom had positive cultures (Bacillus cereus, coagulase-negative staphylococcus). Primary lensectomy was not a risk factor for endophthalmitis, but primary intraocular lens placement was associated with increased risk ($p = 0.05$). The presence of an intraocular foreign body at the time of presentation was also associated with an increased rate of endophthalmitis ($p = 0.037$). Other factors that were not associated with a statistically significant difference in the rate of endophthalmitis included: the presence of uveal prolapse, delay in presentation greater than 5 hours, delay in surgical repair greater than 12 hours, or use of vitrectomy during open globe repair [9].

Key Points

- A standardized protocol including 48 hours of intravenous antibiotics and prompt repair by a dedicated eye trauma service resulted in a post-traumatic endophthalmitis rate of less than 1%.
- Risk factors for endophthalmitis include the presence of an intraocular foreign body and primary lens placement at the time of surgical repair.

Retinal Detachment After Open Globe Injury – 2014 [10]

Purpose
To describe the natural history associated with this outcome.

Methods
This was a retrospective chart review of patients who presented to the Massachusetts Eye and Ear Infirmary between February 1999 and November 2011 with open globe injuries. Open globe injuries were repaired urgently and patients were admitted for 48 hours of intravenous antibiotics as described previously [9]. Multivariate logistic regression was used to identify factors associated with development of retinal detachments. Numerous variables were included in this analysis, which included age, gender, mechanism of injury, initial visual acuity, presence of a relative afferent pupillary defect, vitreous hemorrhage, zone of injury and presence of an intraocular foreign body [10].

Results
There were 893 eyes included in this study, and 255 of these eyes were found to develop retinal detachments (29% incidence). Of these eyes, 27% were found to have retinal detachments within 24 hours of open globe repair, 46% within 1 week of repair and 72% within 1 month of repair. Retinal detachment occurred more than 1 year after open globe repair in only 5% of these patients. Multivariate logistic regression revealed that vitreous hemorrhage, poor initial visual acuity on presentation, and more posterior zone of injury were all independently associated with increased risk of retinal detachment. Based on these findings, the Retinal Detachment after Open Globe Injury (RD-OGI) score was developed. In this model, up to 3.5 points were assigned for impairment in visual acuity, up to two points were assigned for posterior zone of injury, and two points were assigned for the presence of vitreous hemorrhage. The probability of retinal detachment ranged from 1% for 0 points to 95% for 7.5 points (maximum) [10].

Key Points

- Predictors of retinal detachment after open globe injury include poor presenting visual acuity, posterior zone of injury and vitreous hemorrhage.
- The RD-OGI score provides an estimate of the probability of retinal detachment after open globe injury and can be used to determine the need for frequent monitoring and referral to a retina specialist.

Poor Prognoses of Open Globe Injuries with Concomitant Orbital Fractures – 2019 [11]

Purpose

To determine whether the presence of an orbital fracture is associated with a worse prognosis for after open globe injury.

Methods

This was a retrospective case series of patients who presented to the Massachusetts Eye and Ear Infirmary for open globe injuries, both with and without concomitant orbital fractures. Chart review of trauma patients between January 2007 and September 2015 yielded 76 patients with combined open globe and orbital fracture injuries. These patients were compared to 77 patients who presented with open globe injuries alone between July 2014 and June 2015. Open globe injuries were repaired by the ocular trauma service and admitted for 48 hours of intravenous antibiotics. Multiple factors including demographic information, mechanism of injury, the presence of an orbital fracture and detailed characteristics of the ocular injury were included in statistical analysis of outcomes data [11].

Results

Patients with combined open globe and orbital fracture injuries were more likely to have incurred blunt force injuries instead of penetrating injuries. Patients without orbital fractures were more likely to have Zone 1 involvement whereas patients with orbital fractures were more likely to have Zone 2 and Zone 3 involvement as well as involvement of multiple zones. Uveal prolapse was found to be more common in patients with concomitant orbital fractures. Orbital roof fractures were the least frequent wall fractures seen, but they were associated with a higher likelihood of no light perception vision on presentation and the involvement of multiple zones. Patients with orbital fractures were more likely to undergo eventual enucleation/evisceration than patients without fractures (26.3% vs. 6.5%), and multivariate logistical regression revealed that the presence of a fracture was the only factor with a statistically significant effect on the odds of enucleation/evisceration. Excluding patients that underwent enucleation/evisceration, final visual acuity was significantly worse in patients with orbital fractures. The median final best corrected visual acuity was hand motion in patients with orbital fractures versus 20/125 in patients with open globe injuries alone. Patients with orbital fractures were more likely to have no light perception vision (44.6% vs. 7%), and this remained statistically significant after controlling for other factors [11].

Key Points

- Patients with open globe injuries and concomitant orbital fractures are more likely to have posterior ocular injuries that span multiple zones compared to patients with open globe injuries alone.
- The presence of orbital fractures is associated with a worse visual prognosis and higher rates of enucleation.

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