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Chemical Burns of the Eye

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Abstract
Chemical burns of the eye are one of the most common eye injuries. The extent of the ocular surface damage is influenced by the type, temperature, volume, and pH of the corrosive substance and duration of exposure. Limbal ischemia found on eye assessment is the primary determinant of eventual visual outcome. Eye irrigation must be instituted immediately at the scene of exposure and continued in the emergency department to reduce visual impairment. Traditionally lactated Ringer's and normal saline have been used as irrigation fluids, although one systematic review demonstrates similar outcomes with other irrigation fluids. The Morgan Lens is a device that can be utilized to allow the provider to perform "hands free" eye irrigation. Complications of chemical burns are more common with alkali burns as these substances destroy the corneal epithelium and allow this corrosive base substance to penetrate deeper into the cornea. **Key words:** acid, alkali, chemical burns, eyelid eversion, irrigation, limbal ischemia, Morgan Lens, ocular burns

CHEMICAL BURNS of the eye usually occur when a corrosive substance, such as acid or alkali, is accidentally introduced to the ocular surface. Chemical injuries are responsible for approximately 7% of work-related eye injuries treated at US hospital emergency departments (Xiang, Stallones, Chen, & Smith, 2005). One epidemiologic study of chemical ocular burns (Haring, Sheffield, Channa, Canner, & Schneider, 2016) in 900 emergency departments involving nearly 144,149 chemical burns found that injury rates were highest among children 1–2 years of age (28.6 and 23.49 per 100,000 population, respectively). In this same study, alkali burns were found to be more common than acid injuries, and all chemical eye injuries most commonly occur in residential locations. This can also be a common work-related injury among men 20–40 years of age in chemical factories or laboratories (Singh, Tyagi, Kumar, Gupta, & Sharma, 2013).

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Illustrations by Katherine Chemsak, Media Arts, Robert Morris University. Photos courtesy of MorTan, Inc.

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PATIENT PRESENTATION

After a chemical exposure to the eye, patients usually present with severe eye pain, reduced visual acuity, photophobia, and reflex blepharospasm. Depending on the severity of the injury, findings can range from conjunctival injection and chemosis to corneal cloudiness or opacification and perforation. In acid burns, initial findings demonstrate red, swollen eyelids, red conjunctiva, and chemosis. More severe acid burns show blanching of the conjunctiva due to vascular occlusion. Limbal ischemia, signified by white patches on the limbal conjunctiva and scleral vessels, indicates a serious injury as the nerve endings in the eye have been damaged. The amount of limbal ischemia, noted by blanching of the bulbar conjunctival and scleral vessels, is one of the most important factors to determine the amount of ocular damage and eventual visual outcome (Spector & Fernandez, 2008).

PATHOPHYSIOLOGY

The pathophysiology of chemical burns of the eye begins with the change in pH of the ocular tissues. It was previously thought that this was the key element in determining the resultant damage, but recently other factors have been found to influence this damage, such as the temperature of the chemical, for example, a hot solution, can cause more damage than a cool solution as chemicals react more quickly at higher temperatures (Schrage et al., 2000). High temperatures generated by the chemical reaction between the caustic agent and the tears may create temperatures sufficient to also cause ocular thermal burns. Corrosive powders, such as lime or concrete, can be difficult to see and difficult to remove from the deep fornices of the eye and thus cause severe damage if left unnoticed.

Acid compounds are typically found in car batteries, bleach, chemistry laboratories, vinegar, and glass polish. Acid compounds include sulfuric acid, sulfurous acid, hydrochloric acid, acetic acid, and hydrofluoric acid. Acids with a pH less than 4 often cause protein coagulation in the cornea. This creates a barrier that prevents the chemical from deeper penetration. Because of this barrier, acid burns tend to be less severe than alkali burns.

Alkali substances are found in cement, drain cleaners, cleaning agents, and fertilizers. Alkali substances include calcium hydroxide (lime), sodium hydroxide (lye), potassium hydroxide (lye), ammonia, or ammonium hydroxide. Alkali substances with a pH greater than 10 destroy the corneal epithelium, allowing this base substance to continue to penetrate deeper into the cornea long after the initial exposure. Hydrofluoric acid, found in antirust agents, is one acid that acts like an alkali substance. This exposure of hydrofluoric acid results in extensive anterior eye injury. Patients with chemical burns can have irreversible damage to the eye within 5–15 min (Fish & Davidson, 2010). Differential diagnoses to consider with chemical burns of the eye include conjunctival abrasion, conjunctival foreign body, corneal foreign body, corneal ulcer, and corneal opacity.

IRRIGATION PROCEDURE

Copious eye irrigation with water should be instituted immediately at the scene of the exposure after insuring basic airway, breathing, and circulation assessment are complete. Immediate copious eye irrigation is the single most important part of initial treatment and one of the major determinants of the final outcome. Brush off any dry particles on the skin surrounding the eye area to avoid activating any chemical reaction should it be an alkali powder. The eye environment is a moist environment, thus prompt copious irrigation will quickly dilute and remove any chemicals regardless of their acid or alkali nature. The irrigation procedure should still be performed, even if it is delayed, in hopes of preserving sufficient healthy tissue for a later corneal transplant if needed. One should not delay irrigation to perform a comprehensive assessment of the eye. A brief eye assessment should be performed to insure that the patient does not have a ruptured globe or penetrating foreign body of the eye, which is the contraindication for eye irrigation. The recommendation is that this initial immediate irrigation should be no less than 10 min (Schrage et al., 2000). Ocular irrigation should be continued until the pH returns to neutral. The normal pH of the tears is 6.9–7.4 pH level (Forrester, Dick, McMenamin, & Roberts, 2008). It may require irrigation of as much as 20 L of solution to restore the physiologic pH of the eye (Trief & Woodward, 2015). Eye irrigation removes the chemical by elimination and dilution of the corrosive substance and reduces scaring of the cornea, visual impairment, and permanent loss of vision. Sterile balanced buffered solutions such as lactated Ringer's and normal saline solutions are recommended for eye irrigation (Ventocilla, 2016). Irrigation with normal saline has been found to cause a burning sensation in the eye. A systematic review performed by Chau, Lee, and Lo (2011) of four studies involving 302 patients concluded that irrigating fluids including lactated Ringer's, normal saline, normal saline with sodium bicarbonate added, BSS Plus, and Diphoterine solutions all yielded positive outcomes.

Initially, a topical ophthalmologic anesthetic should be instilled into the eye to alleviate the patient's discomfort and facilitate effective eye irrigation. The fornices should be swept with a moistened cotton swab (see Figures 1 and 2) during the initial examination as retained particulate matter can cause persistent damage, despite irrigation (Trief & Woodward, 2015). The intravenous fluids are attached to the infusion set to ensure good control of the rate of irrigation. The eyelids actually provide a watertight, airtight seal when they are tightly closed, so irrigation without opening the eyelids is ineffective; however, care must be taken to open the lids without placing excessive pressure on the globe (Stilp & Bevelacqua, 1997). Any prolonged eye irrigation is best performed using a low-density polyethylene scleral lens, for example, Morgan Lens (see Figure 3; Gardiner, 2016). The more flexible Morgan Lens, similar to a large contact lens except that it does not touch the cornea, can be inserted under the eyelids allowing for a "hands free" method to irrigate the eye and also allows the irrigation fluid to enter the eye without the need to manually hold the eye open. An infant can be swaddled or a young child restrained to initially insert the lens. Initially, start a minimal flow of the intravenous fluid before inserting the Morgan Lens. This allows the fluid to act as a cushion, suspending the lens above the cornea and protecting the injured surfaces from the eyelids.

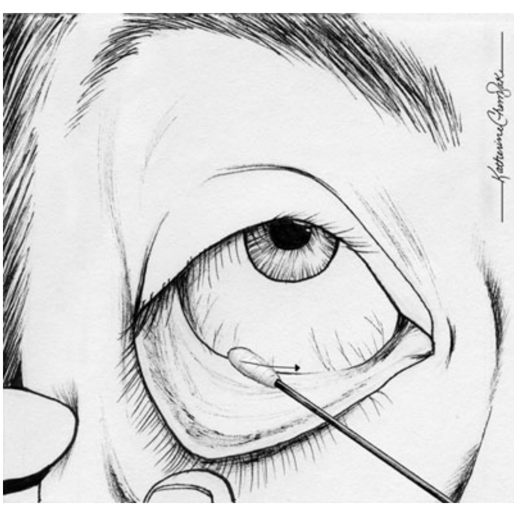

Figure 1. Sweeping of the inferior fornix with a cotton-tipped swab. Illustration by Katherine Chemsak, Media Arts, Robert Morris University.

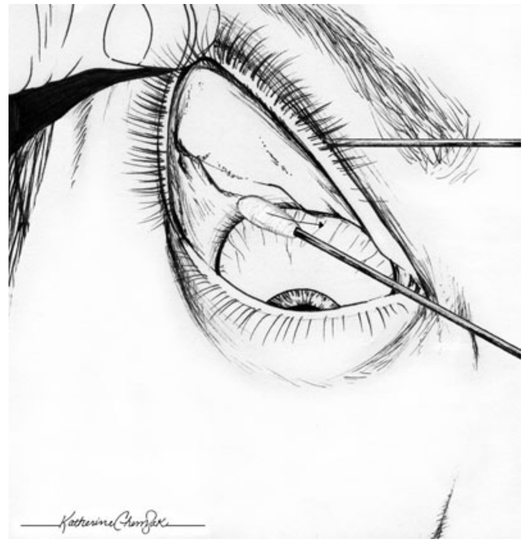

Figure 2. Sweeping of the superior fornix with a cotton-tipped swab. Illustration by Katherine Chemsak, Media Arts, Robert Morris University.

Figure 3. Morgan Lens. Photo courtesy of MorTan, Inc.

Figure 4. Medi-Duct device. Photo courtesy of MorTan, Inc.

Figure 5. Insertion of the Morgan Lens, having the patient look down at his or her toes, and slipping the lens under the upper eyelid. Photo courtesy of MorTan, Inc.

The irrigating fluid must contact the surface of the eye. The best way to achieve this irrigation is with intravenous tubing attached to the lens, for example, Morgan Lens (Ventocilla, 2016; MorTan, Inc. Missoula, MT). A device called the Medi-Duct consists of wicking material inside a plastic sleeve that collects the irrigation fluid leaving the eye. It is attached to the side of the face and thus prevents the irrigation fluid from getting the patient wet (see Figure 4).

To insert the Morgan Lens into the eye, the patient is instructed to look down at his or her toes, and the Morgan Lens is inserted under the upper eyelid and then have the patient look up, while retracting the lower lid and the lens is dropped in place (see Figure 5). Advantages of having the patient look down while inserting the Morgan Lens are that not only does this expose the tougher and less-sensitive sclera but it conveniently has the patient looking away from the lens while it is being inserted. The irrigation fluid can then be opened, and the provider does not need to stay in immediate attendance with the patient while the eye irrigation is being completed. If a Morgan Lens is not available, the eyelids will need to be continuously manually retracted to expose the cornea and conjunctiva for manual irrigation as the injured person may not be able to keep his or her injured eye open due to the pain. One must also be cautious to not apply pressure to the globe while manually retracting the eyelids. When the eye is physically being held open, it fights the natural blepharospasm, making it nearly impossible for the patient to relax.

Once the irrigation is complete, the Morgan Lens is removed by using the opposite technique for insertion while the fluid is still running to avoid contact between the lens and the eye. If the solution runs out or the flow is stopped, the lens is designed so that it vaults the cornea and would contact only the sclera. The pH of the eye should initially be tested after irrigation is complete and then retested after 30 min as chemicals can continue to leach out of the eye for up to 30 min after the irrigation is stopped (Gardiner, 2016). A pH paper strip with a broad range, for example, four to 12 values, will provide the opportunity to check for both acidic and alkali environment until the normal physiologic pH is achieved with continued irrigation. Ophthalmology referral is mandatory for all chemical burns of the eyes.

Any loose particles should be removed with a moistened cotton swab by sweeping in the superior and inferior fornices of the eyelids. Eyelid eversion is an essential component of eye irrigation to allow particles stuck under the upper fornix to be removed (Marsden, 2015). To achieve this, the patient is asked to look down at his or her toes. The provider grabs the upper eyelid eyelashes with his or her gloved hand. While simultaneously pressing with the wooden end of a cotton swab in the middle of the upper eyelid, the upper eyelid tarsal plate is flipped up, thus allowing the inner aspect of the eyelid to be examined and also allow any loose particles or foreign bodies from the superior fornix to be removed with a moistened cotton swab using a rolling action (see Figure 2). Eye irrigation in pediatric patients can be more tolerable by warming the irrigating solution and reinstilling the ocular anesthetic frequently. This can be performed by either injecting the anesthetic into the irrigation tubing or adding it in the proper concentration to the bag of irrigation solution.

POSTIRRIGATION ASSESSMENT

After the pH of the eye has returned to the normal level, a comprehensive eye examination should be performed with attention to the integrity and clarity of the cornea, degree of limbal ischemia, any retained foreign bodies, and any lid or conjunctiva trauma. A complete ophthalmological examination including visual acuity, fluorescein stain with Wood's light examination, intraocular pressure (IOP) measurement, and slit lamp examination should then be performed to assess the extent of injury and ensure that all particles have been removed. Alkali injuries have been noted to cause an elevation of IOP, thus IOP should be measured (Lin, Eksioqlu, Mudumbai, Slabaugh, & Chen, 2012).

POSTEXPOSURE MANAGEMENT

Once the chemical has been completely removed with irrigation, healing of the epithelium of the cornea and conjunctiva can occur. Ophthalmologic consultation is warranted while the patient is in the emergency setting for all chemical ocular burns and advice regarding pharmacological planning and follow-up determined. Artificial tears are essential because eyes that have incurred chemical burns usually poorly produce adequate tears. Topical ophthalmic antibiotic ointment is prescribed to assist with the healing of the eye surface and prevent secondary infections. Topical steroids also assist to reduce inflammation and facilitate healing. If the IOP is elevated, aqueous suppressants are often advised to reduce IOP. In severe chemical burns, pain can be significant requiring management with both topical cycloplegic agents to control ciliary spasm and oral pain analgesia to reduce discomfort. Ophthalmology will determine whether medical treatments are adequate and whether limbal stem cell transplant should be necessary.

CONCLUSION

Chemical burns of the eye are a true ocular emergency and can result in extensive damage to the corneal surface and permanent visual impairment. Limbal ischemia, noted by whitening of the sclera, is the primary determinant of eventual visual outcome. Immediate eye irrigation until the pH is able to return to normal is essential in the treatment. The Morgan Lens allows "hands free" eye irrigation. Complications with alkali burns are more common as this basic material destroys the epithelium of the cornea, allowing a deeper penetration of the alkali substance. Once the chemical has been completely removed, as confirmed by a normal pH reading, medical treatment should be determined with ophthalmologic consultation.

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