Chapter 19

MANAGEMENT OF EYELID BURNS

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INTRODUCTION

Ocular and eyelid involvement in facial burns are common in both military and civilian settings. More than two thirds of burns involving the face may include the eye or periocular area. Moreover, reviews from major burn centers demonstrate that up to 15% of *all* patients treated for burn wounds have burns involving the ocular and periocular region.[1–4] Most patients in civilian burn centers suffer flame burn injuries.[3,4] Frequent ocular injuries seen as a result of facial burns include lid burns, contracture leading to ectropion (outward turning of the eyelids), and lagophthalmos (inability to close the eyelids), conjunctival burns, conjunctivitis, foreign bodies (FBs), corneal burns, abrasions, and perforations. Because of the life-threatening nature of severe burn injuries to the face and the associated massive swelling, ocular injuries may not be noticed early and treatment may be delayed.[1,5–7] Appropriate early intervention can have a significant effect on the final outcome for the burn patient.

Burns to the eyelids may be caused by thermal (especially flame or flash burns), electrical, chemical, or ionizing radiation sources. The severity of burns depends on the intensity of the burning agent (both the quantity of heat generated or transmitted by the burning agent, and the concentration and amount of the burning agent), the duration of exposure, and the body's response.[2,8,9] Thermal injuries are the most frequent cause of ocular and periocular burn injuries. Liquid thermal burns vary in severity depending on the substance. The temperature of noncombustible liquids, like water, is usually less than 70°C on contact, and such liquids dissipate rapidly from the initial contact area, thereby causing only superficial damage. On the other hand, the temperature of combustible liquids, like gasoline, at contact is usually greater than 100°C, and these liquids tend to be more viscous and may ignite clothing. Therefore, the damage is more localized but often deeper. Most injuries seen with flash burns involve the eyelids and are superficial[10] because of the ocular protective mechanisms: rapid reflex closure of the eyelids, abrupt head movements, and elevation of the globe with eyelid closure (Bell's phenomenon).

Burns resulting from electrical injury are unique because the underlying tissue destruction may be much more extensive than the superficial skin injury. Therefore, a high index of suspicion for deep injury is required, even in seemingly minor electrical burns.[11,12]

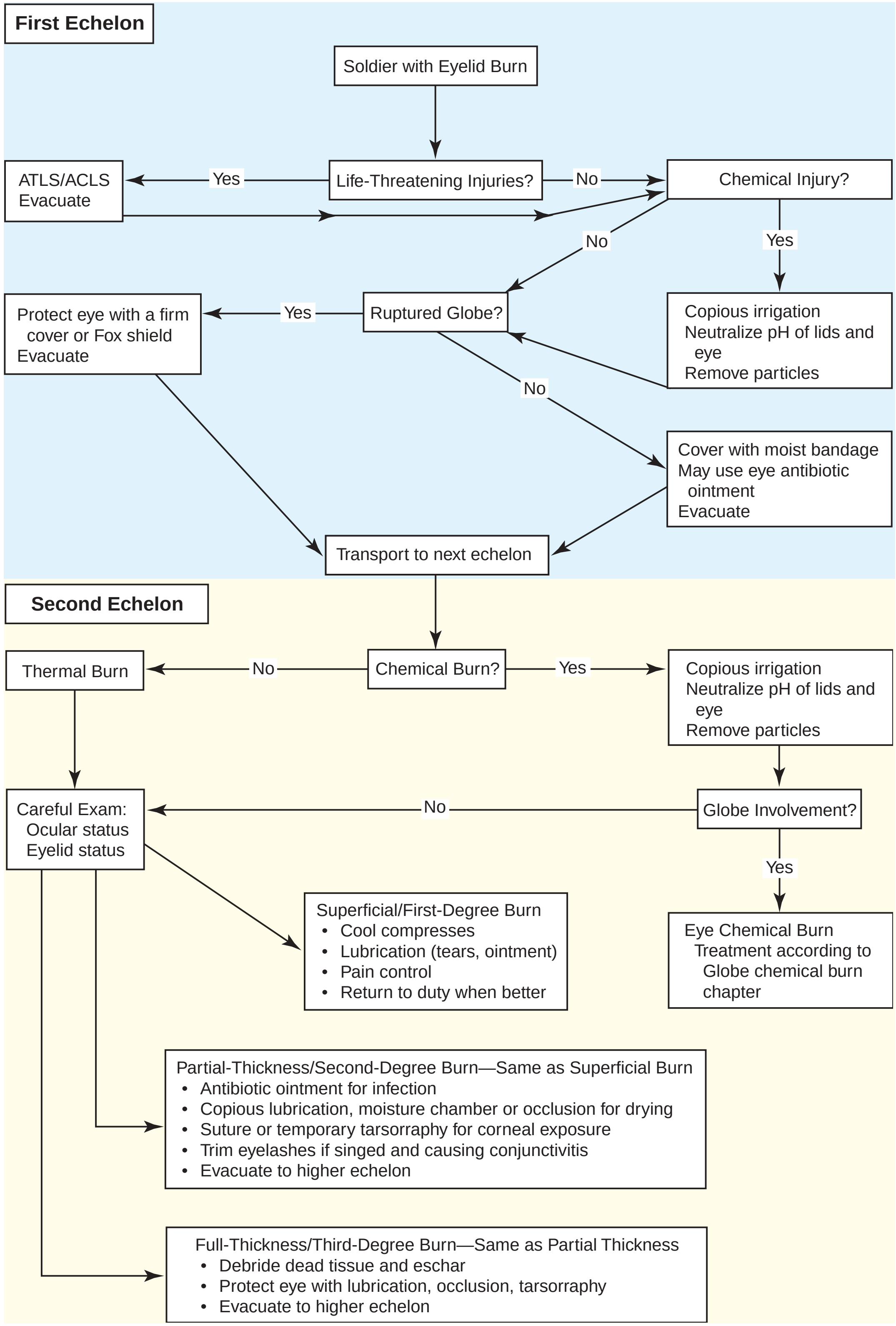
Injuries from acids result in coagulative necrosis, which acts as a buffer against deeper tissue penetration. Alkali burns penetrate much deeper because of tissue saponification and, hence, are associated with greater injury. In the field environment, ionizing radiation injury may occur from exposure to nuclear weapons or radioactive munitions. In most mild-to-moderate exposures, radiation burn damage is delayed until vasculopathy develops. Additionally, long-term, cancer-inducing effects may result.

The history of injury can provide vital clues regarding the nature, extent, and initial therapy for the burn patient.[9,10] Life-threatening systemic injuries must be addressed before beginning eye care. In the acute evaluation of facial, neck, and periocular burns, the medical caregiver must be keenly suspicious of a coexisting inhalational burn injury. Inhaled toxic gases that are incomplete products of combustion may directly damage the lower respiratory tract. Evidence of carbonized sputum in a patient who otherwise appears well but who has had thermal exposure should alert the caregiver to the likelihood of significant airway injury. Airway obstruction may worsen a few hours after presentation because of increasing airway edema. Inhaled hot air can damage the mucous membranes of the mouth and upper respiratory tract. And burn injury to the neck or chest may also contribute to respiratory difficulty.

On the battlefield, evaluation and treatment of burns to the eyes and eyelids are tailored according to the echelon level at which the injury occurs and the medical expertise available. Appropriate securing of the airway may be lifesaving in the acute stages before soft-tissue swelling has occurred. Careful monitoring of fluid replacement is mandatory in this period.[7,8] Adherence to Advanced Trauma Life Support (ATLS) and Advanced Cardiac Life Support (ACLS) protocols is critical.[13] Tetanus immunization status should be evaluated and treated accordingly.[7]

TYPES AND DEGREES OF EYELID BURNS

Burns are usually categorized in two ways: by etiology (type of burn) and by amount of tissue damage (degree of injury). Etiologically, an eyelid burn is any injury to the eyelid skin due to exposure to heat, a caustic chemical, electricity, or ionizing radiation. Eyelid burns due to thermal expo-



ATLS: Advanced Trauma Life Support (American College of Surgeons)
ACLS: Advanced Cardiac Life Support (American Heart Association)

Fig. 19-1. Flow chart for acute management of eyelid burns.

sure are the most common and account for 96%[8] of all burns. Thermal burns can occur from blast injuries, incendiary munitions, or from direct exposure to flames or hot liquids and gases. Typically, flash burns are more superficial than flame burns, because of the short exposure time common with flash burns.[8,9,13,14]

Chemical burns are usually caused by contact with an acid or alkali compound. A burn injury from direct current may be caused by lightning strikes, whereas one from alternating current usually occurs during contact with high voltage. Low-voltage electrical exposure rarely causes a burn injury. Ionizing radiation burns may be secondary to therapeutic exposure, accidental exposure, or the use of nuclear weapons. Except for high-dose exposure, deep-tissue radiation burn damage is usually delayed until radiation-induced vasculopathy develops 6 months to 2 years after exposure. On the other hand, deep-tissue burn damage from chemical, electrical, or thermal injury is immediate.[9]

In the theater of operations, evaluation and treatment of eyelid burns should focus on protecting the eye by diagnosing the extent of damage, intervening rapidly to prevent further damage to the eyes and eyelids, returning soldiers with mild injury to duty quickly, and stabilizing soldiers with more-serious eyelid damage for evacuation and definitive care (Figure 19-1).

As with any other burn injury, eyelid burns are classified as first-, second-, or third-degree in severity. In 1994, however, to better describe their pathology, they were also classified as superficial, partial-thickness, and full-thickness burns.[12] First-degree (superficial) eyelid burns involve the epidermis only. Erythema and edema are characteristic. The skin remains intact; however, there may be some degree of skin shrinkage. A first-degree burn can be likened to a mild-to-moderate sunburn (Figure 19-2). First-degree burns are self-limited and heal spontaneously.

Second-degree (partial-thickness) burns involve the epidermis and part of the dermis. In second-degree burns, the skin often shrinks and blisters. The blisters may break open, causing weeping and crusting of serous fluid. Open blisters with serous exudate provide a significant opportunity for bacterial infections. Second-degree burns are more painful than first-degree burns because sensory nerve terminals have been injured and exposed (Figure 19-3). Second-degree burns often heal spontaneously but with some contracture and superficial scarring.

Third-degree (full-thickness) burns are the most serious. The epidermis is completely destroyed, and the injury involves the entire dermis and part or all of the subcutaneous tissue. Charring and loss of skin characterize third-degree burns. The skin of-

Fig. 19-2. First-degree eyelid burn. Note erythema and mild edema of the upper eyelid along the pretarsal and preseptal skin. There is no loss of epidermis, but there are areas of second-degree burns near the eyebrow.

Fig. 19-3. Second-degree eyelid burn of both upper eyelids. Injury involves epidermal loss and is more painful than a first-degree burn. Blisters and oozing of serous fluid may be present, and lid contraction may occur. Photograph: Courtesy of Department of Ophthalmology, Wilford Hall Medical Center, Lackland Air Force Base, Tex.

ten appears carbonized, white-brown, and waxy. The carbonized, dry eschar provides a nidus for infection and requires frequent debridement. Areas of third-degree burns are painless because of damage to sensory nerves; however, tissue surrounding the burn may be painful due to lesser degrees of burn injury.

Third-degree burns of the eyelids usually imply full-thickness injury, as the lids are approximately 2 mm thick and have very little subcutaneous tissue (Figure 19-4). Lids with severe second-degree and third-degree burns are commonly accompanied by significant burn injury to the surrounding tissues, including the face, forehead, scalp, ears, mouth, neck, and torso. This involvement implies a high risk for life-threatening injuries and damage to the most common sources for skin grafts for eyelid reconstruction.

Fig. 19-4. Third-degree eyelid burn of the right upper eyelid. Injury involves full-thickness skin. Charring and white-brown waxy consistency is often present. Third-degree burns usually are not painful. Tissue is damaged, and contraction and lagophthalmos are usually present. Photograph: Courtesy of Department of Ophthalmology, Wilford Hall Medical Center, Lackland Air Force Base, Tex.

EYELID BURN INJURIES, HEALING, AND COMPLICATIONS

When tissue is exposed to a burn injury, the area of injury often resembles a bull's-eye target, with the severity of injury decreasing from the center to the periphery. In a third-degree burn, the central area is *the zone of coagulation,* where tissue is destroyed and no longer viable, hence its characteristic white, leathery appearance.

The area just peripheral to the center is the *zone of stasis*, which temporarily has decreased vascularity but can recover barring further injury. The zone of stasis can be divided into a superficial zone and a deeper zone. The superficial zone demonstrates early stasis because it sustains greater injury and becomes ischemic within 2 hours, owing to vasoconstriction and platelet aggregation with thrombosis. The deeper zone shows delayed stasis with ischemia beginning between 4 to 24 hours after the injury. If cared for properly, hair follicle epithelial cells remain viable and will repopulate and migrate.

The third and most peripheral area is the *zone of hyperemia.* Vascular structures remain intact and the area blanches on pressure. There is no cell death, only edema and erythema.[11] Second-degree burns do not have a zone of coagulation but do have varying degrees of zones of stasis and hyperemia. First-degree burns demonstrate zones of hyperemia only.

First-Degree Burns

Superficial burns are commonly caused by sunburn, ultraviolet ray exposure, and short-duration flash burns. They are dry burns with edema and no blistering. Erythema and pain are common. Histologically, superficial burns only involve epidermal layers. Healing occurs in 3 to 7 days, accompanied by superficial peeling. There is no scar formation although discoloration may develop.

Second-Degree Burns

Mild (superficial) partial-thickness burns are commonly caused by immersion scalds of short exposure. The wounds blister, weep, and form moist blebs. There is intense erythema, significant pain, and temperature sensitivity. Histologically, epidermis and some papillary dermis are involved. Healing occurs within 7 to 21 days without grafting and with little or no scarring. Pigmentary changes, however, are common.

Moderate (deeper) partial-thickness burns are commonly caused by immersion scalds of longer duration and flame injury. Blisters are large and thick-walled; they increase in size. The skin appears mottled white and pink to cherry-red. Histologically, the epidermis, papillary dermis, and reticular dermis are involved. Some subcutaneous involvement may occur. Healing occurs in 21 to 35 days in uncomplicated cases. If infection or reinjury occurs, the wound may convert to a full-thickness injury.

Severe partial-thickness burns have a propensity to develop hypertrophic scars and to convert to full-thickness injuries.

Third-Degree Burns

Full-thickness burns are usually caused by chemical, electrical, flame, and scald injuries. The skin appears dry, leathery, nonpliable, and there may be charring, eschar, and significant avascularity. There is little or no pain; the hair in the affected area pulls out easily. Histologically, the wound includes the subcutaneous tissue and may include fascia, muscle, tendon, and bone. In a small lesion, healing from the leading edge of the wound may occur over several weeks. In larger lesions, grafting is necessary; otherwise, healing takes many months.[12]

Healing Process

Reepithelialization of wounds occurs from epithelium located at wound edges and skin appendages, such as hair follicles, sebaceous glands, sweat glands, and their ducts. For large areas, granulation tissue must first bridge the wound before epithelialization can occur. Contraction occurs in second- and third-degree wounds and aids in restoring epithelial continuity; however, contraction often distorts the functioning of the eyelids.[15]

Complications of Eyelid Burns

The eyelids serve several functions. They protract, or close, to protect the eye from wind-borne dirt and debris and the drying effects of the environment. The eyelids retract, or open, to provide an unimpeded visual axis for seeing. The eyelids contain glands that secrete the aqueous (accessory glands of Krause and Wolfring) and lipid (meibomian glands) portions of tears. They also blink to spread the tear film evenly over the eye, which is crucial for visual clarity. The lacrimal drainage system begins in the eyelids as the lacrimal puncta and continues as the canaliculi, lacrimal sac, and the lacrimal duct, which empties beneath the inferior turbinate in the nose. The lids act as a lacrimal pump to remove the tears from the ocular surface and drain them into the nose. Burn injuries to the eyelids can compromise one or all of these functions and cause visual debilitation.

Eyelids that cannot close put the soldier at risk of sustaining corneal FBs, abrasions, and ulcers that cause significant pain, impairment, and possible loss of the eye. Eyelids that cannot open because of burns may leave the soldier essentially blind and ineffective in the battlefield. A blinded soldier also requires the help and time of another soldier to assist him or her to safety.

An injured or scarred lacrimal drainage system anywhere along its length may cause epiphora (a wet, tearing eye due to abnormal drainage of tears), which interferes with visual clarity. An abnormal tear pump mechanism can also leave the soldier with epiphora.

Therefore, treatment of eyelid burns is a vital component in caring for warfare injuries. Effective treatment of minor injuries allows the soldier to return to duty with minimal delay. Significant eyelid burns, which are likely to develop any or all of these complications, require proper evaluation and management to protect the eye and limit damage to injured structures. Early evacuation of severely burned patients is required to minimize consumption of resources in the theater of operations and to maintain the best prognosis possible for the soldier.

EVALUATION AND TREATMENT OF EYELID BURNS

Casualties with eyelid burns often have concomitant facial, neck, and upper torso burns (see Figure 19-1). Airway compromise should always be considered. Therefore, immediate evaluation and treatment should follow the ATLS[16] and ACLS[17] protocols.

1st Echelon

If a casualty might have a chemical burn to the eyes, then the eyes and eyelids should be thoroughly rinsed with sterile water or saline. Rapidly irrigating the offending chemical and returning the ocular tear film pH to normal can significantly decrease morbidity and improve visual outcome. The rinse may require several liters of fluid and should be done as soon as possible after the chemical injury. If sterile water or saline is not available, then any neutral, relatively clean liquid will suffice until sterile solutions are available. Particulate matter must be gently rinsed out because it may contain chemical reagents and cause further damage.

Once copiously irrigated and debrided of foreign material, the lids should be covered with a moist bandage, if possible. First-degree burns may need only to be rinsed clean. Bandaging for second- or third-degree burns is desirable, if available.[1,2,13,14] Antibiotic eye ointment (eg, bacitracin, gentamycin) may be used with bandaging. If neither ointment nor bandage is available, the wound should be kept moist to decrease tissue necrosis and eschar formation. Desiccation of a burn wound can increase ischemia in the zones of stasis where partial vascular compromise exists.[12]

If an open globe injury is suspected, then bandaging of lid burns is contraindicated and a protective shield should be placed over the orbital rim to prevent pressure on the eye (Figure 19-5). Direct pressure on an open globe will increase the ocular injury, may expel intraocular contents, and can cause irreversible damage to an otherwise salvageable eye.

2nd Echelon

If a chemical burn is suspected, the eyes should be copiously flushed with normal saline solution to remove any residual chemicals and particulate matter, and treatment should be initiated as described in Chapter 7, Chemical Injuries of the Eye. Additionally, the eyelids and periocular tissue should be rinsed of all chemicals in a similar manner. The remainder of the evaluation is the same as for radiation, electrical, and thermal burns[13] (described below).

Evaluation of the Eyes

The initial 2nd-echelon evaluation determines the status of the eyes. The ocular examination must be performed as soon as possible, because the eyelids often swell shut after an eyelid burn injury. Swollen eyelids and pain associated with first- and second-degree burns often render a delayed examination extremely difficult and possibly hazardous to the injured eye. A complete history is needed to direct the examination and to determine chronic management. The mechanism of injury should be elicited. Specifically, was the burn due to a blast injury or to thermal, chemical, electrical, or radiation exposure?

Initial Visual Acuity. Visual acuity is measured with a standard eye chart or near-vision acuity card. If these are not available, any reading material may be used. The vision must be clearly documented for baseline examinations. If an eye chart is not available, it is sufficient to describe that the patient was able to read fine or large print at reading distance. If the patient cannot see clearly enough to read, the examiner should determine if he or she can count fingers, see hand motion, or detect light in that order. Any measurement should be accurately recorded.

Status of the Conjunctiva (Ocular Mucous Membranes). The examiner should check for lacerations or loss of mucosal surface from blast or burn injury. Injury to the conjunctiva can cause a dry eye due to damage to the tear-producing glands: the accessory aqueous-producing glands of Krause and Wolfring, the mucosal goblet cells, the lipid-producing tarsal meibomian glands, and the ducts of the main aqueous-producing lacrimal gland. A dry eye is at significant risk of ulceration and perforation, especially if the eyelids are damaged and incapable of protecting the ocular surface. Deepithelialization of both the palpebral (lid) conjunctiva and the bulbar (ocular) conjunctiva can cause symblepharon formation (scarring between these two surfaces). Immobile eyelids and a tethered globe may result.

Fig. 19-5. Eye shields. A Fox shield (left) and a modified disposable cup (right). Either may be used to protect the potentially ruptured eye from direct pressure. The shield or cup is placed over the eye with the rim of the shield resting on the bony prominence of the orbital rim. No pressure should be placed on the eyelids or eye itself. The shield is secured in place with a piece of tape.

Status of the Cornea. The examiner should check for lacerations, abrasions, and burn injuries to the cornea and sclera. Corneal and scleral lacerations must be emergently repaired. Corneal abrasions must be treated with lubrication and topical antibiotics to prevent infection and ulceration that can lead to perforation. Ischemia due to coagulation of limbal vessels can lead to corneal breakdown. If ischemia is noted, the examiner should follow the protocol in the corneal burn section.

Anterior Chamber. The examiner should check for a collapsed chamber or hyphema, which can indicate an open globe or significant blunt trauma from a blast injury. Hyphema may lead to increased intraocular pressure, traumatic glaucoma, and corneal blood staining, which can cause significant ocular morbidity.

Shape of the Eye. In difficult cases in which the ocular examination is severely limited because of other severe injuries, the examiner should determine if gross eye deformity is present to rule out a ruptured globe. Ruptured globes should be immediately referred for surgical treatment. If an open globe injury is suspected, treatment should follow the protocol for penetrating injuries. In the interim, the eye should be protected with an eye shield (see Figure 19-5).

Evaluation and Treatment of the Eyelids

Once the eyes have been examined and treated accordingly, the eyelids should be examined. The extent and degree of the eyelid burns are determined, and facial burns adjacent to the eyelids must be noted as well, because contraction of tissue can be transmitted to the eyelids, causing restriction and decreased function. The initial appearance of burned tissue can be deceiving; the extent of damage tends to delineate itself over the next several days. Specifically, severe partial-thickness burns must be aggressively cared for to limit damage and prevent progression to full-thickness injury due to progressive ischemia. The life- and sight-threatening burn wound complication that medical officers must vigilantly guard against is bacterial infections; the organisms most commonly implicated in burn infections include *Streptococcus*, *Staphylococcus*, *Pseudomonas,* and *Proteus* species, and *Escherichia coli*. Burn wounds should be kept clean and moist. Dry eschar increases the likelihood of secondary infection. The examiner must also be alert to several signs that may indicate other impending complications (Table 19-1).

Initial 2nd-echelon treatment involves removing any residual chemicals or foreign bodies, as described above, and protection of the eye and eyelids. Burn injuries to the eyelids are often complicated by decreased tear production from damage to lacrimal, conjunctival, and eyelid glands, all of which contribute to tear production (Figure 19-6). As previously mentioned, decreased tearing increases the risk of corneal drying, abrasions, ulcers, and perforations. Additionally, the burn-injured eyelid is often less mobile and may not

TABLE 19-1

EYELID BURNS: SIGNS OF POSSIBLE COMPLICATIONS

Sign Observed	Possible Complication
Loss of eyelid tissue, causing exposure of the eye and cornea (exposure keratopathy)	Tissue loss requires immediate attention and protection of the eye.
Shrinkage of eyelid tissue with lagophthalmos, causing exposure of the eye	Mild lagophthalmos in an alert patient may be asymptomatic, but burn injuries in an unconscious patient can remove the eye's protective mechanisms (eg, tear production, blink reflex, Bell's phenomenon, and corneal tactile sensitivity) and place the eye in jeopardy. Mild symptoms of exposure can be treated with lubricating drops and ointment. More severe lagophthalmos requires aggressive lubrication and ocular surface protection. In the obtunded patient, even mild lagophthalmos can be devastating because the patient's blink reflex is absent, and there is suppression of the Bell's phenomenon. Loss of Bell's phenomenon increases the risk of corneal drying of the exposed surface.
Loss of eyebrows or lashes in an otherwise normal-looking eyelid	Finding suggests thermal damage, which may result in delayed complications of lid contraction, tissue loss, and corneal exposure. Patients with singed lashes should be observed over the first week to check for delayed effects of thermal damage. These patients may also complain of foreign body sensation, which may be due to lash particles falling onto the ocular surface.

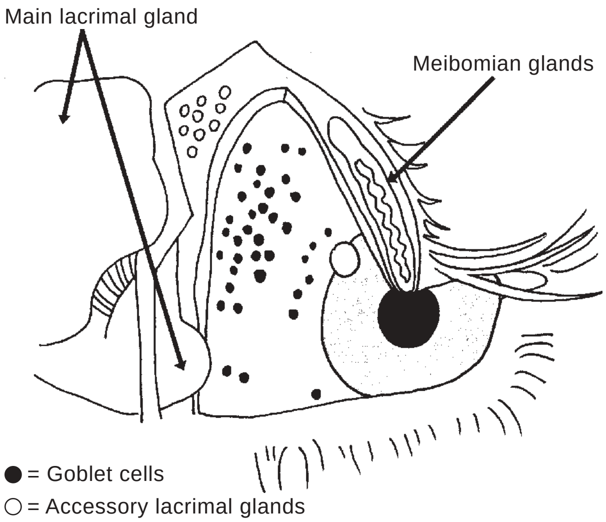


Fig. 19-6. Tear production system. The diagram shows the glands responsible for production of the aqueous and sebaceous components of tears. Any or all of these glands can be damaged by thermal, electrical, chemical, or radiation burns. Drawing: Courtesy of Department of Medical Illustrations, Brooke Army Medical Center, Fort Sam Houston, Tex.

protect the eye sufficiently. Debris in the battlefield can further increase the risk of secondary ocular injury.

Treatment at the 2nd echelon also depends on the type and extent of the burn, and the anatomical structures affected. Chemical injuries should be irrigated copiously (at least 2 L) with normal saline or water. The pH of the injured eye should be checked using pH testing strips to ensure that ocular surface neutrality is attained. When neutral, the patient should be rechecked periodically to verify that no continual damage is occurring by missed particles or chemicals.

Mild first-degree burns with no eyelid contraction or corneal exposure may be treated with topical ophthalmic antibiotic ointment (eg, erythromycin) and cool compresses. Artificial tears may be helpful for mild ocular irritation. Assuming no other injuries, the soldier may be returned to duty. The soldier should be informed of the possibility that a mild second-degree burn might manifest itself in a few days, and that mild pigmentary changes of the skin might also occur.

Significant first-degree burns that cause the eyelids to swell and droop over the pupils (a mechanical ptosis) may require several days of cool compresses, pain control, and topical antibiotic or lubricating ophthalmic ointment. Once the soldier can open his or her eyelids and see, he or she may be returned to duty.

Second- and third-degree burns should be treated similarly to first-degree burns, but they are at greater risk of Gram-negative bacterial infections. Application of gentamycin or tobramycin ointment may be indicated. However, care must be taken to watch for a toxic keratopathy (seen as diffuse staining of the cornea with fluorescein stain under a cobalt-blue light), which may develop with prolonged use of gentamycin and tobramycin. For deeper wounds, wet to dry physiological saline dressings should be used and systemic antibiotics initiated if infection is suspected. The saline dressings are used to decrease formation of dry coagulum (scabbing), which is a nidus for infection, and to decrease progression of ischemia in the zone of stasis.[13,18,19]

Eyelids with second- and third-degree burns often contract and cause some lagophthalmos, and if that happens, the soldier should be evacuated to the 3rd echelon for medical care. If significant exposure of the cornea is evident or if there is lagophthalmos with corneal drying and an epithelial defect, aggressive treatment is required to prevent corneal ulceration or perforation. The first line of treatment is frequent application of ophthalmic antibiotic ointment (at least six times daily). If antibiotic ointment is not available, then a nonmedicated lubricating ophthalmic ointment (eg, Refresh PM, mfg by Allergan, Inc, Irvine, Calif) or even soft, moist saline dressings can be used.

If ointment alone is not effective or if there is insufficient staffing to maintain that regimen, then a moisture chamber or cellophane occlusion should be placed over the antibiotic-ointment-lubricated eye (Figure 19-7). The moisture chamber—acting like a greenhouse—keeps the moisture from evaporating from the surface of the eye. The chamber and the cellophane also keep out foreign material and help maintain a more physiological local temperature. Patients with significant facial and head burns may not tolerate moisture chambers, and if there is periocular skin loss or excessive weeping of serous fluid, a bubble chamber may not stay in place. In these settings, the cellophane patch may be the best alternative.

If the moisture chamber is not available or is ineffective, a temporary tarsorrhaphy suture should be placed (Figure 19-8). A suture tarsorrhaphy is created by passing a double-armed 5-0 suture though a bolster (small piece of foam, rubber, or plastic) and through the lower lid just inferior to the lashes. The needles are passed out through the lower-lid gray line and into the upper-lid gray line.

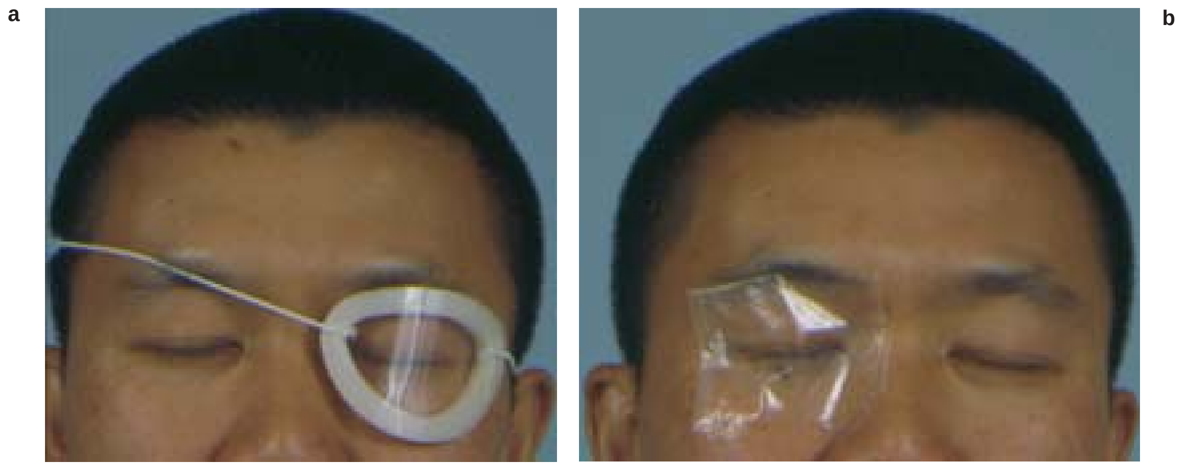


Fig. 19-7. Occlusive moisture dressings. (**a**) A moisture chamber (mfg by Wilson Ophthalmic Corp, Mustang, Okla). (**b**) A cellophane occlusive dressing. Both types of dressing require frequent application of lubricating ointment and act like greenhouses to keep the eye surface moisturized.

The sutures are then passed out the upper-lid skin above the lashes and through another bolster before the suture ends are tied. The sutures may be tied in a bow to facilitate periodic examinations of the ocular surface. The bolster reduces the incidence of sutures "cheesewiring," or cutting through, the eyelid tissues.

It is important to realize that suture tarsorrhaphy is a temporary measure and will not prevent cicatricial changes to the eyelid. Additionally, a suture tarsorrhaphy may be associated with eyelid margin irregularities. In severe contracture, the lids may pull through the tarsorrhaphy suture, which results in a cheesewire laceration of the eyelid. Surgical marginal tarsorrhaphies are not often used because the lid margin anatomy is destroyed, making reconstruction more difficult.

If singed lashes are present, consider cutting the lashes with scissors coated with antibiotic ointment. This will prevent debris from falling into the conjunctival cul-de-sac and irritating the cornea and mucous membranes.[18,19]

3rd Echelon

A patient with eyelid burns should be evaluated by an ophthalmologist at the 3rd echelon. By this time, any acid or alkali burn should have been diagnosed and acutely treated, otherwise severe progressive damage would have occurred. In-depth examination of the eye and periocular structures is essential. Ocular injuries must always be ruled out first. Definitive subacute and chronic eyelid treatment is then provided.[5]

Fig. 19-8. Suture tarsorrhaphy. A double-armed 4-0 suture (silk, nylon, or Vicryl) is passed through a foam or rubber bolster (cut from a surgical drain) and through the eyelid skin 4 mm inferior to the eyelashes. The sutures exit the lower lid through the gray line (middle portion of the lid margin). Both ends are then passed through the gray line of the upper lid and out through the skin about 4 mm above the upper lash line. The sutures are passed through another bolster and tied securely to pull the eyelids closed. Several such sutures may be placed along the length of the lid to achieve maximum corneal protection. The bolster reduces the risk of the suture cheesewiring through the injured eyelid tissue. Caution is necessary to avoid suture contact with the globe. Drawing: Courtesy of Department of Medical Illustrations, Brooke Army Medical Center, Fort Sam Houston, Tex.

Evaluation

The components of the 3rd-echelon eye and eyelid examination are similar to but more extensive than those of the eye and periocular examination at the 2nd echelon. Examinations at the 3rd echelon are conducted by medical officers, some of whom may be trained and certified ophthalmologists.

Visual Acuity. Best corrected visual acuity should be obtained and, if abnormal, correlated with clinical findings to explain the deficit. Results should be compared to the initial visual acuity to determine prognosis and course of the injury. Decreased visual acuity can be due to multiple etiologies, including lid deformities, dry eyes, epiphora, corneal irregularities and scars, anterior chamber hyphema or inflammation, iris damage, cataract, vitreous hemorrhage, retinal injuries, and optic nerve injuries.

Pupil Examination. The pupil examination is performed to determine if significant blunt trauma or blast injury may have damaged the anterior visual pathway, as an afferent pupillary defect (APD) or Marcus-Gunn pupil would suggest. APD is detected by having the patient focus on an object in the distance to prevent accommodative miosis (pupil constriction at near). In a darkened environment, a penlight is shined directly through the pupil of one eye, and the pupil constriction is observed. The light is then immediately shined in the opposite eye, and pupil constriction is observed. If one pupil constricts more sluggishly than the other, does not constrict at all, or actually dilates when the light is brought from the opposite eye, then the more-sluggish pupil is abnormal and is determined to have an APD. Anisocoria (asymmetrical pupils) can be due to a variety of causes including trauma to the iris root, iris sphincter damage, or iris ischemia due to thermal-induced hypovascularity. Intracranial injury may also cause anisocoria from a third–cranial nerve palsy.

Ocular and Lid Motility. The eyes should be examined carefully for motility to rule out orbital or neurological injury. The lid motility is examined as well to determine whether there is mechanical or neurological dysfunction due to burn or blast injury. For example, a ptotic lid with poor mobility can be caused by mechanical restriction from lid edema or burn scarring, or it could be due to a third-nerve palsy stemming from increased intracranial pressure from a related head injury.

Complete Slitlamp Examination. A thorough slitlamp examination is performed. Eyelid margins are examined for damage to the meibomian glands, puncta, and canaliculi. The conjunctiva is examined for lacerations and abrasions that can signal a penetrating globe injury or potential symblepharon formation (contracted conjunctival scarring between the eyelid and eyeball conjunctiva). The cornea is also examined for lacerations, abrasions, limbal ischemia (seen as a white, noninjected border between the sclera and cornea), and FBs. The anterior chamber is examined for FBs, hyphema (blood in the anterior chamber), angle recession (seen as a deeper than normal anterior chamber angle between the iris root and the cornea), and inflammation (seen as haziness in the anterior chamber). Significant anterior chamber "flare" out of proportion to anterior chamber "cell" may signal ischemia ("flare" and "cell" pertain to the gradation of anterior chamber inflammation). The iris is examined for sphincter tears or lacerations. The lens is examined for dislocation, subluxation, or traumatic or ischemic cataract.

Eyelashes. Singed lashes and eyebrow hairs may indicate thermal damage, which may manifest itself over several days. Therefore, patients with singed lashes should be observed. If an FB sensation is due to lash particles on the eye, the lashes should be trimmed and lubricated with ointment.

Eyelids. The degree and extent of burns must be determined to evaluate globe coverage, motility, lagophthalmos (amount of exposure on eyelid closure), ectropion (outward turning of the eyelid margin), entropion (inward turning of the eyelid margin, often with lashes rubbing against the cornea). Children have thin skin and, therefore, experience greater depth of burn with increased scarring and disfigurement.[20]

Face. Look for adjacent burns, which may contract and pull on the eyelids causing ectropion, retraction or lagophthalmos, and exposure keratopathy. Also, note whether the usual donor sites for skin graft (upper eyelids and retroauricular, periclavicular, and inner arm areas) are involved.

Intraocular Pressure. Monitor intraocular pressure (IOP) for elevation or hypotony. Elevated IOP may indicate traumatic glaucoma due to anterior chamber angle injury or traumatic cataract. Low IOP may signal occult globe rupture, choroidal or retinal detachment, or anterior segment ischemia.

Posterior Segment (Fundus) Examination. The posterior segment should be evaluated for inflammation, FBs, retinal detachment, chorioretinal injuries, and optic nerve injuries.

Treatment

Treatment at the 3rd echelon should include copious irrigation of chemical burns if this was not adequately done at lower echelons. Examine the eyes and remove any remaining chemical particles from the conjunctiva and eyelids. Then, proceed according to the protocol for chemical ocular injuries (Chapter 7, Chemical Injuries of the Eye). Once stable, the eyelids should be treated as indicated in the sections that follow.

First-Degree Burns. Because first-degree burns are self-limited and heal well, these superficial burns are seen at the 3rd echelon only because the patient has other injuries. Treatment includes applying cool compresses and providing analgesics as needed. Occasionally mild, transient lagophthalmos and corneal exposure occur and are treated with artificial tears and ointment for lubrication.

More-severe exposure in an obtunded patient may require a moisture chamber (see Figure 19-7). Numerous moisture chambers are commercially available. Some are self-adhesive and are applied much like an elastic bandage. However, the adhesive irritates some patients' skin, and, if the periocular area is lubricated for adjacent burns, this type of moisture chamber does not stay in place well.

Another common type of moisture chamber has an elastic band and is worn like a pirate patch. This system works well if an adhesive chamber irritates the skin or if periocular lubrication is present. The drawbacks to the pirate patch moisture chamber are that the elastic can irritate injured scalp and head skin and when patients turn in their sleep, they can dislodge the patch. More commonly, patients have a mechanical ptosis due to lid edema rather than lagophthalmos. Mechanical ptosis actually protects the eye from exposure, especially in unconscious patients.

Second-Degree Burns. Cicatricial changes usually accompany second-degree or partial-thickness burns. If the patient is awake, corneal and conjunctival exposure and drying should be treated with artificial tears. Ophthalmic lubricants or an ophthalmic antibiotic ointment (if a corneal epithelial defect is present) should be used six or more times per day for an unconscious patient. If drying is severe, the following measures should be considered:

- moisture chambers over the eyes;
- cellophane, ocular-occlusive dressings (applied six times per day); and
- temporary suture tarsorrhaphies (see Figures 19-7 and 19-8).

The cellophane occlusive dressing can be made by cutting a square of cellophane wrap to a size that will completely cover an eye and reach the orbital rims on all sides. The cellophane is kept in place by the adhesive effect of the topical eye ointment. This dressing has the advantage of not irritating the periocular skin because there is no glue adhesive. It also avoids pressure irritation because it has no elastic band. The cellophane dressing stays in place even if the patient moves in bed. If the lids are completely missing, it allows the patient to have some vision while providing barrier protection.

The temporary suture tarsorrhaphy may be necessary if excessive lagophthalmos allows significant corneal drying. The tarsorrhaphy temporarily sews the eyelids closed (see 2nd-Echelon Treatment, above).

If the lacrimal system is involved, nasolacrimal system intubation with silicone tubing should be considered to prevent cicatrization and future nasolacrimal system obstruction and epiphora (Figures 19-9 and 19-10). The tubing is left in place for 3 to 9 months, until the cicatrizing changes of the lid have stopped, or until the patient is unable to tolerate the tubes once initial healing has occurred. If well tolerated, the silicone stents may be left in longer, keeping in mind that burn-scar remodeling continues even past the 1-year mark. Monocanalicular intubation may be more beneficial than a bicanalicular tube, as the bicanalicular tube may cause cheesewiring of the canaliculi as the lid tissue contracts and places excess traction on the canaliculi.

Third-Degree Burns. Aggressive treatment is warranted for third-degree, or full-thickness, burns of the eyelids. Frequent lubrication is essential. Severe cicatrizing ectropion with unresponsive corneal drying should undergo surgical relaxing incisions of the burn scars (Figure 19-11). When the lids are significantly immobilized because of contraction, the skin and underlying scar tissue must be sharply transected to allow the lids to protract over the globe.

If a temporary suture tarsorrhaphy does not hold, then Frost sutures should be placed to keep the lids closed and on traction (Figure 19-12). A Frost suture is created much like a suture tarsorrhaphy. Both ends of a double-armed suture are passed through a bolster and through the lid like a tarsorrhaphy suture. However, instead of passing them through the opposite lid, the trailing ends are taped to the forehead (for the lower lid) or to the cheek (for the upper lid). Again, caution is needed to verify (1) that the suture is correctly passed through the tar-

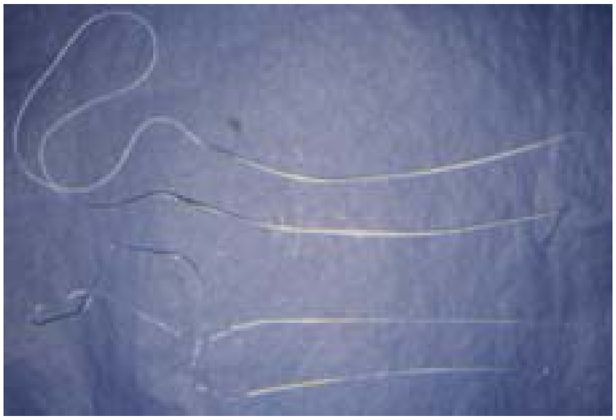


Fig. 19-9. Silicone stents. Shown are two types of silicone stents, which may be passed through the nasolacrimal system to prevent cicatricial closure and obstruction. A Guibor tube (top) may be retrieved with a grooved director. A Crawford tube with an olive-tipped introducer (bottom) is retrieved by a Crawford hook (similar to a small crochet hook).

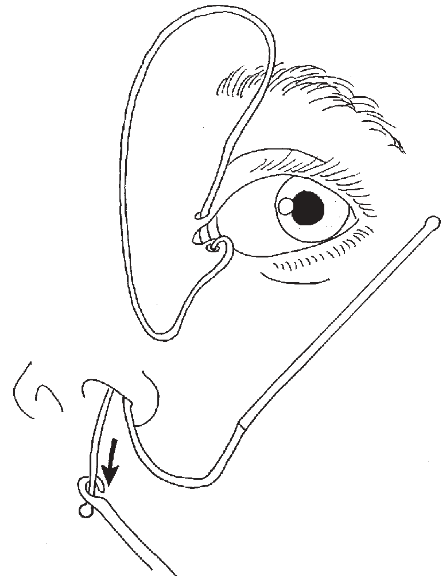


Fig. 19-10. Intubating the nasolacrimal system. The figures show passage of the silicone stents through the vertical and horizontal canaliculi into the nasolacrimal sac and down into the nose through the nasolacrimal duct (a closed loop). The tube is retrieved below the inferior turbinate with a Crawford hook.

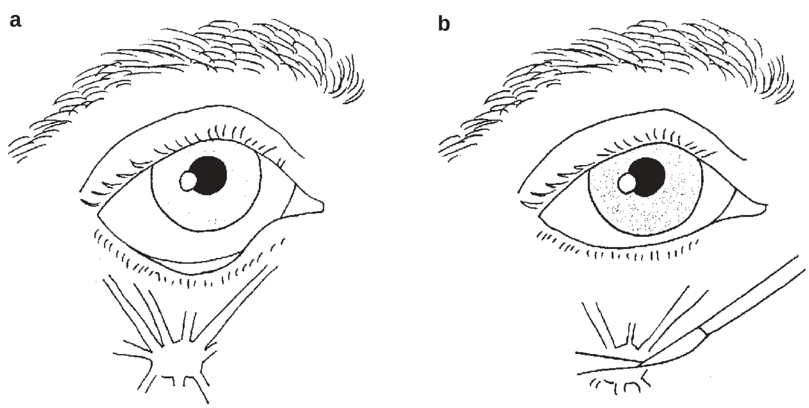


Fig. 19-11. Relaxing incision. The cicatrix (**a**) of the lower eyelid (**b**) is incised with a scalpel blade to release the retraction and ectropion.

Fig. 19-12. A Frost suture is used to put the eyelid on traction, prevent recurrence of retraction, and to allow the eyelid to cover the eye. A Frost suture is placed by passing a double-armed suture (4-0) through the wound and out through the lower eyelid gray line. The suture is pulled up and secured to the forehead with benzoin and plastic tape.

Fig. 19-13. A non-margin-sharing tarsorrhaphy preserves the integrity of the eyelid margin. A scalpel blade is used to incise the upper eyelid conjunctiva and the superior 4 mm of tarsus. Vertical incisions are made with fine scissors, and the shade-like pedicle of tissue is sewn into the upper conjunctiva of the lower lid with 6-0 Vicryl. This technique provides support of the lower eyelid and coverage of the cornea.

sal plate—the thick, fibrous, connective tissue condensation at the lid margin—for adequate fixation and (2) that no suture contacts the globe. It is often difficult to adequately secure the trailing ends of the sutures because of periocular burns and the application of lubricants to the patient's skin.

If necessary before evacuation, non-margin-sharing temporary tarsorrhaphies may be considered (Figure 19-13). (Margin-sharing tarsorrhaphies are not commonly used because they distort the lid margins, making any subsequent reconstruction even more difficult.) Before the technique for non-margin-sharing tarsorrhaphies is outlined, a cross-sectional review of the normal lid anatomy is indicated. The layers of the eyelid going from superficial to deep at the level of the tarsal plate are as follows: eyelid skin, orbicularis oculi muscle, distal end of the levator aponeurosis, tarsus, and conjunctiva. Above the tarsal plate, the layers are as follows: eyelid skin, orbicularis oculi muscle, orbital septum, preaponeurotic orbital fat, levator aponeurosis, Müller's muscle, and conjunctiva. In the lower eyelid, the eyelid retractor components are less well developed. The equivalent of the levator aponeurosis is the capsulopalpebral fascia, and the Müller's muscle equivalent is the inferior tarsal muscle. Otherwise, the layers at and below the level of the tarsus in the lower lid are similar to those of the upper eyelid.

The non-margin-sharing tarsorrhaphy is created by everting the upper eyelid and incising the conjunctiva and tarsus approximately 4 mm above the lid margin. Vertical incisions are made in the conjunctiva and Müller's muscle. The pedicle is then undermined in a plane between Müller's muscle and the levator aponeurosis. Once this is accomplished, the lower lid is horizontally incised on the mucosal side about 2 mm below the lid margin in a length corresponding to that of the upper-lid pedicle flap. The tarsoconjunctival flap from the upper lid is sewn into the lower-lid incision using 6-0 Vicryl (polyglactin) suture.

The non-margin-sharing tarsorrhaphy provides excellent globe coverage in patients with lagophthalmos from significant eyelid burns. This procedure does not distort the lid margin and is created from posterior lamellar lid tissue, which is less often involved in burn injuries. Therefore, secondary reconstruction is less difficult, and reversal of the procedure only requires transection of the flap where it comes off the upper lid and recession of the Müller-conjunctival pedicle to prevent eyelid retraction.

Patients with extensive second-degree burns (lagophthalmos and corneal drying not responding to the use of tears) and third-degree burns of the eyelids should be stabilized, have their globes protected, and be evacuated to the continental United States (CONUS) for definitive care. Patients with these burns usually also have extensive injuries or burns on other body areas, which alone would require evacuation.

Burns of the conjunctiva (ocular mucous membranes) inevitably lead to scarring and contracture and, if not treated early, to symblepharon formation (adhesions between the mucous membranes of the eyelids and the globe). Symblepharon formation is frequently seen with chemical injuries. Necrotic tissue must be removed and a symblepharon ring, spacer, or even a large therapeutic contact lens should be placed to minimize adhesion formation. The eyes should be evaluated at least twice daily, and any early symblepharon should be lysed with a glass rod or a moistened cotton-tipped applicator. Copious lubricating eye ointment should be used to prevent drying and for patient comfort. Antibiotic ointment should be strongly considered, given the risk of infections in burn wounds.

Evaluation and Treatment in the Continental United States

Evaluation in CONUS of patients with eyelid burns should first focus on the status of the eyes. The following must be ruled out: a ruptured globe;

intraocular injury; or ocular surface injury due to the burn itself, exposure, drying, and corneal infection, which may have occurred during the evacuation process. If any of these injuries is noted, appropriate treatment algorithms should be followed as described above.

Once the eye is determined to be healthy, or when the ocular injuries are stabilized, evaluation should focus on the status of the eyelids. Globe protection, eyelid function, and cosmetic appearance should be considered in that order of priority.

Needed interventions are carried out by the fully trained and experienced military ophthalmologists, who will be found at CONUS hospitals.

Evaluation

The CONUS evaluation, when completed, should contain the answers to the following questions:

- How much and to what degree are the eyelids burned?
- How much of the eyelids remain and which parts are missing?
- Is the eyelid ectropic, entropic, or retracted?
- Is the canalicular system involved or destroyed?
- What is the status of the tear film, and which component has been affected?
- What is the status of the globe's protective mucosal covering?
- How does the eyelid look relative to a normal eyelid?

Extent and Degree of Burns. Reassessment is crucial to determine proper short-term and long-term treatment and prognosis. Superficial and mild partial-thickness burns can often be conservatively managed. Severe partial- and full-thickness burns require significant immediate attention. Burns previously billed as partial thickness may have progressed during transit to full-thickness injuries because of infection, desiccation, or less-than-adequate interim care owing to wartime constraints.

Status of Remaining Eyelids. The anatomical status of the eyelids should be evaluated to plan for reconstruction. A systematic approach should be used to evaluate the status of the anterior, middle, and posterior lamellae. The eyelids should be evaluated for their protraction, retraction, tear pump function, and cosmetic appearance. Loss of anterior lamella requires reconstruction with full-thickness skin grafts or rotational or transposition skin and muscle flaps. Posterior lamella loss calls for mucous membrane grafting and, if tarsal support is lost, a tarsal substitute such as hard palate mucosal grafts, donor sclera, and other autologous or synthetic materials. In burn patients, the posterior lamella is involved when injury extends through the anterior lid structures. Therefore, in most instances, full-thickness lid loss is present and more-complex procedures combining vascularized pedicle flaps for one lamella and free grafts for the other lamella are required. Loss of the middle lamella (septum) usually causes scarring and restricted lid movement; reconstruction for this problem involves releasing the scar and placing a "spacer" to decrease additional scarring.

Diminished protraction (lid closure) is caused by mechanical restriction, damage to the orbicularis oculi muscle, or injury to the seventh cranial nerve because of adjacent trauma. Inability to close the eyelids (lagophthalmos) can be mild to severe and should be treated accordingly as previously discussed.

Diminished retraction (lid opening) causes ptosis. Mild ptosis may be asymptomatic but more-significant ptosis can decrease vision if the lid obscures the pupil and interferes with the visual axis. Therefore, persistent ptosis should be repaired for visual rehabilitation.

Proper closure and anatomical position of the eyelid are responsible for tear removal. Abnormalities can cause epiphora (tears running out of the eye onto the cheek). Tests such as the dye disappearance test and the Jones 1 and 2 tests and visual inspection should be performed to evaluate the status of the tear pump.

The dye disappearance test, a diagnostic test of tear pumping and drainage, is performed by instilling fluorescein dye into the eyes and watching for its removal under cobalt-blue lighting. The patient is allowed to blink normally but should not wipe the eyes. At 5 minutes, almost all of the dye should be removed from the eye. If dye is still present, a delayed clearance problem exists. Asymmetry of remaining dye indicates a unilateral (ie, a worse) problem in the eye with the most dye. Tears running down the cheek may indicate a tear pump problem. An abnormal dye disappearance test may be due to an abnormal tear pump, insufficient tear production to wash out the dye, an obstruction or malposition of the puncta, or a blockage of the canalicular–nasolacrimal system.

The Jones 1 test, the second diagnostic test of tear drainage, is performed by instilling fluorescein dye in the eyes, as was done in the dye disappearance test. In the Jones 1 test, a cotton-tipped applicator is placed under the inferior turbinate to detect dye. If dye is present on the cotton-tipped applicator, tears are cleared normally. If no dye is detected, however, either the tear pump is malfunctioning or the canalicular–nasolacrimal drainage system is blocked. Although the Jones 1 test is a physiological test of tear drainage, no dye may be detected in about a third to half the patients with normally functioning drainage apparatuses.

The Jones 2 test, the last of the tests of tear drainage, is performed after an abnormal (no dye detected) Jones 1 test. After the Jones 1 test, residual dye is irrigated from the conjunctival cul-de-sac. Then clear saline is irrigated through the canaliculi while an attempt is made to detect dye beneath the inferior turbinate. If no fluid is recovered from the nose after irrigation, then a blocked drainage system is present. If clear fluid is detected, then the tear pump is malfunctioning and is unable to pump dye into the lacrimal sac; because fluid is recovered, however, the drainage system is anatomically patent. On the other hand, if dye enters the nose with irrigation, then the tear pump functions to push dye into the tear sac, although the drainage system might be functionally or partially blocked. Finally, if the lower eyelid seems lax or there is punctal ectropion, the tear pump may not be functioning well.

Position of the Eyelids at Rest. Is the eyelid ectropic, entropic, or retracted? In addition to the dynamic lid position and function discussed above, the static position of the eyelids at rest should be determined.

An ectropic lid may cause exposure keratitis, epiphora, FB sensation, and blurry vision. Ectropion in burn patients is usually cicatricial, either from direct lid involvement or transferal of traction from adjacent tissue such as a cheek burn. Treatment is aimed at releasing the traction and replacing the lost tissue.

On the other hand, an entropic lid is generally more worrisome than an ectropic one because the sequelae occur more rapidly. An entropic lid can cause a mechanical keratitis from lashes or keratinized lid skin rubbing against the cornea, which can cause significant corneal injury if not immediately addressed. Entropion in burn patients may be due to conjunctival scarring, although this is less common in thermal than in chemical burns. A patient with preexisting lid laxity may have spastic entropion due to ocular irritation after a burn injury. Treatment is aimed at relieving the irritation and breaking the cycle of spasm.

Eyelid retraction in burn patients is usually due to scarring and is treated much like an ectropion.

Condition of the Canalicular System. Is the canalicular system involved or destroyed? Inspection of the canalicular system of the eyelids often reveals that the punctum is closed or ectropic due to scarring. If ectropic and permanent, surgical correction may be necessary. If the punctum is closed, it can be surgically opened with a punctal dilator or sharply cut with a scalpel or Wescott scissors.

If the puncta appear normal and if epiphora is present, the cause should be determined using the dye disappearance test and Jones 1 and 2 tests (described above). Additionally, the canaliculi should be irrigated with physiological saline solution in a 3-mL syringe and a blunt 23-gauge cannula. If fluid reaches the nose, then the lacrimal drainage system is open. If fluid does not reach the nose but instead drains out the opposite punctum (ie, out the upper when the lower punctum is irrigated), then a nasolacrimal duct obstruction is probably present. However, if fluid does not reach the nose but drains out the same punctum that is being irrigated, then the canaliculus being irrigated is obstructed. Note that this is similar to the Jones 2 test discussed previously.

Nasolacrimal duct obstruction is uncommon in burn patients unless severe facial burns around the nose involving the bone are present, or if the patient has a midfacial injury from a blast. If a nasolacrimal duct is obstructed, the patient may need a dacryocystorhinostomy (DCR). In this procedure, an osteotomy is created in the lacrimal sac fossa and a direct connection is made between the lacrimal sac and the nasal cavity. A DCR can be performed endoscopically through the nose or externally through a Lynch skin incision in the medial canthal area. To promote mucosal epithelialization of the bypass tract, anterior and posterior mucosal flaps can be created from the lacrimal sac and nasal mucosa, which are sutured together. Additionally, a silicone stent is usually placed through the canaliculi and through the osteotomy and into the nose to reduce cicatricial closure of the mucosal bypass tract. The stents are removed once healing is relatively complete, usually at about 3 months postoperatively.

Canalicular obstruction or destruction is more common with eyelid burns. If the burn injury is mild (superficial), simple canalicular intubation as previously discussed may be adequate. If severe (partial- or full-thickness), however, canalicular reconstruction is very difficult, owing to scar formation, and the patient may eventually require a conjunctivodacryocystorhinostomy (C-DCR) with a Jones tube. In this procedure, an external Lynch incision is made, much like that in a DCR. An osteotomy at the lacrimal sac fossa is created with rongeur forceps. A no. 69 Beaver blade is passed through the conjunctiva just lateral to the caruncle and into the lid through the osteotomy and into the nasal cavity. A Pyrex Jones tube is then passed through this tract into the nose and secured into place with a suture at the lid margin. The Lynch incision is closed in two layers, and the Jones tube fixation suture is removed in 7 to 10 days. The Jones tube bypasses the entire blocked canalicular system and allows the tear lake to drain directly into the nose by means of gravity and capillary action.

Status of the Tear Film. Which components have been affected? The tear film should be evaluated for its quantity and quality because eyelid burns can alter all components. The meibomian glands at the lid margin can be damaged, reducing the sebaceous (lipid) layer of the tear film; this causes decreased lid lubrication and increased tear evaporation. If the conjunctiva is significantly involved, then the accessory glands of Krause and Wolfring or even the main lacrimal gland could be injured. If this is the case, the aqueous component of the tear film would be diminished, resulting in significant keratitis sicca (see Figure 19-6). Likewise, because the mucous layer of the tear film is made by conjunctival goblet cells, conjunctival injury can cause poor corneal wetting if the inner mucous tear film layer is compromised or missing.

Assessment of the tear film is done mainly with Schirmer's tests, tear break-up time, direct visualization, and, in some medical centers, chemical analysis and impression cytology. Schirmer strips—standardized strips of filter paper—are placed in the inferior conjunctival cul-de-sac and draped over the lower eyelid. The Schirmer 1 test measures basal and reflex tear production. It involves putting the strips onto an unanesthetized eye. The amount of strip wetting is measured in millimeters after 5 minutes (normal = ≥ 15 mm). The Schirmer 2 test measures reflex tear production. It involves placing the strips onto the eye after topical anesthetic is applied. The inferior turbinate is then irritated with a cotton-tipped applicator, and the amount of wetting is measured (normal = > 10 mm). The basal tear secretion test is a variant of the Schirmer tests, in which the strips of filter paper are placed into the anesthetized eye after excess tears have gently been removed with a cotton-tipped applicator. The amount of wetting is measured after 5 minutes (normal = ≥ 10 mm). Care must be taken when drying the surface of residual tears, as excess vigor may stimulate reflex tearing.

The Schirmer tests and the basal tear secretion test measure the aqueous component of the tear film. Tear break-up time, on the other hand, measures the stability of the tear film on the surface of the eye. Nonanesthetic fluorescein dye (usually from moistened fluorescein strips) is placed onto the ocular surface. While at the slitlamp and under cobalt-blue light, the patient is first asked to close his or her eyes, then to open them and resist blinking. The observer then counts the number of seconds before the tear film breaks up on the ocular surface, which, under the blue light, is seen as a dark spot appearing in the uniform green fluid layer on the cornea. The tear film should normally be stable for 15 seconds. Early break-up implies either instability of the tear film because of an insufficient sebaceous layer, allowing early evaporation, or poor wetting because of an insufficient mucous layer on the cornea. Topical anesthetics should not be used in this test, as they alter the test results.

Tear composition analysis and impression cytology are advanced techniques that will not be discussed here. Nevertheless, ophthalmologists can appreciate that a significant alteration in any of the tear components could cause ocular surface disease, patient discomfort, and visual degradation.

Status of the Mucosal Covering. What is the status of the globe's protective covering? As stated earlier, burn injury involving the conjunctiva may result in symblepharon and the globe's being fixed to the eyelids. Careful examination is required to reduce the amount of symblepharon formation and to plan for replacing a mucous membrane layer on the globe and eyelids.

Comparison With a Normal Lid. How does the eyelid look relative to a normal eyelid? Once the functional and ocular protective status of the lids has been evaluated and addressed, then attention can be directed to eyelid aesthetics. Common concerns include skin texture, lash loss, hypertrophic scars, lid and canthal angle positions, medial canthal webbing, and eyebrow hair loss.

Treatment

Treatment in CONUS includes all the lower-echelon treatments described. These procedures are often repeated once the patient has arrived in a CONUS hospital because of persistence of the signs or worsening of the condition. An oculoplastic surgeon should be consulted to perform definitive reconstruction or emergent reconstruction of a severely burned eyelid. Definitive delayed reconstructive surgery should occur no earlier than 3 months after the initial injury. If surgery can be delayed longer (up to 1 year), the outcome of reconstruction may be improved, as postoperative cicatricial changes are reduced by then and better revascularization of the injured tissue will have occurred. However, visual rehabilitation often necessitates earlier repair.

Reconstruction of the burned eyelids should focus first on protecting the eye (protraction), then on visual function (retraction to clear the visual axis), and finally, for the patient's psychological well-being, on cosmetic appearance. Multiple procedures are available to deal with the complex nature of the cicatrized eyelid and are beyond the scope of this book. However, for a basic understanding of what procedures are available, a brief description of selected procedures is provided.

Treatment modalities in CONUS hospitals include conservative treatment to allow scar relaxation and maturation; restoration of lost eyelid tissue; and correction of eyelid and canthal malpositions, disorders of eyelid retraction and protraction, trichiasis, disorders of the mucosal lining of the eyelid, and abnormalities of the tear drainage system.

Conservative Treatment. In eyelid burn patients, if the eyes are well-protected and visual function is adequate, then definitive repair should be delayed up to 1 year, if possible. Cutaneous and subcutaneous burn scars are slow to mature, and maximum natural relaxation of scar tissue is desired prior to surgery. Scar relaxation may be expedited by manual massage, use of topical vitamin E or cocoa butter, and constant, long-term pressure to the wound area using custom-fitted masks made of silicone, Flexan, or plastic, all of which can be manufactured by Uvex or Jobst.[13] Pressure splints placed directly on the eyelids are impractical because they interfere with vision and put pressure on the eye. However, lid malpositions due to adjacent tissue scarring (eg, on the cheek) respond very well to custom-fitted pressure splints. Given the slow process of rehabilitation to give the patient a sense of progress toward recuperation, it is often helpful to engage him or her as much as possible in massage and stretching regimens.

Once the cicatrix has maximally relaxed, or if more-immediate intervention is required to protect the eyes or allow the patient to see, surgical rehabilitation should proceed in an organized, stepwise fashion. The patient should be well-informed about the long road to recovery and the need for multiple operations and revisions.

Restoration of Eyelid Skin. Loss of eyelid skin is treated with skin grafts or, if undamaged eyelid tissue is available, transposition flaps. Cultured autogenous skin[21] and alloplastic material are available for use[22] in patients without an adequate skin source (Exhibit 19-1). The most commonly used free-graft sources for the eyelids include the upper eyelid skin from the normal contralateral lid (if

EXHIBIT 19-1

SKIN GRAFTS FOR RESTORATION OF LOST EYELID TISSUE

Autologous grafts:

In the absence of an adequate skin source, a few of the patient's own skin cells may be sent for culture. Unfortunately, the process of growing human skin is time-consuming and expensive, and even in light of the screening and processing methods used, a concern regarding disease transmission accompanies all grafts—even when the donor and the recipient are the same person.

Alloplastic grafts:

Alloderm (LifeCell Corp, The Woodlands, Tex) is an acellular, nonimmunogenic dermal grafting material that can be used in place of skin. Because it is made from an inert substance, the graft lacks epidermal cells, and the graft recipient's skin cells must migrate onto the biological bed for resurfacing. The process may be even slower if the adjacent tissue also suffered thermal damage.

Allografts:

As an alternative, nonimmunogenic allografts can be used. Apligraf (Novartis Pharmaceuticals Corporation, East Hanover, NJ) is harvested from neonatal foreskin, which is then processed to make it nonimmunogenic. This material, being human in origin, has intact epithelium; therefore, the graft may heal faster.

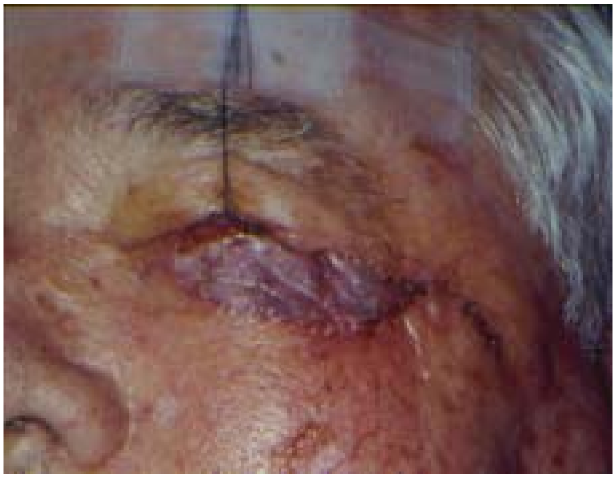


Fig. 19-14. This photograph depicts a full-thickness skin graft to an eyelid defect to correct cicatricial ectropion. The skin graft may be taken from the upper eyelid, the retroauricular or periclavicular areas, or the inner arm or inner thigh. Thin, pliable, hairless skin is preferred. The skin-grafted lid is then put on traction with a Frost suture, and a pressure dressing is placed over the graft for 1 week to prevent hematoma formation below the graft.

present), retroauricular skin, supraclavicular and infraclavicular skin, upper inner arm (volar surface) skin, and inner thigh skin[20,23] (Figure 19-14). Grabosch and colleagues[22] reported successful use of prepuce skin for the eyelid in severely burned patients.

Successful skin graft healing requires a relatively healthy vascular bed. In patients with partial-thickness or localized full-thickness burns, the posterior lamella of the eyelid may be intact, with blood supplied by the palpebral conjunctiva and Müller's muscle. In such cases, the eyelid scar is incised, or a lid crease incision can be performed and the deeper cicatrix released, until the eyelid is mobile and has full excursion. The lid is then put on traction with a double-armed 4-0 suture through the lid margin. The defect is measured, and an oversized graft (usually one-and-a-half to two times the size of the defect) is also measured and then harvested from an appropriate donor site. Care should be taken to keep the graft as thin as possible for optimal function and cosmesis. In some instances, a thick, partial-thickness skin graft (0.4 to 0.5 mm in depth) harvested with a dermatome may give good results with comparatively little contracture.[22–24] The graft is then sewn into place with 6-0 fast-absorbing gut sutures. The traction suture is put on traction and taped into place (on the forehead or cheek, if possible) to keep the graft on stretch and decrease contraction. Antibiotic ointment, a nonadhesive dressing, and a pressure patch or bolster splint are placed on the graft and secured with tape to prevent hematoma under the graft, which might increase the likelihood of graft failure. The patch and the traction suture are removed in approximately 5 days.

In defects that are smaller or that require a vascularized skin source, transposition flaps (eg, from the upper to the lower eyelid with the pedicle based laterally) may be useful. However, the skin adjacent to the burn wound is often damaged as well, and so these transposition skin flaps are not used often. In the medial canthal area, a midline glabellar or median forehead flap may be used for reconstruction.

When there is full-thickness loss of eyelid tissue, both posterior and anterior lamellae require reconstruction. Surgical repair necessitates having at least one vascularized lamella. In burns severe enough to destroy the entire eyelid, it is unlikely that there is adequate adjacent well-vascularized skin, especially for the upper eyelid. Therefore, most reconstruction of the upper eyelid utilizes posterior lamella pedicle flaps with anterior lamella free grafts (described above). If the cheek and face skin are not compromised, a Mustarde flap with a mucosal membrane graft (eg, from the hard palate) can be used to reconstruct the lower eyelid. Otherwise, a posterior pedicle flap must be used as well.

The most common techniques for large, full-thickness reconstruction of the lower eyelid include the modified Hughes tarsoconjunctival flap, the Hewes laterally based tarsoconjunctival flap, and the Mustarde flap. In the modified Hughes procedure (Figure 19-15), the upper eyelid is everted over a Desmarres retractor, and a Beaver blade is used to incise the conjunctiva and tarsus approximately 5 mm above the lid margin for the length of the lower-lid defect to be filled. The dissection is carried out superiorly in a plane between Müller's muscle and the levator aponeurosis. The conjunctiva is incised vertically in a superior direction. The flap is then brought down into the lower eyelid defect and sewn into place with 6-0 Vicryl sutures. A full-thickness skin graft or comparable material is harvested, placed on the pedicle flap, and sewn into place with 6-0 fast-absorbing gut suture.

The wound is dressed in much the same way as a skin graft. The reconstruction is allowed to heal for approximately 6 to 8 weeks, sometimes longer, depending on the vascular status of the burned area. Once healed, the pedicle is transected where it joins

Fig. 19-15. The Hughes tarsoconjunctival advancement flap for the reconstruction of the lower eyelid is a staged procedure, requiring the globe to be covered for 6 weeks. The pedicle is then transected and the lid margin is reconstructed. (**a**) The lower eyelid defect is shown. The tarsoconjunctival flap is being developed. (**b**) The tarsoconjunctival flap is brought down into the lower lid defect. (**c**) Redundant lower eyelid skin is brought over the tarsoconjunctival flap, as in this case, or a full-thickness skin graft can be placed over the mucosal flap. (**d**) The well-healed pedicle can be transected. The lower lid margin can then be reformed.

the upper eyelid and separated into anterior and posterior lamellae. Excess skin is excised, and the mucosa is draped over the lid edge, extending over the lid margin. It is then sewn in place with 6-0 fast-absorbing gut. The mucosa exposed to the environment eventually becomes keratinized. The conjunctiva and Müller's muscle may need recession if the upper lid is retracted after transection of the pedicle flap.

The Hewes flap is similar to the modified Hughes except that it is a laterally based tarsal conjunctival flap with a free skin graft. Because the flap is based at the lateral canthus, the flap does not obstruct the palpebral fissure. Therefore, it is a single-stage procedure.

The Mustarde flap requires an extensive undermining of skin from the lateral lower lid extending to the preauricular area and inferiorly toward the angle of the jaw. The skin flap is then rotated superomedially and sewn into place with deep 5-0 or 4-0 Vicryl sutures and 6-0 fast-absorbing gut or nylon sutures. The posterior lamella is recreated with mucous membrane and often a rigid material to act as a tarsal substitute (eg, banked sclera, high-density porous polyethylene [Medpor, mfg by Porex Surgical Inc, College Park, Ga], nasal septal cartilage, and auricular cartilage). These materials usually require a mucous membrane covering, such as buccal mucosa. Alternatively, hard palate grafts or Alloderm (mentioned above) may be used for the posterior lamella without requiring mucous membrane grafting.

The most common techniques used for large, full-thickness upper eyelid reconstruction include the Cutler-Beard procedure, the glabellar flap, and the laterally based transposition flap from the suprabrow area. The Cutler-Beard procedure (Figure 19-16) involves incising the lower eyelid full thickness below the tarsus (approximately 6 mm) and extending the width of the upper-lid defect. The incision is extended directly inferiorly at each end of the a b c d

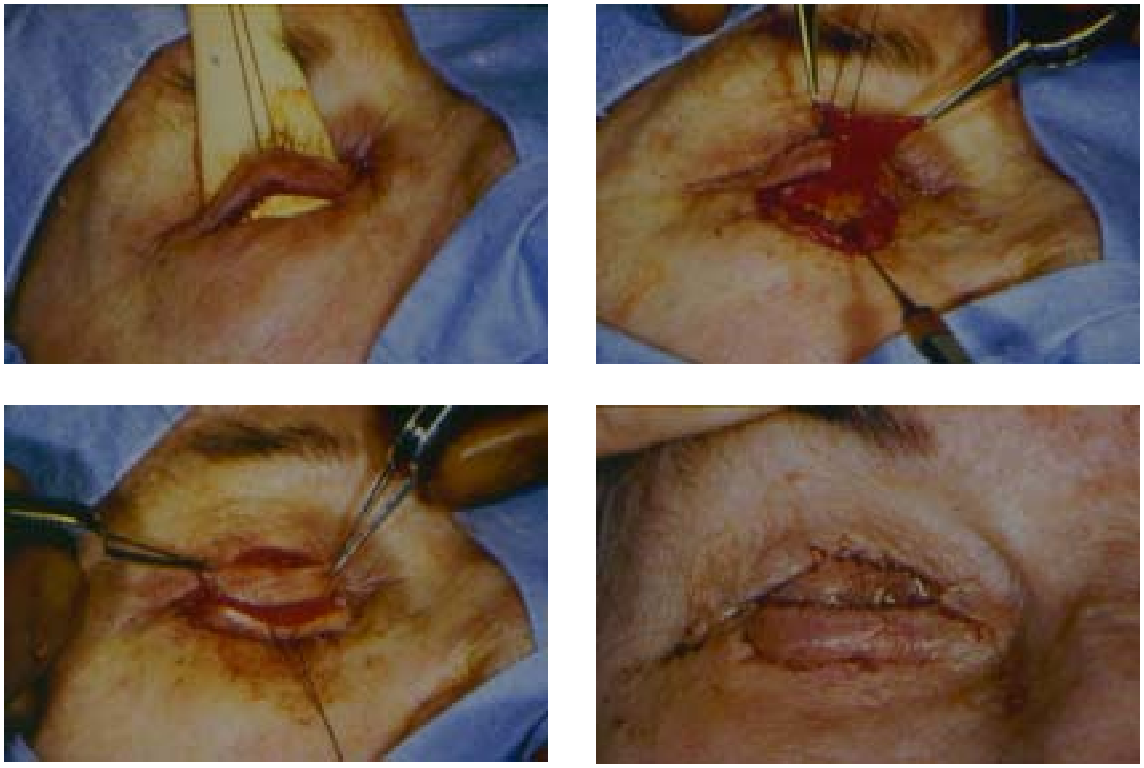


Fig. 19-16. The Cutler-Beard advancement flap for the reconstruction of the upper eyelid is also a staged procedure. (**a**) In this photograph, the upper-lid defect is partially covered by the lid plate. A full-thickness incision is made across the lower eyelid, as shown. (**b**) The conjunctival flap is advanced superiorly. (**c**) The conjunctival flap is sewn into the upper-lid defect, and the skin flap is similarly brought underneath the lower-lid margin bridge and into the upper-lid defect. A tarsal substitute, such as sclera, may be placed between the two lamellae. (**d**) The defect is repaired. The pedicle is transected after 6 weeks, and the upper-lid margin is reconstructed.

horizontal incision so that the full-thickness pedicle can be brought behind the bridging lid margin of the lower lid and into the upper eyelid defect. The lamellae of the pedicle are separated and a tarsal substitute (such as those for the Mustarde flap, above) is sewn between the two lamellae at the level of the superior tarsus. The pedicle is then sewn into the defect in multiple layers with 6-0 Vicryl sutures. The tarsal substitute is sewn edge to edge with any remaining upper-lid tarsus. The skin is closed in the usual fashion.

The glabellar flap is essentially a medially based transposition flap that is brought down from the midline of the forehead and across the upper lid to fill in the defect. The blood supply is based off the supratrochlear vessels. This flap mainly supplies anterior lamella and, if used for full-thickness defects, a mucous membrane graft must be used to line the defect, and a tarsal substitute is required to give the lid rigidity. Unlike in the lower eyelid, a graft of hard palate tissue does not work well in the upper lid because the graft tends to irritate the corneal surface with lid excursions. The temporally based transposition flap has a less well-defined blood supply and, therefore, may not be as useful in cases of complete loss of the upper eyelid.

In cases of full-thickness loss of both upper and lower eyelids on the same side, reconstruction is extremely difficult. The main goal, however, is to protect the globe. In these (albeit rare) cases, we have mobilized forniceal and bulbar conjunctiva from the upper and lower fornices and sewn them together. This provides a mucosal covering for the cornea. The exposed, nonepithelialized surface of the mobilized conjunctiva is covered with skin grafts. A small opening in the conjunctiva may be left centrally and the edge of the mucosa sewn to a corresponding opening in the skin graft. The opening provides a small aperture for vision and for monitoring of the corneal status.

Eyelid Malpositions. Cicatricial ectropion is the most common eyelid malposition caused by eyelid burns. The ectropion may stem from direct eyelid tissue scarring or from transmission of contracture from adjacent tissue (eg, cheek or forehead). Treatment is aimed at releasing the tension on the eyelid, preferably at the site of scarring.

Eyelid cicatricial ectropion is caused by shortening or scarring of the anterior lamella. The main treatment is relaxation of the scar tissue. If the scar is small and damage to surrounding tissue is minimal, the scar can be incised with Z-plasties to reduce the tension on the lid by changing the vector of pull. Unfortunately, in burn patients, the surrounding tissue is often injured, and simple Z-plasty scar relaxation is not adequate to correct the ectropion.

Similarly, advancement or rotational skin–muscle flaps from adjacent sites may be used to fill in the tissue shortage after the scar is released. In cases of significant adjacent tissue loss or burn injury, free grafting is often needed.[25] The free graft of choice is full-thickness skin graft from the upper lid, retroauricular area, periclavicular area, inner arm, or inner thigh where the skin is thin and hairless. If these areas are not available, thick split-thickness skin grafts from hairless areas may be harvested with a dermatome set between 0.4 and 0.5 mm thickness. Alternatively, Alloderm or Apligraf (see above) may be used. After grafting, the lid should be placed on stretch and a pressure patch placed as described above.

In less severe cases of contracture or in cases with deeper scarring, a subperiosteal midface elevation or suborbicularis oculi fat elevation (the SOOF lift) may relieve enough vertically oriented tension from the lower face to correct the eyelid ectropion (Figure 19-17). The SOOF lift is accomplished through either a lower-lid infraciliary or transconjunctival approach to the inferior orbital rim. Once the rim is reached, the periosteum is incised just inferior to the orbital rim, and a subperiosteal dissection is carried out toward the gingival sulcus. The infraorbital neurovascular bundle is left intact. The lower-face periosteum may be released to give further elevation. The deeper facial tissue is suspended with 4-0 nylon sutures to the periosteum at the inferior orbital rim and the lower lateral rim. Alternatively, small suture fixation holes may be drilled at the orbital rim for attachment. The transconjunctival incision may be closed with 6-0 fast-absorbing gut suture, and the lateral canthal tendon is resuspended to the lateral orbital rim at a more elevated position in anticipation of future contraction. If an infraciliary incision is used, the anterior lamella may be augmented with a skin graft as well.

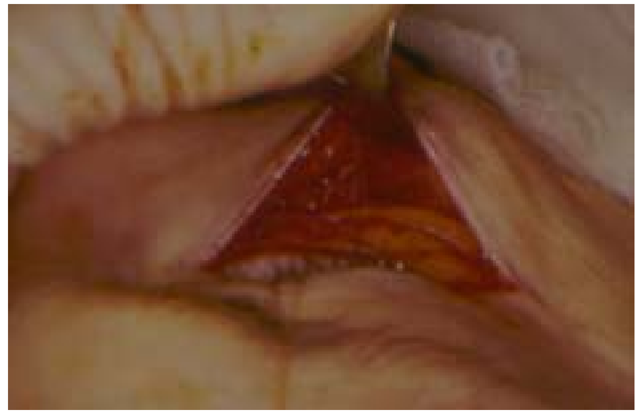
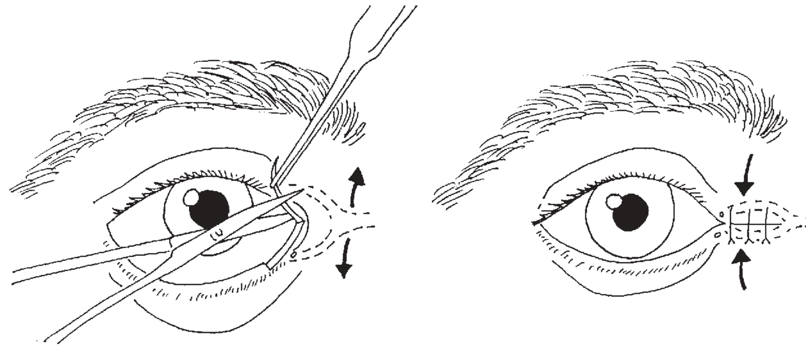


Fig. 19-17. Midface lifting procedure used to release and recess the midface soft tissue. A subperiosteal plane is dissected along the anterior surface of the maxilla. Care is taken to avoid injuring the infraorbital neurovascular bundle, as shown in the photo to the left of the retractor. This procedure facilitates lid elevation and ocular coverage using available skin and soft tissue, possibly circumventing the need for a skin graft.

If additional coverage of the medial globe is required because of medial lid retraction, a medial lid margin adhesion procedure may be performed by deepithelializing the canalicular portion of the eyelid margin and suturing it together using 6-0 Vicryl sutures (Figure 19-18). Care must be used to avoid damaging the canalicular system. Bowman lacrimal probes may be passed into the canaliculi during the procedure as a guide to avoid damaging the canaliculi.

Entropion is less commonly found in burn patients unless there has been a chemical burn to the conjunctival surface. Otherwise, entropion occurs in burn patients only if mild senile entropion is already present. If underlying lower-lid laxity, overriding orbicularis, or retractor dehiscence are present, then irritation from a burn injury or lash debris may cause a spastic entropion. Spastic entropion can be treated by removing the offending cause (eg, an FB) and providing copious lubrication to break the spastic lid closure cycle. Quickert–Rathburn sutures may be helpful to overcome this problem. They are performed by passing double-armed sutures (eg, 4-0 chromic) through the inferior conjunctival fornix, full-thickness through the lid, and exiting just under the lashes. Several such sutures may be used across the eyelid to evert it.

Fig. 19-18. A medial canthal lid margin adhesion procedure performed to maximize globe protection. Care is taken to avoid injury to the canalicular system. Drawing: Courtesy of Department of Medical Illustrations, Brooke Army Medical Center, Fort Sam Houston, Tex.



More severe cases of senile entropion require lower-lid tightening (Figure 19-19), reattachment of the lower-lid retractor to the inferior tarsal border, and occasional debulking of the overriding preseptal orbicularis muscle.

In case of cicatricial entropion, the posterior lamella needs lengthening with mucous membrane grafts, tarsal substitutes, or both, as described above. It is important to repair entropion, because the in-turned lashes can irritate and damage the corneal surface.

Canthal Malpositions. Burn scars may cause displacement of the medial and lateral canthal tendons from their normal positions. They may be dragged in any direction and usually are displaced away from the globe, interfering with proper globe apposition and tear pump function. Repair of canthal malposition is similar to repair of eyelid malposition. Scar relaxation is required and tissue augmentation may be accomplished with transposition or free grafts. Additionally, the medial canthus is often subject to webbing, and the canthal tendons often need resuspension to their proper anatomical positions.

Canthal webbing is usually addressed by incising and relaxing the scarred tissue. Combinations of Z, Y-V and W-plasties are often required. If eyelid tissue is in very short supply, glabellar flaps or skin grafts may be used to augment the medial canthus, and laterally based flaps and skin grafts may be used for the lateral canthus. If the medial canthal tendon is displaced, it must be resuspended to the posterior lacrimal crest so the lid is apposed to the globe. Similarly, the lateral canthus must be suspended to approximate the lateral lid to the globe (see Figure 19-19).

The medial canthal tendon can be isolated through a skin incision along a medial canthal lid fold or incised scar. The tendon is resuspended to the periosteum with a permanent suture. If this is not secure, a suture hole may be drilled into the lacrimal crest from which to suspend the tendon. Screws, plates, and anchors are available for suspension; however, the bone in the medial canthal area is often thin and cannot support this hardware. In severe cases, transnasal wiring may be required for telecanthus repair.

The lateral canthal tendon can be resuspended with a lateral tarsal strip procedure to the periosteum at the lateral orbital tubercle. If the tendon is damaged, a lateral rim periosteal flap can be mobilized for lateral lid attachment. Also, the tendon may be directly secured to the lateral rim with a drill hole for the permanent suture.

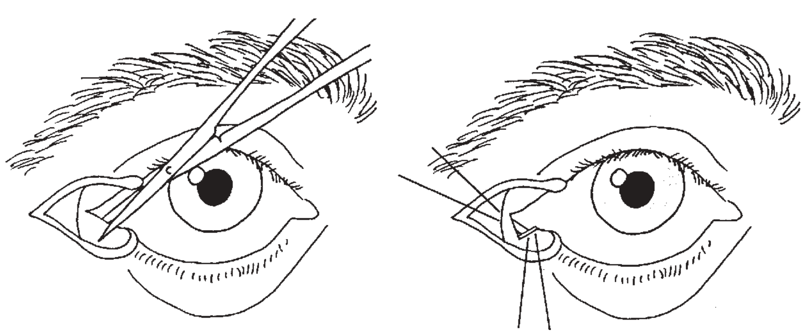


Fig. 19-19. A horizontal lid-tightening procedure similar to a lateral tarsal strip is performed to prevent eyelid laxity and maximize globe protection. Drawing: Courtesy of Department of Medical Illustrations, Brooke Army Medical Center, Fort Sam Houston, Tex.

Disorders of Eyelid Retraction. For the upper eyelid, the eyelid retractors consist of the levator palpebrae and its aponeurosis and Müller's muscle; for the lower eyelid, the retractors are the capsulopalpebral fascia and the inferior tarsal muscle. Proper retractor function, especially of the upper lid, is required for good visual function. Upper retractor dysfunction results in ptosis or a droopy lid, which may block the visual axis. Lower retractor dysfunction may result in a higher-than-normal lid position, or reverse ptosis; however, this does not usually interfere with the visual axis and is less of a concern. Indeed, in a burn patient, a slightly elevated lower lid may help protect the eye from exposure.

Upper-lid ptosis is not very common in burn patients unless the levator aponeurosis has been damaged or the tissue was injured from a blast. In early stages of burn injury, ptosis may be mechanical from swelling. In the chronic stages, however, persistent ptosis is more likely due to middle lamella scarring or retractor damage. The amount of the defect (in this case, ptosis and levator function) will guide intervention. Additionally, forced generations of eyelid closures (isometric contractions of the lids) should be performed if cicatricial restriction of lid excursion is suspected.

If the ptosis is primarily due to scarring, then surgical release of the scar may be required. Intraoperative assessment for multiple causes is usually required; any new findings should be addressed at the time. Once the scar is released, ptosis may still be present because of dehiscence of the levator aponeurosis, which requires repair. In general, ptotic lids with good levator function respond well to aponeurotic surgery, those with moderate excursion may do well with levator muscle surgery, and those with poor function require frontalis slings. Detailed description of ptosis surgery is available in any oculoplastic textbook. Furthermore, a burn patient is more prone to dry eye problems, and a conservative approach to ptosis repair is warranted—especially when function is moderate to poor—because the indicated procedures usually cause some degree of lagophthalmos.

Disorders of Eyelid Protraction. The orbicularis oculi muscle forms part of the anterior lamella of the eyelids and is, therefore, commonly injured in eyelid burns. The orbicularis oculi muscle forms the main protractor muscle. As stated earlier, proper eyelid closure is needed for eye protection, distribution of the tear film, and tear pumping. In most eyelid burns, inability to close the eyes is due to (1) cicatricial eyelid retraction or (2) ectropion due to anterior, posterior, or middle lamella scarring. When the scar is released, the lids often are able to close normally.

In more-severe burns with damage to the orbicularis muscle, eyelid protraction may still be hampered despite release of all cicatricial processes. In such instances, the weak or absent orbicularis muscle requires adjunctive support. Surgical procedures can be aimed at static or dynamic eyelid closure.

Static eyelid closure procedures decrease the palpebral fissure, giving greater protection to the eye and decreasing the distance that a weakened orbicularis muscle would have to move the lid for full closure. These procedures include those described for correcting cicatricial ectropion/retraction (eg, skin grafting, SOOF lift) (see Figures 19-14 and 19-17). The lateral canthal tendon may also be supraplaced, and the lower lid can be supported with semirigid spacers such as hard palate mucosa (Figure 19-20), sclera, ear or septal cartilage, Alloderm, or Medpor. Additionally, tarsorrhaphies may be done both laterally and medially (avoiding the canalicular system) to add further support and lid closure (see Figure 19-18).

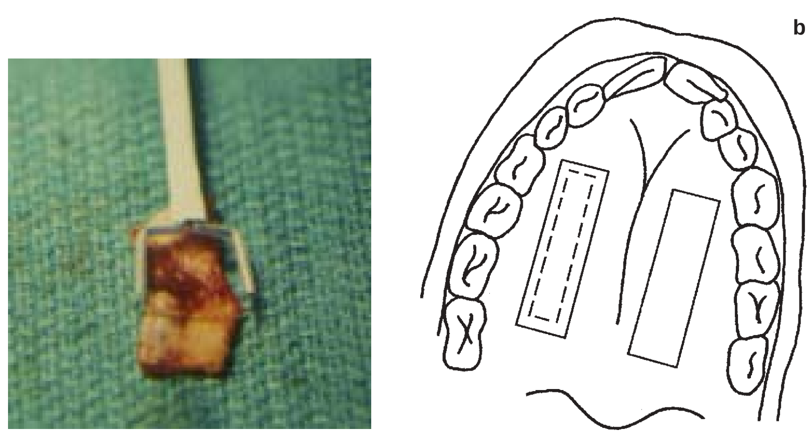


Fig. 19-20. (**a**) Mucosa from the patient's hard palate has been harvested with a radiofrequency mucotome unit for mucosal lengthening of the eyelid. (**b**) Schematic diagram of the hard palate mucosa donor site. Drawing: Courtesy of Department of Medical Illustrations, Brooke Army Medical Center, Fort Sam Houston, Tex.

Dynamic eyelid closure is achieved with placement of either upper-lid gold weights or palpebral springs. The upper-lid gold weight allows gravity to pull the eyelid down when the levator palpebrae is relaxed. The gold weight is placed in a supratarsal position and fixed with permanent sutures. The location is accessed through a standard blepharoplasty incision with dissection carried down to the anterior surface of the tarsal plate. Palpebral springs are similarly placed. They fit into the upper and lower eyelids and close spontaneously when the levator is relaxed. With prolonged use, ptosis from dehiscence of the levator aponeurosis may occur. More-advanced techniques have been tried in patients with facial nerve palsy using temporalis muscle transfers and exogenous nerve stimulation; this information is available in textbooks on facial plastic and head and neck reconstruction and therefore will not be further discussed here.

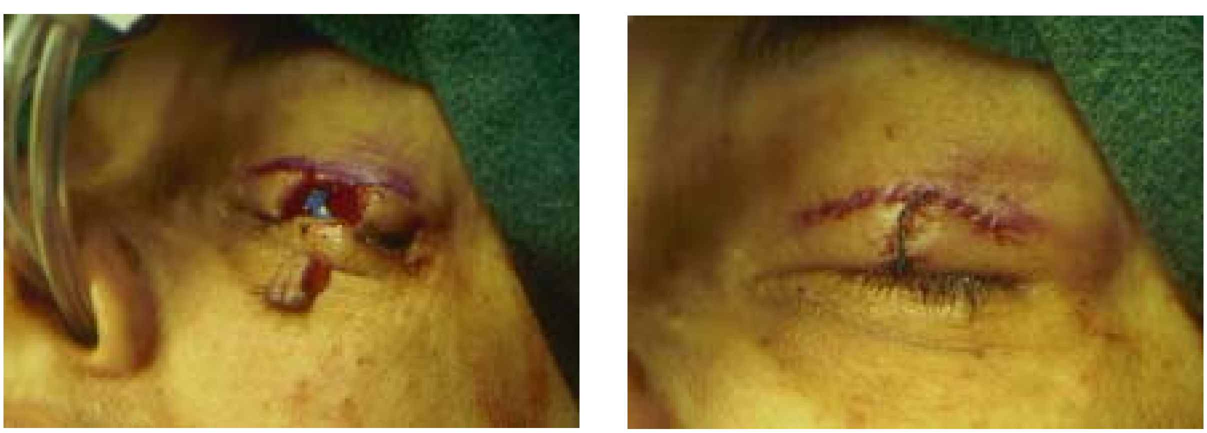
Trichiasis. Eventually, trichiasis (inwardly directed lashes) causes significant damage to the cornea and to visual function. In the early stages, until the burn injury matures, copious lubrication and selective forceps epilation are adequate. In the chronic stage, however, definitive treatment is indicated. If there are only a few offending lashes, they may be permanently destroyed using electrolysis units or a monopolar cautery with a fine needle tip directed at the lash bulbs. Argon laser at a slitlamp can be used to ablate the lash bulbs in an anesthetized lid.

If a group of lashes are localized in one area, then a full-thickness wedge resection can be used to remove them. The wedge resection can also be used to remove a section of distorted lid margin, if needed, to protect the eye from irritation (Figure 19-21). However, this may not be the best option in thermally damaged eyelids with tissue loss. Cryotherapy is also useful in eliminating lash bulbs. Less damage to adjacent tissue occurs when the lid is split into anterior and posterior lamellae at the gray line and the lash follicles are selectively frozen. In severe burns, the anterior lamella can be recessed away from the lid margin and an intervening buccal mucosal membrane graft can be placed with or without meticulous extirpation or excision of all the offending lashes.

Disorders of the Mucosal Lining. In burn patients, abnormalities of the mucosal lining include symblepharon, eyelid posterior lamella cicatrization or tissue loss, and bulbar (eyeball) conjunctiva loss. Definitive repair of symblepharon varies according to severity. Mild symblepharon may simply be surgically lysed. Moderate symblepharon may require mucosal rearrangement after lysing. Rearrangement can be accomplished with multiple Z-plasties and rotational or transposition conjunctival flaps to reduce tension between the bulbar and the palpebral conjunctivae.

More-severe cases have insufficient conjunctival tissue, and mucosal membrane grafting is required. Autogenous mucosal membrane sources (discussed above) include buccal or lip mucosa and hard palate mucosa (which is usually reserved for the lower eyelid to give it vertical support). Once the symblepharon is lysed, the defect is filled with mucous membrane graft tissue. The buccal mucosal graft can be harvested freehand with a scalpel and Wescott scissors, and then cauterized for hemostasis. The graft is sewn into place with 7-0 Vicryl or

a



b

Fig. 19-21. (**a**) A pentagonal wedge resection permits (**b**) reformation of a smooth eyelid contour and removal of trichiatic lashes to restore normal tear pump mechanisms and to avoid ocular irritation.

6-0 fast-absorbing gut sutures. Occasionally, a symblepharon ring (ie, a plastic or silicone conformer ring to prevent conjunctival fornix contraction) must be placed until the mucosa heals in place. Alternatively, double-armed fornix reconstructive sutures placed full thickness through the fornix and out through the eyelid skin may be used to hold the mucosal grafts in place. Full-thickness buccal mucosal grafts work well on the eyelid but are too thick for the ocular surface. A mucotome, used to harvest ultrathin mucosal membrane, may be also be used for bulbar conjunctival replacement. An ultrathin graft avoids the erythematous appearance of full-thickness mucosa on the globe.

Repair of eyelid posterior lamella loss was discussed above. Repairing posterior lamellae addressed release of the scar, replacement of mucosal surfaces, and use of tarsal plate substitutes (see Figure 19-20). Bulbar conjunctival loss may occasionally heal spontaneously, provided there is no palpebral mucosa loss that would cause adhesions and symblepharon. In most cases, grafting is required. Bulbar mucosa can be replaced with autogenous bulbar conjunctiva from an uninjured site or opposite eye. If unavailable, ultrathin buccal mucosal membrane is a good alternative. Shimazaki and colleagues[26] reported the use of amniotic membrane transplantation for ocular surface reconstruction in patients with chemical and thermal burns.

Tear Drainage System Abnormalities. In burn patients, the most common abnormalities of the tear drainage system involve the puncta, canaliculi, and tear sac, owing to the burn injury itself and scar formation involving the eyelids. It is very uncommon for the nasolacrimal duct to be involved because it is protected by the bony nasolacrimal canal. In cases of blast injury or severe burns to the midface involving the facial bones, an injury to the nasolacrimal duct may occur. Malpositions of the eyelid (see earlier discussion) can affect the tear pumping mechanism even though normal tear drainage system components are present. Problems directly involving the puncta, canaliculi, lacrimal sac, and nasolacrimal duct are addressed here.

Punctal stenosis or occlusion from scarring is common in eyelid burns. Mild stenosis can be addressed with sequential punctal dilation with or without placement of a punctal stent. If the stricture is localized to the punctum, a punctal plug may suffice as a stent. If the punctum is occluded or if the stenosis is refractory to dilation, then the punctum may be surgically opened with a supersharp blade, sickle knife, or sharp-tipped Wescott scissors. To prevent reocclusion, a stent may be placed or a two-snip procedure performed. The two-snip procedure is performed by placing one blade of a sharp Wescott scissors into the punctum and the other onto the mucosal surface of the lid. The punctal orifice is then cut on the mucosal side of the lid. This process is repeated just medial or lateral to the initial incision so that a V-shaped wedge of the vertical canalicular wall on the mucosal side of the lid is excised, creating a large, posteriorly placed punctum.

Canalicular stenosis can be addressed with sequential dilation by passing Bowman lacrimal probes of increasing size. Once adequate dilation is achieved, the drainage system must be intubated with Crawford tubes or similar stents to prevent restenosis. Additionally, the canaliculi may be dilated with a balloon catheter such as the LacriCATH (mfg by Atrion Medical, Birmingham, Ala). Once dilated, intubation is still required and should be left in place for 6 to 12 months. If a canaliculus is obstructed and the obstruction is focal and distal to the medial canthus, then the obstructed section can be excised and the canalicular portion of the lid margin primarily repaired over an intubated canalicular system. If the obstruction is focal but close to the medial canthus, then a Bowman probe can be forced through the obstruction and into the sac.

Alternatively, a holmium (Ho) laser with an intracanalicular probe can be used to ablate the obstruction. The canalicular system is then intubated with the hope that mucosal epithelium will migrate toward the center—from normal canalicular mucosa along the stent toward the lacrimal sac and vice versa. Ophthalmologists should note that the success of procedures decreases whenever surgical insult occurs adjacent to tissue damage. If canalicular obstruction persists or is more-severe, then the entire canalicular system must be bypassed via a C-DCR (described above).

If scarring or strictures are mild, then injured lacrimal sacs may be amenable to simple intubation of the lacrimal drainage system with or without balloon dilation. If more-severe, the sac must be surgically explored with an external skin approach and a DCR or C-DCR may be required to restore tear drainage.

Finally, obstruction of the nasolacrimal duct may be partial or complete. Partial obstruction may respond to balloon catheter dilation and intubation along with an antibiotic and steroid regimen to reduce postoperative scarring from inflammation and bacterial colonization. For complete or refractory partial obstructions, a DCR with intubation should be performed.

SUMMARY

Management of eyelid burns—first-degree, or superficial; second-degree, or partial-thickness; and third-degree, or full-thickness—occurs at all echelons of care, from battalion aid stations at the 1st echelon to medical centers in CONUS. At each level of care, the burns—whether acute, subacute, or chronic—receive echelon-appropriate evaluation and treatment before the casualty is transported to the next rearward echelon, where greater medical expertise is available. At the 1st echelon, emergent care focuses on lifesaving ATLS and ACLS principles and techniques and the immediate treatment of chemical burns. Urgent care focuses on diagnosing ruptured globes and ocular injuries and limiting the extent of thermal burn injuries. Management at higher echelons, where military ophthalmologists are found, always includes repeating the steps from the lower echelons, not only to avoid the possibility of misdiagnosis and incomplete treatment of burns but also because the full extent of eyelid burn wounds sometimes manifests over time.

Acute and subacute management focuses on protecting the eye and its visual potential and on limiting the extent of the damage that has occurred to the eyelids and surrounding tissue. Long-term management involves critical evaluation of the injured eyelid in terms of its functional components, malpositions, protraction, and retraction. Scar maturation followed by definitive surgical reconstruction occur in CONUS, where eye protection, then visual function, and finally cosmetic appearance are addressed.

At each echelon, casualties are reevaluated for evacuation, which is necessary for two reasons: (1) diminished vision makes the soldier nonfunctional on the battlefield, and (2) extensive burns to the eyelids are usually accompanied by serious injury to the rest of the body, including the respiratory passages. In general, only patients with first-degree and very mild second-degree burns are kept at the lower echelons and returned to duty, and soldiers with second- or third-degree burns to the eyelids are evacuated back to CONUS.

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