Chapter 24

ORBITAL TRAUMA AND NASOETHMOID FRACTURES

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INTRODUCTION

The goal of saving life, limb, and eyesight in airmen, soldiers, sailors, and marines is the highest priority for head and neck trauma surgeons in the war zone. With the advent of advanced body armor, the incidence of both facial and eye injuries in proportion to total body injuries has risen in the 21st century in comparison to the 20th century.[1–3] The incidence of facial injury in relation to total battle injury ranges from 9% to 19%, and the incidence of eye injuries ranges from 5% to 10%.[2–7] The increased incidence of eye injuries is due to improved body armor, which has resulted in increased survival; casualties who would have died in the past from significant blast injuries to the torso now present with survivable blast injuries to head, face, neck, and eyes. These injuries result from the lack of adequate eye protection (Figure 24-1), combined with the small fragmentary nature of projectiles from modern weaponry.[4] With the establishment of multispecialty head and neck surgical trauma teams, more lifesaving and eyesight-saving treatment can be performed in theater.[1]

Recent data from the Joint Theater Trauma Registry (Operation Iraqi Freedom [OIF] and Operation Enduring Freedom [OEF], January 2003–May 2011) show that the most common site of soft tissue injuries was on the face/cheek, at 48%; 4% of patients had eyelid injuries; and 19% had orbital fractures. The injuries were due to penetrating trauma in 49% of cases, blunt trauma in 26%, and blast injuries in 24%. The overall mortality was 3.5%.[8] Improvised explosive device (IED) blasts caused the majority of these injuries, at times "peppering" casualties with multiple small holes all over their head, face, and neck. These wounds are often contaminated with multiple fragments of metal, rocks, dirt, and other organic material.

Ophthalmologic evaluation of the globe and its adnexa is critical to evaluation and management of orbital trauma and must be accomplished as soon as possible. This chapter will describe the lessons learned by the head and neck team in managing orbital trauma during OIF and OEF. Structures adjacent to the orbit, such as the brain, maxillofacial skeleton, paranasal sinuses, and facial soft tissue and nerves, must also be evaluated and treated concomitantly. The management of these complex wounds requires multiple specialties working together to maintain form and function. The chapter will also review the basic anatomy and critical structures along with in-theater management of these injuries. Emphasis will be placed on the multispecialty team approach.

ORBITAL ANATOMY

Eyelids and Globe

The soft tissues of the eyelids and eyebrows are commonly injured and must be carefully examined for clues of penetrating injuries that can affect the orbital contents. Lid or brow lacerations may be caused by IED fragments that may have also penetrated the globe. The skin of the eyelid is the thinnest in the body. Its anterior margin holds the eyelashes. The "gray line" along the lid margin marks the junction of the skin and conjunctiva. Primary eyelid support is through the bony attachment of the canthi and from the fascial attachment of the orbicularis muscle. The lateral canthus is situated approximately 2 mm higher than the medial canthus. The lacrimal gland is located deep to the upper eyelid at its most lateral extent. The lacrimal system (Figure 24-2) drains tears through the puncta, into the lacrimal sac, and finally through the nasolacrimal duct into the nose. Arterial blood supply is mainly from the internal carotid via the ophthalmic artery. The external carotid artery contributes to the blood supply by the anastomosis of the angular artery, the infraorbital artery, and the superficial temporal artery. Intraorbital soft tissue is composed primarily of the globe, surrounded by extraocular muscles and orbital fat.

Figure 24-1. Marine with ESS Eyepro (Eye Safety Systems Inc, Foothill Ranch, CA) ballistic eyewear; used with permission.

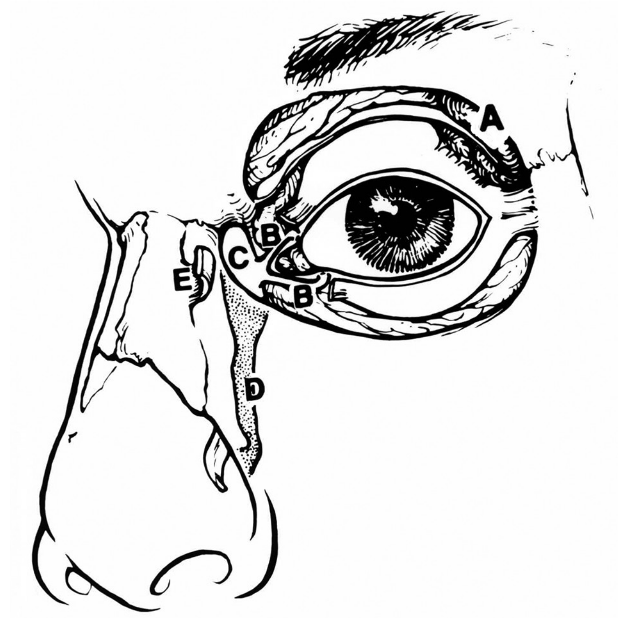

Figure 24-2. Nasal lacrimal system anatomy. (**A**) Lacrimal gland; (**B**) superior and inferior canaliculi; (**C**) lacrimal sac; (**D**) nasolacrimal duct; and (**E**) reflected anterior slip of medial canthal tendon.
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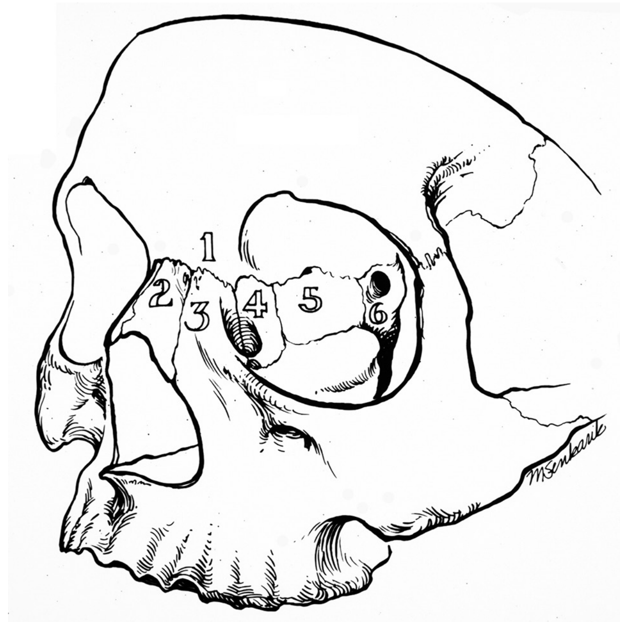

Figure 24-3. Naso-orbito-ethmoid pertinent osteology. (**1**) Nasal process of frontal bone; (**2**) nasal bones; (**3**) nasal process of maxilla; (**4**) lacrimal bone; (**5**) lamina papyracea; and (**6**) lesser wing of sphenoid bone.
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Bony Orbit

The walls of the bony orbit are made up of the maxilla, zygoma, sphenoid, frontal, ethmoid, lacrimal, and palatine bones. The roof of the orbit is composed anteriorly of the frontal bone. The lateral orbit is the strongest wall of orbit and is composed of the zygomatic bone. The orbit's floor is formed by the orbital plate of the maxilla and palatine bones. The medial wall is formed by the ethmoid, frontal, lacrimal, and sphenoid bones. The optic canal, located within the lesser wing of the sphenoid, enters the orbit at the orbital apex and contains the optic nerve and the ophthalmic artery.

Naso-Orbito-Ethmoid Complex

The naso-orbito-ethmoid (NOE) complex is formed by the following six bones: (1) the nasal process of frontal bone, (2) the nasal bones, (3) the nasal process of the maxilla, (4) the lacrimal bone, (5) the lamina papyracea, and (6) the sphenoid bone (Figure 24-3).

Facial Buttress Anatomy

The mid-face buttresses are the support beams of the mid-face (Figure 24-4). They maintain the three-dimensional configuration of the face by providing height (vertical buttress), width (horizontal buttress), and projection (anteroposterior buttress). The three dimensions of buttresses are as follows:

1. **Vertical buttress:** zygomaticomaxillary complex (ZMC), nasomaxillary, pterygomaxillary, and fronto-ethmoid-vomer.
2. **Horizontal buttress:** superior rim, inferior rim, zygomatic arch, maxillary alveolus, and palate.
3. **Anteroposterior buttress:** zygomatic arch, maxillary alveolus, and fronto-ethmoid-vomer.

OCULAR TRAUMA PATIENT EVALUATION

Imaging

Computed tomography (CT) is the best imaging modality for assessing traumatic orbital injuries. The coronal view is the best view for the orbital roof and floor. The axial view is ideal for evaluating the medial and lateral wall. Noncontrast views (3 mm or less) routinely provide sufficient information for the evaluation and management of most orbital trauma; 1.00-mm views can be used to evaluate optic canal trauma and are always preferred if available. Routine use of in-theater magnetic resonance imaging for acute trauma evaluation is not indicated.

History

US service members are at significant risk for ocular and orbital trauma as a result of the high incidence of IEDs encountered on the battlefield. By 2008, it was estimated that over 300,000 soldiers had blast-induced traumatic brain injuries (TBIs). Soldiers with TBI are at higher risk for both penetrating or "open" eye injuries and "closed" eye injuries. According to one study, approximately 75% of soldiers with at least mild TBI complained of visual dysfunction.[9] Therefore, it is imperative to get a good history and physical exam of soldiers who are exposed to blast injury from an IED. The head and neck trauma surgeon must obtain the history at presentation, including

- chief complaint,
- description of traumatic event,
- past surgical history,
- past medical history, and
- allergies.

Reviewing the ocular symptoms with the patient should be accomplished as soon as possible after the injury.

The following case example shows the importance of a thorough exam. A 38-year-old Special Operations soldier, involved in close combat with an enemy soldier, sustained a grenade blast injury to the upper torso and face. On presentation, it was clearly evident that he had an open globe injury to the right eye. However, careful examination of the apparently unaffected, nontraumatized (left) eye was revealing for additional injuries. Visual acuity in the right eye was no light perception (NLP). In the left eye, the visual acuity was light perception (LP). This finding was incongruent with the physical exam of an intact globe with a normal anterior and posterior segment. Based on this information, the ocular surgeon was able to pinpoint the injury to the apex of the orbit. Orbital CT imaging revealed grenade fragments that had penetrated the other eye and were abutting the optic nerve at the contralateral apex. The head and neck team (neurosurgeon; ear, nose, and throat surgeon; and ocular surgeon) was able to collaborate on a surgical strategy to remove the offending fragments.

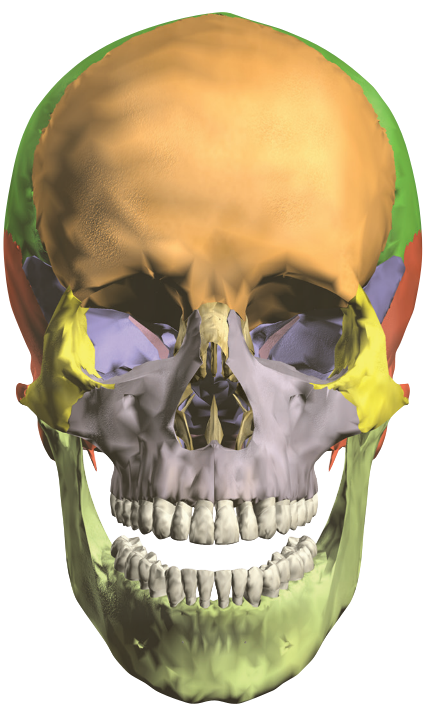

Figure 24-4. Anterior view of articulated skull.
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Physical Examination

A thorough but quick physical exam is the key to guiding the surgeon in the treatment of facial trauma resulting in ocular and adnexal injuries. A good exam will further direct important imaging studies based on the findings. The ocular physical exam consists of the following:

- visual acuity,
- pupil exam,
- visual field exam,
- ocular motility,

- adnexal exam,
- intraocular pressure (IOP),
- anterior segment,
- posterior segment, and
- orbital imaging.

The surgeon must be able to use all available techniques to accomplish the physical exam.

Visual Acuity

Visual acuity is perhaps the most important physical exam finding because it will reveal an intact optical pathway from the cornea to the occipital visual cortex. It is important to check the vision as soon as possible because the trauma may cause progressive intraocular bleeding or cataract formation. The Snellen acuity chart is the gold standard for checking visual acuity, but it may be difficult to use in the trauma setting.

Initially, using a "muscle light" or penlight will determine if the patient can perceive light. Next, asking patients to count fingers held near the face is a gross approximation of any useful vision. Using a near vision exam card or, if not available, the lettering on an intravenous bag at a distance of 14 inches can determine finer visual acuity.

A very important threshold of vision is LP versus NLP. According to the US Eye Injury Registry, only 13% of people presenting with NLP regain any vision in the affected eye. NLP vision necessitates more urgent intervention.

Pupil

A penlight should be used to assess pupil shape, position, and function. The shape of the pupil can quickly reveal ocular injury. A peaked pupil usually indicates that the iris is being pulled toward an opening in the globe (the peak points to the injury location). A secondary pupil can indicate a penetrating injury with a self-sealing corneal wound that would otherwise go unnoticed. It should be noted that treatment with narcotics will constrict the pupil and limit the usefulness of this examination.

Examination for an afferent pupillary defect (APD) or Marcus Gunn pupil will determine the health of the optic nerve. This is accomplished by looking at the direct and consensual response of the pupil when presented with light. The absence of an APD indicates an intact visual pathway and normal optic nerve function. Likewise, the presence of an APD indicates damage to the ocular, retroorbital, or chiasmal portion of the nerve. Patients presenting with NLP vision and an APD have a very poor prognosis for visual recovery.

Visual Field

Visual field examination can only be performed if the patient has hand motion vision or better. The patient should be directed to look straight ahead while the examiner moves his or her finger to various points to assess for vision in all four peripheral quadrants, which will help localize any potential brain disruption of the optical pathway. This test can also identify intraocular posterior segment abnormalities such as retinal detachment.

Motility

The motility exam should evaluate the extraocular muscles in each eye individually and in tandem. Decreased ocular motility might signify a ruptured globe, injury to the muscle body or motor nerves to the muscle, retrobulbar edema or hemorrhage, orbital fractures, or brain injury. Moving the eye through all six cardinal positions will guide the examiner to the location of the injury. Injuries needing more immediate attention are retrobulbar hemorrhage and orbital fractures causing entrapment of the muscle body.

Adnexa

Careful inspection of the surrounding structures for penetrating injuries or lacerations is important. The examiner should determine if the orbital septum has been violated or if there is an injury to the lacrimal system. Orbital fat protrusion from the upper lid is evidence of an injury through the septum. These injuries require further surgical exploration and should not be closed prior to extraction of orbital foreign bodies that might lead to infection. The lacrimal system, if damaged, must also be repaired to ensure normal tear function after recovery (Figure 24-5).

Intraocular Pressure

IOP should be measured only after ensuring that the globe is not open. Pressure cannot be applied to open orbital globes because extrusion of intraocular contents may occur. Normal IOP is between 10 and 21 mm Hg. A tonopen, which measures IOP, is usually available in emergency rooms and battlefield hospitals. If one is not available, then gentle palpation with both index fingers can give an approximate estimation of the IOP.

Anterior Segment

An anterior segment exam is best performed with a slit lamp. A portable hand-held slit lamp may be

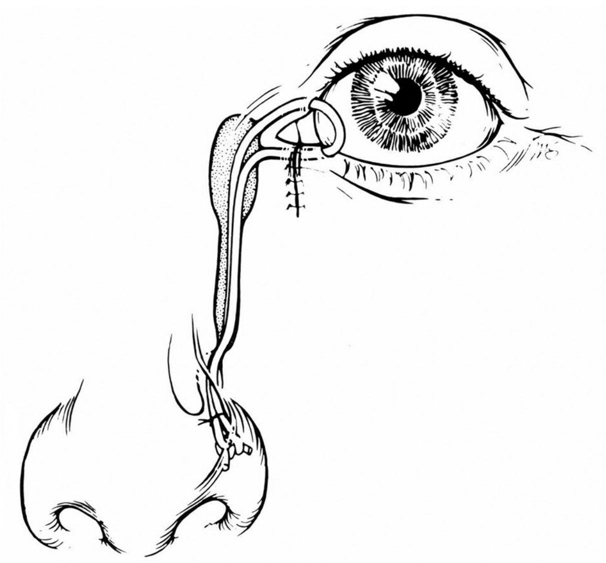

Figure 24-5. Lacrimal stent in place after repair of a medial canthal region laceration. Note the ends of the stent are tied together and sutured to the lateral nasal vestibule.
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available in deployed facilities. The slit lamp will allow the examiner to view the anterior chamber for depth, hemorrhage, iris root trauma, inflammatory cells, and cataracts. Fluorescein staining can also assist with identifying corneal epithelial defects. If a slit lamp is not available, then a penlight will suffice. Shining the light tangentially across the cornea will give an approximation of how deep the chamber is and will show hyphema (blood) or hypopyon (purulence). Viewing finer details is usually not needed in the setting of acute trauma.

Posterior Segment

The posterior segment should be evaluated with an ophthalmoscope to view the optic nerve and macula region through a small, undilated pupil. Patients coming in from the field will often be miotic secondary to narcotics given en route. If no view can be obtained with a direct ophthalmoscope, there is likely anterior or posterior hemorrhage, retinal detachment, or globe disorganization. If possible, with consent from the collaborating physicians, dilating the pupil will allow a much better view to the posterior segment and will allow the examiner to view the periphery of the retina for tears or rupture. Dilating drops used most frequently are phenylephrine 2.5%, atropine 1%, and tropicamide 1%. Consideration for using dilating drops must be balanced with the need to examine papillary response for neurologic status, and requires close collaboration with the trauma team and neurosurgeon.

Orbital Imaging

Head CT with orbital cuts should be performed in 100% of combat trauma injuries involving the eye if the imaging modality is available and the patient is stable. Thin orbital cuts (1 mm) are recommended because thicker cuts through the orbits may miss minute pathology. If the examiner suspects orbital foreign bodies based on physical exam findings such as a large lid entrance wound, a dedicated orbit CT should be performed. Orbital CT without contrast with 1-mm cuts through the orbit is ideal.

ORBITAL, MID-FACE, AND NASO-ORBITO-ETHMOID FRACTURES

Orbital Fractures

Fractures of the orbit are commonly seen in mid-face trauma, and can be isolated or can present in combination with other mid-face fractures. Orbital fractures include fractures of the orbital rim; the so-called "blow-out" fractures, which most commonly involve the floor and medial wall but can involve the lateral wall and orbital roof as well; and orbital apex fractures. Fractures are the result of mechanical overload: failure to resist deformation under loading, which results in the loss of structural integrity.

Researchers have performed detailed analyses of fracture configurations in terms of the force or load, energy release, and specific tissue characteristics. Torque, avulsion, bending, and compression result in specific fracture patterns including transverse, oblique, impacted, or comminuted fractures. The structural disruption is accompanied by disruption of the osseous blood supply. The vascular compromise is more significant in the mandible than the mid-face and orbit due to the relative thickness of the compact bone component affecting intracortical blood supply. However, the overall abundant blood supply of the face aids in healing and resistance to infection.

Clinically, orbital fractures are commonly characterized by pain and swelling, and less commonly by periorbital subcutaneous emphysema that arises from patients blowing their nose postinjury, thus forcing air from the nasal cavity or maxillary sinus into the orbit and then into the subcutaneous periorbital tissues. Particular attention should be paid to diplopia, pulsatile exophthalmos, and muscle entrapment, as these may be indications of a more serious injury. Nonresolving oculocardiac reflex, early enophthalmos, and hypoglobus are indications for immediate surgical repair. In the war zone, most repairs should occur as soon as possible after the injury unless other more serious traumatic injuries prevent immediate repair.

Orbital Rim Fracture

Orbital rim fractures, regardless of location (medial, lateral, inferior, superior), are often the result of direct trauma to the fractured bone. The rim acts as the first buttress and defense for the intraorbital viscera and, as a result, requires significant force to fracture. When present in combination with other mid-face fractures, orbital rim fractures often telescope and collapse, leading to decreased orbital volume and projection of the malar, frontal, and nasal bones.

Orbital Blowout Fracture

Isolated orbital blow-out fractures result from indirect trauma to the orbital floor (usually transmitted through the globe) and often result from significantly less force because of the relatively thin bone involved. The orbital rims are bulky and strong in order to withstand the forces of mastication. In contrast, the four walls of the orbit simply act as bony "slings" to help maintain orbital volume and shape and do not play a significant a role in buttressing the facial skeleton. Consequently, the internal orbital skeleton (the floor and the medial wall in particular) acts as crush zones to dissipate energy delivered to the globe in the event of trauma to the orbital contents, thus diminishing the effect of such an impact on the globe itself.

The location of the fracture within the orbital bones commonly corresponds to the amount of energy delivered. Orbital floor fractures require the least energy, medial wall fractures require more transmitted energy, and lateral wall fractures require the most energy. However, orbital roof fractures rarely occur in isolation and are typically associated with superior orbital rim and frontal bone fractures, penetrating trauma to the forehead, or both.

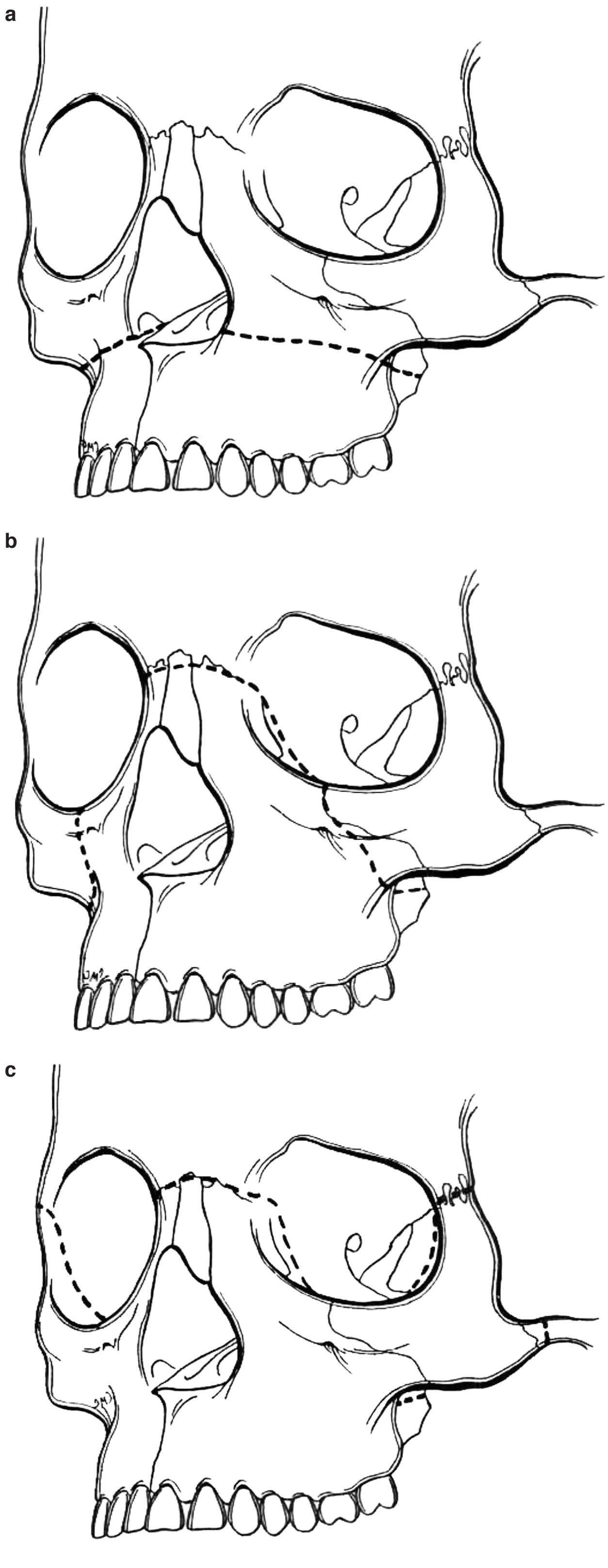
Management of Orbital Fractures

The ideal approach to orbital fracture repair remains controversial. Possible approaches include the transconjunctival approach (preseptal or postseptal), the fornix approach (by definition postseptal), the subciliary approach (preseptal or postseptal), and the direct approach to the orbital floor or medial and lateral orbital walls. Additionally, preexisting lacerations may facilitate exposure. The decision on which orbital approach to utilize will ultimately be determined by the specific fracture location, the surgeon's skill set, and the surgeon's experience.

A good approach for orbital trauma is the postseptal fornix approach. The primary advantage of this approach is that it avoids injury to the orbital septum and the orbicularis oculi, decreasing the likelihood of postoperative lid retraction, ectropion or entropion, and malar descent, all of which can result from the other approaches. The primary drawback of the fornix approach is that it exposes orbital fat, which obstructs visualization of the orbital floor. After adequate exposure of the entire floor and wall defect, including its posterior extent, the defect can be corrected with an autograft (split calvarial bone or nasal septal cartilage) or an alloplast device, such as the Synthes (Synthes CMF, West Chester, PA) preformed titanium orbital floor plates (these are advantageous because they address both the floor and the medial orbital wall). Medpor (Stryker, Kalamazoo, MI) orbital floor plates and titanium mesh are other examples of allografts that may be used. Particular care should be taken to ensure that the bridging material, regardless of type, reaches and sits upon the posterior ledge of the orbital defect. The primary objective in the correction of these defects is to restore orbital volume and to prevent enophthalmos and possible diplopia. Failure to set the plate upon the ledge risks an increase in orbital volume because the premorbid dimensions are not restored. In cases of entrapment, the entrapped extraocular muscle should be released before correcting the defect.

After placement of the appropriate plate, a Frost stitch should be placed through the lower lid and taped to the forehead for 24 to 48 hours to keep the lower lid closed while still allowing the upper lid to open for assessing LP. Forced duction testing should be performed at the conclusion of the case, and any residual entrapment should be explored and corrected at this time. Additionally, postoperative IOP should be assessed grossly by palpation before the patient leaves the operating room, comparing the affected eye to the unaffected eye. Their IOP should be roughly equal.

LP should be checked hourly for the first 4 hours postoperative, then every 2 hours for 4 hours, and finally every 4 hours for the next 16 hours. A loss of LP in the postoperative period is suggestive of an orbital hematoma and necessitates emergent exploration and removal of the hardware. In such cases, repeat repair of the orbital defect should be delayed at least a week,



depending on how long it takes for the visual acuity to return to baseline. Additionally, postoperative diplopia, in the absence of preoperative diplopia, is an indication for exploration. Postoperatively, diplopia lasting more than 48 hours is especially worrisome, because a brief period of diplopia in the acute postoperative period may simply be the result of edema.

Orbital roof fractures occur rarely and may require neurosurgical consultation to assess the likelihood of a dural tear and the need for repair. Pulsatile exophthalmos may be associated with dural tears and possibly a carotid-cavernous sinus fistula. In the absence of a neurosurgical indication for surgery, orbital roof fractures can be treated conservatively if there is no evidence of orbital hematoma, entrapment, frontal sinus injury requiring repair, or other orbital injury.

Mid-Face Fractures

Mid-face fractures and fractures involving the orbits can be divided into two major groups: (1) fractures of the orbit and (2) fractures that do not involve the orbit. While there is no unified classification system to describe all mid-face fractures, the historical classifications are useful in determining the potential morbidity associated with particular patterns of injury, as well as the options for their management. Additionally, any fracture or suspected fracture that involves the orbit or its contents should always include a thorough ophthalmologic evaluation.

Le Fort Fractures

In 1901, René Le Fort, a French surgeon, described the classification of mid-face fractures and osteotomies that bear his name, based on his work on cadaver skulls that were subjected to blunt forces of various magnitudes and vectors. Simply put, a Le Fort-type fracture is one in which the maxillary alveolus is separated from the skull. The plane in which this disruption occurs defines the particular type of Le Fort fracture. Le Fort concluded that there are three predictable fracture patterns that can be associated with certain types of injuries (Figure 24-6).

Le Fort type I. This fracture commonly results from a force exerted posteroinferiorly on the inferior aspect of the maxillary alveolar rim. The pattern is a horizontal maxillary fracture, separating the alveo-

Figure 24-6. Illustration depicting Le Fort fractures: (**a**) type I; (**b**) type II; and (**c**) type III.
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lus from the superior mid-face in a fracture line that passes through the mid-maxilla and lateral pyriform aperture, superior to the teeth apices and inferior to the zygomaticomaxillary junction. This fracture also involves the nasal septum and the pterygoid plates.

Le Fort type II. This fracture usually results from a force exerted more superiorly on the mid-maxillae, again in a posteroinferior direction. Unlike the type I fracture, the type II is pyramidal in shape, with the apex of the pyramid corresponding to the apex of the nasofrontal suture, and the sides of the pyramid extending inferolaterally through the frontal processes of the maxillae, lacrimal bones, inferior orbital rims and orbital floors, and the anterior walls of the maxillary sinuses. Again like the type I, this fracture travels inferior to the zygoma laterally, and involves the pterygoid plates.

Le Fort type III. Also known as craniofacial separation or craniofacial disjunction, this transverse fracture follows trauma to the upper maxilla and nasal root. These fractures pass through the nasofrontal suture, maxilla-frontal suture, medial and lateral orbital walls, the zygomaticofrontal junctions, and zygomatic arches. Due to the thickness of the sphenoid bone posteriorly, the fracture does not commonly continue into the optic canal, but instead continues inferolaterally along the floor of the orbit and the inferior orbital fissure. Intranasally, the fracture extends through the perpendicular plate of the ethmoid and through the vomer. As in the type I and II fractures, the pterygoid plates are fractured as well.

In theory, this classification system describes a pattern of injuries associated with increasing force and a progressively superior point of impact. In practice, however, the fracture pattern is more often asymmetric, involving one Le Fort type on the ipsilateral side and a different Le Fort type on the contralateral side. This is due to the asymmetric nature of the causative trauma; not everyone with a mid-face fracture is traumatized from a direct anteroposterior blow in the midline. While useful, the Le Fort classification is not comprehensive, and fails to account for some fractures that result from unilateral trauma, upward trauma, or trauma in a direct anteroposterior direction not involving a downward vector.

Management of Mid-Face Fractures

As with any type of head and neck trauma, management of mid-face fractures should start with a thorough trauma workup, including evaluation of the airway, breathing, circulation, intracranial injuries, cervical spine injuries, and any potential penetrating trauma. As previously stated, any injuries involving the orbit warrant a full ophthalmologic evaluation as well.

The first step of fracture repair is to identify what fracture, or combination of fractures, are present, and then triage them in decreasing order of importance. For example, an isolated, minimally displaced nasal fracture is not as pressing as an orbital roof fracture with pulsatile exophthalmos and entrapment. In determining the appropriate course of management, consultation should be sought with other specialties as required, including neurosurgery, ophthalmology, vascular surgery, and trauma surgery.

A good rule of thumb is to first explore the fractures that have been identified to determine the extent of the bony and soft tissue injuries involved. After adequate reduction of the fractures, fixation should be accomplished from stable bone to unstable bone. This will help ensure that the reduction is properly aligned and enduring.

In Le Fort fractures, the primary goal is to restore premorbid dentoalveolar occlusion. Portions of the pterygoid plates and associated musculature are still attached to the posterior portion of the maxilla, so passive mobilization of the fracture can be difficult. Without passive mobilization, class III occlusion abnormalities may persist in the postoperative period. This occurs because when patients are placed into mandibulomaxillary fixation (MMF) during surgery, soft-tissue tension from the attached musculature moves the mandibular condyles in the glenoid fossae. When the MMF is removed, the condyles re-seat themselves into their normal position, bringing the mandibular dentition forward, creating a class III malocclusion. To properly achieve a passive position of the maxilla, the maxilla requires strong mobilization forces using varied instrumentation: Rowe disimpaction forceps, Stromeyer hook, Tessier retromaxillary mobilizers, etc. Hence, all facial fractures should be exposed and reduced prior to fixation.

Closed reduction can be considered in patients with Le Fort type I, II, or III fractures if they present with minor malocclusion that is easily correctable with maxillary disimpaction and manipulation, and are relatively stable. Additionally, patients with malocclusion in whom general anesthesia is contraindicated can also be treated with closed reduction. These patients will benefit from the application of arch bars and elastics. In Le Fort fractures that do not meet the preceding criteria, open reduction and internal fixation should be undertaken. Le Fort type I fractures, after adequate placement of Erich arch bars, require a gingivobuccal incision that will provide adequate exposure for reduction of the fracture using Rowe forceps. The patient is then placed into MMF and the fracture is plated laterally along each zygomaticomaxillary buttress or lateral buttress and medially along each side of the pyriform aperture (medial buttress).

Le Fort type II fractures may require a mid-face degloving approach and, in particularly difficult cases, an accompanying coronal approach in order to expose, reduce, and fixate the zygomatic buttresses, infraorbital rims, and nasofrontal buttresses. Again, arch bars should be applied prior to mobilization and reduction of the fracture segments, followed by MMF. After adequate MMF, care should be taken to start with the most stable point of fixation first, and then move to the corresponding fracture on the contralateral side, in order to ensure continued alignment (fixating all the fractures on one side before proceeding to the contralateral side may result in malalignment of the fracture segments).

Le Fort type III fractures may require a combination facial degloving approach and coronal approach to achieve adequate exposure. Arch bars are first applied, followed by mobilization and reduction of the fracture segments in much the same manner as for type I and II fractures. The addition of the Carroll-Girard T-bar technique in which a threaded T-handle reduction tool is screwed into the ZMC to facilitate movement and reduction of the segment, may facilitate adequate bony reduction. MMF is then applied, and the fractures plated in the following order: zygomaticofrontal buttresses bilaterally, nasofrontal buttresses, and the zygomatic arch if needed.

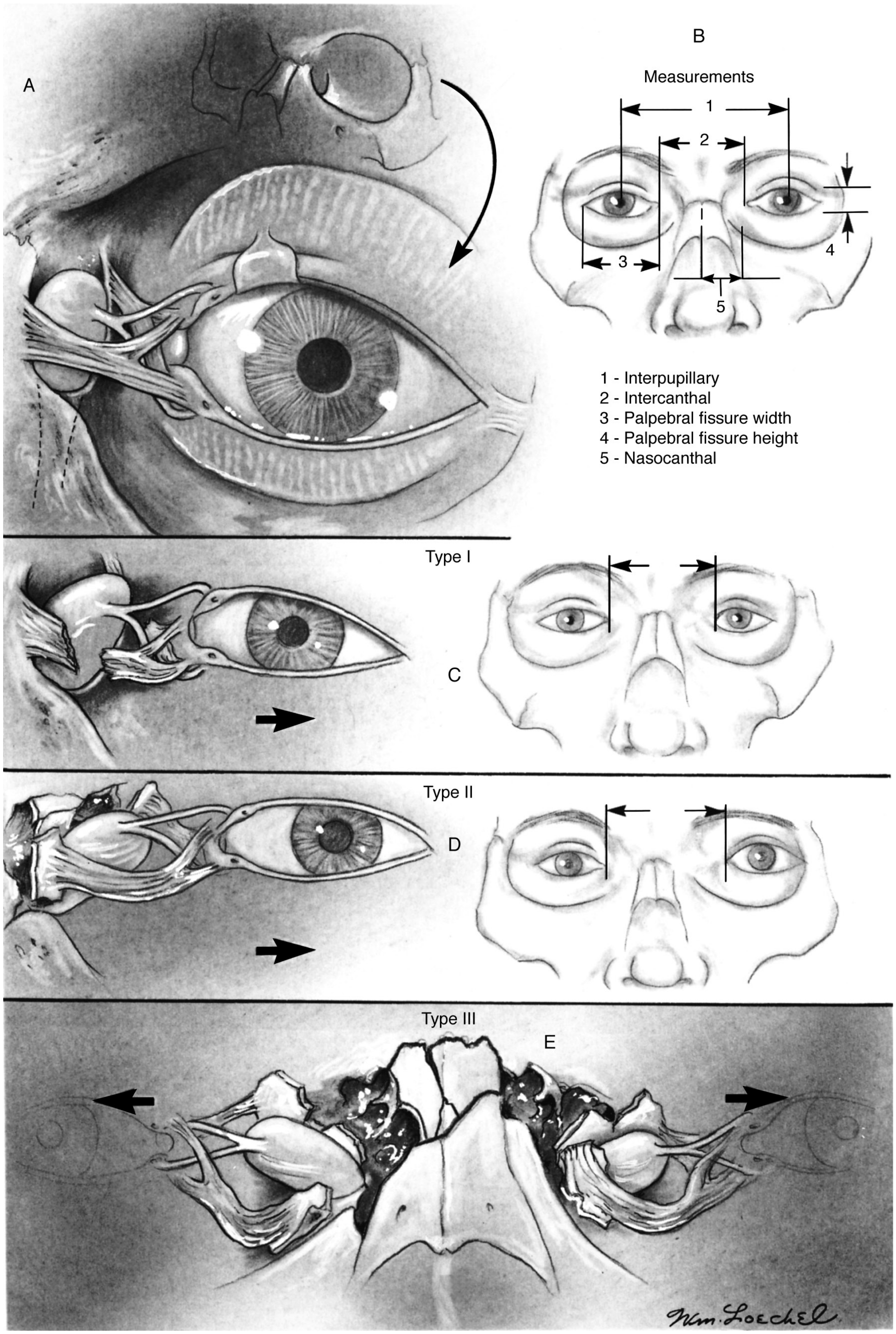
In all Le Fort fractures, once the fracture has been fixated, the MMF should be released to assess occlusion. If malocclusion is present (class III is the most common), it is likely due to malposition of the condyles relative to the glenoid fossae. In this case, plates should be removed, the condyles reseated, and the process of reduction and fixation resumed. Once satisfied with the adequacy of the occlusion, the surgeon must make a decision about the need for continued MMF. It has been argued that in the compliant reliable patient, MMF can be discontinued safely as long as the patient maintains a soft diet for at least 6 weeks. However, if there is any doubt about the patient's ability to follow the appropriate restrictions, the surgeon should have a low threshold for continued MMF, using wires for 1 to 2 weeks, followed by elastics for up to another 4 weeks afterwards. Prolonged wiring of the jaw can lead to ankylosis of the temporomandibular joint and should be avoided. In-theater wiring poses additional airway risks when patients are transported out of theater due to potential airway compromise. Wire cutters must be readily available for either the patient or transport staff to cut wires as needed. In unstable patients, the airway should be secured with a tracheotomy before transport.

Zygomaticomaxillary Complex Fractures

The ZMC is the primary source of malar projection and plays a key role in the appearance and function of the mid-face. The ZMC consists of four "legs" that form a pyramid with the malar projection at its apex: (1) the zygomaticofrontal buttress, (2) the zygomaticotemporal buttress, (3) the zygomaticomaxillary buttress, and finally (4) the zygomaticosphenoid buttress. Erroneously known as a tripod fracture, ZMC fractures result in decreased malar projection because of the telescopic effect of the fractures. On initial evaluation of the ZMC, special attention should be paid to the orbital floor because it is almost universally involved due to the telescoping of the fracture. Additionally, the infraorbital nerve runs through the weakest part of the floor and is often injured, with sensory deficits along the ipsilateral V2 maxillary nerve distribution. More common in males by a 4:1 ratio, the most common injury mechanism is blunt trauma from an altercation (accounting for the higher proportion on the left side, because most attackers are right-handed), sports injuries, or motor vehicular trauma. ZMC fractures are among the most common blunt trauma facial fractures treated in theater.

Management of ZMC fractures follows the same principles as that for other types of facial fracture: exposure and mobilization should precede fixation, which proceeds from stable to unstable bone. Unique to the ZMC fracture, however, is the concept that not every fracture line needs to be plated. Although it is imperative that at least the infraorbital rim fracture and the zygomaticofrontal fracture both be plated, 2-point fixation is usually enough to ensure stability of the fracture. A common pitfall in treating these fractures is failing to assess reduction of the fractures from multiple sites prior to fixation. The three-dimensional nature of this fracture necessitates a three-dimensional approach to its repair, and a failure to do so often results in inadequate reduction and malar flattening. A gingivobuccal (Keen) incision to assess the reduction of the infraorbital rim and the zygomaticomaxillary

Figure 24-7 (*right*). Naso-orbito-ethmoid classification. *Type I*: single-fragment bone segment with intact canthal tendon insertions; *type II*: comminuted central bone segment with fractures remaining external to the medial canthal tendon insertion; and *type III*: comminuted single fragment with fractures extending into the bone bearing the canthal insertion. Detachment of medial canthal tendon from bone.
Reproduced with permission from: Mathog RH, Shibuya T, Carron MA. *Mathog's Atlas of Craniofacial Trauma*. Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2012: Chap 66, image 1a.


A
B
Measurements
1
2
3
4
5
1 - Interpupillary
2 - Intercanthal
3 - Palpebral fissure width
4 - Palpebral fissure height
5 - Nasocanthal
Type I
C
Type II
D
Type III
E
Wm. Loechel

buttress, a fornix incision to assess and plate the infraorbital rim, and a lateral rim incision to assess and plate the zygomaticofrontal buttress are commonly used. Additionally, the gingivobuccal incision allows for reduction of the zygoma fracture using a Gillies elevator. Alternatively, the reduction can be accomplished through a temporal (Gillies) incision, or the previously mentioned Carroll-Girard T-bar technique can be used.

Naso-Orbito-Ethmoid Fractures

In evaluating patients with ZMC fractures, it is possible to overlook an ipsilateral NOE fracture. As the energy directed to the malar eminence increases, the ZMC is the first to give way. If the energy delivered exceeds the ability of the ZMC to fully dissipate that force, then that force can be transmitted medially along the inferior orbital rim to the frontal process of the maxillary bone, leading to a hemi-NOE fracture. NOE fracture refers to injuries involving the area of confluence of the nose, orbit, ethmoids, the base of the frontal sinus, and the floor of the anterior cranial base. The area includes the insertion of the medial canthal tendons. NOE fractures are by definition a different entity than isolated nasal bone fractures, although they are often associated with fractures of the nasal bones.

The most widely used classification of NOE fractures divides them into three categories: (1) type I, a single large NOE fragment bearing the medial canthal tendon; (2) type II, a comminution of the NOE area, but with the canthal tendon remaining attached to a fragment of bone; and (3) type III, a comminution of the NOE area, as in type II, but with detachment of the medial canthal tendon from the bone (Figure 24-7).[10]

The clinical presentation of these fractures is characteristic with increasing periorbital ecchymosis (raccoon eyes) and edema, as well as telecanthus and subcutaneous emphysema (Figure 24-8). The nasal bridge will be depressed as well, and particular attention should be paid to possible cerebrospinal fluid leaks and nasal septal hematoma. The intercanthal distance should be roughly equal to the width of the palpebral fissures and also roughly equal to the alar base width. The bow string in which the surgeon grasps the eyelid or skin in the medial canthal area and applies lateral traction while palpating the tendon attachment to detect movement of fracture segments may indicate a fracture of the underlying bone. Also, bimanual palpation of the medial canthal area while pushing laterally with an instrument inserted into the nose will help identify instability and an associated fracture. As with any injuries involving the orbit, complete ophthalmologic evaluation should be accomplished.

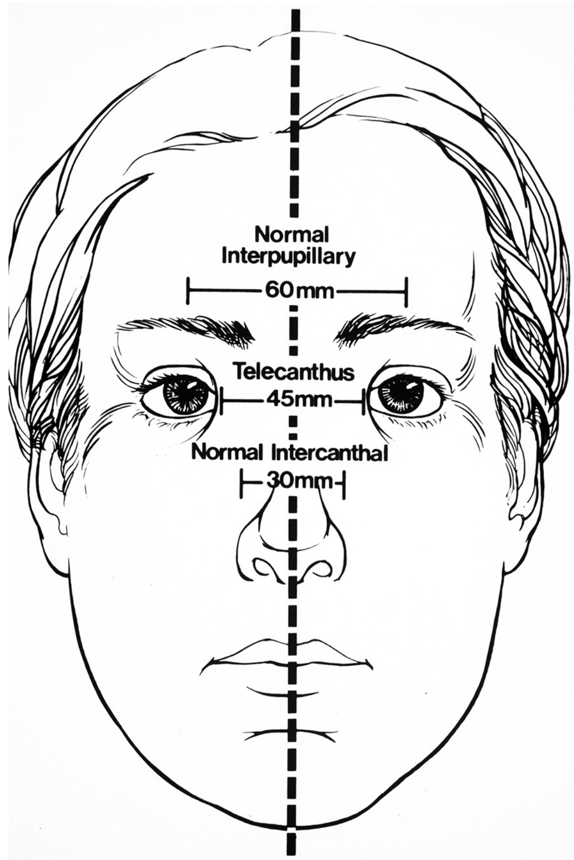


Figure 24-8. Normal interpupillary and intercanthal distances, and traumatic telecanthus.
Reproduced with permission from: *Resident Manual of Trauma to the Face, Head, and Neck*. Alexandria, VA: American Academy of Ophthalmology–Head and Neck Surgery Foundation; 2012: Figure 3.14. 2012 Copyright American Academy of Otolaryngology–Head and Neck Surgery Foundation, http://www.entnet.org/mktplace/Trauma.cfm.

NOE fractures are particularly challenging to treat. Cerebrospinal fluid leaks and other intracranial injuries must be properly assessed and managed with neurosurgical consultation. The patient must be hemodynamically and neurologically stable before repairs can be made. If no traumatic lacerations exist, then type I fractures may require a coronal incision to adequately expose the NOE region in question. Type II and III fractures may also require a lower lid incision and a gingivobuccal sulcus incision to provide adequate exposure. The key to treatment is to restore the intercanthal distance and stabilize the NOE region, because proper functioning of the lacrimal apparatus and the eyelids depends on a stable medial canthus. In most type I fractures, plate and screw fixation of the fracture segments to the superior orbital rim and pyriform aperture is often sufficient to correct the defect. In some type I and most type II fractures, however, intercanthal wiring is usually required to restore the relationships of the medial canthi, followed by plating of the segments to the stable portions of the facial skeleton. The most common error in intercanthal wiring is placing the wires too anterior, resulting in posterior flaring of the medial walls and poor apposition of the lids to the globes, with an increased intercanthal distance.

In type III fractures, in addition to the above repairs, the medial canthus must be reconstituted, often requiring that the intercanthal wiring incorporate not just the bony segments but the tendon itself. Sargent has described the following common technique: Two drill holes (vertically oriented) approximately 4 to 5 mm apart are made at the anterior portion of the canthal tendon insertion. The ends of a 28-gauge wire are passed through these two holes and twisted together on the nasal side. The two twisted wires are then twisted together in the midline under direct vision until the fracture is reduced. Twisting the two wires together symmetrically reduces and stabilizes the canthal-bearing bone fragments at the same time. The NOE complex is then secured at the superior orbital rim (the nasofrontal suture) with microplates or miniplates. The inferior orbital rim is the least important area of stabilization; reduction here is more for contour than stabilization. Plates are avoided around the canthal area. This technique may be difficult for the inexperienced surgeon to perform and assess through a coronal incision, so making a short vertical incision at the radix of the nose can help. The small scar in this area is well worth obtaining a secure symmetric intercanthal reduction.[11]

OTHER ORBITAL INJURIES AND THEIR MANAGEMENT

Foreign Bodies

Foreign bodies penetrating the orbit can cause significant destruction depending upon the type of foreign body, its exact location within the orbit, its velocity, and the surrounding tissue damage. The primary goals are to assess the airway for injuries and then to rule out an open globe injury. An open globe demands urgent evaluation, diagnosis, and surgical management.

Foreign bodies that penetrate the globe can be obvious or subtle. Figure 24-9 shows an obvious ruptured globe caused by a penetrating foreign body in theater, resulting in only a small remnant of posterior scleral tissue. Additionally, a medial avulsion that severed the patient's nasolacrimal system can also be noted. However, a foreign body can also cause more subtle findings, as in Figure 24-10. In this patient, small pieces of fragment caused a foreign body to be lodged in the superior sclera, causing a full thickness scleral wound. On examination, his conjunctiva is elevated and injected, and a hyphema exists with an ectatic pupil. Surgical exploration and timing was critical in this patient, revealing a 14-mm superior scleral wound, which was repaired.

Figure 24-9. Ruptured left globe with scleral remnant and nasolacrimal laceration.

Figure 24-10. Ruptured left globe with ectatic pupil, hyphema, and superior subconjunctival hemorrhage.

Figure 24-11. Importance of ballistic eyewear. (*Top*) Note damage from improvised explosive device.

The majority of combat eye injuries are due to high-energy explosives and IEDs. The foreign bodies most typically encountered in OEF and OIF include metal fragments, rocks, and dirt. Although US troops in combat are issued ballistic goggles that can withstand significant force (Figure 24-11), local nationals often do not have access to such protective gear yet are exposed to the same projectile foreign bodies. Any sort of eye protection will prevent the majority of both ocular and orbital injuries.[12–14]

Open Globe Injury

If ocular disruption results from wartime trauma, a ruptured globe repair in theater is generally attempted. The hallmarks of scleral rupture are a severe reduction in visual acuity, an APD, hypotony, an abnormally deep anterior chamber, decreased ocular ductions, severe subconjunctival edema, hyphema, and vitreous hemorrhage.[15] Vitreous hemorrhage and hyphema often accompany the rupture and may render ophthalmoscopy difficult to complete.

The radiographic image in Figure 24-12 shows a right globe containing rocks or other high-density radio-opaque contents. The patient's physical exam showed a large corneal scleral laceration, and repair was performed. As expected, the lens was missing and vitreous and retina were both affected. Even if repair is successful at producing a "water-tight" globe, the eye is at risk for the long-term and short-term complications of infection, retinal detachment, optic nerve compromise, and sympathetic ophthalmia. The retina and choroid are also likely torn, and fibrovascular proliferation can occur.

Enucleation

Evisceration or enucleation is performed when the globe is no longer salvageable. In US troops in theater, this is rarely performed; the ruptured globe is normally repaired and the service member is then moved stateside. Primary evisceration or enucleation is performed only if the eye has auto-eviscerated or, in a host country national, if the risk of infection is high and salvageable vision is unlikely. Figure 24-13 shows

Figure 24-12. Computed tomography image of a ruptured right globe with posterior metallic foreign bodies.

Figure 24-13. Ruptured right globe with multiple foreign bodies and facial soft tissue injuries.

a case in which no ocular contents remain. After the globe auto-eviscerated, only a remnant of scleral tissue, rocks, and debris remained. In this eye, the evisceration was completed during surgery.

Evisceration leaves any intact sclera in place but removes ocular contents, whereas enucleation detaches extraocular muscles in order to remove sclera. To maintain volume, an ocular implant may be placed at the time of surgery.

Implants

An implant placed in a deployed location involves different considerations than an implant placed in the United States. Additionally, most implants placed will be used for local national patients. Most US troops will incur secondary surgery as necessitated once back in the United States.

Many different materials and types of implants exist. The two main categories of implants are porous and nonporous. Porous implants generally have a limited role in theater because their surgical removal is more difficult. Fibrovascular ingrowth occurs within the porous channels, and with the increased risk of infection in theater, removal of an infected porous implant would be problematic. Therefore, a nonporous implant is generally preferred in host and invaded country nationals. However, because fibrovascular ingrowth does not occur in nonporous implants, their risk of extrusion is higher. Figure 24-14 shows an extruding silicone marble implant, and Figure 24-15 demonstrates placement of a dermis fat graft after removal of the extruding implant.

Figure 24-14. Extruding orbital implant.

Closed Globe Injury

All facial trauma has the potential to cause a closed globe injury. The first thing to rule out is an occult

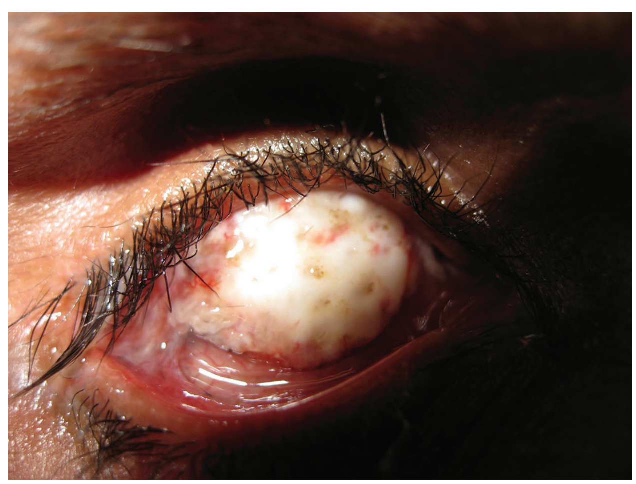


Figure 24-15. Dermis fat graft in place of extruding orbital implant.

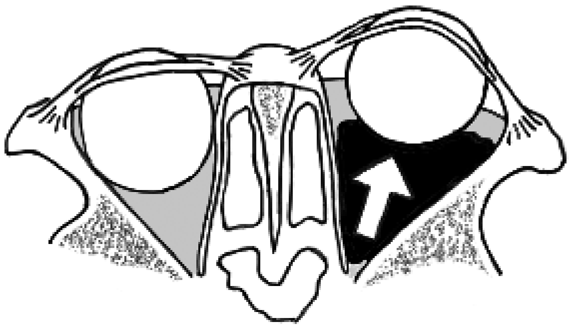


Figure 24-16. Retro-orbital hemorrhage.

or subtle ruptured globe. If there is any suspicion of rupture, globe manipulation should not be performed until surgical exploration is completed.

Blunt or closed globe injury occurs when the scleral wall is intact but the eye is injured by a coup-contrecoup mechanism. The blunt trauma causes the globe to be compressed anteroposteriorly, resulting in either a compensatory stretch equatorially or a rupture. From anterior to posterior, vulnerable areas of the anterior globe include the sphincter papillae, damage to which can cause a sphincter tear, and the anterior ciliary body, damage to which can result in angle recession and present as a hyphema in the short term and as glaucoma in the long term. Cyclodialysis can also occur from separation of the ciliary body and scleral spur. The zonules can also be damaged, potentially causing lens dislocation, as can the trabecular meshwork and the retinal attachment at the ora serrata.

Posterior Ocular Damage

Blunt trauma can also present as commotio retinae, retinal pigment epithelial edema, choroidal rupture, or optic nerve evulsion.[16] Traumatic macular holes and retinal detachment can also occur. In theater, if an optic nerve injury is suspected, treatment with high dose intravenous steroids within 8 hours of injury can carry far greater risks than potential benefits. Therefore, surgical decompression is indicated in the field trauma setting.

Retro-Orbital Hemorrhage

A special consideration for any patient presenting with orbital trauma is retro-orbital hemorrhage. During the course of evaluation, a patient with the triad of decreased vision, proptosis, and high IOP consistent with retro-orbital hemorrhage may need immediate intervention in the emergency department (Figure 24-16). As the hemorrhage expands, the eye is pushed forward in the orbit until it is stretched as far as possible. Once the eye has reached its limit on forward expansion secondary to the medial and lateral canthal tendons, the orbital and IOP begin to rise quickly, which compromises nerve function.[17] Timely surgical decompression by lateral canthotomy and cantholysis (Figure 24-17) will allow for extra orbital expansion of the hemorrhage and an immediate decrease in IOP. The procedure involves the following seven steps:

1. Anesthetize the lateral canthal area with 1% to 2% lidocaine with epinephrine.
2. Use a hemostat to compress and crush the lateral canthal tissue to decrease bleeding.
3. Use Westcott (Westcott, Fairfield, CT) or iris scissors to cut laterally 1 to 2 cm through the lateral canthus (Figure 24-17A).

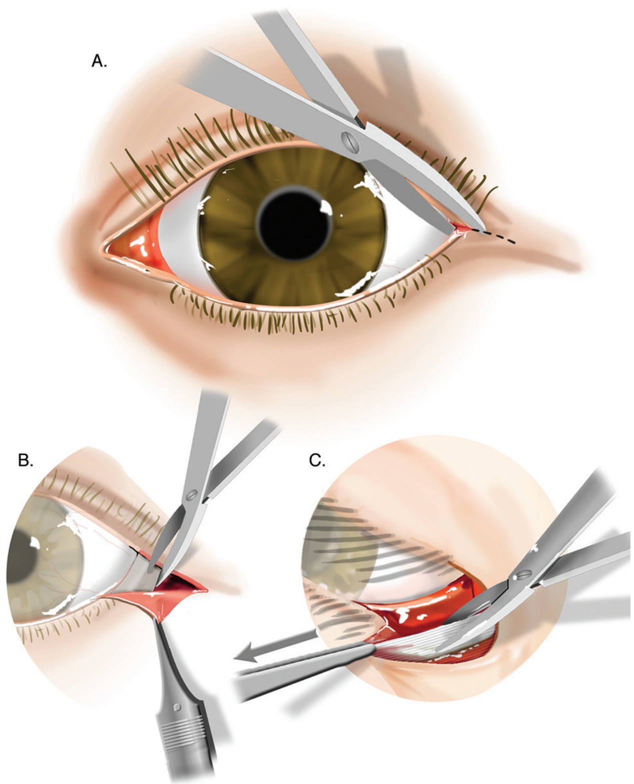


Figure 24-17. Lateral canthotomy and cantholysis: (**A**) lateral canthotomy; (**B**) grasp the lateral lower eyelid with toothed forceps; and (**C**) pull the eyelid anteriorly, point the scissors toward the patient's nose, strum the lateral canthal tendon, and cut.
Reproduced with permission from: Gerstenblith AT, Rabinowitz MP. *Wills Eye Manual: Office and Emergency Room Diagnosis and Treatment of Eye Disease.* Philadelphia, PA: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2012: Chap 3, section 10, image 2.

4. Grab the lower lid with forceps Figure (24-17B) and, pulling anteriorly and inferiorly, expose the inferior crus of the lateral canthal tendon.
5. Direct the scissors inferiorly and cut the thick tendon (Figure 24-17C). The lower lid should then move very freely.
6. Do not worry about cosmesis during this procedure; the lower lid can be reconstructed once the hemorrhage has resolved.
7. Recheck IOP and ensure the pressure has come down to below 40 mm Hg.[2]

Intraocular Hemorrhage

Intraocular hemorrhage can occur after blunt trauma and can originate either from the anterior chamber, manifesting as a hyphema (Figure 24-18), or from the posterior chamber (vitreous, preretinal, and choroid), manifesting as a blunted red reflex and shallow anterior chamber. The IOP must be evaluated and managed.

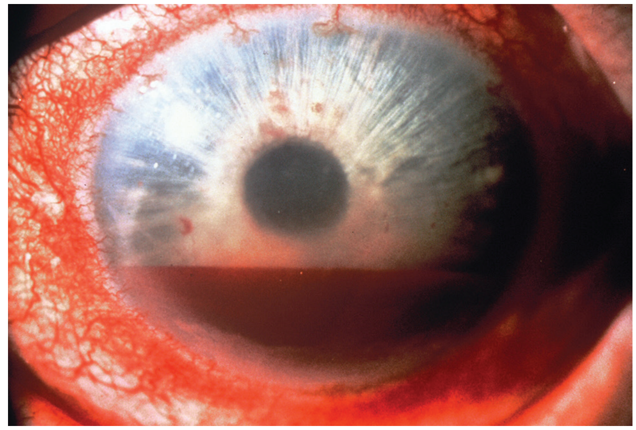


Figure 24-18. Hyphema of the globe is seen as layered blood in the anterior chamber.
Reproduced with permission from: *Resident Manual of Trauma to the Face, Head, and Neck*. Alexandria, VA: American Academy of Ophthalmology–Head and Neck Surgery Foundation; 2012: Figure 3.16. 2012 Copyright American Academy of Otolaryngology–Head and Neck Surgery Foundation, http://www.entnet.org/mktplace/Trauma.cfm.

Adnexal and Soft Tissue Injury

While the assessment and preservation of ocular function is the first priority in orbital injury, adnexal injury often coexists. Complex lacerations can occur of the eyelid margin, canaliculus, levator muscle, and medial and lateral canthi. In a deployed setting, infection is an omnipresent issue. Tissue loss, tissue edema, and hematomas often accompany these injuries. Systemic antibiotics, steroids (if not otherwise contraindicated), and local wound care should be started early. Foreign bodies can often be buried within the wounds and must be removed with irrigation or surgery. Following a blast injury, there are often many superficially embedded foreign bodies, and not all can be removed. When the eyelid is injured, it is important to delineate the anterior and posterior lamella. Prolapsed fat indicates violation of the orbital septum with an increased chance of posterior involvement. Closure of wounds while respecting the layers should commence without suturing septum in order to avoid later lid retraction. All subdermal foreign bodies should be removed, the levator aponeurosis inspected, and the anatomical planes carefully reapproximated. The tarsus is closed first, then the eyelid margin, taking care to evert the edges to prevent notch formation (Figure 24-19). Marginal sutures are left long to protect the cornea.

Shearing forces can also disrupt the canalicular system, and direct injury can occur along the course of the nasolacrimal system. The medial canthal tendon may be involved because the tendon's deep head attaches to the posterior lacrimal crest and is posterior to the canaliculus. Lacerations to the deep head of the medial canthus can cause telecanthus.

Chemical Injuries

Chemical burns can result in blindness. Chemical burns damage the skin, conjunctiva, and cornea, and deeper penetration of the chemical irritants can cause cataracts and glaucoma. Alkaline burns are more harmful to the ocular surface than acidic burns. Prompt irrigation combined with early management provides the best potential outcome. Injury severity depends on the duration of exposure, concentration of chemical, and penetration of the compound. Two major classifications exist for grading the degree of cornea burn: the Roper-Hall and Dua schemes.[18,19] The Roper-Hall scheme is based on corneal involvement and limbal ischemia, while the Dua scheme is based on clock hours of limbal involvement and conjunctival involvement.

Acids

Hydrogen damage can cause protein denaturation, coagulation, and precipitation. The coagulation actually prevents further penetration of the acid and often results in a "ground glass" appearance of the cornea.

Alkaline

Alkaline causes external eye damage through a hydroxyl ion that saponifies cell membranes and allows deeper penetration of the agent through the cornea

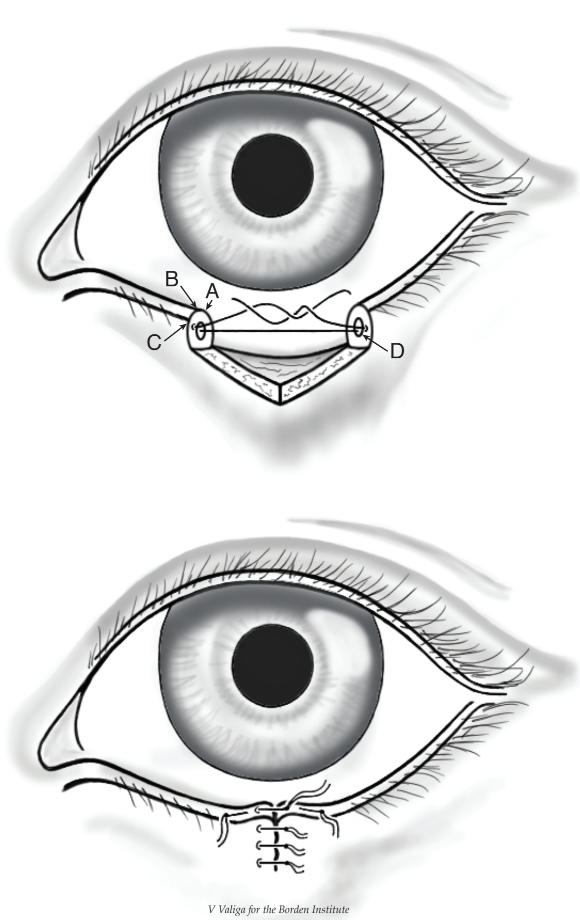


Figure 24-19. Location of cardinal suture placement for full thickness laceration of eyelid margin. (**A**) Meibomian orifices; (**B**) gray line; (**C**) lash line; and (**D**) tarsus.

and anterior chamber. Stromal haze can result, and inflammatory mediators are released that can cause further ocular sequelae (Figure 24-20).

Treatment

A graded treatment approach is used, depending on the severity of the injury caused by chemical burns. Mild burns may respond to medical treatment with lubrication while more severe injuries may require surgical therapy. The goals of treatment include removing and neutralizing the offending agent, promoting healing of the ocular surface, and controlling inflammation and IOP. Irrigation should continue until the pH is brought to 7. Patients should receive an antibiotic to prevent infection as well as a steroid to help control inflammation. An amniotic membrane can be applied, which promotes surface healing of the cornea and conjunctiva as well as decreasing the inflammatory mediators.

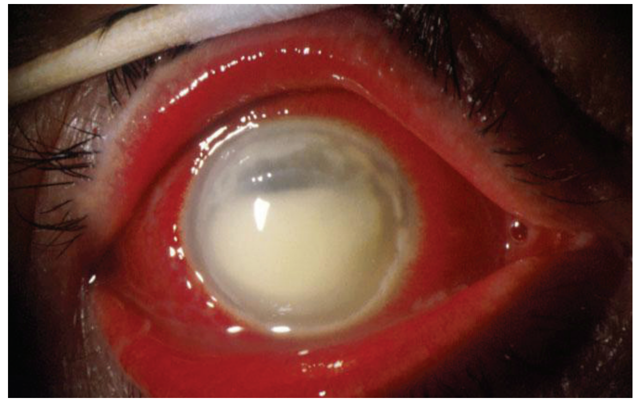


Figure 24-20. Late effects of alkali burn secondary to an improvised explosive device blast with medial symblepharon, tethering of globe medially, corneal scarring, and chronic discharge.

Figure 24-21. Medial symblepharon from chemical injury causing severe gaze restriction.

Conjunctival Adhesions and Symblepharon

Conjunctival adhesions and symblepharon can also be a late manifestation of an ocular burn. The patient in Figure 24-21 was assembling a bomb when it exploded in his face, causing an alkaline burn. The resulting symblepharon tethered his globe medially, which gave him diplopia and gaze restriction. The scar tissue was released, the medial rectus muscle explored, and an amniotic membrane was placed.

Sympathetic Ophthalmia

Sympathetic ophthalmia is a rare inflammatory response following trauma or injury to one eye. Its incidence ranges from 0.2% to 0.5% after penetrating ocular trauma.[20] Following injury, the melanin-containing structures of the retina's photoreceptor layer are exposed to the immune system. The immune system targets the structures as foreign antigens and begins the process of attacking them. This process can occur anywhere from days to years following the inciting trauma. The diagnosis is clinical, based upon an inflammatory or uveitic response of the sympathizing eye.

If an injury results in a blind, painful eye, evisceration or enucleation of the traumatized eye should be considered within 2 weeks of injury to lessen the likelihood of sympathetic ophthalmia. Care must be taken during the surgery to remove all of the uveal tissue. After evisceration the inner surface of sclera is treated with absolute alcohol to denature any possible remaining antigenic proteins. If sympathetic ophthalmia is already in progress, the antigens have already accessed the sympathizing eye and thus treatment is directed at immunosuppressive therapy. This is an important consideration in a service member exposed to ocular trauma because it is a potential cause of bilateral blindness.

SUMMARY

The face is damaged in at least one-third of all injured service members, and the importance of eye protection cannot be underestimated. A surface wound mapping study of battlefield oculofacial injuries demonstrated that the most commonly injured area of the face is the lower third (60%), with 40% of injuries found in the upper and middle thirds. The upper and middle thirds of the face are protected by the helmet cover and ballistic goggles. Chin and neck protection is far less effective.[21] Wade et al[6] reported that 80% of wounded US service members were wearing eye protection, compared with 93% wearing body armor. Reasons cited for not wearing eye protection included restricted field of vision and degraded vision caused by misting of goggles. Total ballistic goggle compliance by a Marine Corps mechanized battalion in Iraq during OIF reduced the incidence of ocular injuries from 6% to 0.5%.[22]

Research on closed globe injuries after exposure to powerful blasts and TBI is just beginning. Preliminary studies on patients exposed to blast injuries demonstrate that patients can develop visual acuity changes and field of vison defects at a later time despite relatively normal visual acuity near the time of injury. Closed globe injuries causing visual function impairment and requiring pharmacological therapies with ongoing rehabilitation will adversely affect the quality of life of many TBI patients.[9] Lessons learned from OIF and OEF include careful and diligent collaboration among all members of the head and neck team to assure the best patient outcomes. Early identification and treatment of eye-related injuries, with a high index of suspicion for potential bilateral eye injuries, is paramount. For local national patients, it is important to perform procedures in a stepwise fashion, taking into account poor nutrition, increased risk of infection, poor living conditions, and inadequate follow-up.

CASE PRESENTATIONS

Case 24-1: Motor Vehicle Accident

Presentation

A 25-year-old Afghan contract worker reporting to work on his scooter was rear-ended by a mine-resistant ambush-protected (MRAP) vehicle and thrown face forward over the handle bars onto the pavement. The patient was not wearing a helmet. He presented via ambulance to emergency room with his father, who was carrying some of his teeth and a portion of his upper lip, which were recovered from the scene.

Physical Exam

The patient presented with active bleeding from the mouth and nose and a decreased level of consciousness secondary to head trauma. He was unable to control his airway. He was rushed to the operating room and emergent tracheotomy was performed. The patient's wounds were then packed and he was taken to the CT scanner for scans of the head and face.

Imaging Findings

CT scans demonstrated multiple facial fractures including a mandible fracture, an NOE fracture, a maxillary fracture, and a nasal fracture (Figure 24-22). No intracranial bleed was noted.

Operative Assessment

Severe facial lacerations with an avulsion injury were noted, with loss of a large amount of facial soft tissues including the entire tip of the nose, the majority of the upper lip, and an upper central incisor. Telecanthus was also noted, with loss of nasal projection (Figures 24-23 and 24-24).

Operation

The patient was returned to the operating room and conservative tissue debridement was performed. Upper and lower arch bars were placed using 24-gauge wire, and the patient was placed in occlusion. The NOE fracture was exposed with a bicoronal incision. An NOE type II fracture on the left and an NOE type III fracture on the right were noted. The fragments were reduced and plated using 1.3-mm synthes plates and screws.

Next, a 2.0-mm cantilever plate was secured to frontal bone to reduce the nasal fracture. The telecanthus resolved and the patient's nasal dorsal profile was restored. The bicoronal incision was then closed with deep VICRYL (Ethicon Inc, West Somerville, NJ) suture and skin staples. Attention was then given to the upper lip and nasal tip soft tissue defects. The internal nasal septal deviation was repaired using a submucosal approach. A columellar strut was secured in place between medial crus to support nasal tip soft tissues. The nasal

a

b

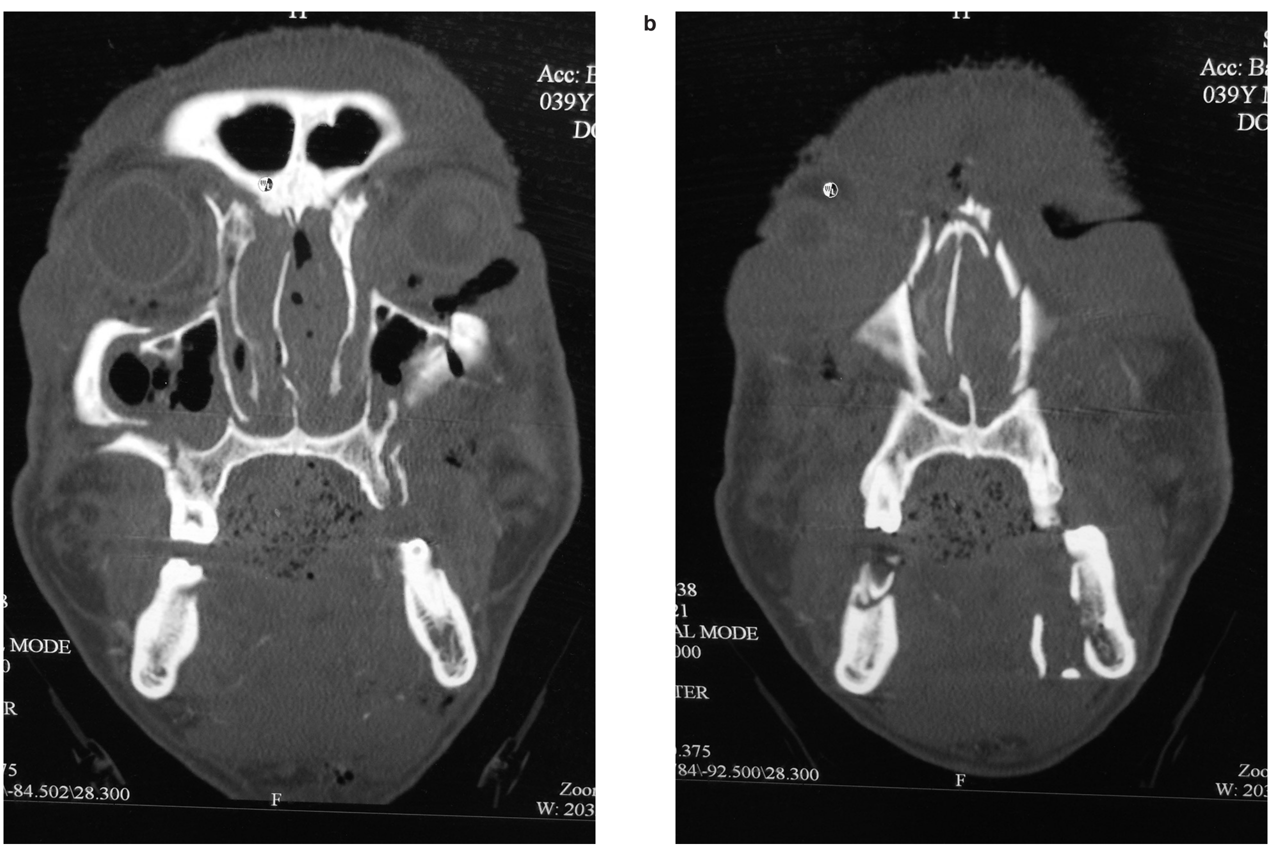


Figure 24-22. Coronal computed tomography scans.

Figure 24-23. Anterioposterior view of extensive soft tissue injuries.

dorsum skin was redraped and secured to underlying remaining cartilage, and left lower lateral crus reconstruction was performed using thinned septal cartilage. The nose was then packed bilaterally to support the internal septum and overlying tissues and to maintain patency of the nasal orifice. The nasal skin closed with 5-0 PROLENE (Ethicon Inc, West Somerville, NJ).

Finally, the upper lip was reconstructed by using advancement flaps bilaterally in a cleft lip repair fashion, in which back cuts were used to advance soft tissues medially. The orbicularis muscle was isolated and reapproximated to maintain oral function. The gingival buccal mucosa was then advanced from inside the mouth outward to augment the red lip portion of the upper lip and to provide fullness of area, thereby preventing a whistler's deformity in the future. The symphysial mandible fracture was repaired by using lag screws to reapproximate the bone. The nondisplaced condylar head fracture was treated with intermaxillary fixation wires, and subsequent maxillomandibular fixation using elastic bands was planned.

Figure 24-24. Lateral view of soft tissue injuries.

Figure 24-25. Six weeks postoperative.

Postoperative Course

The patient was then kept on Unasyn (Pfizer, New York, NY) intravenous while packed for 8 hours. The packing was removed and the patient was decannulated at 48 hours. He was then treated with Peridex (3M, St Paul, MN) rinses and outpatient Augmentin (GlaxoSmithKline, Brentford, England) for 7 days. He was eventually switched to maxillomandibular fixation elastic bands and instructed on proper diet. The patient was followed up every 7 to 10 days for evaluation of wounds and eventual removal of arch bars. He was scheduled for forehead flap reconstruction of his nasal tip defect and also for upper lip revision in 6 weeks. He is shown at 6 weeks after the initial operation in Figure 24-25.

Lessons Learned

Immediate control of the airway is often accomplished by field medics, who may perform cricothyroidotomy in the field if the patient's airway is a concern. These cricothyroidotomies are then converted to tracheotomies in the operating room upon patient arrival to field hospital. Conservative skin debridement of facial wounds is imperative. Facial vasculature allows for quick revascularization and increased survivability of apparently devitalized tissues. Typically, areas of the skin that appear dusky and concerning at presentation eventually return to normal. The initial impulse to extensively debride all suspect skin edges and then proceed to complete and comprehensive reconstruction should be avoided. Initially establishing a scaffold and a foundation for later reconstruction was performed in this patient, which improves the success of his later complex nasal tip reconstruction.

Figure 24-26. Afghan National Army soldier after exposure to improvised explosive device blast.

Case 24-2: Open Globe and Facial Trauma From Improvised Explosive Device

Presentation

A patient presented with multiple members of his squadron after a dismounted IED blast. The right side of his body and face sustained all the impact. He was not wearing eye protection at the time of the blast, which is common for Afghan National Army soldiers, who are only partially equipped for their duties.

Physical Exam

Using the near card, the patient's visual acuity was found to be 20/hand motion in the right eye and 20/30 in the left. Pupil exam showed that his right eye peaked superiorly and was nonreactive to light, and his left eye was round and reactive to light. Extraocular movements were restricted; the right eye exhibited minimal movement superiorly and temporally, and the left eye had normal movements. IOP was deferred in the right eye and was normal in the left. The remainder of the left eye exam was normal. Figure 24-26 shows the adnexal exam. The patient had multiple foreign bodies embedded in the face. The skin and anterior lamella was evulsed from the right upper lid down to level of the orbital septum. The lid was retracted with a Desmarres retractor to reveal the right eye injury. A partial thickness corneal laceration was present centrally, extending 5 mm to the limbus at the 1 o'clock position and becoming full thickness 2 mm from the limbus (Figure 24-27). Iris tissue was plugging the wound superiorly, causing the peaked pupil. The anterior chamber was flat. There was severe chemosis, but no uveal tissue was noted under the conjunctiva.

Treatment Course

The patient was taken to the operating room, where the right side of the face was prepped and then debrided extensively. Mud, rocks, and small metallic fragments were removed with forceps and entrance wounds were copiously flushed. Attention was then

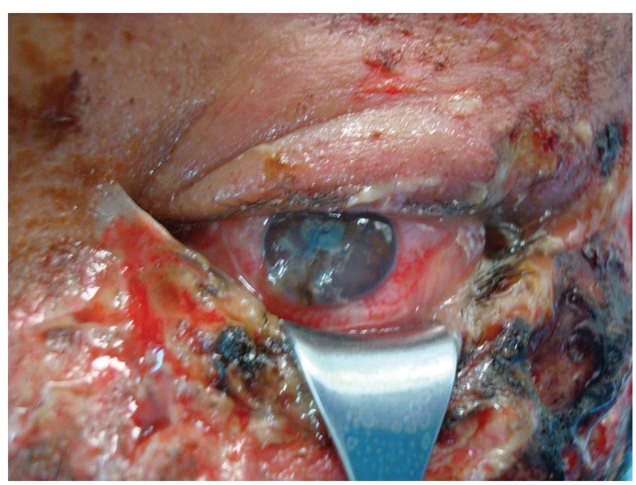


Figure 24-27. Partial thickness corneal laceration present centrally and extending 5 mm to the limbus.

turned to the right open globe. The face was draped and an eyelid speculum was placed in the right eye. A surgical microscope was brought over the eye and further examination was done. Viscoelastic material was injected into the open wound to push the iris back into the anterior chamber. Then, 10-0 nylon was used to close the corneal wound at the limbus first and then continuing along the wound centrally. Fluorescein was used to ensure the wound was water tight. A 1-mm paracentesis was made in the cornea with a stab blade, and balanced salt solution was injected into the eye. The viscoelastic was removed with a 27-gauge cannula on a 1-mL syringe. More balanced salt solution was then injected into the eye. The eye became normotensive and the pupil returned to a round normal shape.

Because of the chemosis and subconjunctival hemorrhage, a 360° periotomy was performed to expose the underlying sclera, looking for any occult ruptures. None were found, and the conjunctiva was closed with 6-0 plain gut suture. Subconjunctival Ancef (GlaxoSmithKline, Research Triangle Park, NC) and dexamethasone were given at the conclusion of the case. After the speculum and drapes were removed, the facial wounds were dressed with bacitracin ointment.

The patient was brought back to the operating room 1 day later for skin grafting of the upper eyelid. The facial wounds were cleaned and packed. Postauricular skin was then harvested to transplant on the upper eyelid (Figure 24-28). It was sutured with 6-0 PROLENE and then dressed with antibiotic ointment.

The patient's wounds were cleaned and dressed, and he was transferred to a local hospital in Kabul 2 days later. His visual acuity in the right eye was 20/400 upon discharge, with the vision limited by vitreous hemorrhage. Unfortunately, he was lost to follow-up at Bagram Air Base.

Figure 24-28. Postauricular full thickness skin graft to upper eyelid.

Lessons Learned

Facial soft tissue, adnexal, and ocular injuries are common with IED blast exposure when the service member is not wearing protective gear. Soft tissue injuries must be debrided of all organic material to lower the risk of infection. A simple dressing with antibiotic ointment is usually all that is necessary for this highly vascular, quick healing tissue. Open globe injuries must be addressed as quickly as possible to give the patient the best chance for regaining functional vision. These patients need coordinated care between otolaryngology and ophthalmology to address all wounds.

Case 24-3: Improvised Explosive Device Fragment in Right Eye

Presentation

A 14-year-old local national male was herding sheep when one of the sheep detonated an IED. The patient walked to a local forward operating base, presenting 4 days after injury with a foreign body in the right orbit (Figure 24-29) and was immediately evacuated to Craig Joint Theater Hospital in Bagram, Afghanistan.

Physical Exam

A metallic piece of fragment was found to be projecting through the right orbit and through the frontal fossa floor. The patient's Glasgow Coma Scale score was 15, and he was responding appropriately to questions and commands. The patient was examined by otolaryngology, neurosurgery, and ophthalmology providers.

Figure 24-29. Large cylindrical improvised explosive device fragment noted in right eye.

Imaging

CT scan demonstrated a cylindrical metallic foreign body measuring approximately 2.5 cm in diameter penetrating the right orbital roof and anterior inferior right frontal lobe, with associated severely comminuted fractures of the orbital roof within the right frontal lobe (Figure 24-30). Associated fractures of the anterior and posterior walls of the right frontal sinus extended into the NOE region, with opacification of the left ethmoid air cells. Blowout fractures of the medial wall and right orbital floor were noted, with fracture fragments of the orbital floor displaced inferiorly by proximally 8 mm in greatest extent. The right frontal lobe had intraparenchymal hemorrhage and slight midline shift.

Figure 24-30. Coronal computed tomography scan demonstrating foreign body in right orbit.

Operation

Surgery consisted of a bifrontal craniotomy with removal of the foreign body in a controlled fashion (Figures 24-31 and 24-32). The right frontal fossa floor was repaired with titanium mesh. The frontal sinus was cranialized and a pericranial graft was overlayed. Duragen (Integra, Plainsboro, NJ) was used to cover the dural defect. The right eye was enucleated and closed. The orbit was cleaned of debris and explored for globe fragments, which were removed. Only the posterior third of the globe was seen attached to the optic nerve and neurovascular bundle, and the attachment was ligated with a clip. The upper lid avulsion defect was repaired 3 days later with nasolabial flap. A buccal graft to repair the superior conjunctival defect and a prosthesis placement were planned for later.

Postoperative Course

The patient was seen 4 weeks postdischarge at the local Egyptian hospital. No parent was available. He reported pain around the region of the right orbit and lids but had no fever or cerebrospinal fluid leak. The

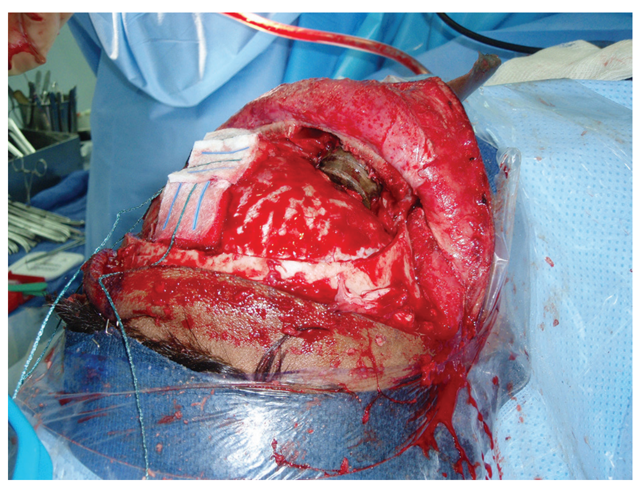


Figure 24-31. Bifrontal craniotomy. Note penetration of frontal lobe by a large metallic improvised explosive device fragment.

Figure 24-32. Excised improvised explosive device fragment.

Figure 24-33. Nasolabial flap reconstruction of full thickness upper lid defect.

periorbital sutures were removed, and the forehead incision and nasolabial flap to the upper lid were found to be intact (Figure 24-33), and the conformer in place.

Lessons Learned

The patient traveled for a long time to arrive at the forward operating base because no other medical care was available in the area. Rapid transport and care prolonged this patient's life. The uncertainty of follow-up and the concern for infection dictated a robust pedicled flap rather than a skin graft for reconstruction of the upper lid defect. Staged repair of the patient's injuries helped prevent a cerebrospinal fluid leak and helped ensure the viability of his initial repair before any subsequent complex repairs could be initiated.

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